A Risk Methodology and Tool for Managing Risks incurred in Large Scale Construction Projects

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Abstract

In large scale construction projects, risks can be incurred by project stakeholders (owners, contractors, consultants, and other private and public entities) in different phases and with different scale of magnitudes. Thus, effective controlling and managing risks are mandate for all project stakeholders. This paper presents a risk management methodology and the development and application of a risk tool for risk control and management of large scale construction projects. An real example of how to manage risks in a Design and Build Project for a Drinking Water Treatment Plant is presented to show the usefulness and applicability of the methodology and the tool.

Keywords: risk control; risk management; water treatment plant, design and build

1 Introduction

In large scale construction projects, there exists a vast number of uncertainties and potential hazards that if they are occurred, would lead to significant consequences and losses. As uncertainties of events and hazards occur in a certain range of probability, risks are then the multiplication of the probability and measurable consequences the hazard events might trigger. In order to minimize and mitigate risks incurred in a large scale construction project, which are the mandate of all project stakeholders (owners, contractors, consultants, and other private and public entities), a feasible risk management methodology must be tailored to suit the expectation of stakeholders regarding the requirements for risk management. Moreover, a risk tool must be developed based explicitly on the used methodology to be appropriately used in practical situations.

2 Background

Risk management is one of the important pillars of project management [PMI, 2003]. This is practically true for a large scale construction project, in which stakeholders of the project have to confront with daily hazard events and threads that could potential cause considerable loss (e.g. fatality due to accident in construction phase, increasing of CAPEX due to non-optimal design due to the lack of value engineering). Risks are distributed in all phases of a project (e.g. design, construction, and commission) and incurred by different stakeholders with different scale of magnitude. For example, in design and build of a large

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scale water treatment plant, the design and build contractor is required to energize equipment, machine, main switch-gear to test and synchronize them together. This task might cause a certain hazard such as electric shock that can eventually lead to fatality or cause a short circuit issue that might damage entirely a new and expensive equipment. The contractor might face a huge loss if such an event occurs. Not only him/her, the project might be delayed that subsequently affect the expectation of Owner in term of project delivery. In brief, different stakeholders see a particular hazard event in their own perspectives, from the likelihood of that event to the consequence it might cause.

When considering such a diverse distribution of risks incurred by stakeholders, it is the task of project managers and project directors as well as the entire project team to come up with a unified risk management plan that serves all stakeholders. Simply because, if any risk occurs, it will negatively affect all stakeholders regardless of how small or large the consequence might be incurred.

Theoretically and practically, there are two distinct risk management methodologies: 1) the qualitative risk management method; and 2) the quantitative risk management method. Over the last decades, a large volume of research papers and books has been documented on these two methodologies. Thus, here, an overview of these two methodologies is skipped. Readers can refer to the definition of these two methodologies in the works of [McNeil et al., 2011], which is a good reference book on the risk topic. For the sake of readers, in this section, we focus on describe the limitation of existing practical quantitative methodology so as to position the scope of work and contribution of this work.

In mathematical term, risk is the multiplication of probability (likelihood) and consequence. In this view, in order to evaluate any risk, both the values of probabilities and consequences must be obtained. The probability space is in the range from 0 to 1 and the space of consequence, ideally, should be measurable in monetary units.

With regard to the estimation of probability of a hazard event, it is, practically, not a straightforward process as the derivation of probability must come from either a deterministic function or from statistic numbers, which again require the analysis of historical data. As a matter of fact, historical data of a new project is not existed. Also using case-base reasoning on the historical data of other projects might only give a hint, but not a absolute value. In summary, it is not practically to use the probability space in managing risks of a construction project.

Similarly, consequence requires also the precise calculation of loss in monetary units. Many scholars and practical engineers have an argument that there is thing that cannot be quantified as monetary unit. However, from mathematical point of view, things that cannot directly converted into monetary units can be indirectly convert to monetary units using the concept of willingness to pay [Breidert, 2006, Adey et al., 2012]. Unfortunately, even if the concept of willingness to pay is applied, it is impractically to precisely capture the values of loss.

