A Project Management Model that considers Risk Failure, Stakeholder Involvement and Communication Effectiveness

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Abstract. In Project Management, Risk Management Plan and Communications Management Plans are developed in the Project Planning Phases. These plans are approved by the Project Sponsor and disseminated to all stakeholders. However, during the Project Execution Phase, potential problems (risks) are identified and communicated but no action provided by the stakeholders. On the other hand, these risk communication messages often fail to reach the intended stakeholders of the project. Thus, once neglected and not handled properly, risks can altogether bring down the overall success of a project. One of the most crucial factors that can affect the effectiveness of risk management is communication management. In risk analysis and decision-making, a high involvement of the key stakeholders is imperative. It is through their active cooperation and participation that all possible problems and concerns may be efficiently addressed and resolved. As such, integrating communication management with risk management has been seen necessary in order to effectively communicate risks and implement strategies to mitigate them. This study proposes a mathematical model that does not only exhibit the costs involved from expected risk losses and from implementing specific risk reduction strategies but also incorporates the costs of the communication media used among the stakeholders as well as the risk costs brought about by communication failures occurring among them.

Keywords: *Risk Failures, Risk Cost, Communicating Risks, Communication Failures, Stakeholder Involvement*

1. INTRODUCTION

Projects are commonly undertaken across all organizations, making project management imperative in order to ensure meeting all project requirements and to increase the probability of achieving project success (Project Management Institute, Inc., 2008). In the same way that projects are universal, risks are also common to exist in and affect any endeavor or any project (Dey, 2001). Risks may pose several negative effects that can lead to higher amounts of delays and costs that can eventually result in project failure (Tavares, 2002). Nonetheless, one important factor in dealing with risks is the effective communication among all project stakeholders (Taig, 1998). Communication can bring about the level of participation and cooperation among stakeholders needed to have effective work relationships and decision-making efforts (Kennedy, McComb, & Vozdolska, 2011). Then again, if not properly established, communication misunderstandings and failures can also generate more project risks that may further prolong schedule delays, increase project costs and even decrease the probability of project success (Muller, 2003). As such, risk communication emphasizes the integral role of effective communication management in risk management when identifying, analyzing and implementing strategies to mitigate the negative effects of project risks as well as avoiding additional communication risks (Taig, 1998).

1.1 Theoretical Framework

Analyzing risks may be aided by mathematical models given that total losses incurred when risks occur can be quantified and established through corresponding monetary values or costs (Tavares, 2002). An example of this mathematical application is a study done by Fan et al. (2008) in selecting risk-handling strategies at the minimum total cost of implementing them. Establishing that the total risk level of a risk event is equal to the product of the probability of the risk’s occurrence and its impact on the project, the study of Fan et al. (2008) basically focused on reducing the overall risk level or total expected monetary loss by either decreasing the risk's probability of occurrence (i.e. through a strategy called risk prevention), lessening the negative effects of risks (i.e. through a strategy called risk adaptation), or by doing both strategies.

Similarly, Pan & Chen (2008) also developed another mathematical optimization model that allowed for the selection of specific risk abatement actions at a minimum cost. With this, total costs do not only entail the total expected loss or the risk level brought about by risk events but also include the corresponding costs of actually implementing selected risk abatement actions.

From these two studies, quantifying and analyzing risks meant looking at risk levels (i.e. the product of the probability of the risk's occurrence and its total monetary impact) upon implementing corresponding risk reduction strategies that will decrease the overall risk level within a project (Fan, Lin, & Sheu, 2008; Pan & Chen, 2008). However, effective communication through maximizing the involvement of key stakeholders in risk assessments and decision-making plays a big role in the success of planning and implementing risk responses (Lofstedt, 2004; Fan, Lin, & Sheu, 2008; Kennedy, McComb, & Vozdolska, 2011). As such, what these mathematical models seem to neglect is quantifying the significant impact of communication management on risk management through effective risk communication. Failure in communication, especially when decisions are reached and implemented, also brings about additional project risks, which can significantly add corresponding risk costs or even lessen the effectiveness of corresponding risk reduction actions (Muller, 2003). This then entails maximizing stakeholder participation in decision-making (Lofstedt, 2004), especially during risk assessments, seeing that communication among the different stakeholders greatly affects project risks and vice versa (Muller, 2003). After all, focusing on risk communication will enable not only maximized satisfaction of stakeholder expectations but also effective preparation and understanding of future stakeholder needs (U.S. Environmental Protection Agency, 2004; de Beus & Oosterveld, 2011), which can then lead to better decision-making and higher probabilities of project success given the lower risk levels brought about by effective risk communication (Muller, 2003; Kennedy, McComb, & Vozdolska, 2011).

