Proposal on Hybrid Risk Evaluation Method (HREM) for bidding decision in international infrastructure project

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Abstract
This paper describes a proposal on a new method that enables the appropriate and practical decision making in bidding before submitting a proposal to participate in the bidding for a large-scale international infrastructure project. Such a method has been demanded by potential bidders in order to overcome the recent trend that Japanese companies have given up in participating in such projects in spite of opportunities to extend their business in highly potential overseas market. For this, we have established a comprehensive evaluation method for risk assessment with reference to actual experiences of one of the leading Japanese consultants in establishing the basis of the proposed method, and conducted a post-evaluation to verify and validate the proposed method based on assumptions for the Suvarnabhumi Airport Rail Link (ARL) construction project in Thailand. Based on the assessment, we have obtained a positive result to ensure the effectiveness and the validity of the theory assumed as well as the proposed method, with suggestion for further improvement.

Keywords: Project management, Decision making, Massive infrastructure projects, Risk assessment, Check list method, Management of technology, Design knowledge management

1. Introduction

The Japanese Government has been keen on exporting the Japanese Technology in infrastructure as a package, which has been the core of the strategy for sustainable development of Japanese industries. One of the main components of the said package is the railway systems that comprise rolling stock, train control system, power supply system, automatic fare collection system, etc. for urban mass transits and high speed railways, which Japanese railway industries have spent years to accomplish safe, international competitive and highly reliable system. The Japanese high speed railway technology, well known as Shinkansen, has been successfully introduced in Taiwan and the mass transit systems by Japanese technologies have been widely adopted in various countries, which were financed by the Japanese ODA and with the management by Japanese consulting firms, e.g. Delhi Metro in India, Purple Line in Thailand, etc. These projects were bid through the International Competitive Bidding (ICB) and the contractors wishing to win the project have to participate in the bidding process. Although the projects were partly or entirely financed by the Japanese Government, there were some projects in which no Japanese firm has participated in the bidding due to high risks residing in the bidding process and in the contract conditions, e.g. non-familiarity with modern practice of project implementation (Niraula et al., 2008), unfair modification of FIDIC based conditions (Matsuba et al., 2011). Disputes at the court in case the arbitration on the claims by the contractor is not successful could bring about serious financial impacts on the business model of the contractor due to the increase of the project cost by the result of disputes (Onishi, et al., 2002). Upon these cases, the Overseas Construction Association of Japan (OCAIJ) has submitted a request to Japan International Cooperation Agency (JICA) to improve the bidding conditions in order to avoid high risks that prevent Japanese firms from bidding. In the recent international infrastructure projects, bidding documents can be considered as the major decisive factor in understanding the project viability at the time of the bidding since the bidding documents cover all
conditions to be applied during the bidding and the construction phase until the completion of the project. Contractors are able to make appropriate profit if the contract conditions are fair and clear. On the other hand, in case the contract conditions are unclear and/or one-sided to the employer, there are high risks that finally result in great loss to the contractor at the completion. Such loss causes negative impact to the company as a whole, and the magnitude of the impact is significant if the company’s scale is small to medium. In addition, if the project is largely delayed due to the reasons of the employer, the present value of the profit from the project decreases at the time of the project completion.

As the discount rates in the developing countries are relatively high, the present value of the project after the extension of the project period could be significantly lower than that originally expected. Delay in the project may also affect smooth implementation of other projects of the company due to longer engagement of staff in project (Ohtsu et al., 2012).

Unfortunately, it is the fact that there is no well-structured and proven evaluation method for risks in international infrastructure projects that enables the company management to make the right decision if they should go for the bidding or not. Therefore, companies have made go or no go decision based on the limited information available and their past experiences, which are often vague and uncertain. The accuracy of the decision could be high if the company has extensive experiences in the same client, same country and/or similar projects, whereas new comers have no sufficient information to understand what kind of risks they should consider, thus they can only rely on illogical decision with little available information.

To overcome the current situation of the risk evaluation, we have conducted a study to establish a new risk evaluation method that can be applied at the time of making decision for bidding in international infrastructure projects.

2. Related researches and detailed purpose of this research

Various studies have been carried out in the past to assess the risks in different kinds of projects. One of the methods effective to reduce the long-term project risk is the Discovery-Driven Planning (DDP), (McGrath and Macmillan, 2009). The DDP is to continuously update the planning during the project referring to the knowledge obtained through the project. Projects often start with status in 3 types, i.e. haste start-up without careful consideration, plan without flexibility, and start-up with the DDP. The first one highly contains the possibility of not achieving the planned target due to vague objective at the beginning. The second one may luckily lead to the planned target but also be likely not to achieve the target due to its inflexibility. Plans with the DDP assure the project to achieve the planned target by periodically modifying and adjusting the plan in the course of the project. The DDP consists of the Reverse Profit and Loss Calculation, by which components related to profit making and the level of their impact to the profit can be identified, and the milestone planning that enables the periodical adjustment of the plan at the right time (Fukuzawa and Ogawa, 2009).

