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CORRUPTION AND INFRASTRUCTURE DEVELOPMENT BASED ON STOCHASTIC ANALYSIS

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SUMMARY

The effects of corruption in urban development and urban affairs management in several south Asian countries are examined through a series of specific, distinctive, and provocative cases for which the data is more readily available. The stories and themes provide a starting point for analyzing corruption as a symptom and factor of underdevelopment, affecting efforts to use and allocate scarce resources for a higher quality of life in cities. It shows how corruption stifles imaginative and creative solutions to urban challenges while increasing future revenue sources. 3Ps has provided a chance for the public section to look at various funding expertise and options from the business sector to prepare the public infrastructure.

On the other hand, governments in the source of budget limitations and other competing demands for state sources can't supply each citizenry's infrastructure. Besides, the private sector has been considered a better resource manager, and the government should concentrate on policymaking. Where P3s are put to fair use, the advantages are immense. Unfortunately, vulnerable to bribery.

This is the case; whatever benefits 3P offers in reducing the urban infrastructure deficit may be eroded due to corruption, which could lead to an increase in construction or facility costs.' rehabilitation. Secondly, a PPP process marred by corruption could lead to inferior construction substances. One of the fund's big chunks will be diverted to the public officials' bribing via the project company. Thirdly, a corrupt process could compromise officials' integrity that has been charged with accountability for inspecting and approving construction works.

Keywords: *Urban Infrastructure, Optimization, Private sector, Public-Private Partnerships (PPP), Public sector.*

INTRODUCTION

The symptom of crime is an (unaddressed) problem for city administrators, who are either helplessly confronted by various aspects of crime or are so entrenched in it that they are unlikely to become significant players in enacting effective anti-corruption laws. There is a call for more accountability. It is proposed that current corruption activities be converted into regularized payment service fees to honour good teamwork and decrease corruption's counter-productive developmental consequences.

The partnership among the public and private sections, so-called P3s, has some historical genealogy supplementing or restoring the *"traditional"* governmental accountability to supply and introduce standard economic interest services. Nonetheless, as with every type of private section partnership, P3s are instruments that present difficulties to public management [1]. This is all truer because *"with sweeping privatisation of public sector and other significant government roles, the ability and capacity of governments in public administration are seriously reduced"* [1]. Starting very differently in shaping and form, these cooperation models have to balance the private partner's managerial autonomy and democratic responsibility of the public section. They are characterised via horizontal connections and shared accountabilities [2,3]. They also epitomise that the cutting lines among the private and public spheres blur and have to be re-analyzed.

Overall, P3s are shaped to upraise potentials for a – qualitative and quantitative – development of public services due to increased managerial, technical, or financial efficiency [4]. Having an *"iconic condition around the world"* [5], they are usually viewed as a professional and sophisticated option for current urban infrastructure administration. This promise, also optimizm from P3 many times, advocates are required, did not fully realise. The reasons can be endogenous to the shape of a single project or more general exogenous elements in PPPs' execution procedure (as an instance, e.g., [6]). Numerous weaknesses could be noted here, as deal complexity requires long-run equity or issues associated with computing public section expenses [2].

Even if the 3P execution and implementation procedure seem to be comparable to contracts on other shapes of standard accountabilities among the private and the public section, there are essential distinctions, specifically considering contract duration and shape and the composition of players involved. PPPs' characteristics might make them specifically vulnerable to bribery, even if a fair number of contexts address the general monitor-impact of private section inclusion [7].

The paper's contribution to the ongoing argument on the utilize of P3s in addition to that is twofold. First, a problem more or less ignored via the proper context is analysed theoretically. Second, tackling the origins of immoral behaviour and bribery in P3s is more related. These instruments are utilized in developing nations whose legal order might shield P3s sufficiently towards corruption and improve nations, and these legal tools are not available in emerging markets. Hence, carving out the vulnerable points in 3P contracts might raise awareness considering this issue and enable DMs to install suitable monitor mechanisms, if required, on the project level.