1.2 Problem Statement

There is a lack of consideration of communication risks brought about by communication gaps during risk assessment and decision-making. Hence, there is an opportunity to create a mathematical model that takes into account not only the risk costs involved in actual risk levels and in implementing risk reduction actions but also the corresponding communication costs and communication risk costs generated by the level of stakeholder involvement in a project.

2. LITERATURE REVIEW

2.1 Project Risk Management

In any project or endeavor, risks can be anticipated. Risks and uncertainties affect all projects, be it in a positive way or not (Dey, 2001). All projects naturally imply certain levels of risks because of exposure to uncertainties that may result to problems that hinder the accomplishment of one or more project objectives (Pan & Chen, 2008). Thus, projects are generally non-deterministic due to the inevitability of unexpected external factors and other complexities that may lead to unfavorable project outcomes or even project failures (Fan, Lin, & Sheu, 2008).

Risks can often be associated with uncertainties on the time duration and resources necessary for each project activity given that schedule delays often incur unwanted additional costs and resources (Tavares, 2002). Normally, the success indicators of projects rely on its time of completion and its compliance with the allocated budget as well as with its technical requirements (Dey, 2001).

As such, this gives a clear reason why project risk management becomes essential in every project. Identifying and managing risks appropriately and effectively may lead to a higher probability of project success (Fan, Lin, & Sheu, 2008). There is always a need to anticipate and prepare for potential unexpected circumstances in order for negative effects to be mitigated and even prevented (Dey, 2001).

2.2. Integrating Project Communication Management

Project complexity affects how teams and stakeholders perform and communicate during a given project (Kennedy, McComb, & Vozdolska, 2011). Project teams could either maximize or minimize their performance through the frequency of communication and the effectiveness of the communication approaches or media used (Kennedy, McComb, & Vozdolska, 2011). It has been proven that having stable communication practices within and outside the organization is essential for the success of projects, especially those that are related with intricate information technology applications (Muller, 2003).

Communication is a fundamental element in decision-making, especially in risk management, because it enables a group of decision makers to choose the right direction and implement the decision well given that all concerns and opinions will be accounted for (Taig, 1998). Muller (2003) has pointed out how communication can influence project risks and vice versa. Failure to have effective communication channels may lead to additional risks as communication is a major tool in planning and managing project risks. Furthermore, in any project, once project risks get higher, there is sure to have a need for not only an increase in the frequency of direct communications but also effective means of communication since the nature and intensity of project risks often affect the kind of communication that is necessary between the project manager and the other stakeholders (Muller, 2003).

Effective communication leads to cooperation, coordination, knowledge sharing, efficient information processing, better work relationships and, most importantly, better decision-making (Kennedy, McComb, & Vozdolska, 2011). This is greatly evident in risk response decision-making, where uncertainties are dealt with and standardized management guidelines are lacking (Fan, Lin, & Sheu, 2008). Fan et al. (2008) highlighted that because of the difficulty in obtaining defined and accurate risk-related parameters, risk assessments are often done subjectively and collaboratively by experts and key stakeholders of the project during brainstorming sessions and regular focused discussions. Risk-handling strategies are based on the personal or educated discretion of directly involved stakeholders.

2.3. Project Risk Management Models

Applying operations research in project management has brought it means to understand and represent projects more comprehensively as well as to aid decision-making more effectively (Tavares, 2002). Tavares (2002) has enumerated possible objective functions when using operations research in project management decision-making efforts.

