An integrated approach for risk assessment in port projects

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Abstract
Port risk management is utilized to describe a sequence of the analysis and management activities focused on creating specific responses to inherent risks in port projects. Risk assessment is taken into account in the projects; however, it is still comparatively neglected for the assessment process with non-parametric resampling techniques and interval analysis. The required data and experts’ judgments in developing countries are often small. Hence, traditional approaches cannot assist such problems remarkably. An integrated approach is proposed in this paper for risk assessment in port projects for the use of the bootstrap and interval computations. In an application example, the proposed approach is investigated in detail. Finally, the traditional and proposed approaches are compared.

Keywords: Port projects, Risk management, Resampling techniques, Interval analysis.

1 Introduction
Risks and uncertainties within port projects are related to national and international trade, political instability at regional and global levels, environmental damages, and security threats. Decisions made by the project manager in port projects are often challenging. Risks in port investment and management can be categorized by construction, country, social, operational, environmental, financial, commercial and monetary risks [1].

Project risks can be regarded as uncertain events that can have negative or positive impacts on its success [1]. These risks can affect on the cost, schedule, scope or quality of the projects [2-11]. Project risk assessment is the process that concentrated on evaluating the probability, in which potential risks in the risk identification stage may be considered [3].

There are limited papers discussing risk management for port projects. Balas et al. [12] extended a project management model that handles the risk factors and uncertainties encountered in the different phases of mega projects. Trbojevic and Carr [13] developed a step-wise approach for safety improvement in port
operations. Yip [14] concentrated on port traffic risk issues by regarding historic accidents in Hong Kong port for risk management.

This paper presents an integrated approach based on non-parametric bootstrap techniques and interval risk score (IRS) to data provided by port industry experts’ judgments. The bootstrap is utilized to estimate confidence intervals for the criteria of risk analysis, such as probability and impact criteria. Then, interval computations for evaluating risk data are introduced for precise analysis in port risk assessment process. The remaining sections of the paper are organized as follows. In Section 2, the proposed approach is described in three phases. In Section 3, the computational results in a port project as an application example is provided. Finally, conclusions and further researches are provided in Section 4.

2 Proposed approach

This paper identifies and appraises the important risks in order to make them understandable and manageable more effectively. There are numerous techniques for the risk identification and assessment of port projects [15, 16]. These techniques provide a list of risks that often do not directly assist top managers in knowing where to focus risk management attention. The evaluations can help us to prioritize identified risks by estimating common criteria and recognizing the important risks.

The proposed approach is applied in the application example. Risk planning of port project is considered in the phase one. In this phase, organizational and project environmental are taken in to account. After planning the project risks, the core of the proposed approach is constructed in the next two phases: Phase two in turn falls into two steps. In Step 2-1, data of port projects are reviewed in order to identify risks. In Step 2-2, the risk breakdown structure (RBS) is developed in order to organize different categories of project risks. Phase three of the proposed approach falls into seven steps. These steps are as follows: In Step 3-1, descriptive scales are determined for transferring linguistic variables of probability and impact criteria to quantitative equivalences; in Step 3-2, the risks are filtered at the lowest level of the RBS regarded as initial risks; in Step 3-3, the identified port risks (i.e., initial risks) are classified into the important and negligible risks; in Step 3-4, the non-parametric bootstrap technique is applied for the important risks; in Step 3-5, confidence interval is calculated for the criteria of risk assessment; in Step 3-6, interval computations are conducted for scoring risk data; and in Step 3-7, the final ranking of the important project risks is obtained.

Phase 1: Project risk planning

Risk planning is the first phase of the proposed approach. This phase is needed to establish the organizational and project environmental, and to specify the main vision, goals, objectives and outcomes required. Project risk planning is regarded as the process of developing and documenting an organized and comprehensive strategy. Techniques are also considered for identifying and appraising risk issues, developing risk handling plans, and monitoring how risks have changed [17–20]. To carry out the proposed integrated approach, a team of port industry experts and risk management experts is formed. Duties of the team are as follows: (1) Revision of the proposed approach: They are requested to check the integrated approach prepared by a non-parametric bootstrap technique and interval computations, comment on the applicability of the approach, and propose revisions. (2) Determining descriptive scales for the probability and impact criteria: Experts are required to specify descriptive scales. They should make a decision how the overall risk ratings may change with different linguistic expressions of risk levels and influencing factors. (3) Risk identification: The team is to present the port project risks in hierarchical, manageable and definable packages in order to provide a basis for identifying and assessing risks and to depict a graphical presentation of the port project risks. (4) Risk assessment: They are requested to analyze risk score that appears in the proposed integrated approach.
**Phase 2: Project risk identification**