P3s address innovative techniques utilized via the public section for agreement via the private section, which brings its capital and capability to deliver projects on time to the budget. In contrast, the public section retains the accountability to provide these services to the public to benefit the crowd and offer economic improvement and life quality development [8]. PPP projects' worldwide popularity is justified because P3s can effectively eschew the often-negative impacts of either exclusive on the one hand, public ownership and distribution services, or outright privatization. Additionally, P3s mix both entities' best: the public section via its regulatory acts and protection of the public interest; and the private section with its sources, technology, and management skills.

IMMORAL BEHAVIOUR AND BRIBERY AS GOVERNANCE ISSUES IN P3S

Immoral behaviour and corruption as governance issues in P3s regarding an extensive range of acts and measures that can be categorized as *"immoral Behaviour"* such as nepotism, or *"corruption"* in the literature of P3s, socio-economic, political, or more philosophical point of view on this title are of interest [9]. as the component element in the author's perspective, the – most clandestine – Using delegated authority for personal benefit, whether by government officials or others, stands out [10]. This fact is even more related as – in the literature of current institutional economics's economic theory– some principal-agent-connection exists in all assigned power cases. A principal who delegated authority and an agent who wielded it but couldn't move on it be managed via the principal characterise such a solution. This is right; although not all obligations breaches are the same, principal-agent issues can be considered immoral or corrupt.

The underlying presumption is societal agreement on the acceptable range of actions and a clear awareness of where authority or assigned power abuse begins Caiden, & Caiden, [9]; Von Arnim, Heiny and Ittner [10]. This concept encompasses a wide range of behaviors, regardless of whether or not the individual conduct is subject to prosecution in specific texts. While corruption is banned in most countries worldwide, prosecution schemes and attitudes toward immoral behavior varies significantly. As a result, even if unique conduct is socially acceptable – such as distorting the tendering process in favour of a business with whom a public official may be associated – it leads to the negative impacts of corruption.

According to principal-agent and contract theory, P3s are vulnerable to immoral behavior because of three classifications: the very incomplete and somewhat discretionarily decided to contract via high transaction expenses, the multi-step classifications of implementation and execution, and the underlying ones multi-level or life-cycle concept. This susceptibility can take the form of a variety of specialized routes for immoral behavior, exposing them to it more than other contractual arrangements or public-private collaborations [11,12]. These characteristics provide both reasons and opportunities for such behavior.

Individuals' decisions will be based on the incentive in a particular solution and the predicted expenses – including transaction expenses – and benefits from their decision, given that they have no implicit perspective on more or less moral behavior. As a result, immoral behavior can be described as an income function for both the *"bribe payer"* and the *"bribe."* The core concept is that the private sector has an incentive to bribe government officials (not vice versa). While the decision to collaborate through the private sector is political (pre-tender), management is in charge of the tendering and implementation process (ex-ante and ex-post to the project execution). As a result, in the vast majority of circumstances, the bribe's recipient will be the general public: During the pre-tendering phase, corruption may occur at the political level, with businesses attempting to persuade politicians to open up portions for P3s or, more concretely, to turn a single project into a 3P. When a private section aspires to join a freshly formed P3, the goal will be to reach the management level. The government apportioned the genuine cost of serving the market (which is usually a monopoly). The same principle applies to bribery throughout the project's execution phase or after it has been completed (in the literature of re-negotiations or agreements renewal).

P3S SELECTION IN THE URBAN INFRASTRUCTURE INVESTMENT PLANNING PROCEDURE

As mentioned earlier, the P3 procedure might be regarded as one of the more expansive public investment administration procedure branches. A project is simultaneously chosen as one of the potential PPPs, and after that, it follows a P3-specific procedure. Nonetheless, such branching may occur at various points in the public investment procedure. As an instance, this can be:

The following budgeting as one of the public investment projects, like the case in the Netherlands and Australia, the procurement options (e.g., PPPs) have been evaluated following a project approval and budgeting as one of the public investment projects. In the case of the subsequent implementation of the project as a PPP, the budget allocations would be adjusted analogously [13].

Following the project approval and appraisal as one of Chile’s public investments, each project underwent a cost-advantage evaluation through the National Planning Commission and met a specific social return rate for public investment. Moreover, the P3 projects have been taken from the above list.