However, although the DDP can be applicable to projects in which most of factors can be internally managed and controlled within the company, the effectiveness of the DDP is limited in construction projects that are directed and driven by the employer and the contract conditions prepared by the employer. Therefore, a new risk evaluation method suitable for construction projects having such restriction is highly desired.

Complicated process of obtaining building permits, unfair and unclear requests from the employer and lack of resources (material and equipment) are given as the major risk factors in international construction projects from the contractor’s point of view in the study of the reference (Ohtsu et al, 2002), and it is stated that adding the risk premium in the contract amount is one of the ways to mitigate such risks during the construction phase and to achieve certain level of profit. Notwithstanding the presence of such risks in most of the international infrastructure projects, there is no definite risk evaluation method that can be applied at the time of the bidding. In this Study, it is aimed to combine the qualitative risk evaluation method mainly for due consideration and assessment at the time of the bidding and the quantitative risk evaluation method for cost factors affecting the profitability that can be estimated during the construction phase, so that the risk evaluation covers various aspects and throughout the entire project before bidding. This method, which is designed to be conducted before submitting the bidding proposal, can be applied to prepare for risk control during the project as well as to consider risk financing to be included in the bidding proposal as well.

3. Needs in risk evaluation and research objective

Needs in more precise and effective risk evaluation to determine whether or not to participate in the international infrastructure projects have been recognized as comprehensively and structurally understanding the potential risks as
well as the impact of such risks to the profitability is essential for such determination. Potential risks cannot be simply quantitatively evaluated as the identifiable risks are of qualitative natures, although the evaluation of the project at the completion is mainly the profitability through the calculation of the project related components in cost. In this Study, a Hybrid Risk Evaluation Method (HREM) is proposed based on a theory that the risk evaluation by the combination of both qualitative and quantitative evaluation of risk factors (Isaka et al., 2015) (Isaka et al., 2016), where the qualitative evaluation is valid for speedy and effective screening of a massive volume of potential risk factors residing in projects and the quantitative evaluation can provide the result of the risk evaluation, reflecting the result of the qualitative evaluation, in numerical values for use in the process of decision-making by the company’s top management. Risk evaluation by the HREM at the time of participating in the bidding process can be achieved in the following manner:

![Diagram of HREM](image)

Fig. 1  A flowchart of proposing Hybrid Risk Evaluation Method (HREM) in bidding decision. Elements from start until first branch express a qualitative evaluation process of project risk using check list. Elements from first branch to second branch express a quantitative evaluation process based on sensitive analysis.

As indicated in Figure 1, the HREM enables easier and more accurate decision making in participating in the bidding or not by having 2 steps of understanding the potential risks in the project and estimating the expected project profitability. Accordingly, this HREM can be the effective tool for decision making at or before the start of the bidding process if the project is considered worth bidding and profit making to the company.

In the Study, a case study was carried out with the actual project implemented by the ICB and already completed, namely Suvarnabhumi Airport Rail Link (SARL) Project in Bangkok, Thailand, in which the author was deeply involved as the consultant to the employer. Reasonable assumptions were used to justify the effectiveness of the HREM in the post evaluation of the actual project.

4. Qualitative risk evaluation method
4.1 Proposition of check list method in HREM

Experiences as the consultant involved in the employers’ sides in various international infrastructure projects and the request of OCAJI to JICA are referred to in the case study carried out in this study. A check list was established as the major component of the qualitative evaluation, covering potential risk factors involved in the international infrastructure projects at each phase and attributable to various stakeholders, which are categorized into 3 levels by the stakeholders as Level 1, phases and natures of risk items as Level 2, and detailed risk factors as Level 2, where Level 2 is further broken down in Tables 3 – 5 by the attributes of the risks in each phase. Categorizing risk factors by stakeholder, type and detail elements makes it easier to clarify the relationship of risk factors and project stakeholders as well as to identify the time of the risk occurrence as indicated in Tables 1 to 5.
### Table 1  Risk factors related to the country of the project

| Level 1 | Level 2 | Level 3 |
|---------|---------|---------|
| Country | General | Economy / Financial conditions |
|         |         | Approved budget for project |
|         |         | Consistency with national plans and laws/regulations |
|         |         | Force majeure |
|         |         | Abnormal climate conditions |
|         |         | Culture / customs / conventions / public safety and peace |
|         |         | Legislation on safety and environment consideration |
|         |         | Building permit |
|         | During  | Change of legislation during construction |
|         | Construction | Political change, Coup De Tat, etc. |

### Table 2  Risk factors affected by the construction industry (market)

| Level 1 | Level 2 | Level 3 |
|---------|---------|---------|
| Construction Industry | General | Market situation and change |