**Step 2-1: Review project data**

Any source of information that allows recognition of a potential risk problem can be utilized for risk identification. This information include risk identification techniques and key project documents, such as questionnaires, checklists, brainstorming, expert judgment, cost analysis, scope definitions, and any other relevant documentations about the port project and its purpose. Furthermore, within comparative sessions, the project risk team is presented with the various potential risk data emerged from a careful review of the literature [21-24].

**Step 2-2: Define risk breakdown structure**

The RBS is developed to organize the different categories of risks. To improve the risk identification process, risks can be classified according to their levels. Project risks are divided into eight levels (i.e., construction, social, operational, environmental, monetary, country, commercial, and financial). The presented RBS can assist in the identification of risk factors by simplifying the risk structure into smaller units for estimating the effect of the project risks.

**Phase 3: Project risk assessment**

Phase three strives for deeper understanding of potential project problems after identifying the project risks. This phase is the process of evaluating potential risks documented in the preceding phase, ranking the risks and allowing the team to select the important ones.

**Step 3-1: Determine descriptive scales for the probability and impact criteria**

The probability and impact criteria are two commonly used criteria in project risk management [2,3]. The descriptions of these criteria are as follows:

**Probability criterion:** Risk probability assessment investigates likelihood that each specific risk will occur. This paper rates likelihood in terms of annual occurrence on a seven-point descriptive scale, showing the likelihood of port risks arising and leading to the assessed levels of consequences as illustrated in Table 1.

**Impact criterion:** Risk impact assessment investigates potential effect on a project objective, such as time, cost, scope, or quality. This paper utilizes consequences in terms of the impacts on a five-point descriptive scale and reviews carefully the consequences scales as illustrated in Table 2.

| Probability scale | Description                  | Number |
|-------------------|------------------------------|--------|
| Very low (VL)     | Possible, but very unlikely  | 0.05   |
| Low (L)           | Possible, but unlikely       | 0.15   |
| Slightly low (SL) | Possible, but slightly unlikely | 0.3   |
| Medium (M)        | Possible, and likely         | 0.5    |
| Slightly high (SH)| Likely                       | 0.7    |
| High (H)          | Highly likely                | 0.85   |
| Very high (VH)    | Very highly likely           | 0.95   |
Step 3-2: Obtain initial risks
The identified risks in the lowest level of proposed RBS are regarded as initial risks in this step.

Step 3-3: Purify initial risks
To apply the hybrid bootstrap–IRS approach for analyzing risks in port projects, we need to classify the identified port risks into the important and negligible risks. The negligible risks were not taken into consideration in the next step, which they have minor impacts and low probability of occurrence. A list of important risks with the probability and impact criteria is illustrated in Tables 3 & 4 consisting of 12 important risks obtained through the decision making process. These important risks and analysis criteria are utilized as the bootstrap input data in the next step.

| Risk  | Description                                                                 |
|-------|-----------------------------------------------------------------------------|
| R1    | Changes in laws                                                             |
| R2    | Common policy                                                               |
| R3    | Excessive port tariff                                                       |
| R4    | Faults in laws                                                              |
| R5    | Inflation rate volatility                                                   |
| R6    | Interest rate volatility                                                    |
| R7    | Lack of attention to international laws and regulation                      |
| R8    | Lack of coordination among port public and private firms                    |
| R9    | Lack of expert human resources                                              |
| R10   | Lack of prerequisite training                                               |
| R11   | Operation cost overrun                                                     |
| R12   | Permits delayed or take longer than expected                                |

Table 2: Risk impact scale for port projects.