Following a strategic or prefeasibility options analysis that has been done in the Republic of Korea, a potent P3 has been specified since a comprehensive project appraisal like cost-benefit analysis and or technical feasibility investigations. Notably, they are part of the PPP appraisal procedure. The same strategy has been observed in South Africa. The PPP has been implemented as a part of the initial need’s analysis and option evaluation of a potential public investment project.

MATERIALS AND METHODS

The urban project selection problem

The decision analysis and SCM studies have considerably attracted the Urban project selection problem. It is becoming one of the beneficial research topics for operational research and administrative science disciplines. For example, Ho et al. [14] assessed integrated and individual DM strategies thoroughly during 2000-2008 for aiding the urban project selection issue. Additionally, Chai et al. [15] provided a systematic assessment of literature based on the DMs methods that assisted the urban project selection between 2008 and 2012. It classified the above methods into three classes: mathematical programming, artificial intelligence, and (Multiple Criteria Decision-Making = MCDM).

It should be noted that the current project management demands the DMs for maintaining the strategic partnerships with some but reliable projects that efficiently decline the project expenses and enhance the competitive advantage [16]. Hence, both the common price factor and the promising urban project selection policy must rely on broader quantitative and qualitative criteria like delivery, quality, lead-time, and flexibility [17]. Finally, Dickson [18] specified 23 criteria that should be considered when the project manager identifies the urban project selection.

The urban project selection problem addressed in the present paper is presented here. Firstly, a set of candidate projects would be assessed in terms of criteria by engaging a group of experts. Notably, all experts prefer to order the criteria' importance. Therefore, all experts know the upper and lower bounds regarding the evaluation outputs for all projects in each criterion's deterministic values. Hence, an individual expert possibly produces interval evaluation values for measuring each project function. An (Interval project selection matrix = ISSM) is established to cover the project assessment and choice.

Moreover, various experts can create distinct intervals for specific projects. The interval formulation is triggered from the observation that different weight elicitation techniques in MCDM can produce different weights, even for an analogous issue. Thus, it has been assumed hard to reach the exact weights [19]. Analyzing a set of projects using interval values is essential in decision analysis. The present paper has aimed to develop an advanced procedure for resolving the (Stochastic multi-objective acceptability analysis = ISSM) mentioned above and providing a detailed rank of the candidate project s. Though most of the investigations on the multi-criteria urban project selection help guide the project manager to choose suitable projects effectively, it would be essential to know the impacts of interval values on the project assessment and choice. There is not enough information about such an attractive and critical topic as far as we are aware. The present study fills the above gap by shaping an Interval Urban project selection Matrix and utilizing the SMAA-2 to supply the candidate projects' holistic rank. Finally, this kind of investigation addresses the powerful incentives and guidelines for the managerial, policy-associated, and academic implications.

(Stochastic multi-objective acceptability analysis = SMAA) algorithm introduced by Lahdelma et al. [20] has been proposed as one of the methods seeking for aiding (Multiple-criteria decision-making = MCDM) with numerous experts or professionals in situations wherein there is limited or no weight information. Notably, the criteria values are uncertain, and it does not require the experts to explain their input data implicitly or exactly. Moreover, it supplies multiple meaningful and beneficial indices like adaptability indices for all alternatives that measure diverse input data, which give all other options the best-ranking position, confidence factor demonstrating the analysis reliability, and the central-weight that illustrates the preferences of an expert who supports an option. Consequently, Lahdelma & Salminen [19] extended SMAA by examining each rank and providing the holistic SMAA-2 evaluation to recognize suitable compromise alternatives. However, for those issues that have ordinal criteria information, Lahdelma et al. [21] developed one of the novel SMAA-O methods, and Durbach [22] presented an SMAA by gaining the functions (SMAA-A) for a discrete choice decision, which examines what combination(s) of the aspirations would be essential for making each alternative the prioritized one. Also, Lahdelma & Salminen [23] developed the cross-confidence elements according to the calculation of confidence elements for other options using others' central weights.