### Table 3  Risk factors driven by the project implementation agency

| Level 1 | Level 2 | Level 3 |
|---------|---------|---------|
| Employer (Implementation Agency) | General | Capability of Implementation Agency |
|         | Before Bidding | Coordination with financier(s) |
|         |         | Recognition and acceptance by residents |
|         |         | Coordination with third parties (electricity, water, etc.) |
|         | Preparation by Employer | Realization of the project (land acquisition, etc.) |
|         |         | Realization of the project (access to project sites) |
|         |         | Realization of the project (obstructions in project site) |
|         |         | Project financing |
|         |         | Appropriateness of project contingency budget |
|         | Project Implementation Plan and Scheme | Appropriateness of contract packaging |
|         |         | Appropriateness of project budget |
|         |         | Appropriateness of project / contract period |
|         | Bidding Scheme / Bidding Conditions | Appropriateness of bidding period |
|         |         | Bid bond |
|         |         | Quality if Instruction to Bidders document |
|         |         | Possibility of delay in bid evaluation |
|         |         | Appropriateness of pre-qualification (PQ) requirements |
|         |         | Bid evaluation method |
|         |         | Appropriateness of bid evaluation criteria |
|         | During Construction | Delay in land acquisition / resettlement |
|         |         | Acceptance for additional cost for additional works |
|         |         | Extension of time due to unforeseen impact / damage due to abnormal climate |
|         |         | Delay due to works by third party |

### Table 4  Risk factors attributable to the employer’s consultants

| Level 1 | Level 2 | Level 3 |
|---------|---------|---------|
| Employer / Before Planning | Planning | Quality of project planning |
### Consultant Bidding (Design Phase)

| Consultant Bidding (Design Phase) | Design | Other Contract Package(s) |
|-----------------------------------|--------|---------------------------|
| Cost Estimate                    | One-sided conditions in design requirement | Possibility of delay due to work progress of other contract package(s) |
| Contract type                     | Appropriateness of contract type (re-measurement, lump-sum, etc.) | Appropriateness of contract type (re-measurement, lump-sum, etc.) |
| Conditions of Contract            | Appropriateness of authorities given to the Engineer | Appropriateness of authorities given to the Engineer |
|                                  | One-sided conditions | One-sided conditions |
|                                  | Conditions for project completion / handover | Conditions for project completion / handover |
|                                  | Appropriateness of applicable laws and regulations | Appropriateness of applicable laws and regulations |

### During Bidding

| Extension of Time and Additional Cost | During Bidding |
|--------------------------------------|---------------|
| Extension of time due to design change by the Employer | Extension of time due to design change by the Employer |
| Additional cost due to design change by the Employer | Additional cost due to design change by the Employer |
| Condition for extension of time due to design change | Condition for extension of time due to design change |
| Extension of time and additional cost due to third party requirement | Extension of time and additional cost due to third party requirement |
| Liquidated damage for delay | Liquidated damage for delay |
| Change of contract period depending on commencement of contract | Change of contract period depending on commencement of contract |

| Tender Documents and Drawings       | During Bidding |
|-------------------------------------|---------------|
| One-sided conditions in design standards and codes | One-sided conditions in design standards and codes |
| Quality of General Specifications   | Quality of General Specifications |
| Quality of design documents and drawings | Quality of design documents and drawings |
| Given conditions                    | Given conditions |

### During Construction

| Quality Assurance                  | During Construction |
|------------------------------------|----------------------|
| Method of quality assurance and quality control | Method of quality assurance and quality control |

| Contract Language                  | During Construction |
|------------------------------------|----------------------|
| Contract language for correspondences and documents | Contract language for correspondences and documents |

| Arbitration                        | During Construction |
|------------------------------------|----------------------|
| Conditions for arbitration         | Conditions for arbitration |

| Consultant                         | During Construction |
|------------------------------------|----------------------|
| Quality and experience of consultant for bid evaluation | Quality and experience of consultant for bid evaluation |

| Consultant                         | During Construction |
|------------------------------------|----------------------|
| Quality and experience of consultant for construction supervision | Quality and experience of consultant for construction supervision |

### Table 5  Risk factors initiated by the contractor

| Level 1              | Level 2                                                                 | Level 3                                                                 |
|----------------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Contractor           | Corporate strategy                                                     | Consistency with corporate strategy                                    |
|                      | Competitiveness                                                        | Competitiveness against competitors                                     |
|                      | Understanding of country                                               | Experience in and understanding of the project country                  |
|                      | Bidding team                                                           | Readiness for preparing bid proposal                                     |
|                      | Capability                                                             | Capability of construction                                             |
|                      |                                                                         | Implementation structure for construction                               |
|                      | Local Staff and Labors                                                 | Own local staff                                                         |
|                      | Working Capital                                                        | Capability of mobilization of local staff                               |
|                      | Sub-contractors                                                        | Availability and quality of sub-contractors                             |
|                      | Construction Materials                                                 | Increase of construction materials costs                                |
|                      | Delay in Construction                                                  | Delay in works caused by the Contractor                                 |
Building Permit Experience and knowledge in obtaining building permit

Based on listed risk factors, this paper proposes a risk scoring method qualitatively. In product development process, the FMEA (Failure Modes and Effects Analysis) method is often used to specify, score, and improve the risks inside the design and manufacturing phases (Wada 1996). From inspiration by the FMEA, this research proposes a risk scoring method using following four criteria:

1) Importance, which describes a financial impact of the risk factor to the project (in FMEA, similar concept with severity)
2) Criticality, which describes an impact of the criticality to the project implementation
3) Probability, which describes the occurrence frequency or possibility of the risk factor (in FMEA, similar concept with probability or occurrence)
4) Recognition, which describes a probability to realize before the factor occurs (in FMEA, similar concept with detection).

