The simulation of schedule risk paths in submarine pipeline projects using bayesian networks

Ying Zou\textsuperscript{1}, Bingbing Xu\textsuperscript{2}, Shuai Liu\textsuperscript{3} and Jing Zhou\textsuperscript{4, 5}

\textsuperscript{1}City Institute, Dalian University of Technology, Dalian, 116600, China
\textsuperscript{2}Department of management and economics, Tianjin University, Tianjin, 300060, China
\textsuperscript{3}City Institute, Dalian University of Technology, Dalian, 116600, China
\textsuperscript{4}Ministry of engineering, Dalian University of Technology, Dalian, 116000, China
\textsuperscript{5}E-mail: zhouj@dlut.edu.cn

\textbf{Abstract}. This research aims to simulate the risk paths among critical schedule risks of submarine pipeline projects by identifying and quantifying risk paths. We first identified forty-three schedule risks by literature review and grouped them into three subsets: project participants, project, and environment. Then twenty-three critical schedule risks were ascertained through expert survey and case study. Utilizing Bayesian Network model, six interrelated risk paths on schedule were identified by quantifying conditional probability of critical schedule risks. Considering the interdependent effect of schedule risks, this research identified and quantified the schedule risk paths in submarine pipeline projects, which could provide specific guidance for schedule risk management and improve time performance of projects.

1. Introduction

As a way of transporting oil and natural gas, the submarine pipeline has the characteristics of convenience, safety and stability. In order to alleviate the pressure of energy supply, massive submarine pipeline projects are constructed in China. At present, China has completed a total of nearly 2000km of submarine pipeline. The longest of them is the South China Sea oil pipeline, which has a length of more than 1,000km, bearing the oil and gas transportation of 13 oil and gas fields in the south China sea [1]. And yet, schedule delays are common in submarine pipeline construction projects and have an effect on successful project delivery. Frequent delays in submarine pipeline projects influence the achievement of the construction goal and cause financial loss for project participants. Therefore, it is necessary to take schedule risk management in advance.

Delays on submarine pipeline projects derive from the high levels of risk and complexity, which is caused by project-specific factors and the dynamic interactions among them [2]. The submarine pipeline project has the following characteristics: (1) The large amount of seabed engineering: seabed parts account for 80% of submarine pipeline construction while the ground and elevated parts take about 20%. There are numerous risks involved in complex geological and hydrological conditions which is one of the important factors leading to delay. (2) Concurrent linear engineering: The submarine pipeline often takes the concurrent construction scheme, which would be very hard to coordinate and manage. Schedule risks arise in submarine pipeline projects because of the above characteristics. Therefore, identifying and quantifying schedule risks, simulating the causal
relationships among them, and responding properly are effective steps towards improving the chances of timely completion of projects [3].

The significant risk factors for delays have been identified and quantified in many scientific journals. The literature has suggested two types of studies. First, schedule risks were identified as independent factors, and their relative importance was also evaluated. Assaf divided these factors into nine categories and identified seventy-three schedule risks. The seventy-three schedule risks were qualified and sorted by frequency of occurrence, degree of severity, and importance index in Assaf’s research [4]. Moreover, there are a lot of researches devoted to identifying and evaluating the relative importance of schedule risks factors in various construction projects, such as highway projects, rapid transit railway projects, bridge projects [5-9]. In the literature above, researchers paid attention on the differences of schedule risk factors caused by project-specific characteristics and their relative importance. As far as is concerned little research has been done on schedule risks of submarine pipeline projects with complex project-specific characteristics.

Other researches on risk management focused on identifying and qualifying interactions among risk factors. Luu developed a Bayesian belief network model to forecast the probability of schedule delays in construction projects [10]. Iyer and Mohammed suggest the use of interpretative structural modeling to prepare the interrelationships of risks in highway projects [11]. Eyboosh demonstrated that causal relationships exist among various risk factors, which initiated from diverse vulnerabilities of the project system. 36 interrelated risk paths of international construction projects were identified by using structural equation modeling [12]. Review of the extant literature shows that little effort has been committed to research on identification and quantification of the interactive relationships of schedule risks in spite of its vital role in contributing to the success of submarine pipeline construction projects.