| Impact scale | Description                                               | Number |
|--------------|------------------------------------------------------------|--------|
| Very low (VL)| Impact may be safely ignored                               | 0.05   |
| Low (L)      | Impact minor with routine management procedures           | 0.20   |
| Medium (M)   | Large impact, but can be managed with effort using standard procedure | 0.40   |
| High (H)     | Critical event, potential for major costs, or delays      | 0.60   |
| Very high (VH)| Extremely event, potential for large financed costs or delays or damage to the project organization’s reputation | 0.85   |
Table 4: Risk observed data using linguistic terms.

| Risk | DM₁ | DM₂ | DM₃ | DM₄ |
|------|-----|-----|-----|-----|
| R₁   | H   | M   | H   | VH  |
| R₂   | SL  | M   | L   | M   |
| R₃   | SH  | H   | M   | H   |
| R₄   | H   | H   | SH  | M   |
| R₅   | H   | H   | VH  | M   |
| R₆   | M   | H   | H   | SH  |
| R₇   | M   | M   | L   | M   |
| R₈   | H   | H   | VH  | M   |
| R₉   | M   | H   | M   | SH  |
| R₁₀  | H   | M   | SH  | M   |
| R₁₁  | H   | M   | H   | SH  |
| R₁₂  | H   | M   | H   | L   |

Observed risk data regarded as outcome of the step 3-3 are depicted in Table 4. Since these data contain linguistic terms, the linguistic terms first are transformed into numbers by using the conversion scales (See Tables 1 & 2). Then results (original sample) are presented in Table 5.

Table 5: Observed risk data (i.e., original sample) transformed into numbers.

| Risk | DM₁ | DM₂ | DM₃ | DM₄ |
|------|-----|-----|-----|-----|
| R₁   | 0.85| 0.4 | 0.85| 0.6 |
| R₂   | 0.3 | 0.4 | 0.15| 0.6 |
| R₃   | 0.7 | 0.6 | 0.85| 0.4 |
| R₄   | 0.85| 0.6 | 0.7 | 0.4 |
| R₅   | 0.85| 0.6 | 0.85| 0.5 |
| R₆   | 0.5 | 0.6 | 0.85| 0.6 |
| R₇   | 0.5 | 0.4 | 0.15| 0.6 |
| R₈   | 0.85| 0.6 | 0.85| 0.6 |
| R₉   | 0.5 | 0.6 | 0.85| 0.4 |
| R₁₀  | 0.85| 0.4 | 0.7 | 0.4 |
| R₁₁  | 0.85| 0.4 | 0.5 | 0.6 |
| R₁₂  | 0.85| 0.4 | 0.85| 0.2 |

**Step 3-4: Apply the non-parametric bootstrap technique**

Non-parametric bootstrap principle is as follows [25]:

I. Conduct the experiment to obtain the random sample \( x = \{X_1, X_2, ..., X_n\} \) and calculate the estimate \( \hat{\theta} \) from sample \( x \).

II. Construct the empirical distribution, \( \hat{F} \), which puts equal mass, \( 1/n \), at each observation, \( X_1 = x_1, X_2 = x_2, ..., X_n = x_n \).

III. From the selected \( \hat{F} \), draw a sample, \( x^*_b = \{X^*_1, X^*_2, ..., X^*_n\} \) for \( b = 1, 2, ..., B \), where \( x^*_b \) called the bootstrap resample.

IV. Approximate the distribution of \( \hat{\theta} \) by the distribution of \( \hat{\theta}^* \) derived from \( x^* \).
Step 3-5: The bootstrap principle for calculating confidence intervals for the criteria of risk analysis

The bootstrap principle for calculating confidence intervals for the criteria of risk analysis is as follows [25]:

I. Resampling the bootstrap principle.

II. Calculate the mean of all values in \( P^* \) and \( I^* \) (\( P \) and \( I \) stand for probability and impact criteria respectively).

III. Repeat steps I and II a large number of times to obtain a total of \( B \) bootstrap estimates \( \hat{p}_1^*, \hat{p}_2^*, ..., \hat{p}_B^* \) and \( \hat{i}_1^*, \hat{i}_2^*, ..., \hat{i}_B^* \).