Fan et al. (2008) developed a quantitative approach in choosing risk-handling strategies that are aligned with relevant project characteristics. The main objective is concerned with minimizing total cost by carrying out risk-handling strategies that would mitigate expected loss by either reducing the risk probability and/or the negative impact of a particular risk event.

The study of Fan et al. (2008) categorized risk-handling strategies into either risk prevention or risk adaptation. Prevention strategies deal with ways to reduce the probability of occurrence (represented by P). It was assumed that before executing any risk-handling strategy, a risk event has a probability of occurrence that is equal to P1 and will be reduced to P2 after risk handling, hence giving the relationship $P2 \leq P1$. On the other hand, adaptation strategies are more concerned with reducing the negative impacts or the total loss (represented by L) coming from the occurrence of the risk event. Prior to risk handling, the total loss of a risk event resulting from its occurrence is L1. This is expected to be reduced to L2 after risk handling, thus the relationship $L2 \leq L1$.

The main goal of the model developed by Fan et al. (2008) is to reduce the overall expected loss or risk level (represented by R, and is equal to P x L) into an acceptable level. The initial risk level R1 have been deemed unacceptable and shall be reduced to a more acceptable level R2 after reducing P1 and/or L1. With this, the following relationships have been established by the authors: R2 = P2 x L2 , where R2 < R1. Then again, given that either both or only one of the two strategies, i.e. prevention or adaptation, can be applied to reduce the initial risk level R1, R2 may either result from P2 x L1 (after implementing only risk prevention strategies) or P1 x L2 (after implementing only risk adaptation strategies). This graph illustrates how the expected loss can be reduced to R2 using any of the three proposed risk-handling strategies – prevention (line YC), adaptation (line YA) or a combination of both (line YB).

With this, the predicament for managers becomes not only reducing risk level to an acceptable level but also doing it at the lowest implementation cost. Consequently, an optimization analysis was carried out by Fan et al. (2008) in order to determine an optimal strategy for reducing project risk with the minimum total cost.

This basic model is expanded as Fan et al. (2008) mathematically defined the components of total cost, which is the sum of the costs of risk prevention (C_P) and risk adaptation (C_L) strategies. Risk prevention costs basically pertain to the costs incurred in reducing the probability of the occurrence of a risk event, implying that decreasing P_2 will further increase C_P. On the contrary, risk adaptation costs can be the solution to either of the two types of loss – monetary loss or schedule delay loss. In monetary loss, the aim is to maintain a buffer to make the risk adaptation cost an opportunity cost instead of incurring the entirety of the loss from the risk event. In schedule delay loss, on the other hand, risk adaptation costs rely on the time buffer or the amount of slack in the project. In any case, decreasing L_2 indicates an increase in C_L.

With the mathematical model developed, managers only need to specify three parameters in order to use the model in determining an optimal risk-handling strategy. These parameters include the acceptable risk level (R2), the unit prevention cost (k) and the unit opportunity cost (r). The model was verified through its application on a particular risk event identified in a construction project.

Another model intended for risk management was developed by Pan & Chen (2008). They also created an optimization model yet for choosing specific risk reduction actions. Although the main objective is also centered on minimizing total cost, the model is more focused on the economic selection of particular risk response activities that can be executed for a number of risk events. The researchers verified this method by means of applying it in a Chinese software industry. The model developed generally rendered a new decision-making tool for project managers implementing capability maturity model integration (CMMI)-based software project risk management (SPRM).

Pan & Chen's model (2008) focused on the selection of specific risk response actions that will minimize total costs as opposed to the model of Fan et al. (2008), which concentrated on the reduction of the risk level of a particular risk event at a minimum cost. Pan & Chen (2008) pointed out that even though risk reduction actions reduced risk level, if implementing such actions cannot reduce the total cost of the project as well, efforts would only be futile. Project risk management may be essential in identifying and planning ahead potential risks as well as the risk responses that will decrease risk probability and its negative impacts (Project Management Institute, Inc., 2008). However, implementing risk responses will only be effective and significant if the costs incurred for this will be at a minimum, not adding a substantial amount to the total cost of the project (Pan & Chen, 2008).