Moreover, Lahdelma & Salminen [24] combined the SMAA-2 and DEA methods to assess the multicriteria options. They also devised the SMAA-P technique in 2009, which combined the prospect theory's piece-wise linear difference functions with the SMAA method. Furthermore, Lahdelma et al. [25, 26] presented and compared the simulation and multi-variate Gaussian distribution techniques for treating dependency information and uncertainty of the SMAA-2 (Multiple-criteria decision analysis = MCDA) method. Consequently, Tervonen and Lahdelma [27] presented effective techniques for conducting computations via Monte Carlo simulation, analyzing complexity, and evaluating the presented algorithms' accuracy. In this regard, Corrente et al. [28] integrated the stochastic multicriteria acceptability analysis and (Preference ranking organization algorithm for enrichment evaluation = PROMETHEE) for exploring the parameters consistent with the preference information presented by a DM and Angilella et al. [29] as well as Angilella et al. [30] combined Choquet integral-preference algorithm with the stochastic multi-objective acceptability analysis algorithm for obtaining appropriate recommendations and Robust Ordinal Regression (ROR). Finally, Durbach and Calder [31] investigated literature wherein the DMs could not or do not wish assessment of the tradeoff information in SMAA accurately.

Besides the method development on SMAA, a lot of applied papers are found in related publications such as forest planning [31], facility location [21]., descriptive multi-attribute choice algorithm [32], elevator planning [33], estimating a satisficing model of choice [32], mutual funds' performance analysis [34-46], the project portfolio optimisation [47] as well as data envelopment analysis (DEA) aggregation of cross-efficiency [48].

A major share of the present is presented briefly here. We express an ISSM for describing the urban project selection problem wherein all experts have particular but uncertain evaluation outcomes on a set of candidate projects. Hence, this urban project selection problem with interval values has been considered one of the stochastic optimization problems [34-46]. Secondly, the SMAA-2 algorithm, concepts of the rank acceptability index, confidence factor, and central weight vector have been proposed. Thirdly, the SMAA-2 method has been applied for the urban project selection issue with interval data and proposed one of the candidate projects' holistic ranks [49-52]. Though experts in the field mainly explored the classical urban project selection problem, the present paper has dealt with a novel aspect and functional and academic values and significance.

HOW TO EXPLAIN THE PROBLEM?

The urban project selection issue investigated in the present paper is shaped. Hence, a set of I candidate projects is evaluated based on J criteria by engaging a committee of K experts. Each measure is supposed to be beneficial. We may take the transformation of reciprocal or negativity about the cost-type criteria. Therefore, a decision matrix $G_{IJ} = \left[x_{ij} \right]_{IJ}$ depicts the fundamental framework of the multicriteria urban project selection issue:

(1)

$$G_{IJ} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1J} \\ x_{21} & x_{22} & \cdots & x_{2J} \\ \vdots & \vdots & \vdots & \vdots \\ x_{I1} & x_{I2} & \cdots & x_{IJ} \end{bmatrix}$$

here $x_{ij}, x_{ij} \in \left[0,1\right], i = 1,2,...,I,\ j = 1,2,...,J$ refer to each expert's exact values and thus have been normalized to eliminate the data's magnitude [52]. Moreover, the analysis score of a project is calculated through the weighted sum of the criteria measures concerning the above project, namely:

(2)

$$S_i = \sum_{j=1}^{J} x_{ij} w_{ij}, i = 1,2,...,I$$

So that w_{ij} represents the weights of a factor j related to the project i, and $\sum_{j=1}^{J} w_{ij} = 1, w_{ij} \geq 0$?

Therefore, each expert $k, k = 1, 2, ..., K$ has been realised via a particular preference on the criteria sequence. Hence, without losing generality, we consider that the criteria would be arranged in descending order of importance for a specific expert $k, k = 1, 2, ..., K$, namely $w_{i1}^k \geq w_{i2}^k \geq \cdots \geq w_{iJ}^k$. Thus, the sequence would change among various experts. As a result, a particular expert $k, k = 1, 2, ..., K$ can express this mathematical algorithm for aggregating the most desirable function for each project i :

(3)

$$US_i^k = \max \sum_{j=1}^{J} x_{ij} w_{ij}^k$$

$$\text{s.t. } w_{i1}^k \geq w_{i2}^k \geq \cdots \geq w_{iJ}^k, i = 1, 2, ..., I$$

$$\sum_{j=1}^{J} w_{ij}^k = 1, w_{ij}^k \geq 0, i = 1, 2, ..., I, k = 1, 2, ..., K$$

.

Theorem 1.