IV. Approximation of the distribution of \( \hat{p} \) and \( \hat{i} \). Sort the bootstrap estimates into increasing order to obtain \( \hat{p}_1^* \leq \hat{p}_2^* \leq \ldots \leq \hat{p}_B^* \) and \( \hat{i}_1^* \leq \hat{i}_2^* \leq \ldots \leq \hat{i}_B^* \) where \( \hat{p}_{(k)}^* \) and \( \hat{i}_{(k)}^* \) is the \( k \)th smallest of \( \hat{p}_1^*, \hat{p}_2^*, ..., \hat{p}_B^* \) and \( \hat{i}_1^*, \hat{i}_2^*, ..., \hat{i}_B^* \) respectively.

V. Confidence interval. The desired \( (1-\alpha)100\% \) bootstrap confidence interval is \( (\hat{p}_{(q_1)}^*, \hat{p}_{(q_2)}^*) \) and \( (\hat{i}_{(q_1)}^*, \hat{i}_{(q_2)}^*) \) where \( q_1 = \left\lfloor \frac{B\alpha}{2} \right\rfloor \) and \( q_2 = B - q_1 + 1 \).

It is worth mentioning that this phase of the proposed approach is iterative. This means that we have to resample original samples with different \( B \) until the lower bound (L) and upper bound (U) of the confidence interval for the probability and impact criteria will be stabilized. Typical value for \( B \) as the number of iterations is often between 25 and 1000. For instance, \( B \) can be selected from \( \{ 1000, 750, 500, 250, 25 \} \) or any other similar set. After determining appropriate \( B \), confidence intervals for the criteria of risk analysis is regarded as an input for the risk scoring with interval computations.

Step 3-6: Calculate interval risk score

The IRS for each important risk under probability and impact criteria is calculated as follows:

\[
IRS = P \times I
\]  
(1)

A definition of multiplication for interval numbers for each criterion, represented as pairs of real numbers, follows from elementary property of the inequality relation [26]. We have

\[
P \times I = [p^L, p^U] \times [I^L, I^U] = [\min(p^L I^L; p^L I^U; p^U I^L; p^U I^U), \max(p^L I^L; p^L I^U; p^U I^L; p^U I^U)]
\]

Step 3-7: Determine the final risk ranking

After determining the score of risks in interval form, we need to compare IRSs. Suppose that \([r_1^L, r_1^U]\) and \([r_2^L, r_2^U]\) are two IRSs that we aim to rank them. In other words, we want to know which one is greater or smaller than the other. IRS is alternatively represented as \( IRS = [V(IRS), A(IRS)] \), where \( V(IRS) \) and \( A(IRS) \) are the mid-point and half-width (or simply be termed as width) of IRS, i.e.,

\[
V(IRS) = \frac{1}{2} [r_1^L + r_1^U]
\]

and

\[
A(IRS) = \frac{1}{2} [r_1^U - r_1^L].
\]

After this representation, the comparing technique is utilized [27] by calculating value and ambiguous for an interval number. In this case, the value (V) and the ambiguous (A) of an interval number is the same as
the midpoint and half-width of it, as mentioned above. The following sub-steps to rank two interval numbers IRS₁ and IRS₂ are suggested:

I. Compare V(IRS₁) and V(IRS₂). If they are “approximately equal”, then go to the next sub-step. Otherwise rank IRS₁ and IRS₂ according to the relative position of V(IRS₁) and V(IRS₂).

II. Compare A(IRS₁) with A(IRS₂). If they are “approximately equal”, then conclude that IRS₁ and IRS₂ are indifferent (almost equal). Otherwise rank them by considering DM’s attitude toward the uncertainty and the relative position of A(IRS₁) and A(IRS₂). In other words, a DM with an optimistic attitude toward the uncertainty could prefer the interval with greater width, whereas a pessimistic DM could prefer the interval with small width.