Level 1 category is subject to evaluation by setting corresponding values for its importance by the relative evaluation, whereas each detailed risk factor in Level 3 is subject to evaluation for 3 criteria, i.e. criticality, probability and recognition, in values ranging from 1 to 5, where 5 is the highest in risk. Scores of each criterion from 1 to 5 are based on the theory that can be applicable to risk evaluations in general. For example, the definition of each score for Recognition was determined as follows:

1: Fully recognizable and controllable prior to the occurrence of the event
2: Recognizable and controllable if certain study/research is carried out
3: May be recognizable but not fully controllable within the limited time before the end of bidding process
4: Difficult to recognize and control the event before the end of bidding process
5: Impossible to recognize and control the event before the end of bidding process

Then, the value of individual business risk of each risk factor is calculated by multiplying the input values of importance and 3 criteria. Multiplication method is applied to obtain the individual business risk value as each of the evaluation criteria is fully dependent and the impact of high value can more severely affect the individual business risk. An extract of the input result carried out for the SARL Project is shown in Table 6.

Here, individual business risk in Table 6 is calculated by following equation:

$$ b^i = s^i \times c^i \times p^i \times r^i $$

where

- $s^i$: scored importance of factor $i$
- $c^i$: scored criticality of factor $i$
- $p^i$: scored probability of factor $i$
- $r^i$: scored recognition of factor $i$
- $b^i$: calculated business risk of factor $i$

Table 6  Example of estimated quantitative factors (Suvarnabhumi Airport Rail Link Project)

| Risk Factor                                | Importance $s^i$ | Criticality $c^i$ | Probability $p^i$ | Recognition $r^i$ | Individual business risk $b^i$ |
|--------------------------------------------|------------------|------------------|------------------|------------------|-------------------------------|
| Country                                    |                  |                  |                  |                  |                               |
| Approved budget for project                | 4                | 5                | 3                | 3                | 180                           |
| Force majeure                              | 4                | 4                | 5                | 5                | 400                           |
| Abnormal climate conditions                | 2                | 2                | 4                | 3                | 128                           |
| Political change, Coup de Tat, etc.        | 2                | 2                | 4                | 3                | 128                           |
| Construction Industry                      |                  |                  |                  |                  |                               |
| Market situation and change                | 2                | 3                | 3                | 3                | 54                            |
| Employer / Implementation Agency           |                  |                  |                  |                  |                               |
| Capability of Implementation Agency        | 4                | 4                | 4                | 3                | 192                           |
| Recognition and acceptance by residents    | 3                | 3                | 3                | 3                | 108                           |

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4.2 Proposition of qualitative scoring method in HREM

Next, qualitative scoring is carried out by inputting values for each risk factor in the qualitative check list. In the proposed qualitative method, scoring of the evaluation results is made by the average probability, the distribution of the individual business risks and the sum of all individual business risks which become the overall project risk score.

Table 7 Average probability and threshold

| Importance Level | Average Probability | Threshold |
|------------------|---------------------|-----------|
| Level 5          | 2.00                | 2.00      |
| Level 4          | 2.47                | 2.50      |
| Level 3          | 2.70                | 3.00      |
| Level 2          | 2.65                | 3.50      |
| Level 1          | 3.00                | 4.00      |

The evaluation of the risk probability is done by setting a threshold value for each importance level, which is the allowable upper limit of the probability as it is not realistic if the average probability of the higher importance level is higher than that of the lower importance level, considering the less possibility of the occurrence of risks with higher importance. According to the result shown in Table 7, it is confirmed that each average probability is slightly less than the threshold values. Then, referring to the individual business risks composing factors in Tables 1 to 5, the overall project risk is determined in point (score) from 0 to 100. The formula to calculate the score of the overall project risk is made as 0 point for the sum of the highest individual business risks and 100 points for the sum of the lowest individual business risks. Assuming “M” as the sum of the possible highest individual business risks for the project where a number of potential risks are assumed, and “m” as that with possible lowest risks assumed, a formula to calculate the score of the overall project risk can be described as follows:

$$y = \frac{100}{M-m} x + \frac{100M}{M-m}$$  \hspace{1cm} (2)

where \(y\): Overall project risk score (point)
\(x\): Sum of individual business risks

Using the formula shown in (2) above, the sum of the individual business risks in score (point) can be calculated.
The minimum required score is set in advance in order to finally evaluate the project viability in such a way that the minimum required score is higher than the sum of the individual business risks when the average probability of each level is at the value of the threshold. If the minimum required score is set lower, the overall project risk score becomes always higher if the average probability is higher than the value of the threshold, meaning the evaluation based on the overall project risk score is meaningless. Therefore, the minimum required score is set to avoid such cases. By having the minimum required score, the evaluation of the average probability and the overall evaluation become valid and meaningful. The result of the overall project evaluation for the case study is shown below.

