A PRACTICAL RISK MANAGEMENT APPROACH FOR IMPOUNDING KARUN 3 DAM RESERVOIR : A REAL-LIFE CASE STUDY IN IRAN

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ABSTRACT

A practical and innovative risk management methodology is implemented for the management of huge bridge connecting Karun 3 hydropower dam reservoir in Iran. Impoundment of large dam reservoirs represents many uncertainties that need to be carefully considered. Risk management is a unique tool in this context. Due to the lack of proper risk management including risk identification, assessment, and monitoring, many projects are facing several problems such as considerable cost/ time increases and delay in project delivery. However, if the risks are identified proactively then the impact of unwanted issues will be greatly reduced. This paper aims at elaborating the implementation of risk management procedure for the construction of Sebalutak cable bridge project using a systematic approach in several steps: step 1) Identification of risks, step 2) Qualitative analysis of the risks in order to prioritize them according to their importance, step 3) Quantitative analysis of the risks, step 4) Make strategy for response to the prioritized risks, and step 5) Monitor and control the risks. Each step will be presented in details and consequent discussions will be provided. The key benefit of this practical risk management was that the Sebalutak bridge was successfully completed on time, within the budget, and requested quality and as such, the Karun 3 dam reservoir was impounded on time and tremendous amounts of time and costs were saved.

Keywords *: risk, assessment, analysis, Bridge Management, Dam Reservoir*

1. INTRODUCTION

Karun 3 dam is an under operation hydropower project, double curve concrete dam with the height of 203 m, and a huge reservoir with the length of 45 KM, as shown in Figure 1. Because the reservoir crossed main provincial roads, many new structures such as bridges, roads, and tunnels had to be constructed over the reservoir before the impoundment. Among the new structures, Sebalutak cable bridge, faced with serious risks and was the most complex and challenging project within which it needed to be completed within the estimated budget, duration, and defined quality, otherwise, the impounding of Karun 3 dam reservoir would seriously face substantial delays and other challenges.