Conventionally, risk analyses are done with the concentration only on the effects of the risk on project objectives such as time and cost. These are often in the form of probability models, which are limited by the burden of detailed quantitative information required as well as by its applicability in the real world (Dey, 2001). As such, Dey (2001) indicated the inevitable need for project risk assessments to have subjective evaluations of the key stakeholders.

2.4. Synthesis

Risk management is undeniably a crucial component of project management due to the inevitability of the presence of risks that may hinder achieving project success. Then again, it is also a given fact that although risk analyses may be done objectively through mathematical models, subjectivity cannot be eliminated completely. Thus, communication management can be seen as another vital component of project management, especially when integrated with risk management. Effective risk communication is essential in significantly reducing risk levels within a project and in turn allowing for higher probabilities of project success.

3. MATHEMATICAL MODEL

Integrating the costs and risks related to the effective communication among the various stakeholders involved in decision-making entails scrutinizing the level of involvement of every stakeholder. This implies taking into account how many stakeholders are actively engaged and properly informed given the communication media or approach being utilized.

With this approach, additional parameters must be obtained and considered. First, the average unit risk cost of failure in communicating with distinct stakeholders (k) must be determined. This will be the corresponding additional cost to be incurred when a number of stakeholders are not properly informed or included in decision-making, especially during project risk analyses. Another key additional parameter is an effectiveness rating (f) assigned to the communication channels in a given project. This basically exemplifies how accurate and successful the established communication methods are in distributing relevant information to stakeholders and taking into account all their concerns in decision-making. Aside from the two already mentioned, it is also important to identify the total or ideal number of stakeholders in the project (N) as well as the corresponding unit cost of the communication media being used (m) and the budgets (B) allocated for both risk and communication management efforts of the project. Finally, it is also crucial to consider not only the actual reduction rate caused by a risk action on a risk event given maximum stakeholder involvement but also the adjusted reduction rate after incorporating the effect of actual stakeholder involvement.

Given these additional parameters and incorporating more of Pan & Chen's model, a model with two sets of decision variables shall be formulated. The first decision variable, x, corresponds to the binary or switch variable that indicates whether or not a specific risk action will be implemented to address a particular risk event. On the other hand, the second decision variable, y, signifies the number of stakeholders to be involved and satisfied in risk decision-making. This decision variable is significant in deciding the specific risk actions that will be matched with particular risk events. As such, the two set of decision variables are as follows:

Let x_{ij} = 1, if risk action i will be selected for risk event j
= 0, if otherwise

y_{ij} = the number of stakeholders to be involved and satisfied in risk decision-making when choosing action i for event j

where: i = 1, 2, 3, … (number of risk actions available)
j = A, B, C, … (risk events identified)

With the aim to have a minimum total cost yet with the highest possible level of stakeholder involvement, multiple objective functions can be generated:

$$Min\ TC = \sum_i \sum_j (x_{ij} \cdot a_i) + \sum_j \left\{ R_j \cdot \prod_i [Max(1 - x_{ij}, 1 - r_{ij})] \right\} + \sum_i \sum_j (y_{ij} \cdot m_{ij}) + \sum_i \sum_j [k_i(N - f_{ij} y_{ij})] \quad (1)$$

$$Max\ \ Y_{ij} = y_{ij} \quad ,\forall i, \forall j \quad (2)$$

Given the objective functions described previously, a number of constraints are important to take into account in completing the mathematical model being formulated:

$$\sum_i \sum_j (x_{ij} \cdot a_{ij}) + \sum_j \left\{ R_j \cdot \prod_i [Max(1 - x_{ij}, 1 - \ r_{ij})] \right\} \leq B_{risk} \quad (3)$$

$$\sum_i \sum_j (y_{ij} \cdot m_{ij}) + \sum_i \sum_j [k_i(N - f_{ij} y_{ij})] \leq B_{comm} \quad (4)$$