3 Computational results

In this section, we take advantages of the proposed integrated approach in the studied case. Sampling four values with replacement from the set \(( P₁, P₂, P₃, P₄)\) and \(( I₁, I₂, I₃, I₄)\) provides a bootstrap sample \(( P₁', P₂', P₃', P₄')\) and \(( I₁', I₂', I₃', I₄')\). The sampling of \(( P₁, P₂, P₃, P₄)\) and \(( I₁, I₂, I₃, I₄)\) with replacement is repeated \( B \) times, each time producing a bootstrap estimate \( P' \) and \( I' \). Then the confidence interval of the resamples with 25, 250, and 500 replications are calculated with \( \alpha = 5\% \). The \( q_i \) and \( q_\ast \) are calculated for each risk in Table 6 based on the third phase.

| Risk | 25          | 250         | 500          |
|------|-------------|-------------|--------------|
|      | \( P \)     | \( I \)     | \( P \)      | \( I \)     | \( P \)      | \( I \)     |
| R₁   | 0.850       | 0.925       | 0.400       | 0.600       | 0.850       | 0.940       | 0.450       | 0.650       | 0.850       | 0.940       | 0.450       | 0.650       |
| R₂   | 0.225       | 0.500       | 0.400       | 0.550       | 0.235       | 0.550       | 0.400       | 0.550       | 0.235       | 0.550       | 0.400       | 0.550       |
| R₃   | 0.588       | 0.850       | 0.450       | 0.600       | 0.580       | 0.840       | 0.450       | 0.600       | 0.580       | 0.840       | 0.450       | 0.600       |
| R₄   | 0.738       | 0.850       | 0.400       | 0.500       | 0.750       | 0.855       | 0.400       | 0.550       | 0.750       | 0.855       | 0.400       | 0.550       |
| R₅   | 0.588       | 0.850       | 0.450       | 0.738       | 0.588       | 0.850       | 0.500       | 0.790       | 0.588       | 0.850       | 0.500       | 0.790       |
| R₆   | 0.500       | 0.763       | 0.450       | 0.600       | 0.580       | 0.835       | 0.450       | 0.600       | 0.580       | 0.835       | 0.450       | 0.600       |
| R₇   | 0.188       | 0.450       | 0.500       | 0.600       | 0.250       | 0.450       | 0.450       | 0.600       | 0.250       | 0.450       | 0.450       | 0.600       |
| R₈   | 0.850       | 0.950       | 0.400       | 0.600       | 0.870       | 0.950       | 0.400       | 0.650       | 0.870       | 0.950       | 0.400       | 0.650       |
| R₉   | 0.550       | 0.813       | 0.400       | 0.500       | 0.550       | 0.750       | 0.400       | 0.550       | 0.550       | 0.750       | 0.400       | 0.550       |
| R₁₀  | 0.738       | 0.850       | 0.250       | 0.400       | 0.840       | 0.750       | 0.250       | 0.400       | 0.840       | 0.750       | 0.250       | 0.400       |
| R₁₁  | 0.500       | 0.725       | 0.500       | 0.600       | 0.500       | 0.775       | 0.450       | 0.600       | 0.500       | 0.775       | 0.450       | 0.600       |
| R₁₂  | 0.588       | 0.880       | 0.200       | 0.350       | 0.655       | 0.890       | 0.200       | 0.450       | 0.655       | 0.890       | 0.200       | 0.450       |

The third phase of the hybrid approach is an iterative process because original data should be resampled for many times. This procedure continues for each important risk until both confidence intervals of probability and impact criteria converge into constant values. In other words, we have to resample original samples with different \( B \) until confidence intervals for the analysis criteria of risks will be stabilized. This convergence occurs for the lower bound and upper bound of important risks after \( B = 250 \). Hence, resample \( B=250 \) is the best strategy for ranking the important risks in the studied case according to the approach.

This paper illustrates how the interval computations can be used in analysis of the important project risks. In Step 3-6, we calculate IRS for the important risks. There are twelve important risks and two main criteria. To increase accuracy, interval numbers from the bootstrap are used to describe and treat the uncertainty of the risk ranking. The interval numbers of \( P \) and \( I \) criteria for the important risks are considered based on 250-resample illustrated in Table 7. The IRS for each risk is calculated using Equation (1). In order to rank these important risks, the comparison of interval numbers is conducted.
according to Step 3-7. In this case, DMs considered pessimistic attitude toward the risk and uncertainty. Thus, DMs prefer an interval of \( A(IRS) \) with small width. Finally, the ranking of the important risks based on the interval computations is as follows:

\[
R_1 > R_8 > R_3 > R_4 > R_9 > R_5 > R_{11} > R_6 > R_{12} > R_{10} > R_2 > R_7.
\]