An optimal score of the projects i obtained from a mathematical algorithm (3) equalled $\max_{j=1,2,...,J} \left\{ \frac{1}{j} \sum_{t=1}^{j} x_{it} \right\}$.

Proof. After denoting $v_{ij}^k = w_{ij}^k - w_{i(j+1)}^k \geq 0, j = 1, 2, ..., J-1, v_{iJ}^k = w_{iJ}^k \geq 0$, we obtain

(4)

$$\begin{aligned}
\sum_{j=1}^{J} w_{ij}^k &= \left(w_{i1}^k - w_{i2}^k\right) + 2\left(w_{i2}^k - w_{i3}^k\right) + \cdots + (J-1)\left(w_{i(J-1)}^k - w_{iJ}^k\right) + J\left(w_{iJ}^k\right) \\
&= v_{i1}^k + 2v_{i2}^k + \cdots + Jv_{iJ}^k \\
&= \sum_{j=1}^{J} j v_{ij}^k \\
&= 1.
\end{aligned}$$

We also incorporate $\varphi_{ij}^k = \sum_{t=1}^{j} x_{it}$ and then have

(5)

$$\begin{aligned}
\sum_{j=1}^{J} x_{ij} w_{ij}^k &= x_{i1} w_{i1}^k + x_{i2} w_{i2}^k + \cdots + x_{iJ} w_{iJ}^k \\
&= \left[\left(w_{i1}^k - w_{i2}^k\right) x_{i1}\right] + \left[\left(w_{i2}^k - w_{i3}^k\right)\left(x_{i1} + x_{i2}\right)\right] + \cdots + \\
&\quad \left[\left(w_{i(J-1)}^k - w_{iJ}^k\right)\left(x_{i1} + x_{i2} + \cdots + x_{i(J-1)}\right)\right] + \left[w_{iJ}^k \left(x_{i1} + x_{i2} + \cdots + x_{iJ}\right)\right] \\
&= v_{i1}^k \varphi_{i1}^k + v_{i2}^k \varphi_{i2}^k + \cdots + v_{iJ}^k \varphi_{iJ}^k \\
&= \sum_{j=1}^{J} v_{ij}^k \varphi_{ij}^k.
\end{aligned}$$

Hence, mathematical algorithm (3) is the same as the explanation below [35]:

(6)

$$US_i^k = \max \sum_{j=1}^{J} v_{ij}^k \varphi_{ij}^k$$

$$\text{s.t. } \sum_{j=1}^{J} j v_{ij}^k = 1$$

$$v_{ij}^k \geq 0,\ j = 1, 2, ..., J \ .$$

The twofold of (6) is

(7)

$$\min z_i^k$$

$$\text{s.t. } z_i^k \geq \frac{1}{j}\varphi_{ij}^k \ .$$

Moreover, the optimal objective value of (7) would be obtained when $z_i^k = \max_{j=1,2,...,J}\left\{\frac{1}{j}\varphi_{ij}^k\right\}$ the optimal, accurate value of (3) is for $US_i^k = \max_{j=1,2,...,J}\left\{\frac{1}{j}\sum_{t=1}^{j} x_{it}\right\}$. Therefore, it is the most desirable assessed value specified via an expert k for the project i with a decision matrix (1). Based on the recognized sequence of criteria supplied via a typical expert, algorithm (3) is understandable and easily applied [49-52]. It may be effectively solved without eliciting the weights' exact values.

Accordingly, considering the least favourable assessment scores via the expert k for the project i is crucial, and thus an analogous mathematical algorithm is given below:

(8)

$$LS_i^k = \min \sum_{j=1}^{J} x_{ij} w_{ij}^k$$

$$\text{s.t. } w_{i1}^k \geq w_{i2}^k \geq \cdots \geq w_{iJ}^k, i = 1, 2, ..., I$$

$$\sum_{j=1}^{J} w_{ij}^k = 1, w_{ij}^k \geq 0, i = 1, 2, ..., I, k = 1, 2, ..., K \ .$$

Theorem 2.

The optimum score of the projects i carried out from a mathematical algorithm (8) is $\min_{j=1,2,...,J}\left\{\frac{1}{j}\sum_{t=1}^{j} x_{it}\right\}$.