Taking into consideration of these two points, for practical implementation of risk control and management, engineers and managers use a simplified way to define the probability and consequence. The probability is defined as likelihood with a discrete range value $i = 1, 2, \cdots, I$ (I is the maximum integer value of the range). The space of consequence is also defined in a discrete range $j = 1, 2, \cdots, J$ (J is the maximum value of the range). The definition of value in the range can be, for instance, for likelihood $i = 1$ can infer to unlikely to occur and $i = 5$ can be inferred to almost certain to occur; for consequence $j = 1$ can infer to minor loss and $j = 5$ can be infer to catastrophic loss. For further description of these ranges, example of a scale using for both likelihood and consequence given in Table 1 is referred. Note that the size of the scale of the likelihood and consequence might not necessary to be the same.

Conventionally, if follow the true definition of risk as the multiplication of likelihood and consequence, the space of risks must be in a matrix with its size of $I \times J$ with minimum value of 1 and maximum value of $I \times J$. An example of the risk matrix is given in Table 2.

As can be seen in Table 2, values of risks come directly from multiplication of the likelihood and

Table 1: Example of likelihood and consequence scales

Likelihood		Consequence	
Scale	Definition	Scale	Definition
$i = 1$	Very unlikely	$j = 1$	Minor
$i = 2$	Unlikely	$j = 2$	Major
$i = 3$	Possible	$j = 3$	Severe
$i = 4$	Likely	$j = 4$	Critical
$i = 5$	Almost certain	$j = 5$	Catastrophic

Table 2: Example of risk matrix (direct multiplication method)

Likelihood	Consequence				
	$j = 1$	$j = 2$	$j = 3$	$j = 4$	$j = 5$
$i = 1$	1	2	3	4	5
$i = 2$	2	4	6	8	10
$i = 3$	3	6	9	12	15
$i = 4$	4	8	12	16	20
$i = 5$	5	10	15	20	25

consequence. This multiplication gives results or risk levels in a symmetric matrix. This matrix inherits a major issue. For example, when $i = 2$ means the hazard event is unlikely to occur and when for the same event $j = 4$ as consequent, eventually, the risk level is 8 (2×4). However, when $i = 4$ and $j = 2$, the same risk level of 8 (4×2) is seen as the result. This cannot be true in practical situation.

This work is formulated in order to overcome this limitation in practical situation. The remaining part of the paper is organized as follows: Section 3 describes the developed methodology in brief and presents the development of a risk tool using excel VBA [1]; An example of risk plan implemented for a real world project using the tool is detailed in section 4. The last section gives a conclusion and highlight the applicability and usefulness of the work.

3 The Methodology and the risk tool

In favor of previous works on developing risk management plans, an improvement is made on the definition of the space of the risk. It is believed that the value of risk for practical context, cannot be a direct multiplication of the likelihood and the consequence. Instead, the value of risks should be defined as a combination of the intensity and consequence. Here, the word "likelihood" is no longer in use to avoid the confusion with the probability space. In fact, the intensity level of risk is more or less the right word to be used as it can be both qualitatively and quantitatively measurable.

When the value of risk is the combination of intensity and consequence, direct multiplication is no longer existed, instead users have their own freedom to define the range of risk according to their own experiences. For example, the values of risk matrix can be the values as shown in Table 3

A direct comparison in the value of risk matrices shown in Table 2 and Table 3 shows that fundamentally, values associated with risks as a combination of the intensity and consequence are significant different from that defined as a multiplication. For example, in the former risk matrix the combination of $i = 2$ and $j = 4$ is $k = 8$. However, in the later risk matrix, such combination gives the risk value of $k = 15$, which is much higher than $k = 8$.