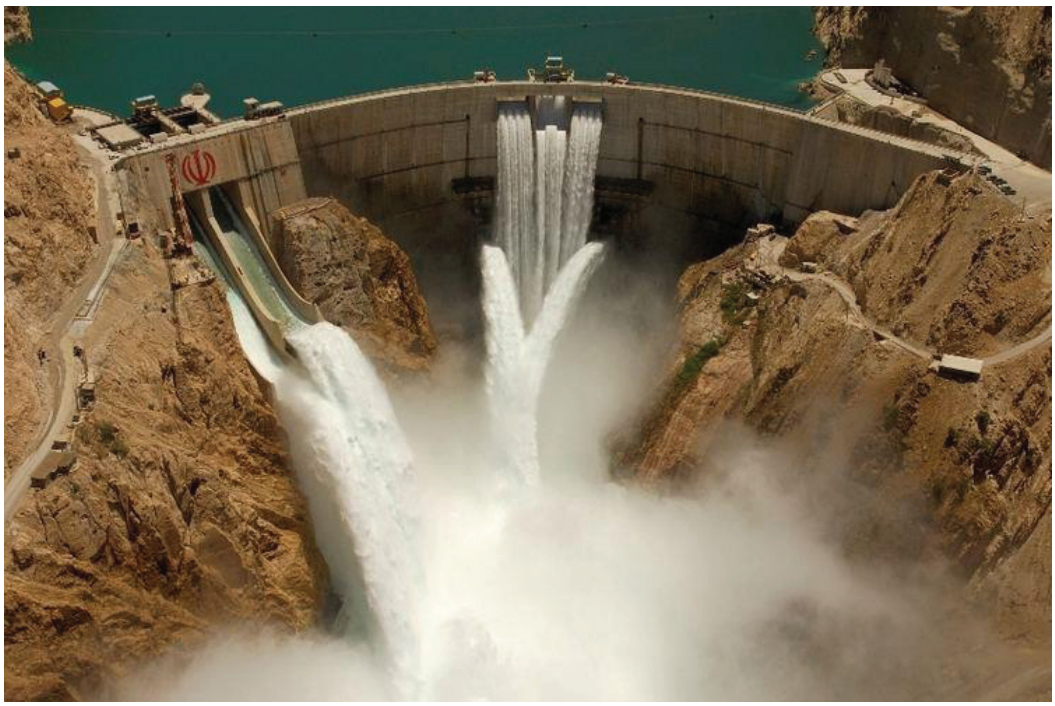

Figure 1 : Karun 3 Dam and Reservoir

In order to overcome the challenges and achieve the project objectives, an innovative risk management methodology was defined and successfully implemented for the bridge project. This paper describes the risk approach including: The proposed risk management for the Sebalutak bridge provided excellent outcomes and benefits during design and execution of the project so that the bridge was completed on time and as such, the dam reservoir was impounded in a right critical timing. Hence the aim of this research is conducting a risk management plan for Sebutalak project (Figure 2).

Figure 2 : Sebalutak Cable Bridge in the Karun 3 Dam Reservoire

2. METHODOLOGY DEVELOPMENT

In order to achieve the aim of this research which is the development of a risk management plan for the Sebutalak project, the following step-by-step approach is carried out:

Step (1) Identifying risks:

120 hours of meeting with stakeholders including client, contractor along with their representatives and consultant has been held. And through brainstorming and lessons learned from similar and past projects, risks have been identified.

Step (2) Analyzing and prioritizing the identified risks:

Through two different methods of qualification and quantification the priorities and score has been allocated to each risk. Initially qualitative analysis and risks with higher priorities are selected for quantitative and more detailed analysis.

Step (3) Preparing response for high-level risks:

People with related knowledge to each category of risks have been invited to meetings and their opinions on appropriate response for the risks have been included.

Step (4) Monitor and control risks:

Different strategies according to the priority of the risks have been defined and specific monitoring plans have been considered.

3. DEVELOPMENT OF RISK MANAGEMENT PLAN

Step (1) identify various types of risks;

A risk management team have been gathered including client, contractor and their representatives along with consultant. Through regular brainstorming sessions, initial risks within projects have been identified. All of the risks mentioned had to be registered within a table named "risk register table". And this table had to be updated regularly.

A risk register table has been prepared which includes RBS (risk breakdown structures). the risks are categorized based on trading, financial, climate change, technical, organizational, HSE, political, access, social, legal, and other indirect impacts. Also the risk register table include cause, risk description, effect, impact score, probability, risk score, status (active, observe and close), owner of risk and response strategy and a risk response plan, as shown in Table 1.