Regarding the strength of the obtained least and most favourable assessment scores for the project i via the expert k, we express an ISSM $\Omega_{IK} = \left(\left[LS_i^k, US_i^k\right]\right)_{IK}$ that describes the uncertain judgment of each expert on each project. Proper assessment of the project i by an expert k must lie in $\left[LS_i^k, US_i^k\right]$:

(9)

$$\Omega_{IK} = \begin{bmatrix} \left[LS_1^1, US_1^1\right] & \left[LS_1^2, US_1^2\right] & \cdots & \left[LS_1^K, US_1^K\right] \\ \left[LS_2^1, US_2^1\right] & \left[LS_2^2, US_2^2\right] & \cdots & \left[LS_2^K, US_2^K\right] \\ \vdots & \vdots & \vdots & \vdots \\ \left[LS_I^1, US_I^1\right] & \left[LS_I^2, US_I^2\right] & \cdots & \left[LS_I^K, US_I^K\right] \end{bmatrix}.$$

Be consistent with [36]; it is possible to view the derived ISSM as one of the stochastic MCDM issues. Therefore, we initiate the SMAA-2 algorithm reported via Lahdelma and Salminen [19] to efficiently solve the stochastic MCDM issues by presenting each alternative's holistic rank.

SMAA ANALYSIS

It is widely accepted that stochastic multi-objective acceptability analysis represents one of the families of methods for helping multiple-criteria decision-making with uncertain, inexact, or relatively missing input data. Therefore, the reasoning behind stochastic multicriteria acceptability analysis is discovering the weight space for describing the preferences, making all alternatives the most preferred choice, or granting a specific ranking place for a particular option. In this regard, Lahdelma et al. [20] initiated this topic and proposed the rank acceptability indices, confidence factor, and central weight vector for other options. Then, Lahdelma & Salminen [19] extended the initial stochastic multicriteria acceptability analysis by addressing each rank in the evaluation and provided more holistic SMAA-2 studies to recognize acceptable compromise alternatives graphically.

ISSM Analysis

According to the interval project selection matrix introduced in Section 4.1, a committee of K -experts possesses a set of I projects to be assessed and chosen. On the other hand, any expert-particular assessment values and weights are unknown. Therefore, it is assumed that it is possible to represent each expert evaluation's decision maker's preferences through a real value utility function $g(i,w), i=\{1,2,...,I\}$. The weight vector w quantifies the decision makers' subjective preferences within the experts' judgments. Uncertain evaluation of values from the experts on the project s are also expressed by the stochastic variables ξ_{ik} with the density function $f(\xi)$ or approximated in the space $X \subseteq \Re^{I\times K}$. Also, the unknown weight vector is represented by a weight distribution with the density function $f(w)$ in a set of possible weights illustrated in Eq. (10):

$$W = \left\{ w \subseteq \Re^K : \sum_{k=1}^{K} w_k = 1, w_k \geq 0 \right\}. \tag{10}$$

The total lack of the weight vector information is represented in the *"Bayesian"* spirit through a weight distribution that is consistent in W, i.e., $f(w) = \frac{1}{Vol(\mathrm{W})} = \frac{(K-1)!}{\sqrt{K}}$.

Therefore, the utility function would then be used for mapping the stochastic experts' evaluation values and weight distribution into the utility distribution $g(\xi_i, w)$.

We denote a ranking function representing each project rank as an integer from the best position (=1) to the worst rank (=I) that is:

$$rank\ (\xi_i, w) = 1 + \sum_l \rho(g(\xi_l, w) > g(\xi_i, w)), \tag{11}$$

where $\rho(\text{true}) = 1$ and $\rho(\text{false}) = 0$.

Notably, SMAA-2 relies on the evaluation of the sets of desirable rank weights $W_i^r(\xi)$ defined as

$$W_i^r(\xi) = \{ w \in W : rank(\xi_i, w) = r \}, \tag{12}$$

So that the weight $w \in W_i^r(\xi)$ guarantees that the alternative ξ_i reaches rank r.