**Table 8 Comparison of result of overall project evaluation and minimum required score**

| Overall Project Risk Score (0 – 100) | 63 |
|--------------------------------------|----|
| Minimum Required Score               | 65 |

From Table 8 above, it is observed that the overall project risk score, which is the sum of the individual business risk points, resulted in lower than the minimum required score. In addition to this evaluation, another assessment was carried out by categorizing the individual business risks into 3 groups of critical level by the extent of the points.

**Table 9 Extent of individual business risk**

| Extent | Critical Level | Description |
|--------|----------------|-------------|
| Individual Business Risk ≤ 340 | Critical | The project has high potential of risk and the success in the project is assumed to be difficult without proper plans to reduce the risk. |
| Individual Business Risk ≤ 144 | Attention | The risk in the project is moderate but an attention shall be paid to avoid the potential risk from arising. |
| Individual Business Risk < 144 | Allowable | The project has little risk and the overall project risk is manageable and controllable. |

As shown in Table 9 above, values at the border between attention item and allowable item and that between critical item and attention item are set at 144 and 340 respectively, which are calculated from the following formulas:

- Boundary between attention item and allowable item = average of importance value × 3 × 3 × 3
- Boundary between critical item and attention item = average of importance value × 4 × 4 × 4

Applying the above formula, the evaluation can be made objectively for different type of projects. The result of the classification of the extent of the individual business risk of each risk factor is as follows.

**Table 10 Classification of extent of individual business risks (extract)**

| Risk Factor (Level 3) | Individual Biz. Risk | Extent | Critical Level |
|-----------------------|----------------------|--------|----------------|
| Force majeure         | 400                  | ≥ 340  | Critical       |
| Capability of Implementation Agency | 192 | ≥ 144  | Attention |
| Appropriateness of project / contract period | 192 |  |
| Approved budget for project | 180 |  |
| Appropriateness of cost estimate and government project budget | 180 |  |
| Abnormal climate conditions | 128 |  |
| Political change, Coup de Tat, etc. | 128 |  |
| Acceptance of additional cost required due to the Employer | 120 |  |
| Recognition and acceptance by residents | 108 |  |
| Delay in works due to incompleteness in design | 108 |  |
| Experience in and understanding of the project country | 84 |  |
| Escalation clause | 72 |  |
| Availability and quality of sub-contractors | 70 |  |
| Appropriateness of pre-qualification (PQ) requirements | 64 |  |
From Table 10, it is observed that the critical item in the project is considered as the force majeure and also that careful attention needs to be paid to the appropriateness of the project budget and the contract duration. This result can be justified by the fact that the project country has been politically unstable for a long period and that the project implementation agency has no experience in the implementation of similar projects in the past which could imply high possibility of deviation from the planned project budget and duration.

In summary of the result and assessment of the qualitative evaluation, we consider that the measures to avoid risks taken by the contractor of the case study project were insufficient at the time of bidding. Without proper measures against the force majeure, such as coup de tat, and plans to achieve better contract conditions during negotiation with the employer before signing the contract, the project is evaluated as not decent one and implementing the project involves high risks of low profit or loss.

5. Qualitative Risk Evaluation Method in Proposed HREM
5.1 Application of Proposed Evaluation Method

In this Study, a qualitative evaluation to estimate the expected profit from the project was made by the Reverse Profit and Loss Calculation. The Reverse Profit and Loss Calculation is to identify the components, or factors, affecting the overall profit of the project by the top down method instead of the normal calculation by the bottom up method in which costs of each detail component is summed up.

![Fig. 2 Influence diagram of international infrastructure project.](image_url)

Fig. 2 Influence diagram of international infrastructure project.

Relationships between factors which are related with each other is connected as a diagram. This diagram is created by interviewing a project manager of Suvarnabhumi Airport Rail Link (ARL) in Bangkok. A flowchart of proposing Hybrid Risk Evaluation Method (HREM) in bidding decision. Elements from start until first branch express a qualitative evaluation process of project risk using check list. Elements from first branch to second branch express a quantitative evaluation process based on sensitive analysis.