Table 1 : Risk Register Form

Risk Register

Project Name: Sebalutak Cable Bridge

	Response Strategy	Pre- Response: Probability	Impact Schedule(Day)	Impact Cost (Rial)	Risk Score	Probability	Impact Score	Effect	Risk Description	Cause	RBS	Risk ID
1- آموزش به اپر 2- خارج شدن ب	Avoidance	75%	180	10,000,000,000	6.3	0.7	9	از بین رفتن بارج و قطعه، تلفات جانی و تعطیلی کارگاه	سقوط قطعه در حال نصب بر روی بارج	ضعف و یا نقص در ماشین آلات سیستم حمل و بالا رونده	HSE	9E+07
1- انجام مطالعات توسط یک نفر پا کارفرما	Avoidance	65%	180	20,000,000,000	4.9	0.7	7	تخریب و دوباره کاری ،عدم مسئولیت پذیری کار اجرا شده ،	عدم تایید کتبی نقشه های AFC از سوی مشاور کارفرما	مفروضات اولیه طراحی که از جانب مشاور همکار اعلام گردیده و اجرای کار با تایید شفاهی نقشه ها از سوی مشاور کارفرما	مدیریتی و سازمانی	9E+07
1- پیگیری ساخ 2- عقد قرارداد ب 3- تامین نقدینگ 4- پی گیری سری کارگاه(بر اساس 5- ساخت ، حمل 6- شروع نصب 7- اولویت قرارد	Mitigation	70%	60	8,000,000,000	4.9	0.7	7	خسارت ناشی از افزایش هزینه ها نسبت به براورد اولیه	افزایش زمان حضور کارشناسان شرکت خارجی نصب کابل و سیستم کشش بیش از دوماه	تاخیر در روند نصب قطعات فلزی عرشه	مدیریتی و سازمانی	9E+07
اجبار سازنده به جرثقیل بلند کننده	Avoidance	65%	30	5,000,000,000	4.9	0.7	7	از بین رفتن قطعه و تعطیلی کارگاه	سقوط قطعه در حال نصب بر روی دریاچه پس از حرکت بارج	ضعف و یا نقص در ماشین آلات سیستم حمل و بالا رونده	HSE	9E+07
1- استفاده از انف 2- کنترل مضاع 3- اتمام عملیات	Avoidance	75%	30	2,000,000,000	4.9	0.7	7	آسیب دیدگی پایه P2، سرستون، تاورکرین و قالب های سرستون یا پایلون	پرتاب سنگ ناشی از انفجار به سمت پایه و تجهیزات	انفجار محل کوله A2	HSE	9E+07
1- تهیه و تامین 2-کنترل و افزای	Mitigation	45%	90	10,000,000,000	4.5	0.5	9	خسارت مالی و تعطیلی کارگاه	توقف عملیات اجرایی تاورکرین	نقص فنی تاور کرین در حین عملیات اجرایی	HSE	9E+07
1- استفاده از اس 2- عدم تردد ماش 3- پیش بینی جر 4- اصلاح و بهب	Mitigation	55%	180	30,000,000,000	4.5	0.5	9	انجام کار با تاخیر و پرت شدن مواد مصالح و زمان بر بودن تهیه مجدد از خارج از کشور	سقوط کامیون حامل کابل یا غلاف کشش کابل	بارندگی و لغزندگی سطح جاده دسترسی اصلی دهدز به گذر امام زاده شهپیر	اقلیمی و محیط زیست	9E+07
1- انجام مطالعات 2- تهیه طرح تثب 3- اجرای طرح ت	Avoidance	55%	300	50,000,000,000	4.5	0.5	9	ایجاد ناپایداری کلی در سازه در حین اجرا و پس از بهره برداری،تغییر ماهیت طراحی،تعطیلی جبه های کاری و کارگاه،ازبین رفتن کوله A1 و تلفات جانی،	ناشاقولی پایه P1 و تغییر نیروی کابل ها	حرکت و ناپایداری شیرواني منتهی به فونداسیون P1 پس از ساخت پل	فنی	9E+07
1- نصب تابلوها 2- اسکورت بار 3- عدم بارگیری	Mitigation	50%	30	500,000,000	3.5	0.5	7	خسارت مالی و جانی،تاخیر در پروژه	واژگون شدن ماشین های سواری و سنگین	کوهستانی بودن جاده و عرض کم و نداشتن شانه	دسترسی و ترافیکی و حمل ونقل	9E+07

Step (2) Analysis:

The next step is analysing the risks in order to priorities risks and identify risks which are high-level. As a result, qualitative analysis has been used. Though, the risks that need more detailed analysis quantitative analysis have been used later on.

3.1 Qualitative analysis

With respect to the qualitative analysis a score for each risk is obtained. Score include probability of risk occurring as well as the impact of each risk which is allocated based on past experiences and similar projects and through meetings with stakeholders.

Using Table 2 the probability has been considered.

Table 2 : Probability

Level of importance	Probability
Very low	0.1
low	0.3
neutral	0.5
High	0.7
Very high	0.9

Also, the impacts have been assigned using Table 3.

Table 3 : Impact

Level of importance	Impact
Very low	1
low	3
Neutral	5
high	7
Very high	9

The scoring has been achieved using multiplying probability by impact. For the score, more or equal to 4.5 have been considered high and labelled with red color. The scores between 1.5 and 4.5 neutral and yellow color and the ones below and equal to 1.5 have been considered low and shown with green. Hence, a matrix has been plotted, as shown in Figure 3, and Figure 4.