$$r_{ij} = d_{ij} \cdot \frac{y_{ij}}{N} \quad (5)$$

$$cN \leq y_{ij} \leq N \quad (6)$$

$$0 \leq r_{ij} \leq 1 \quad (7)$$

$$0 \leq f_{ij} \leq 1 \quad (8)$$

Table 1: Definition of variables

Variable	Description
TC	Total Cost
Y_{ij}	Level of stakeholder involvement for every risk action and risk event
a_i	Unit cost of implementing action i
d_{ij}	Actual percentage risk reduction caused by action i on event j, assuming maximum stakeholder involvement
r_{ij}	Adjusted percentage risk reduction caused by action i on event j after considering the effect of actual stakeholder involvement
R_j	Initial risk level of event j
m_{ij}	Unit cost of communication media used for deciding action i with event j
k_i	Unit risk cost of communication failure for analyzing action i
c	The established acceptable minimum effectiveness rating of communication
N	Total number of stakeholders in the project
f_{ij}	Percentage rating assigned to the effectiveness of the communication channels for deciding action i with event j
B_{risk}	Budget allocated for corresponding risk costs
B_{comm}	Budget allocated for corresponding communication costs

The following are the assumptions underlying the generated model:

Higher stakeholder involvement, i.e. more stakeholders involved in decision-making, entails a more effective risk communication management.

Risk levels for each event (Rj) are computed beforehand (unlike in the previous models discussed, where the probability of occurrence and the impact were separately defined)

Regardless of whether or not a specific action will be selected for a particular risk event, stakeholders must be involved in the decision and costs of communication still apply. Thus, communication channels should still be open.

The total number of stakeholder (N) pertains to those key stakeholders that may or should be involved in risk planning and decision-making.

The risk cost assigned to communication failure can be considered a part of either communication costs or risk costs depending on the decision of management or the project team. For this study, it shall be part of the communication costs.

The acceptable minimum effectiveness rating of communication always depends on the standards set by management or the project team.

4. RESULTS AND DISCUSSION

4.1. Results of Model Application

In applying the generated model of this study, sample information and data will be mostly taken from Pan & Chen's model application (2008) on a Chinese software company. This project basically deals with completing a new enterprise system for taxation. From the example given by Pan & Chen (2008), 12 risk events were identified. For the purposes of this smaller scale application of the study, only 3 risk events from the examples given will be considered. Moreover, all monetary values will be converted to Philippine peso using the conversion of Yuan to Philippine Peso during the year Pan & Chen's paper (2008) was published, with all values rounded off to the nearest thousands. Table 2 enumerates the risk events that will be part of this study, along with the corresponding risk levels or expected loss (Rj) brought about by each event.

Table 2: Risk events with corresponding risk levels*

Risk Event	**Risk Level (Rj)**
A: Imprecise definition of requirements	Php 410,000
B: Unsuitable design of function mode interfaces	Php 60,000
C: Definition of an overly complex graphical user interface (GUI)	Php700,000

*Reference: Pan & Chen (2008)

From the same study of Pan & Chen (2008), 13 risk actions were proposed; for this study, only 3 risk actions will again be considered. 錯誤! 找不到參照來源。 lists these 3 risk actions with their equivalent implementation costs (ai) and guesstimated average unit risk costs for communication failure (ki).

Table 3: Risk actions with corresponding costs

Risk Action	Cost*(a_i)	Unit Risk Cost (k_i)
1: Reduction of the requirements of the system	Php98,000	Php200
2: Hiring a consulting company for design improvement	30,000	120
3: Searching for more relevant information for design improvement	7,000	160

*Reference: Pan & Chen (2008)

Table 4 enumerates all the other values of the parameters necessary to run the proposed model that integrates risk and communication costs. Actual risk reduction rates that assume maximum stakeholder involvement (d) were patterned from the effects of each action to each event as established in Pan & Chen's study (2008). Given the limited data presented in Pan & Chen's study (2008) and the lack of mathematical models in literature incorporating communication costs, the other parameters to be used in validating the new model were based on educated guesstimates. Such estimates were based on unit communication costs (m) from the current cost of living in the country in terms of transportation costs (for face-to-face meetings/encounters) as well as Internet and phone costs (for e-mail notifications, phone calls and the like), depending on the estimated communication frequency entailed by each risk action (Winterfeld, 2009).