The schedule risks of submarine pipeline projects are related to project-specific characteristics, including complex geological and hydrological conditions, complex surrounding conditions of marine climate, and concurrent and linear engineering. In this paper, the critical schedule risks and risk paths of submarine pipeline projects were identified and quantified so that we could simulate the propagation process of critical schedule risks in submarine pipeline projects. This study has three main steps: the first step is to identify critical schedule risks by case study and expert interviews. The second step is to develop a Bayesian network modeling to analyze the causal relationships among critical schedule risks. Risks paths of critical schedule risks were quantified by conditional probability of nodes in the end step. In this research, we attempted to simulate the propagation process of critical schedule risks and forecast the probability of schedule delays in submarine pipeline projects, which can improve understanding of interactive schedule risks and enhance performance of schedule management for the project managers.

2. Research methodology

2.1. Overall research framework
The methodology employed in this study adapted from Luu et al.’s and Eybpoosh et al.’s research. It is based on a comprehensive literature review, questionnaire survey and case study for data collection. Bayesian network was used as quantified tools for data analysis.

2.2. Questionnaire survey

2.2.1. Questionnaire design. In this research, three questionnaires were designed. They were used for collecting data about schedule risks, the causal relationships among schedule risks, and the schedule risk probability of occurrence respectively.

The questionnaire 1 was used to calculate importance index and it consisted of two sections. The first section included questions about the personal information of these experts in submarine pipeline projects. In the second section, the experts were asked to evaluate the frequency of schedule risks and
their degree of severity to schedule. There were 41 schedule risk factors based on a comprehensive literature review and several delay cases.

The research used the questionnaire 2 to determine the interactive relationships to develop the Bayesian network model. The questionnaire 2 was designed in comparative matrix form, including 23 critical schedule risks of submarine pipeline projects identified by expert survey and case study. In the comparative matrix, there are 506 items should have been answered by the experts, which would obviously reduce the efficiency and accuracy of the research. Therefore, we deleted parts of the items that were obviously non-existent, such as the interactive relationships between design defect and severe weather. After that, the questionnaire was shrunk down to 192 items and the respondents were asked to use a five-point Likert scale to determine the strength of the causal relationships (from 0 = “no effect” to 4 = “very strong effect”) [13].

The questionnaire 3 was used to collect the conditional probability of nodes in Bayesian networks model. The questionnaire 3 consisted of two sections. The first section asked respondents to estimate the conditional probability of nodes based on their practice experiences of submarine pipeline projects. The second section included questions meant to profile these respondents in submarine pipeline projects. The respondents were asked to use unified probability scale in order to avoid subjective differences in the rating process [14].

2.2.2. Data Collection. In this research, we used expert survey to identify critical schedule risks and determine the causal relationships to develop the Bayesian network model because this method could preferably solve the complex uncertain problems [15]. Firstly, 16 experts were invited to respond questionnaire 1, 6 of whom were professional researchers in project management and risk management and 10 were practical managers in submarine pipeline projects. Then based on the finding of questionnaire 1, 16 experts were asked to determine the causal relationships in questionnaire 2, which was sent and collected by email.

175 survey questionnaire 3 were sent out to 30 submarine pipeline projects in Mainland China aggregately. A total of 117 complete questionnaires 3 were returned, representing a response rate of 66.86%, which was in accordance with the norm of 20–30% with most questionnaire surveys in the construction industry [16]. In the end, 97 valid questionnaires 3 were used for data analysis. Among respondents of questionnaire 3, 45.5% of them were project managers from owners, 38.7% were project managers from contractors and 15.8% were project managers from designers or supervisors. The average practical experience in the submarine pipeline projects of the respondents of questionnaire 3 was more than 5 years, which would ensure that the responses collected were accurate and trustworthy.

2.3. Relative importance ranking technique

This research adopts relative the importance ranking method to identify critical schedule risks. There are a large number of factors explored in the survey as the schedule risks. Choosing the ones ranked top 10 (out of 43 risk factors) is assumed to be an appropriate way to represent the critical schedule risks, which is in line with existed researches [17]. The questionnaire 1 surveys feedback including the likelihood of schedule risks and the magnitude of its effects on schedule to calculate the relative importance index \( \gamma \).