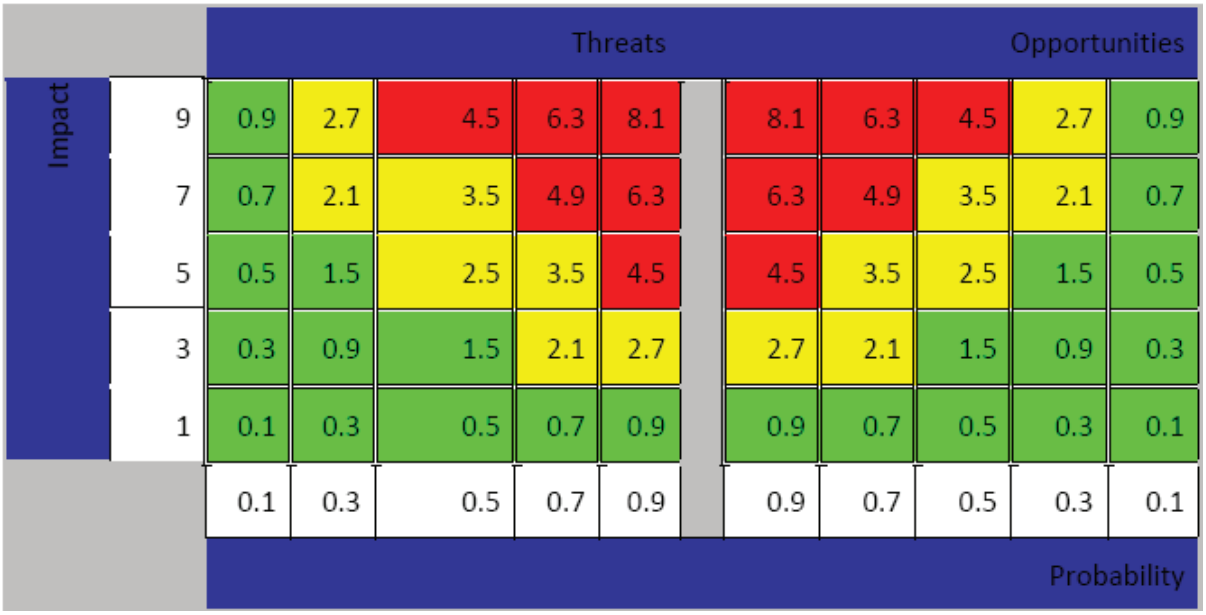

Figure 3 : Probability-Impact Matrix for Prioritizing the Risks

Risk Score	*Probability*	*Impact Score*	*Risk Description*	*Risk ID*
6.3	0.7	9	سقوط قطعه در حال نصب بر روی بارج	94051111
4.9	0.7	7	عدم تایید کتبی نقشه های AFC از سوی مشاور کارفرما	94040603
4.9	0.7	7	افزایش زمان حضور کارشناسان شرکت خارجی نصب کابل و سیستم کشش بیش از دوماه	94040619
4.9	0.7	7	سقوط قطعه در حال نصب بر روی دریاچه پس از حرکت بارج	94051112
4.9	0.7	7	پرتاب سنگ ناشی از انفجار به سمت پایه و تجهیزات	94051120
4.5	0.5	9	توقف عملیات اجرایی تاورکرین	94040630
4.5	0.5	9	سقوط کامیون حامل کابل یا غلاف کشش کابل	94041501
4.5	0.5	9	ناشاقولی پایه P1 و تغییر نیروی کابل ها	94051107
3.5	0.5	7	واژگون شدن ماشین های سواری و سنگین	94040609
3.5	0.5	7	سقوط عوامل اجرایی از ارتفاع به داخل دریاچه کارون ۳ و غرق شدن	94040624
3.5	0.5	7	سقوط تاورکرین	94040628
3.5	0.5	7	عدم تکمیل عملیات ساخت قطعات فلزی مرتبط مطابق با برنامه زمان بندی	94041511
3.5	0.5	7	ناشاقول شدن پایه P1	94041533

Figure 4 : Identifying High-Level Risks

After prioritizing identified risks, for the risks highlighted as high-level and neutral a further the response strategies have to be prepared. It is worth to mention response to risk is the most important part of a risk management plan which is the criteria for assessing the success or failure of a project. And the risks with lower importance are kept in a watch list and investigated regularly to make sure their status have not changed. The next section indicates the quantitative analysis for the high-level risks.