The risk management methodology follows industrial lead procedure with the modification to suit the scope. The overarching risk management methodology is depicted in Figure 1 with detailed steps

[1]Excel is the spreadsheet program developed by Microsoft Corp. and VBA is the abbreviation name of Visual Basic language program

Table 3: Example of risk matrix (combination method)

Likelihood	Consequence				
	$j=1$	$j=2$	$j=3$	$j=4$	$j=5$
$i=1$	1	3	10	13	14
$i=2$	2	5	11	15	19
$i=3$	4	6	12	17	23
$i=4$	7	9	18	21	24
$i=5$	8	16	20	22	25

described herewith

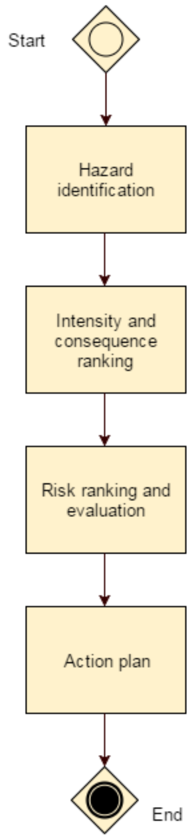

Figure 1: overarching risk methodology

As can be seen from Figure 1, the risk management plan involves four main work packages: 1) Hazard identification; 2) Intensity and consequence ranking; 3) Risk ranking and evaluation; and 4) Action plan. These work packages are supported with the steps described herein.

The step by step procedure for registering and evaluating hazard events and associated risks is itemized as follows

- Step 1: Register the hazard event into a designated field of the risk register table. Describe it as clear as possible and try to eliminate any ambiguity description of hazard,
- Step 2: Register in words the consequences such hazards can bring into the project. This is important step as the description of consequence will provide stakeholders an insightful understanding on the impacts that hazards can cause,
- Step 3: Define the levels of intensity and consequences for registered hazard events. These levels are considered when the hazard events have not been mitigated.

- Step 4: Register the current measurement (if any) against hazard events
- Step 5: Define the levels of intensity and consequences for registered hazard events in the case of having the measurement.
- Step 6: Frequently monitor the hazard events and their associated intensity and consequence to verify whether or not the levels reflecting the reality
- Step 7: Register the mitigation action/plan to minimize or eliminate hazard events. Mitigation action must be described in clear wording and must reflect what actually implementing on the construction site or in the office.
- Step 8: Define the levels of intensity and consequences for registered hazard events in the case of having the mitigation action implemented.

The work packages and steps above should be placed in a continuous process for total quality management. It has a direct link to the Deming cycle (Plan-do-Check-Act) [Walton, 1986], and it is advisable for all stakeholders of the project to implement the cycle . An illustration of a Deming cycle for risk management is shown in Figure 2

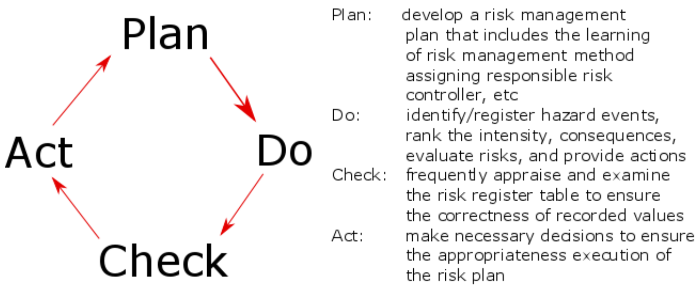

Figure 2: Deming cycle for risk management

A risk management tool has been developed to allow project's stakeholders to actualize the risk management practices for any project. The tool was developed in Microsoft Excel environment, with codes in Visual Basic format. Users can download the limited version and the code on the Github site [2]. The details of the tool are presented along with the example in Section 4.

4 Example

4.1 Project overview

The project is to Design and Build (D&B) a new Water Treatment Plant with capacity of XXX million liter per day (MLD) in an urban area of Metro Manila, the Philippines. With the capacity of XXX MLD, the project is a relatively large scale project and involves three (3) major stakeholders: 1) the Owner is a Water Services company, who invests and later operates and maintains the Plant; 2) the D&B Contractor, who is an international consortium formed of a world reputable water engineering corporation and a local partner; 3) GHD Ply Ltd, who is the Consultant of the Owner and acts act in the project in the position of Owner's Engineers (OE). Other stakeholders include private and public entities and local people living in the vicinity of the project. The project has been scheduled to complete in two (2) years, including Design phase, Construction Phase, Testing and Commissioning.