The three points rating scales are chosen for the likelihood \( \alpha \) and the magnitude of effect \( \beta \) respectively, according to Zou et al. and Shen et al. [18]. The likelihood \( \alpha \) “highly likely” takes a value of 1.0, “likely” takes a value of 0.5 and “less likely” takes a value of 0.1. The magnitude of effect \( \beta \) “high magnitude” takes a value of 1.0, “medium magnitude” takes a value of 0.5, and “low magnitude” takes a value of 0.1. The relative importance index of each schedule risk was calculated through Eq. (1), where \( i = \text{ordinal number of schedule risks} \).

\[ \gamma_i = \alpha_i \beta_i \]
2.4. Bayesian belief network method
Bayesian belief networks (BBNs) method is applied to simulate the propagation path of critical schedule risks and forecast the probability of schedule delays in submarine pipeline projects. BBNs describes the interactive relationships among critical schedule risks through directed acyclic graph (DAG), which is an effective tool to analyze, reason, and predict uncertainty problems [19]. As a probabilistic DAG model, the BBNs model consists of nodes, arcs, and conditional probability table [20]. The nodes represent the stochastic variables, and the arcs reflect the interactive relationships between the nodes. The nodes of BBNs model are classified into three categories: the top node, the bottom node, and the middle node. And the nodes are conditionally dependent upon their nodes, which is based on conditional probability theory. According to the data of questionnaire 2 and 3, the BBNs model was built using the freely downloaded software Agenarisk 6.2 in this research.

3. Results and discussion

3.1. The identification of critical schedule risks
The primary list contained 43 schedule risk factors based on a comprehensive literature review and 14 delay cases. The 43 risks were categorized into three groups, with 16 risks relating to project stakeholders, 14 risks relating to project-specific factors, and 13 risks relating to project environment.

The likelihood of 43 schedule risks and its magnitude of effect are assessed through three rounds of expert survey. Using relative importance ranking method, 19 critical schedule risks ranking in top 10 were identified. However, one disadvantage of this approach is that some risks with low-probability but high-impact risk events are often ignored [21]. Therefore, the rest of schedule risks were analyzed for handling this shortcoming. Then, 4 schedule risks with low-probability but high-impact were found, including the fault of vehicles and signal, improper decisions of owner, international large-scale social activities, and severe weather. Finally, 23 schedule risks table 1 were identified as critical risks causing delays in submarine pipeline projects.

3.2. Determination of the interactive relationships among schedule risks
The purpose of this part is to determinate the interactive relationships among 23 critical schedule risks identified in section 3.1 passage. The data of questionnaire 2 was statistically analyzed, and used to calculate the average scores of causal relationship strength and the standard deviations. Table 2 shows 29 significant pairs, of which the average score of causal relationship strength is more than 2.0. The procedure yielded 9 top nodes, namely variations by owner, improper decisions of owner, inadequate designers’ experience, inadequate contractors’ experience, inadequate supervisors’ experience, public protest, maritime rights related issues, complex geological condition, and severe weather.

3.3. Developing a Bayesian belief network model
Based on 29 interactive relationships among 23 critical schedule risks, the BBNs model was built to simulate the propagation process of those risks and forecast the probability of schedule delays in submarine pipeline projects. The BBNs model contains 24 variables, namely 9 top nodes, 14 middle nodes, and only one bottom node. The only one bottom node is schedule delay. Each node has its name, status, relationship with other nodes, and conditional probabilities. The node takes either “Occur” or “NotOccur” state. With computerized model built using Agenarisk6.2, the data of questionnaire 3 was used to quantify critical schedule risks paths in figure 1.
Table 1. Critical schedule risks and relative importance scores.