Indexes

This sub-section presents multiple helpful indexes introduced via SMAA-2. The first is the (Rank acceptability indices = RAI), b_i^r illustrated as the expected volume of a set of desirable rank weights. Moreover, b_i^r measures different valuations granting the alternative ξ_i rank r that is computed by

$$b_i^r = \int_X f(\xi) \int_{W_i^r(\xi)} f(w) dw d\xi. \tag{13}$$

According to the above relation, the rank acceptability indices b_i^r have been considered to belong to the interval $[0,1]$. At the same time, $b_i^r = 0$ it denotes that the alternative ξ_i reaches rank r and $b_i^r = 1$ report that the option ξ_i constantly obtains the position r, neglecting the weights' impacts. Furthermore, it is possible to directly employ the rank acceptability indices in the multicriteria assessment of other options. However, for large scale problems, one of the iterative processes has been presented where analysis of *n* best ranks *(nbr)* acceptability is done at each interaction *n*:

$$a_i^n = \sum_{r=1}^{n} b_i^r. \tag{14}$$

nbr-acceptability a_i^n has been proposed to be one of the various preferences granting alternative ξ_i any of the *n-best* ranks. Therefore, the evaluation proceeds till one or more choices reach a sufficient majority of the weights.

It is possible to depict the weight space concerning *n* best-rank related to an alternative via the concept "central *nbr* weight vector" w_i^n :

$$w_i^n = \int_X f(\xi) \sum_{r=1}^{n} \int_{W_i^r(\xi)} f(w) w dw d\xi / a_i^n. \tag{15}$$

Concerning the weight distribution, the central *nbr*-weight vector has been considered the most acceptable single-vector representation to prefer a DM who assigns an alternative any rank from one to *n*.

The 3rd indices are the *nbr*-confidence element p_i^n, which is defined as the probability that the alternative reaches any rank from one to *n* in case of determination and computation of the central *nbr* weight vector through

$$p_i^n = \int_{\xi : rank(\xi_i, w_i^n)} f(\xi) d\xi. \tag{16}$$

The study reported by Lahdelma and Salminen [19] contains further information on the indices, and Tervonen and Lahdelma [27] presented a manual on the practical stochastic multicriteria acceptability analysis implementation.

HOLISTIC ANALYSIS FOR THE RANK ACCEPTABILITY

About the rank described above the strength of acceptability, the step below is the development of a complementary method, which combines RAI into (Holistic acceptability indices = HAI) related to each alternative:

$$a_i^h = \sum_{r=1}^{I} \alpha^r b_i^r, \tag{17}$$

Here α^r represent the meta weights for making the HAI and satisfying $1 = \alpha^1 \geq \alpha^2 \geq \cdots \geq \alpha^I \geq 0$?

Eliciting the so-called meta-weights has been considered crucial for a weight determination process of the lexicographic Model (of Brand Evaluation) decision problem that acceptably allocates the most massive value to α^1 and the last one to α^I. Like assignment of the weights to the ranks, Barron & Barrett [50] introduced three mechanisms called the reciprocal of the ranks strategy; that is $\alpha^r(RR) = \frac{1/r}{\sum_{r=1}^{I} 1/r}, r = 1, 2, ..., I$, (Rank-order centroid = ROC) algorithm; that is, $\alpha^r(ROC) = \frac{1}{I}\sum_{r=1}^{I}\frac{1}{r}, r = 1, 2, ..., I$ and rank-sum way; that is, $\alpha^r(RS) = \frac{2(I+1-r)}{I(I+1)}, r = 1, 2, ..., I$. Therefore, it is possible to apply rank-order centroid for determining $\alpha^r, r = 1, 2, ..., I$ because of their higher effectiveness, accuracy, and understandability, indicating one of the suitable implementation tools [43].

As seen, holistic evaluation of the rank acceptability index would result in an overall measure of acceptability of each alternative that would help rank and arrange the options effectively.

NUMERICAL EXAMPLE

For applying the SMAA-2 algorithm for solving the ISSM, we draw the data from the numerous criteria urban project selection problems studied via Heydari, et al. [39]. Therefore, three criteria called quality, service, and price are rated using the 3-point scale, i.e., 1, 2, and 3, reflecting low, middle, and high for the price criterion, and good, middle, and inadequate for the requirements of service and quality. Hence, our problem is selecting five among 14 candidate projects that contain a committee of 6 experts.