[2] `https://github.com/namkyodai`

Table 4: Definition of intensity levels

Scale	Intensity level	Definition
1	Very unlikely	Very unlikely, it can be assumed that it may not be experienced
2	Unlikely	Unlikely to occur
3	Possible	Possible sometime during the project
4	Likely	Likely to occur
5	Almost certain	Almost certain to occur

Table 5: Definition of consequence levels

Scale	Consequence level	Definition
1	Minor	Could result in injury or illness and not resulting in a lost work day. Small variation, delay of 1 day or less
2	Major	Could result in injury or illness resulting in one or more lost work days, financial loss to XXX million Peso, delays up to 2 weeks
3	Severe	Could result in permanent disability, major financial loss, severe project consequences to time (delays greater than 2 weeks up to 2 months) losses up to XXX million Peso
4	Critical	Could result in disability, great financial loss, serious project consequences to time and budget exceeding 2 months
5	Catastrophic	Could result in fatality, irrecoverable financial loss, project shutdown

As part of the requirements of the Owner, the Consultant is the one to facilitate the risk management task. However, to be clear, risk management is the responsibility of all stakeholders. Each stakeholder is on his/her own foot to take care of the four main tasks in risk management i.e. 1) Risk identification; 2) Risk ranking (including the evaluation on the likelihood and consequences); 3) Risk Evaluation; and 4) Risk mitigation.

4.2 Intensity, Consequences, and Risk definitions

4.2.1 Intensity

The intensity of an hazard event is defined in a range of 5, with 1 is the lowest level of intensity (very unlikely to occur) and 5 is the highest level of intensity (Almost certain to occur). As mentioned in section 3, the intensity is a qualitative level of measuring how likely the hazard event can occur. It links directly to the likelihood (or probability). However, as probability value is hard to be quantified. It is practical to use a discrete scale to represent the quantitative nature of the probability. The range of 5 is good enough to represent the nature of likelihood as it is easy for managers and practical engineers to capture the sense of likelihood. The definition of the intensity is given in Table 4.

4.2.2 Consequences

The consequence of an hazard event is also defined in a range of 5, with 1 is the lowest level of consequence (minor) and 5 is the highest level of consequence (catastrophic). As mentioned in section 3, the consequence is a qualitative level of measuring how the magnitude of lost incurred if a hazard event occur. Lost can be understood either as non-monetary units or monetary unit. In many practical cases, it is not straightforward to explicitly define an absolute value of monetary units for a level of consequence. In this regard, a better approach is to describe the consequence in an understandable definition for managers and engineers to capture the sense of how consequence will be after an occurrence of a hazard event. The definition of consequence used for the project is detailed in Table 5.

Table 6: Definition of risk levels (risk matrices)

Intensity	Scale	Consequences				
		Minor	Major	Severe	Critical	Catastrophic
		1	2	3	4	5
Almost Certain	5	8	16	20	22	25
Likely	4	7	9	18	21	24
Possible	3	4	6	12	17	23
Unlikely	2	2	5	11	15	19
Very unlikely	1	1	3	10	13	14

4.2.3 Risk matrices

By true definition, risk is the multiplication of probability and consequences. This infers that both probability and consequences must be measurable. In addition, the probability must take a space between 0 and 1 and the consequences must be measurable in term of lost in monetary units. However, as earlier mentioned in section 3 and subsections 4.2.1 and 4.2.2, the risks being considered in this project are not a direct multiplication of the scale as it will be wrong to do so. Thus, for practical use, the implication of multiplication should be translated into combination. The use of combination will more or less reflect the distribution in the level of risks. The definition of risks as a set of combinations of the scale of the intensity and the scale of consequence is given in Table 6.

For the purpose of visualization, each level of risk is coded with a distinct color, which is also depicted in the table. These ranges of colors associated with risks will be used to pain the background of cells. Users can define their own choices of colors by directly change the background colors in the risk matrices of worksheet "definition" of the risk tool. This range of colors will later be used to provide eye-catching visualization of risks in the "risk register worksheet" and "risk profile worksheet", which will be shown in sub-sequence subsections.

4.3 Risk Register

As a matter of fact, as the project progresses daily, weekly, and monthly, the levels of intensity associated with hazard events will change and so does with the levels of consequences. The changes in the level of intensity and consequence for each risk can happen based on the nature of the works, the current measurement against such hazard events, and the actual implementation of risk mitigation action. Such changes must be recorded and evaluated in "risk register" worksheet.