3.2 Quantitative Analysis

In order to undertake quantitative analysis within this paper, Primavera Risk Analysis software has been used. Some opportunities and positive risks as well as negative and threatening risks have been identified. They are briefly discussed below.

Negative or threatening risks;

For the negative or threatening risks, four difference responses strategies such as avoidance, Mitigation, Transfer and acceptance have been considered For further analysis.

Opportunities or positive risks:

For the positive risks and opportunities, three response strategies of exploit, share and enhance have been studied that for each risk one response is finalized.

After developing response strategy plan, quantitative analysis based on time and cost of each risk occurring has been prepared. Also, based on strategy selected for each risk the degree of decreasing probability of risk occurring, cost, time or disappearing within a project have been analyzed. And based on these analyses the risk register table will be updated.

However, using Primavera analysis, there is an opportunity to develop three different scenarios according to the risks, as shown below:

(1) Initial plan which aims to deliver project on time and within budget and no risk is identified.

(2) Pre-mitigated impacted: risks have been indicated however no response plan have been considered. Only negative or threatening risks in their worst scenario will cause project to face problems.

(3) Post-mitigated impacted: within this assessment, risks along with their responses have been considered, hence since there is a response plan, the probability of risk will be considered as none, therefore the cost of actions in order to respond to the risks will be added to the total cost of the project.

The result of analysis shows risks with higher priority, based on pre-and post-mitigated situation are different. For these two different scenarios of pre and post mitigated high-level risks according have been anaylsed based on time and cost.

4. DISCUSSIONS

The risk management plan for the Sebutalak project has been done according to guideline of PMBOK, 2016. Initially, a qualitative analysis has been done using brainstorming sessions with stakeholders. And a final score by multiplying probability and impact of each risk have been obtained. As a result, 8 risks have been marked as high-level as shown in Figure 4. The risks with higher priorities include sections falling while constructed on barge, lack of written approval of AFC maps from client's consultant, falling of elements on the lake after moving the barge, facilities' breakdown, tower crane, failure of trucks carrying cables and change in cable forces. Also, 50 risks with neutral importance have been highlighted. For both high-level and neutral risks, response plan for each risk is prepared. Furthermore, a quantitative analysis has been done, including assessing the impact of each risk on cost and time of the project, along with their performance either mitigated or not.

Within this research, the analysis of impacts of risks on duration and cost of project has been evaluated using Primavera software. The analysis was carried out by the software in two approaches: 1) the impacts of risks itself; 2) the impact of risk on time and cost of the project.

Assessing the impact of risk on duration of the project, if all the risks occur on critical path and they have the maximum delay, the project can delay up to 1418 days. In the other words, the project will delay around 70%. However, if we are optimistic and accept 20% of risks, this could change to 1333 days and 61% increase. This huge increase is very significant and an appropriate response to them has to be considered.

Based on sensitivity analysis of risks according to time and cost either pre-or post-mitigated, the project management team decided that the most influencing factors on timing of the project are the risks related to the force in the cables, misalignment of columns, falling of materials, and tower crane related issues. However, in post mitigated situation, lack of adequate quality of structural elements, misalignment of base, falling of elements and tower crane issues are the most critical one. This change of order of risks is related to the response plan.

The analysis of the research based on quantitative analysis in pre-mitigated form proves that the identified risks can impact the cost of project up 120%. Also, there is 80% chance that project cost will increase up to 71%, and all of these facts and figures are as a result of risks identified within this research.

Post mitigated analysis shows that the response plan prepared could decrease the cost of risks significantly and up to 95% of project could finish with 50 million USD. It is worth to mention that this cost increase is only feasible if response plan is considered, otherwise the cost would remain as it has been said.