| No. | Categories                          | Critical schedule risks                      | Relative importance |
|-----|-------------------------------------|----------------------------------------------|---------------------|
| 1   | Related to project-specific characteristics | Increase of quantities (X₁)                   | 0.53                |
| 2   |                                     | Shut-downs (X₂)                             | 0.49                |
| 3   |                                     | Defective works and reworks (X₃)             | 0.40                |
| 4   |                                     | Change of line (X₄)                         | 0.37                |
| 5   |                                     | Collapse (X₅)                               | 0.34                |
| 6   |                                     | Overhanging and unstable of line (X₆)       | 0.33                |
| 7   |                                     | Fault of signal (X₇)                        | 0.22                |
| 8   | Related to owners                   | Backward in operation and management (X₈)   | 0.58                |
| 9   |                                     | Tight project schedule (X₉)                  | 0.56                |
| 10  |                                     | Variations by owner (X₁₀)                   | 0.34                |
| 11  |                                     | Improper decisions of owner (X₁₁)           | 0.19                |
| 12  | Related to designers                | Design variations (X₁₂)                     | 0.45                |
| 13  |                                     | Inadequate designers’ experience (X₁₃)       | 0.41                |
| 14  |                                     | Design deficiency (X₁₄)                     | 0.33                |
| 15  | Related to contractors              | Inadequate contractors’ experience (X₁₅)    | 0.56                |
| 16  |                                     | Lack of effective site management (X₁₆)     | 0.56                |
| 17  |                                     | Inappropriate construction methods (X₁₇)    | 0.53                |
| 18  |                                     | Inadequate program scheduling (X₁₈)         | 0.41                |
| 19  | Related to supervisors              | Inadequate supervisors’ experience (X₁₉)     | 0.45                |
| 20  | Related to sociocultural environment | Public protest (X₂₀)                        | 0.49                |
| 21  |                                     | Maritime rights related issues (X₂₁)         | 0.16                |
| 22  | Related to natural environment      | Complex geological condition (X₂₂)          | 0.58                |
| 23  |                                     | Inclement weather (X₂₃)                     | 0.12                |

3.4. Analysis and reasoning of critical schedule risks paths

3.4.1. Analysis of the interactive relationships among schedule risks. After data input in BBNs model, the probabilities of each node’s states were evaluated and illustrated in Table 3. In the 9 top nodes, probability of occurrence in the top three are public protests (0.6823), complex geological condition (0.6420), and inadequate contractors’ experience (0.5802). It shows that risks of schedule delays in submarine pipeline projects mainly come from social environment, geological condition, and contractor competency in submarine pipeline projects.

At implementation stage of submarine pipeline projects, backward in operation and management are the most common risk event caused schedule delay. Its probability of occurrence is 75.69%. When the status of this risk event was set to “Occur” in BBNs model, the probability of schedule delays increased from 65.88% to 87.03%, namely having a growth rate of 32.1%.
Table 2. Twenty-nine interactive relationships among critical schedule risks.

| Rank | Interactive | Mean  | SD   | Rank | Interactive | Mean  | SD   |
|------|-------------|-------|------|------|-------------|-------|------|
| 1    | X₂₀—X₈     | 3.65  | 0.948| 16   | X₁₄—X₁₂    | 2.99  | 1.058|
| 2    | X₈—X₂      | 3.63  | 0.862| 17   | X₆—X₁₂     | 2.82  | 1.138|
| 3    | X₂₂—X₁₇   | 3.52  | 1.018| 18   | X₅—X₁₂     | 2.80  | 0.901|
| 4    | X₄—X₁₅    | 3.47  | 1.020| 19   | X₁₃—X₁₄    | 2.76  | 1.041|
| 5    | X₁₁—X₉    | 3.44  | 0.922| 20   | X₅—X₁₋₁₂   | 2.76  | 0.809|
| 6    | X₂₂—X₄    | 3.41  | 1.007| 21   | X₁₇—X₆     | 2.70  | 0.860|
| 7    | X₂₂—X₁₇   | 3.36  | 0.861| 22   | X₇—X₃      | 2.67  | 1.227|
| 8    | X₁₅—X₁₆   | 3.17  | 0.754| 23   | X₁₉—X₁₇    | 2.67  | 0.907|
| 9    | X₈—X₁₅    | 3.15  | 0.950| 24   | X₁₀—X₁₂    | 2.62  | 1.205|
| 10   | X₅—X₁₅    | 3.15  | 1.097| 25   | X₁₃—X₉     | 2.54  | 1.100|
| 11   | X₁₇—X₈    | 3.11  | 1.004| 26   | X₁₂—X₄     | 2.50  | 0.993|
| 12   | X₉—X₁₈    | 3.09  | 1.108| 27   | X₁₆—X₆     | 2.33  | 0.826|
| 13   | X₁₅—X₁₇   | 3.04  | 0.844| 28   | X₁₄—X₇     | 2.12  | 1.132|
| 14   | X₈—X₁₇    | 3.04  | 0.963| 29   | X₁₁—X₈     | 2.09  | 0.871|
| 15   | X₂₃—X₁₂   | 3.01  | 0.901|      |             |       |      |

Figure 1. The BBNs model and base-run probabilities for nodes’ states.