Table 7: Results of the traditional and proposed approaches.

| Important risks | Traditional approach | Proposed approach |
|-----------------|----------------------|-------------------|
|                 | \( RS_{mean} \) | \( RS_{mean} \) | \( IRS \) | \( \mu(IRS) \) | \( V(IRS) \) | \( A(IRS) \) | \( IRS \) | \( \mu(IRS) \) | \( V(IRS) \) | \( A(IRS) \) |
| \( R_1 \)     | 0.438               | 0.467             | \( R_1 \)  | 0.383 | 0.611 | 0.497 | 0.114 | \( R_1 \)  | 0.383 | 0.611 | 0.497 | 0.114 |
| \( R_2 \)     | 0.163               | 0.450             | \( R_2 \)  | 0.094 | 0.303 | 0.198 | 0.104 | \( R_8 \)  | 0.348 | 0.618 | 0.483 | 0.135 |
| \( R_3 \)     | 0.399               | 0.438             | \( R_3 \)  | 0.261 | 0.504 | 0.383 | 0.122 | \( R_5 \)  | 0.294 | 0.672 | 0.483 | 0.189 |
| \( R_4 \)     | 0.366               | 0.399             | \( R_4 \)  | 0.300 | 0.470 | 0.385 | 0.085 | \( R_4 \)  | 0.300 | 0.470 | 0.385 | 0.085 |
| \( R_5 \)     | 0.467               | 0.366             | \( R_5 \)  | 0.294 | 0.672 | 0.483 | 0.189 | \( R_3 \)  | 0.261 | 0.504 | 0.383 | 0.122 |
| \( R_6 \)     | 0.351               | 0.351             | \( R_6 \)  | 0.261 | 0.501 | 0.381 | 0.120 | \( R_6 \)  | 0.261 | 0.501 | 0.381 | 0.120 |
| \( R_7 \)     | 0.199               | 0.351             | \( R_7 \)  | 0.113 | 0.270 | 0.191 | 0.079 | \( R_7 \)  | 0.225 | 0.465 | 0.345 | 0.120 |
| \( R_8 \)     | 0.450               | 0.287             | \( R_8 \)  | 0.348 | 0.618 | 0.483 | 0.135 | \( R_9 \)  | 0.220 | 0.413 | 0.316 | 0.096 |
| \( R_9 \)     | 0.287               | 0.284             | \( R_9 \)  | 0.220 | 0.413 | 0.316 | 0.096 | \( R_{12} \) | 0.131 | 0.401 | 0.266 | 0.135 |
| \( R_{10} \)  | 0.284               | 0.229             | \( R_{10} \)| 0.188 | 0.336 | 0.262 | 0.074 | \( R_{10} \)| 0.188 | 0.336 | 0.262 | 0.074 |
| \( R_{11} \)  | 0.351               | 0.199             | \( R_{11} \)| 0.225 | 0.465 | 0.345 | 0.120 | \( R_2 \)  | 0.094 | 0.303 | 0.198 | 0.104 |
| \( R_{12} \)  | 0.229               | 0.163             | \( R_{12} \)| 0.131 | 0.401 | 0.266 | 0.135 | \( R_7 \)  | 0.113 | 0.270 | 0.191 | 0.079 |

4 Conclusions

This paper has aimed to recognize and assess the risks in port projects. For this purpose, an integrated approach is introduced. First, the non-parametric bootstrap technique is utilized to calculate the confidence intervals for the common criteria of the risk analysis for important risks in port projects. The bootstrap has been used in this paper for the criteria by only few data in these projects. Second, risk score technique with interval numbers has been taken into account by the bootstrap because of the fact that determining the accurate values of the risks is often difficult. An application example has been provided and the proposed approach in the port projects has been demonstrated in detail. The computational results have highlighted that the bootstrap has the high performance when the sample size is small. The proposed integrated approach has improved the data collection and statistical analysis in the risk assessment process and also interval analysis has produced reliable results. The bootstrap regression model can be regarded as further research for project risk assessment in the port projects.

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