On the other hand, effectiveness ratings of communication channels (k), ideally, should be based on the organization's history of performance and other relevant experiences regarding their communication practices. However, in the case of this study, effectiveness ratings were approximated based on the percentage of stakeholders who are most likely deemed to be part of such decision to whether or not implement a specific risk action (i) on a particular risk event (j). The key stakeholders involved in risk analysis and decision-making are the project manager (1) and his team of direct subordinates (3), the design team (4), the main customers requesting for the system (5) and the project sponsors (2), giving a total of 15 key stakeholders (N = 15).

Table 4: Corresponding values of parameters

Action/Event	**A**	**B**	**C**
1	d = 0.5 m = 170 f = 0.6	d = 0.4 m= 170 f = 0.5	d = 0.5 m= 200 f = 0.7
2	d = 0.6 m = 130 f = 0.4	d = 0.6 m= 170 f = 0.5	d = 0.45 m= 120 f = 0.6
3	d = 0.15 m = 120 f = 0.5	d = 0.6 m= 120 f = 0.7	d = 0.3 m= 130 f = 0.6

Finally, budget constraints were set arbitrarily at Php1,000,000 for the total risk costs and Php25,000 for the total communication costs, while the acceptable minimum effectiveness rating for communication (c) was set to 40%. Seeing that the current total risk costs amount to Php1,170,000, there is really a need to reduce risk levels in order for incurred costs to be within the set budget and even be at a minimum cost.

With these values set and using MS Excel solver, the following values were generated (as shown in Table 5):

Table 5: Generated values of decision variables

Action/Event	**A**	**B**	**C**
1	x = 1 y = 6	x = 0 y = 6	x = 1 y = 11
2	x = 1 y = 6	x = 0 y = 6	x = 1 y = 7
3	x = 1 y = 6	x = 1 y = 11	x = 1 y = 6

Given the corresponding budget constraints, costs of each risk action and effect of the level of stakeholder involvement in risk reduction rates, the model suggests to carry out risk action 3 over all risk events as well as further reducing the risk level of risk events A and C by also implementing risk actions 1 and 2 over each.

Moreover, because of the acceptable minimum effectiveness rating established, the optimal solution yielded the minimum acceptable level of stakeholder participation of 6 stakeholders for addressing the risk entailed by imprecise definition of requirements (risk event A across all three risk actions 1, 2, and 3). The same number of stakeholders is also found to be optimally involved in deciding not to implement reducing system requirements and hiring a consultant company (risk actions 1 and 2) for addressing the risk on the unsuitable design of function mode interfaces (risk event B); and there are also 6 stakeholders involved in deciding to implement searching for more relevant design improvement information (risk action 3) for the risk on a defined overly complex GUI (risk event C). On the contrary, 7 stakeholders were found to be optimally involved in deciding for the implementation of hiring a consulting company (risk action 2) to address the overly complex GUI (risk event C), while 11 stakeholders for implementing a reduction in system requirements (risk action 1) to resolve the overly complex GUI (risk event C) and a search for more relevant information (risk action 3) to deal with the unsuitable design of function mode interfaces (risk event B).

From these values, it is also noticeable how the higher stakeholder involvement was concentrated on the risk event and risk action pair with highest communication effectiveness rating (f) as well as with a relatively high actual risk reduction rate (d), i.e. y1C and y3B. This may entail that a higher risk reduction may be obtained at a relatively minimum level of communication risk cost given that the actual risk reduction rate (d) is affected by the actual level of stakeholder involvement (y).

With these results, the following total costs were obtained, fully utilizing the budget for communication costs to ensure maximized stakeholder involvement.

Table 6: Final values

TC	Php878,128.53
Total Risk Costs	Php853,128.53
Total Communication Costs	Php25,000

4.2. Additional Case Scenarios

This section of the paper shall test the sensitivity of the model by significantly changing a few of the parameters. This shall be carried out by decreasing the original risk level of one of the risk events and decreasing the unit risk cost of communication failure to a constant amount.