The risk register worksheet is the work space that users can enter/register new hazard event per row. Upon registering new hazard event, users can define its the current measurement against such event as well as the mitigation action to mitigate or minimize the exposure of risk. In a nutshell, there are 3 distinct fields (unmitigated, current, and mitigated) for each hazard event. Along with these fields are levels of intensities and consequences.

As the matter of fact, the level of intensity and consequence must be in descending order. For the sake of demonstration, a typical hazard event is given herewith. For example, during the construction phase, it is always likely that major accident can occurs, this is safety issue and such a hazard should be registered with a highest level of intensity (5 is the highest level in intensity scale). Impacts or consequences incurred as a result of the accident can be a fatality loss, which imposes a serious thread to all stakeholders and might cause not significant delay of the project and therefore the level of consequence is 5. The combination of 5x5, per the definition Table 6, is 25. Next the users check the if there exists a set of measurement against such a safety issue. Measurement against safety issue is normally written in the form of safety and occupational health guideline. This guideline is, in most of the case, imposed to all

Table 7: Grouping and classifying hazard events

Risk categories	Team	Chair person
Approvals	A	
Planning, scoping	A	
Stakeholders	A	
Commissioning	B	
Detailed design	B	
Construction	C	
Procurement	C	
Delivery	D	
Environment	D	

stakeholders and they have to read/learn it before entering the construction site for executing the works. This means, thanks to having the measurement, it is expected that both the intensity and consequences can be reduced to a certain level (e.g. levels of intensity and consequence are 4 and 5, respectively). The last step in this process is to implement the practical action against the hazard (e.g. assign safety controllers to different areas of work, strictly impose the safety and occupational health plan, weekly or monthly organizing short on-site safety meeting).

Aside from the steps described in earlier section, users can have their flexibility to register each hazard under a set of categories and assign risks to be under specified stakeholders for convenience of monitoring and control. An example of how to organize such a set of categories is shown in the Table 7 Having such a set of categories will also provide convenience for project managers and project directors to organize regular interim risk workshops and give a clear message of risks to each and every team, who must be responsible for implementing an effective risk management plan.

An extracted part of the risk register worksheet for the project is shown in Figure 3.

4.4 Risk Profile

Risk profile is a worksheet summarizing the results of all previous steps described in subsection 4.3. Further than that, it has been designed to provide a graphical visualization of risks, which serves as a good way to describe the importance of each and every risk incurred in any phase of a project. The graphical representation of risk provides an ease for project managers and directors to summary the risks and action plans in a report form, which is often required by the Owners.

An extracted part of the risk profile worksheet for the project is shown in Figure 4.

5 Conclusion

This paper presents a risk management methodology and a risk tool that can be used for risk control and management of large scale construction projects. The methodology was developed aiming for practical application. The methodology is different from the conventional methodology in the way of defining risks as combination of intensity and consequence but not on the multiplication of likelihood and consequence, which has been proved to be incorrect. A risk tool was developed using Excel VBA and is released as an open source code for educational purposes. It has a friendly user-interface to help project managers and directors as well as engineers to implement risk management plans in practical situation. The methodology and the tool has been successfully implemented for a large scale construction project (Design and Build of a drinking water treatment plan with a capacity of XXX MLD) in Metro Manila, the Philippines.