The four risk events, namely “defective works and reworks”, “increase of quantities”, “shutdowns”, and “inadequate program scheduling”, have an immediate impact on schedule delay in submarine pipeline projects. Among the four risk events, the probability of shutdown is the highest (67.35%), while the probability of inadequate program scheduling is the lowest (30.77%). The BBNs model described the directed acyclic propagation of critical schedule risks, that 9 top nodes influence the bottom node through 14 middle nodes. As a result, the probability of schedule delay is up to 67.26%.
Table 3. The probability of critical schedule risks.

| Name | Probability | Name | Probability | Name | Probability |
|------|-------------|------|-------------|------|-------------|
| X15  | Occur 0.5802 | X14  | Occur 0.1846 | X21  | Occur 0.3042 |
|      | NotOccur 0.4198 |      | NotOccur 0.8154 |      | NotOccur 0.6958 |
| X19  | Occur 0.4503 | X10  | Occur 0.3302 | X23  | Occur 0.2013 |
|      | NotOccur 0.5497 |      | NotOccur 0.6698 |      | NotOccur 0.7987 |
| X13  | Occur 0.2879 | X8   | Occur 0.7569 | X4   | Occur 0.2192 |
|      | NotOccur 0.7121 |      | NotOccur 0.2431 |      | NotOccur 0.7808 |
| X20  | Occur 0.6823 | X9   | Occur 0.6187 | X3   | Occur 0.3647 |
|      | NotOccur 0.3177 |      | NotOccur 0.3813 |      | NotOccur 0.6533 |
| X11  | Occur 0.2671 | X6   | Occur 0.3457 | X1   | Occur 0.5942 |
|      | NotOccur 0.7329 |      | NotOccur 0.6543 |      | NotOccur 0.4058 |
| X17  | Occur 0.4937 | X5   | Occur 0.2832 | X2   | Occur 0.6735 |
|      | NotOccur 0.5063 |      | NotOccur 0.7168 |      | NotOccur 0.3265 |
| X16  | Occur 0.3029 | X7   | Occur 0.2651 | X18  | Occur 0.3077 |
|      | NotOccur 0.6971 |      | NotOccur 0.7349 |      | NotOccur 0.6923 |
|      | Occur 0.6421 |      | Occur 0.5176 |      | NotOccur 0.6726 |
| X22  | NotOccur 0.3579 | X12  | NotOccur 0.4824 |      | NotOccur 0.3274 |

3.4.2. Reasoning of the interactive relationships among schedule risks. The BBNs model can also be used in diagnostic reasoning. While the status of the bottom nodes “schedule delay” was set to “Occur”, table 4 showed the change of probability of critical schedule risks. Public protests have the greatest impact on schedule delay with a 69.15% probability. And inclement weather has the weakest effect on schedule delay with a 20.36% probability.

Table 4. Changes of the probability of critical schedule risks.