The analysis of time and cost of the project based on the scatter graph shows the interrelationship between time and cost of the project, meaning that if time of project extends certainly there would be cost increase. Another finding of this graph shows that the success of the project is based on specific time and budget. This means that if the project is planned to be done within 32 month, 960 days and 50 million USD, the chance of its success is 74%.

Considering the high importance of response plan, analysis and assessment of responses, comparison of the Monte Carlo analysis of pre-mitigated and post mitigated, we could have a clear understanding of pre-and post-mitigated situation.

Compared to distribution analyser, using two different scenarios the impact of response plans could be evaluated. Scenario 1: pre-mitigated plan which only measures the impact of time and cost of risks without response plan, and Scenario 2: post mitigated plan which evaluated the impact of time and cost of project without a response plan. Also, the cost of response plan has been added to the total cost of the project, which indicates that if a response plan is considered, there is 80% chance that timing of the project with will decrease up to 1 year. For reducing the cost based on response plan it is essential to considered thee cost increase or decrease to be assessed. This means that 80% of responses, 24.7 million USD costs of project which might arise from the risks could reduce. In overall, it could be realised that from comparison of Monte Carlo analyses, the three response plan could be a better decision.

Using Primavera software and pre-and post mitigated analysis shows a clear indication of the impact of responses, and in overall, it could be seen that if the response plan is prepared there is 80% chance, the cost of the project could reduce to 18.75 million USD.

It is worth to mention that the lack of using proper risk management could delay this essential and massive project of water and power plant up to 70% compared to the initial plan, and, the cost could increase up to 120%. Though the process of the identification of risks, quantitative and qualitative analysis as well as a proper response plan, there would be 80% chance to reduce delay of the project to 17% and only 11% cost increase compared to initial plan (Figure 5).

				Post- Response					Project Name: Pre- Response				
Work packag name ...SP ID	Budgeting for Response	START	Timing	Probability	Impact Schedule (Day)	Impact Cost (Rial)	Risk response plan	Response Strategy	Probability	Impact Schedul (Day)	Impact Cost (Rial)	Risk Score	Risk ID
نصب قطعات فلزي عرشه	2,500,000	94/09/01	30	0%	180	10,000,000,000	1- آموزش به اپراتور بارج جهت خارج شدن از زیر بار 2- خارج شدن بارج از زیر بار به محض بلند شدن بار از روی بارج	Avoidance	75%	180	10,000,000,000	6.3	####
خدمات طراحي و مهندسي	2,000,000,000	94/08/15	60	0%	180	20,000,000,000	1- انجام مطالعات ژئو تکنیک و ارائه گزارش نهایی به کارفرما 2- مدیریت ژئوتکنیک توسط یک نفر پاسخگو در دستگاه پیمانکار و ارتباط کاری مرتبط با مشاور همکار و کارفرما	Avoidance	65%	180	20,000,000,000	4.9	####
نصب قطعات فلزي عرشه	1,000,000,000	94/08/15	60	5%	60	8,000,000,000	1- پیگیری ساخت و ارسال سریع ورق عرشه از فولاد اکسین 2- عقد قرارداد با شرکت صنایع فلزی ایران 3- تامین نقدینگی مورد نیاز 4- پی گیری سریع شروع ساخت قطعات فلزی و ارسال سریع قطعات ساخته شده به کارگاه(بر اساس زمان بندی ابلاغی) 5- ساخت ، حمل و نصب قطعات صفر و زوج قطعات یک و دو(قبل از خرداد 1395) 6- شروع نصب کابل ها پس از اجرای سه لیفت از بخش نهایی پایلون 7- اولویت قراردادن تخصیص منابع اجرا به پایلون ها نسبت به سایر عملیات اجرای بتن	Mitigation	70%	60	8,000,000,000	4.9	####
نصب قطعات فلزي عرشه	3,000,000,000	95/03/01	60	5%	30	5,000,000,000	اجبار سازنده به مجهز نمودن سیستم پارا شوت (ترمز اضطراری برای سیستم گیربکس جرثقیل بلند کننده قطعات)	Avoidance	65%	30	5,000,000,000	4.9	####
کوله A2	100,000,000	94/09/01	30	0%	30	2,000,000,000	1- استفاده از انفجار خفیف(کنترل شده) 2- کنترل مضاعف واحد HSE 3- اتمام عملیات انفجاری قبل از نصب قالب جهنده	Avoidance	75%	30	2,000,000,000	4.9	####
پایلون P1 , P2	600,000,000	94/08/01	30	5%	10	1,000,000,000	1- تهیه و تامین قطعات يدكي مهم و حساس تاورکرین 2-کنترل و افزایش بازدیدهای دوره ای (هر دو هفته یکبار)	Mitigation	45%	90	10,000,000,000	4.5	####
تامین اقلام خارجي	500,000,000	95/01/15	60	5%	180	30,000,000,000	1- استفاده از اسکورت جهت بارهاي خاص 2- عدم تردد ماشین با بارخاص در زمان بارندگي 3- پیش بینی جرثقیل یا ماشین آلات سنگین جهت مهار 4- اصلاح و بهسازی مسیرهای دسترسی قبل از حمل	Mitigation	55%	180	30,000,000,000	4.5	####
پایلون P1	###########	94/08/15	90	0%	300	50,000,000,000	1- انجام مطالعات ژئو تکنیک 2- تهیه طرح تثبیت و پایداری شیروانی 3- اجرای طرح تثبیت قبل از نصب اولین کابل	Avoidance	55%	300	50,000,000,000	4.5	####
بخش P,C	100,000,000	94/08/01	10	2%	30	500,000,000	1- نصب تابلوهاي هشداردهنده درمسیر 2- اسکورت بارهاي خاص مانند قطعات فلزي عرشه ، کابل و ادوات مربوطه 3- عدم بارگیری و حمل در زمان بارندگی با توجه به اطلاعات هواشناسی	Mitigation	50%	30	500,000,000	3.5	####
پایلون P1 , P2	300,000,000	94/08/01	30	2%	60	2,000,000,000	1- رعایت موارد ایمني شامل بستن کمربند نجات ، پوشیدن جلیقه نجات و . . . 2- سختگیري کارگاهي و برخورد عوامل ایمني با افراد خاطي(جریمه نقدی پیمانکارو یا اخراج عوامل اجرایی در صورت عدم رعایت)	Mitigation	55%	60	2,000,000,000	3.5	####