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Ref	Team	Risk Category	Brief descriptor	Hazards/Threads	Potential Consequence	Unmitigated			Current Risk reduction measurement	Current			Prepared risk reduction measurement	Action by	Action time (days)	Action status	Mitigated		
						L	C	Risk		L	C	Risk					L	C	Risk
1	A	Approvals	Change in regulations impacts outfall	Change in regulations impacts outfall for brine	Project is suspended for consideration of next steps.	4	5	24	SCOTV need to submit application for discharge permit + engineers report ASAP Unknown outcome at this time.	4	5	24	MWCI engagement with LLDA as the proponent to establish impacts of new regulations. SCOTV coordinates on permit Proposal is to submit discharge permit for review and approval before the new regulations are adopted by LLDA.	Michael Rubio	ASAP	Commenced	2	2	5
15	B	Detailed Design	Late completion of geotech	Late completion and approval of geotech report	Resulting in - late submissions of DED drawings resulting in delay construction works particularly on slope protection	5	4	22	Open Areas - Intake Channel Detaield Design, Intake Access Road Design, Pipelines and Outfall	3	3	12	SCOTV to complete detailed designs and expedite constructrion of critical areas.	Abe Pacleb	Ongoing	Commenced	2	2	5
26	C	Construction	Raw Water Pipeline Route	Raw Water Pipeline Route selected along original Barangay Road	Delays in construction due to limitations and constraints of the route include utility relocations, management of impacts to residents, temporary works, and so on.	5	4	22	Currently awaiting submission, review and approval of detailed designs Preliminary method statements completed Initial engagement with residents	4	4	21	Provision of detaield design and appropriate construction methodology and equipment. Construction planning and schedule. Adequate Resources	Mike Cunanan	ASAP	Commenced	3	3	12
9	A	Approvals	Transmission of wrong file	Transmission of wrong file (not updated file) or incorrect standards adopted in the design or incorrect calculation	Misinformation and rework	4	5	24	Currently not consdiered to be a majot project risk.	3	3	12	Weekly report should be accomplished. GHD should ensure document control numbering in place to ensure accurate file and timely submission of report is achieved. Workshop between GHD and MWCI to present report (e.g. twice a month)	Sheila Tumang	Ongoing	Commenced	2	2	5
48	D	Delivery	Poor performance of sub-contractors	Poor performance of sub-contractors results in increased costs and/or delays - Structural Design	Resulting in - Increased cost and time, re-work and delays	5	4	22	Schedule Performance Risk Remains SCOTV to ensure inter-discipline review of the structural design SC+OTV resources engaging with Subs.	4	3	18	Schedule monitoring and control Subcontractor commitment Resource review and checking	Abe Pacleb	Ongoing	Commenced	3	3	12
55	D	Environment	Contaminants from construction site	Contaminants from construction site run-off resulting in environmental pollution and/or water quality issue. - Dregding - Raw Water PS/ Intake Works - Outfall works	Resulting in - Pollution clean up costs, delay, rectification works, compensation.	5	4	22	Sheet Pile Coffer Dam for the RWIPS Wetwell We do NOT have solution for Intake Channel of Outfall construction yet. Required to settle the detailed design of Intake and Outfall to scope dredging contractor.	4	4	21	Identify appropriate means and methods to prevent dsicharge of sediments in the lake.	Mike Cunanan	ASAP	Not commenced	3	3	12
56	D	Environment	Dust and Noise	Environmental Impacts: - Dust - Noise	Resulting in - Community Impacts	5	4	22	Make sure we have a dust and noise control plan? Planning to install well for water supply for dust control.	4	4	21	Implement EMP & Dust Mitigation Plan Implement EMP & Noise Mitigation Plan Ongoing Envionment Auditing	Mario Valentos	ASAP	Commenced	3	2	6
11	A	Approvals	Difficulty in internal quality check	Difficulty in internal quality check within SCOTV within limited time	Delay in submission of approved plans	4	4	21	SCOTV need to formalise the interdiscipline review process for final designs.	4	4	21	Close coordination between SC & OTV to finalise plan	Esmael	ASAP	Commenced	3	2	6
12	A	Stakeholders	Complaints from stakeholders	Complaints from external stakeholders (e.g. fisherfolks, local residents, LGAs)	Media exposure	4	4	21	Ongoing engagement with affected communities	4	3	18	Coordination with MMT team Planning of stakeholder engagement, stakeholder mapping Good documentation of stakeholder engagement	Mario Valentos	Ongoing	Commenced	3	2	6
20	B	Detailed Design	Delaying Detaield Design	Delay in the detailed design of one discipline eg structural	Resulting in delays in other discipline including testing and commissioning	4	4	21	Ongoing design coordination within SCOTV	4	4	21	Prioritise design submissions and approvals, conduct frequent workshops, coordination with other disciplines Monitoring of design progress to Code 1 Ongoing review of schedule impacts Effective interdiscipline review	Abe Pacelb	Ongoing	Commenced	3	2	6