Each element as the input data is the quantitative factor that can be managed and controlled by the contractor and is related to the input data for the qualitative check list. On the other hand, the output data may be also managed and
controlled by the contractor but is variable affected by the input data. Qualitative elements are those that can be controlled by the contractor itself by improving its own capability, understanding the country’s situation, etc., whereas the external elements are the factors beyond control of the contractor, such as natural disaster, capability of the employer, etc. Risks of such external elements can be mitigated to some extent by taking proper measures against the potential risks that could actually occur. The Influence Diagram, as shown in Figure 2, needs to be prepared not only including variables affecting the project profit but also the qualitative elements and the external elements. It is important to include factors in the Influence Diagram that directly affect the project profit, but also those indirectly affecting the project profit which are the major components in the Influence Diagram. After preparing the Influence Diagram, a flow chart for the Reverse Profit and Loss Calculation is prepared with only variable elements in the Influence Diagram.

![Influence Diagram](image)

**Fig. 3** Reverse-profit diagram of international infrastructure project (extracted).

Elements which organize an overall profit are connected with links via equations. This diagram is created by interviewing a project member of Suvarnabhumi Airport Rail Link (ARL) Construction Project in Bangkok.

Figure 3 only shows a part of the Influence Diagram prepared for the railway systems contract in the case study project. In typical railway construction projects, either a new line or an extension of the existing line, civil works contract(s) and railway systems contract(s) are bid and awarded separately, whereas the case study project, i.e. SARL Project, was uniquely implemented with one contract comprising the civil works and the railway systems. Although in one contract, the civil works and the railway systems are separately managed by each contractor for each portion with different type of contract conditions, thus the Reverse Profit and Loss Calculation was carried out separately for the civil works and the railway systems portions, which are also internally managed separately by 2 contractors comprising the consortium. With the Reverse Profit and Loss Calculation, a logic and relationships among each cost element comprising the project profit can be clarified. After the flowchart is prepared, the amount of each cost element is input into the Profit and Loss Assessment table to calculate the expected profit or loss of the overall project. An extract of the summary of
the profit and loss assessment in shown in Table 11.

**Table 11 Summary of profit and loss assessment (extract)**

| Cost Element                                | Amount / Volume | Unit    |
|---------------------------------------------|-----------------|---------|
| Target Profitability = 3.7 %                |                 |         |
| Target Profit Amount                       | 1.52 billion-yen|         |
| Contract Amount                            | 42.54 billion-yen|        |
| Total Expenses                             | 41.02 billion-yen|       |
| Bidding Cost                               | 0.1 billion-yen |         |
| Document Preparation Cost                  | 6.65 billion-yen|         |
| Equipment / Sub-system Procurement Cost    | 28.04 billion-yen|        |
| Manufacturing Cost                         | 19.64 billion-yen|        |
| Material Cost                              | 6.2 billion-yen |         |
| Procurement Cost                           | 8.4 billion-yen |         |
| Transportation and Delivery Cost           | 0.49 billion-yen|         |
| Installation Cost                          | 4.7 billion-yen |         |
| General Requirements Cost                  | 1.04 billion-yen|         |

The amounts of each cost element were input based on the assumptions of the authors with best knowledge and experience, as they are confidential within the contractors. In order to achieve the target profitability, the amount of each cost element needs to be comprehensively adjusted among all elements. However, in reality, the actual cost required for each cost element varies depending on various factors, such as the company’s strategy, applied construction methods, actual work site conditions, construction market in the country and overseas, etc. Therefore, some cost elements need to be considered with certain level of range, extract of which are shown in Table 12:

**Table 12 Summary of profit and loss assessment with range (extract)**

| Cost Element                               | Amount / Volume | Unit     | Max. | Standard | Min. |
|--------------------------------------------|-----------------|----------|------|----------|------|
| Components Procurement Cost                | 10              | billion-yen | 20   | 10       | 5    |
| Equipment Manufacturing Cost               | 1.29            | billion-yen |      |          |      |
| Material Transportation Cost               | 1.5             | billion-yen | 3.5  | 1.5      | 1    |
| Sub-contracting Cost                       | 4               | billion-yen |      |          |      |
| Assembly Cost                              | 5               | billion-yen | 5.5  | 5        | 4.5  |
| Inspection and Testing Cost                | 0.1             | billion-yen |      |          |      |
| Manufacturing Management Cost              | 6.4             | billion-yen |      |          |      |
| Manufacturing Labor Cost                   | 5.4             | billion-yen |      |          |      |
| Labor Unit Cost                            | 2               | JPY/day   | 4    | 2        | 1    |
| Number of Labors                           | 3               | thousand/day | 4   | 3        | 2    |
| Contract Period (excl. System Integration) | 930             | day      |      |          |      |
| Original Contract Period                   | 900             | day      | 1,000| 900      | 800  |
| Extended Period                            | 30              | day      | 1,000| 30       | 0    |
| Administration Cost                        | 10              | billion-yen | 12   | 10       | 8    |

By having ranges for some cost elements, measures can be taken to adjust costs for each element during the construction phase in case of the occurrence of uncertain and unforeseen events. For example in the Study, the contract period was assumed to be extended by 1,000 days as the worst case, by 30 days as the standard case, and no extension (0 day) for the best case. The Profit and Loss Calculation was conducted by reflecting the result of risks in the qualitative check list.