Figure 5 : Risk Response Strategy for High-Level Risks

5. CONCLUSIONS

This paper presented an innovative risk management approach that was implemented for the construction of a large cable bridge (named as Sebalutak) which has been built over Karun 3 HPP dam reservoir. All steps to complete the approach was step by step explained and the techniques and tools used, was conveniently presented. The risk management team spent 120 hours in total to identify 114 risks. Eight risks were identified as high-level risks, 54 neutral risks, and 52 lower importance. After identification and prioritizing risks, appropriate risk response strategies have been defined and based on each response strategy, necessary actions took place.

Based on quantitative analysis for the risks with higher priorities, it can be concluded that the lack of proper risk management could significantly delay the project and as such, the cost of the bridge project could increase between

70% and 120%, compared to the initial budget of the project. It was also discussed that completing the proposed risk management approach could considerably lower the mentioned percentages between 17% and 11%, accordingly.

Based on this practical and fruitful approach, it is recommended that when constructing the massive projects of power and water resources, there are always ongoing related projects such as bridges or dam along with them which facilitates easy access and connection within the area and is a responsibility of contractor or operating companies. Delay in constructing required structures such as bridges could postpone the dam impoundment process. Hence, it is required to pay careful attention to the construction of related structures such as bridges connecting reservoir and considering and managing their associated risks. In this research, the process of Sebutalak bridge construction, which is constructed over karun 3 dam lake, was completed according the risks and many uncertainties in such complicated projects. One of the main results of this methodology was the change of procurement and based on risks of the project, the bidding process changed. If the risk management had not been carried out for the Sebalutak project, it would have totally different adventure and even, the Karun 3 dam operation would be failed.

REFERENCES

PMBOK, (2016), Project Management Body of Knowledge (PMBOK) Guideline, Published by Project Management Institute (PMI), Pennsylvania, the USA.