Figure 3: Part of risk register worksheet

Ref	Team	Risk Category	Brief descriptor	Potential Consequence	RISKs Mitigated	RISKs Current	RISKs Unmitigated	RISKs Last month	RISKs Champion
1	A	Approvals	Change in regulations impacts outfall	Change in regulations impacts outfall for brine	5	24	24	20.0	Michael Rubio
15	B	Detailed Design	Late completion of geotech	Late completion and approval of geotech report	5	12	22	20.0	Abe Pacleb
26	C	Construction	Raw Water Pipeline Route	Raw Water Pipeline Route selected along original Barangay Road	12	21	22	20.0	Mike Cunanan
9	A	Approvals	Transmission of wrong file	Transmission of wrong file (not updated file) or incorrect standards adopted in the design or incorrect calculation	5	12	24	16.0	Sheila Tumang
48	D	Delivery	Poor performance of sub-contractors	Poor performance of sub-contractors results in increased costs and/or delays - Structural Design	12	18	22	16.0	Abe Pacleb
55	D	Environment	Contaminants from construction site	Contaminants from construction site run-off resulting in environmental pollution and/or water quality issue. - Dredging - Raw Water PS/ Intake Works - Outfall works	12	21	22	16.0	Mike Cunanan
56	D	Environment	Dust and Noise	Environmental Impacts: - Dust - Noise	6	21	22	16.0	Mario Valentos
11	A	Approvals	Difficulty in internal quality check	Difficulty in internal quality check within SCOTV within limited time	6	21	21	16.0	Esmael
12	A	Stakeholders	Complaints from stakeholders	Complaints from external stakeholders (e.g. fisherfolks, local residents, LGAs)	6	18	21	16.0	Mario Valentos
20	B	Detailed Design	Delaying Detaield Design	Delay in the detailed design of one discipline eg structural	6	21	21	16.0	Abe Pacelb
21	B	Detailed Design	Raw Water Pipeline Route not Finalised	Raw Water Pipeline Route not Finalisaed	6	21	21	16.0	Abe Pacelb
36	C	Construction	Construction within the Lake	Engineering difficulties or problems to construct intake channel and outfall along fish pen / other crowded lake .	12	21	21	16.0	Mike Cunanan
54	D	Delivery	Right of Way acquisition	Right of Way acquisition at WTP site	5	21	21	16.0	Nats Belmonte
58	D	Delivery	Variability in exchange rates	Variability in exchange rates for overseas supplied items (pumps, pipes, valves etc)	6	12	21	16.0	Remi Thelisson
25	C	Construction	Major Safety Incident	Major Safety Incident	19	24	24	15.0	Andrew Dela Paz
42	D	Delivery	Ineffective safety management	Ineffective safety management	19	24	24	15.0	Andrew Dela Paz
4	A	Approvals	DPWH permit is not secured	DPWH permit is not secured for the pipeline laying	2	17	17	15.0	Bong Hagacer
14	A	Planning	Resources	Provsion of Adequate Construction Labour Resources	12	21	22	15.0	Nap/Remi
35	C	Construction	Non-payment/delayed payment	Non-payment/delayed payment to Vendors, Subcontractors, Suppliers and underpaid salaries for HE operators	12	21	21	12.0	Bong Hagacer
40	D	Delivery	Community backlash	Community backlash - Intake Brgy Road, Pipe Laying	12	21	21	12.0	Mike Cunanan
23	C	Construction	Excess noise	Excess noise (primarily) or other environmental impacts causes problems with local community - all areas	6	21	21	12.0	Michael Rubio
24	C	Construction	Interface with distribution pipeline	Interface with distribution pipeline (ABDA)	2	21	21	12.0	Isagani Colocani
27	C	Construction	End-user inputs not fully considered.	Operational and constructability smarts/needs/inputs not fully realised or not incorporated by Contractor. Detailed design cannot be effectively and efficiently constructed. End-user not satisifed with outcomes.	1	17	21	12.0	Esmael

Figure 4: Part of risk profile worksheet