4.2.1. Decreasing Risk Level (R)

The first case scenario to test the sensitivity of the model is by decreasing the risk level of one of the risk events. In the example given to test the model, the highest risk level was that of risk event C, with a risk level of Php700,000. Decreasing this risk level by 50%, making the new risk level Php350,000, the new set of values of the decision variables will be as follows, assuming all the other parameters remain the same (See results in Table 7):

Table 7: New generated values if decision variables (changed R)

Action/Event	**A**	**B**	**C**
1	x = 0 y = 6	x = 0 y = 6	x = 0 y = 6
2	x = 1 y = 7	x = 0 y = 6	x = 1 y = 11
3	x = 1 y = 6	x = 1 y = 14	x = 1 y = 6

These results show that risk action *1* is not anymore a desirable choice for any of the risk events due to its high implementation costs. Given that the original risk level of risk event *C* was halved, there was also a diminished need to further reduce the risk level of the event. With this, total costs for risk and communication were also reduced significantly to the following:

Table 8: New final values (changed R)

TC	**Php616,246**
Total Risk Costs	Php591,248
Total Communication Costs	Php24,998

4.2.2. Decreasing Unit Risk Cost of Communication Failure (k)

For this case scenario, the value of k will be set to a constant, at a reduced value of Php100. Given this parameter, the following values of decision variables were obtained (See results in Table 9):

Table 9: New generated values of decision variables of decision variables (changed k)

Action/Event	**A**	**B**	**C**
1	x = 0 y = 12	x = 0 y = 13	x = 1 y = 15
2	x = 1 y = 15	x = 0 y = 13	x = 1 y = 15
3	x = 1 y = 15	x = 1 y = 15	x = 1 y = 15

From this scenario, it can be seen that there is an increase in the number of stakeholders to be included in decision-making. This increase was obtained because of the transferred budget put into the cost of communication rather than being eaten up by the risk cost of communication failure. The comparisons of such costs are seen in Table 10. Possible causes of this decrease in the average unit risk cost of communication failure rely on the actual media used for communication and the cost of the added effort to make up for communication failures.

Table 10: Comparison of final costs (changed k)

	Total Cost from Comm	Cost of Comm Media	Risk Cost of Comm Failure
Original k	Php25,000	Php9,700	Php15,300
New k	Php24,990	Php18,760	Php6,230

5. CONCLUSION

Risk and communication are two essential knowledge areas in project management that are strongly linked yet have never been considered together in an operations research application. This study was able to translate the concept of project communication management into mathematical terms and in conjunction with the concept of project risk management. The generated basic model in this study looked into the additional project costs brought about not only by project risk costs but also by communication media costs and even risk costs in communication failures. Minimizing total costs while ensuring that stakeholder involvement is maximized assume an effective risk communication management as exhibited in this study. Lower stakeholder involvement (y) will have a negative effect on the actual risk reduction rate (d) of implementing a specific risk action to address a particular risk event. As such, such a mathematical model formulated entails fully utilizing the budget for communication in order to maximize as well the number of stakeholders involved in every decision made. Then again, selection of risk actions also relies not only on the implementation cost of each action (a) but also on the initial risk level of the event (R). Risk actions are more concentrated on risk events with higher initial risk levels and are chosen considering both the individual costs of implementation (a) and the adjusted risk reduction rate (r) after incorporating the effect of the level of stakeholder involvement. Finally, it is also crucial to take into account the risk costs incurred due to communication failures or low stakeholder involvement. It has been proven how it is better to utilize communication budget by maximizing communication media costs than having a high communication risk costs. By concentrating budget on improving the effectiveness of the communication media used, more stakeholders can be accommodated and be satisfied during decision-making as opposed to spending more on communication risk costs that only yield low stakeholder involvement.

6. RECOMMENDATION FOR FURTHER STUDIES

For further studies, it is recommended to also take into account the importance of each distinct stakeholder in relation to the nature of each type of risk event when determining the cost of communications. Breaking down the roles of the stakeholders can further classify and make accurate estimates of communication costs and risk costs brought about by communication failures. In addition, for a more detailed study, the risk levels brought about by communication failures can also be further scrutinized in order to properly assess its effects and the costs involved.

Another area for further development of the mathematical model is by adding another objective function. It may be more beneficial to the project stakeholders to have a model that does not only minimize costs incurred in risk analysis and communication approaches but also maximize risk reductions and communication effectiveness levels at the same time.

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