| Name | Changes of the probability | Name | Changes of the probability | Name | Changes of the probability |
|------|---------------------------|------|---------------------------|------|---------------------------|
| X15  | Occur 0.5862 Rate 0.0100  | X14  | Occur 0.1855 Rate 0.0005  | X21  | Occur 0.3088 Rate 0.0151  |
| X19  | Occur 0.4505 Rate 0.0004  | X10  | Occur 0.3638 Rate 0.1018  | X23  | Occur 0.2036 Rate 0.0114  |
| X13  | Occur 0.2891 Rate 0.0007  | X8   | Occur 0.7872 Rate 0.0399  | X4   | Occur 0.2430 Rate 0.1086  |
| X20  | Occur 0.6915 Rate 0.0135  | X9   | Occur 0.6253 Rate 0.0107  | X3   | Occur 0.4265 Rate 0.1695  |
| X11  | Occur 0.2710 Rate 0.0146  | X6   | Occur 0.3694 Rate 0.0686  | X1   | Occur 0.6823 Rate 0.1483  |
| X17  | Occur 0.4985 Rate 0.0010  | X5   | Occur 0.2998 Rate 0.0554  | X2   | Occur 0.7453 Rate 0.1066  |
| X16  | Occur 0.3251 Rate 0.0732  | X7   | Occur 0.2774 Rate 0.0443  | X18  | Occur 0.3277 Rate 0.0650  |
| X22  | Occur 0.6683 Rate 0.0409  | X12  | Occur 0.5581 Schedu le Delay NotOccur 1 |

Suppose the status of the bottom nodes “schedule delay” is set to “Occur”, the probabilities of the following 7 risk events, namely “defective works and reworks”, “change of line”, “variations by owner”, “lack of effective site management”, “overhung and unstable of line”, “design variations”, and “collapse”, change greatly. The changing rate were 0.1695, 0.1086, 0.1018, 0.0732, 0.0686, 0.0661, and 0.0554 respectively. In addition, when the state of schedule delay was already set, the occurrence probability of “increase of quantities” and “shut-downs” are still higher than that of “defective works and reworks” and “inadequate program scheduling”, nevertheless the probability of “shut-downs” increased from 36.47% to 42.65%, namely having a growing rate of 16.95%.

4. Discussions and conclusions
In this research, 3 critical schedule risks were identified in submarine pipeline projects, which can be classified into three categories: project-specific factors, project stakeholder, and project environment.
Based on 29 interactive relationships among 23 critical schedule risks, the BBNs model was built to simulate the propagation process of critical schedule risks and forecast the probability of schedule delays in submarine pipeline projects.

The BBNs model shows that schedule delays risks mainly come from social environment, geological condition, and contractor competency in submarine pipeline projects. At implementation stage of submarine pipeline projects, the backward in operation and management is the most important risk event caused by public protests, which led to deferred start on site and shut-downs.

Furthermore, the general underground parts take about 70% of submarine pipeline projects and triggered a lot of risks. This research has found that complex geological condition plays a pivotal role in schedule delay. From the point of project participants, contractors with inadequate experience makes a negative impact on schedule more strongly than owners, designers, and supervisors. Once the state of schedule delay was already set, the probability of 7 risk events changed greatly, namely “defective works and reworks”, “change of station or line”, “variations by owner”, “lack of effective site management”, “overhung and unstable of line”, “design variations”, and “collapse”. Moreover, the probabilities of “increase of quantities” and “shut-downs” are higher, which have an immediate impact on schedule delay in submarine pipeline projects.

Finally, 9 risk paths were identified and quantified as shown in figure 2. ① “public protest” → “backward in operation and management” → “shut-downs” → “schedule delay”; ② “public protest” → “backward in operation and management” → “design variations” → “change of station or line” → “increase of quantities” → “schedule delay”; ③ “inadequate contractors’ experience” → “lack of effective site management” → “overhung and unstable of line” → “design variations” → “change of station or line” → “increase of quantities” → “schedule delay”; ④ “Inadequate contractors’ experience” → “lack of effective site management” → “overhung and unstable of line” → “defective works and reworks” → “schedule delay”; ⑤ “complex geological condition” → “overhung and unstable of line” → “defective works and reworks” → “schedule delay”; ⑥ “complex geological condition” → “overhung and unstable of line” → “design variations” → “change of station or line” → “increase of quantities” → “schedule delay”; ⑦ “complex geological condition” → “increase of quantities” → “schedule delay”; ⑧ “complex geological condition” → “design variations” → “change of station or line” → “increase of quantities” → “schedule delay”; ⑨ “variations by owner” → “design variations” → “change of station or line” → “increase of quantities” → “schedule delay”.

This research is to identify and quantify critical schedule risk paths in order to simulate the propagation process of critical schedule risks in submarine pipeline projects, thus revealing the interactive relationships among schedule risks.
5. Limitation
Although extensive efforts have gone into this study, limitations are unavoidable. Each node can be assigned more than the two states (Occur and NotOccur) used in BBNs model. Future research could collect objective probability of schedule risk events to validate the interactive relationships.