Using the influence diagram, qualitative factors and quantitative factors are connected. The qualitative factors are
defined as the qualitative elements in the Influence Diagram (Fig. 2), and the constraint elements are calculated as the numerical result from it. For example, when the qualitative factor ‘economic conditions’ is ‘good’, the labor cost increases by 10%.

Figure 4 shows such relationship between the qualitative and quantitative factors. In Figure 4, a part of the elements related to works during the extended period, which is used in the calculation to be described later, is defined in the Influence Diagram. As an example shown in Figure 4, the expected extension period is calculated caused by the Coup de Tat after inputting the risk index for the Coup de Tat shown at the right in the figure. In the Study, the risk index is given from the qualitative check list. According to the qualitative check list, it can be recognized that the Coup de Tat is related to the Force Majeure. Probabilities of each risk factor and their values are essential and thus adopted in the quantitative calculation, whereas values of the recognition of each risk factor are not referred as those values are negligible. The risk index is calculated by the formula utilizing the values in the qualitative check list.

\[
R^k = \frac{\sum_{i=1}^{n} s^i c^i p^i}{\sum_{i=1}^{n} s^i c^i}
\]

where
- \( s^i \): scored importance of factor \( i \)
- \( c^i \): scored criticality of factor \( i \)
- \( p^i \): scored probability of factor \( i \)
- \( n \): number of input elements of factor \( k \) on influence diagram
- \( R^k \): calculated quantitative risk of factor \( k \)

According to the above formula (3), the risk index of the Coup de Tat is calculated as 5, which is the maximum value of the risk index. In this project, expected days of delay (extension) are prospected by the following formula:
\[
\begin{align*}
\text{(4)} \\
d &= R^k \times 7
\end{align*}
\]

where \( s_i \): scored importance of factor \( i \)
\( c_i \): scored criticality of factor \( i \)

In equation (4), the number 7 is a magic number which is estimated by considering the delay days in the past similar projects. It means that to construct the relationships between the qualitative and quantitative factors, it is necessary to collect practical data from the past experiences. These are not analytical processes, but quite implicit and actual processes. The equation (4) is only an example. Every relationship is different and it is difficult process to automate.

From the above formula, it is observed that the expected days of delay (extension) caused by the Coup de Tat would be 35 days. In this example, the risks residing in the project are assessed and evaluated by calculating the qualitative elements and the external elements identified in the Influence Diagram based on the values in the qualitative check list. Accordingly, it was confirmed that the overall project can be evaluated in a hybrid way by both qualitative evaluation and quantitative evaluation.

5.2 Evaluation result and discussions

Based on the output and the result of each calculation, a tornado chart was prepared as the sensitive analysis and the Monte Carlo simulation (Mooney 1997) (Hukushima and Nemoto 1996) was carried out based on the Influence Diagram, the Reverse Profit and Loss Calculation and the Profit and Loss Assessment table.

The Tornado Chart (Eschenbach 1992) shown in Figure 5 indicates the range of profitability with possible range in the horizontal axis and the cost elements in the vertical axis. A wider range, meaning longer bar in the chart, means a larger fluctuation in the potential profitability or the risk at the end. Therefore, those elements with the wide range have a larger impact in the success of the project and thus they should be carefully managed and controlled at the beginning. It can be said from the simulation result that the labor cost and the number of labors have a large impact on the profitability of the overall project. In fact, it can be assumed that the increase of the labor cost due to the change in the legislation during the construction period would have a significant impact on the profitability of the project, especially in the civil works portion. Therefore, the result in the Study is considered reasonable and justifiable on the validity of the evaluation method.

![Fig. 5](image)

A calculation result of impact analysis of element changes. The impacts on overall profitability by changing each element such as ‘Labor Unit Cost’ or ‘Number of Labors’ are shown in horizontal bar graph. The length of bar indicates how each element is going to affect the final profitability. Each element has conceivable range in this project.
The Monte Carlo simulation is a simulation to obtain the tendency by conducting millions of repeated calculations using random numbers, which are given from the progression to recognize the range of values as the actual values of random variables on the computer. The Monte Carlo simulation was carried out in order to understand the range of possible profitability of the case study project.

Figure 6 shows the distribution of the profitability in the horizontal axis and the number of occurrences in each value in the vertical axis. From the graph in Figure 6, it is observed as a result of the simulation that the average value is 1.56 and the standard deviation is 5.85. Based on these results, the confidence interval of the profitability is calculated by the interval estimation of the science of statistics.

Table 13 Interval estimation

| Average (%) | Deviation | Confidence | Max. (%) | Min. (%) |
|-------------|-----------|------------|----------|----------|
| 1.56        | 5.85      | 0.68       | 7.41     | - 4.29   |
|             |           | 0.95       | 13.26    | - 10.14  |

As show in Table 13, in case the confidence is 0.68, the confidence interval becomes 13.26% at the maximum and - 4.29% at the minimum, whereas the interval of those in case of 0.95 becomes 13.26% at the maximum and - 10.14 at the minimum. Accordingly, the average profitability from the simulation is calculated as 1.56%. As a result, the possibility of achieving the balance is calculated as approx. 64%, whereas that of achieving the target profitability is approx. 43%.

The expected profitability can be calculated from the result of the Monte Carlo simulation. By increasing the number of the distribution of the profitability in the Monte Carlo simulation, the average value of the distribution of the profitability and the accuracy of the expected profitability calculated by the number of occurrence can be improved and more practical.

Table 14 Expected project profit

| Sum of ranges in Histgram | Times | Average of ranges in Histgram | Each Expected Profit margin |
|---------------------------|-------|-------------------------------|-----------------------------|
| -37.28                    | 1     | -18.64                        | 0.00                        |
| -36.50                    | 0     | -18.25                        | 0.00                        |
| -35.72                    | 0     | -17.86                        | 0.00                        |
|                           | 0     | -17.47                        | 0.00                        |
| 37.19                     | 1     | 18.59                         | 0.00                        |
| 37.97                     | 1     | 18.64                         | 0.00                        |
| 38.75                     | 0     | 19.38                         | 0.00                        |
| 39.54                     | 0     | 19.77                         | 0.00                        |
| 40.32                     | 1     | 20.16                         | 0.00                        |

| Simulation times | expected project profit margin |
|------------------|-------------------------------|
| 10000            | 1.57                          |

Table 14 indicates that the expected profit for the project is 1.57%. The result from the interval estimation and that from the expected project profit both imply that the project is not highly profitable. In reality, it can be assumed that the contractor of the case study project could not achieve sufficient profit from the project. Therefore, the result from the case study is considered valid, practical and reliable to some extent. Although the success of the project is often determined by the actual profit made from the project, it is also important to note that the target profitability largely depends on the company’s scale, the objective and the financial status. For example, if the company’s main objective of the project is to have an experience in the project country rather than making a large profit from the project, the project is considered to be allowable and worthwhile even though the target profitability is relatively low. This can be strengthened if there are other stable projects or business activities in the company that can make up the low profit or a certain loss from the project. On the other hand, companies that have no such project or business activity should only
aim at projects in which medium to high profitability can be expected.

In summary for the result and the assessment of the quantitative evaluation for the case study project, it can be said that the expected profitability would highly likely become relatively low as only 1.5% unless proper measures to manage the labor unit costs and the number of labors. Therefore, the case study project was considered to be only doable by companies that have other projects and/or business activities that can assure making up the anticipated low profit or even a loss from the project. In other words, companies which have no such project and/or business activity shall avoid bidding the project.

6. Conclusion

In this Study, a Hybrid Risk Evaluation Method (HREM) was proposed as a tool for decision making on go or no go for international infrastructure projects based on the theory that the combination of the qualitative and quantitative approaches could improve the accuracy of the determination of risks residing in the project by the indication of the result in numerical value, and the assessment of the verification of the effectiveness of the HREM was carried out. A case study based on the actual project was conducted as the post evaluation applying the realistic assumptions on various data, and the result of the assessment showed that the project was not worthwhile and not profitable. Possible measures to mitigate the potential risks can be summarized as follows:

- In the qualitative evaluation, proper measures against force majeure, such as Coup de Tat, should have been considered, e.g. requesting the employer of the project at the time of the contract negotiation to include an appropriate compensation against the negative impacts due to the force majeure.
- In the quantitative evaluation, careful considerations should have been made against the possible increase in the labor unit costs and the number of labors, e.g. including contingency for potential increase of the labor costs in the price proposal.

Without proper measures for above mentioned issues, the project could have been considered as not the right project for profit making. It is quite difficult or impossible to properly and in detail evaluate potential risks of the project only by the consideration of project characteristics as the qualitative evaluation or the simple calculation of the profitability of the project by costs as the quantitative evaluation. A combination of the qualitative evaluation of the potential risks residing in the project that cannot be quantified and the quantitative evaluation of the cost factors attributable to the project profit enable the comprehensive and integrated evaluation of the overall project risks. To precisely and accurately carry out both qualitative and quantitative evaluations, it is essential and inevitable that the contractor’s staffs carrying out the evaluations deeply understand the project characteristics and the elements required to implement the project. Nevertheless, the result of the post evaluation of the actual project has more or less proved that the theory assumed as mentioned above was worth considering and taking into account in the decision making as the result obtained is assumed to be consistent with the actual situation of the contractor in the project.

We envisage that the next step of the Study is (1) to improve the validity of the criticality and the probability of risk
factors by clearer evaluation criteria, and (2) to carry out more case studies for the completed projects in order to increase the practicality and generality of the quantitative evaluation, particularly the cost factors and the quantification of the qualitative and external elements, so that the proposed HREM could be widely applied to various kinds of projects.

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