Moreover, all outcomes ought to be limited to one group of the pipeline stakeholders. The future research was suggested to complement from other stakeholders such as island/shore residents or government departments.

References
[1] Xiaoping L and Jin Z 2017 Formation and distribution characteristics of proterozoic–lower paleozoic marine giant oil and gas fields worldwide Petroleum Science 14(2) L237-260
[2] Li X, Chen G, Zhu H and Zhang R 2017 Quantitative risk assessment of submarine pipeline instability Journal of Loss Prevention in the Process Industries 45 L108-115
[3] Chapman HA 2014 Repair and regeneration of the respiratory system: complexity, plasticity, and mechanisms of lung stem cell function Cell Stem Cell 15(2) L123
[4] Assaf S and Nour M 2015 Potential of energy and water efficiency improvement in abu dhabi’s building sector – analysis of estidama pearl rating system Renewable Energy 82 L100-107.
[5] Assaf SA and Al-hejji S 2006 Causes of delay in large construction projects International Journal of Project Management 24(4) L349-357
[6] Han SH, Yun S, Kim H, Kwak YH and Park HK 2009 Analyzing schedule delay of mega project: lessons learned from korea train express Engineering Management IEEE Transactions on 56(2) L243-256
[7] Choudhry RM, Aslam MA, Hinze JW and Arain FM 2014 Cost and schedule risk analysis of bridge construction in pakistan: establishing risk guidelines Journal of Construction Engineering & Management 140(7) L04014020
[8] Mahamid I 2011 Risk matrix for factors affecting time delay in road construction projects: owners’ perspective Engineering Construction and Architectural Management 18(6) L609-617
[9] Mahamid I 2013 Contributors to schedule delays in public construction projects in Saudi Arabia: owners’ perspective *Journal of Construction Project Management and Innovation* 3(2) L608-619

[10] Luu VT, Kim SY, Tuan NV and Ogunlana SO 2009 Quantifying schedule risk in construction projects using Bayesian belief networks *International Journal of Project Management* 27(1) L39-50

[11] Iyer KC and Sagheer M 2009 Hierarchical structuring of PPP risks using interpretative structural modeling *Journal of Construction Engineering and Management* 136(2) L151-159

[12] Eybpoosh M, Dikmen I and Birgonul MT 2011 Identification of risk paths in international construction projects using structural equation modeling *Journal of Construction Engineering and Management* 137(12) L1164-1175

[13] Luu VT, Kim SY, Tuan NV and Ogunlana SO 2009 Quantifying schedule risk in construction projects using Bayesian belief networks *International Journal of Project Management* 27(1) L39-50

[14] Zhu Z, Hu Y and Guo X 2012 Study on gender imbalanced risks conduction based on Bayesian Networks *Journal of Public Management* 4(12) L99-110

[15] Ryan JJCH, Mazzuchi TA, Ryan DJ, Cruz JJDL and Cooke R 2012 Quantifying information security risks using expert judgment elicitation *Computers and Operations Research* 39(4) L774-784

[16] Akintoye A 2000 Analysis of factors influencing project cost estimating practice *Constr. Manag. Econ* 18 (1) L77–89

[17] Zou PXW and Sunindijo RY 2013 Skills for managing safety risk, implementing safety task, and developing positive safety climate in construction project *Automation in Construction* 34 L92-100

[18] Zou PXW, Zhang G and Wang J 2007 Understanding the key risks in construction projects in china *International Journal of Project Management* 25(6) L601-614

[19] Khodakarami V and Abdi A 2014 Project cost risk analysis: a Bayesian Networks approach for modeling dependencies between cost items *International Journal of Project Management* 32(7) L1233-1245

[20] Khakzad N, Khan F, Amyotte P and Cozzani V 2013 Domino effect analysis using Bayesian Networks *Risk Analysis* 33(2) L292-306

[21] Tam CM, Zeng SX and Deng ZM 2004 Identifying elements of poor construction safety management in china *Safety Science* 42(7) L569-586