All experts enjoy a particular preference on the criteria significance, i.e., price-quality $\succ$ service, price $\succ$ service $\succ$ quality, quality $\succ$ price $\succ$ service, quality $\succ$ service $\succ$ price, service $\succ$ price $\succ$ quality, and service $\succ$ quality $\succ$ price that are respectively represented via notations “1”, “2”, “3”, “4”, “5” and “6” (See table 1).

Table 1. Data on ISSM

Project	Price	Quality	Service	Price (Norm)	Quality (Norm)	Service (Norm)
1	2	1	1	0.0600	0.0370	0.0400
2	3	1	1	0.0400	0.0370	0.0400
3	1	2	2	0.1200	0.0741	0.0800
4	2	2	2	0.0600	0.0741	0.0800
5	3	2	1	0.0400	0.0741	0.0400
6	1	2	3	0.1200	0.0741	0.1200

7	1	3	1	0.1200	0.1111	0.0400
8	1	1	3	0.1200	0.0370	0.1200
9	2	2	1	0.0600	0.0741	0.0400
10	2	2	3	0.0600	0.0741	0.1200
11	3	3	1	0.0400	0.1111	0.0400
12	3	2	2	0.0400	0.0741	0.0800
13	2	3	1	0.0600	0.1111	0.0400
14	2	1	3	0.0600	0.0370	0.1200

Source: Zhang, et al. [31]

The ISSM $\Omega_{IK} = \left(\left[LS_i^k, US_i^k\right]\right)_{IK}$ has been gained utilizing Eqs. (3) and (8), where table 2 shows the results of each expert's interval analysis for each project.

Table 2. Interval urban project selection matrix.

Project	Expert					
	1	2	3	4	5	6
1	[0.0457,0.0600]	[0.0457,0.0600]	[0.0370,0.0485]	[0.0370,0.0457]	[0.0400,0.0500]	[0.0385,0.0457]
2	[0.0385,0.0400]	[0.0390,0.0400]	[0.0370,0.0390]	[0.0370,0.0390]	[0.0390,0.0400]	[0.0385,0.0400]
3	[0.0914,0.1200]	[0.0914,0.1200]	[0.0741,0.0970]	[0.0741,0.0914]	[0.0800,0.1000]	[0.0770,0.0914]
4	[0.0600,0.0714]	[0.0600,0.0714]	[0.0670,0.0741]	[0.0714,0.0770]	[0.0700,0.0800]	[0.0714,0.0800]
5	[0.0400,0.0570]	[0.0400,0.0514]	[0.0514,0.0741]	[0.0514,0.0741]	[0.0400,0.0514]	[0.0400,0.0570]
6	[0.0970,0.1200]	[0.1047,0.1200]	[0.0741,0.1047]	[0.0741,0.1047]	[0.1047,0.1200]	[0.0970,0.1200]
7	[0.0904,0.1200]	[0.0800,0.1200]	[0.0904,0.1156]	[0.0756,0.1111]	[0.0400,0.0904]	[0.0400,0.0904]
8	[0.0785,0.1200]	[0.0923,0.1200]	[0.0370,0.0923]	[0.0370,0.0923]	[0.0923,0.1200]	[0.0785,0.1200]
9	[0.0580,0.0670]	[0.0500,0.0600]	[0.0580,0.0741]	[0.0570,0.0741]	[0.0400,0.0580]	[0.0400,0.0580]
10	[0.0600,0.0847]	[0.0600,0.0900]	[0.0637,0.0847]	[0.0741,0.0970]	[0.0847,0.1200]	[0.0847,0.1200]
11	[0.0400,0.0756]	[0.0400,0.0637]	[0.0637,0.1111]	[0.0637,0.1111]	[0.0400,0.0637]	[0.0400,0.0756]
12	[0.0400,0.0647]	[0.0400,0.0647]	[0.0570,0.0741]	[0.0647,0.0770]	[0.0600,0.0800]	[0.0647,0.0800]
13	[0.0600,0.0856]	[0.0500,0.0704]	[0.0704,0.1111]	[0.0704,0.1111]	[0.0400,0.0704]	[0.0400,0.0756]
14	[0.0485,0.0723]	[0.0600,0.0900]	[0.0370,0.0723]	[0.0370,0.0785]	[0.0723,0.1200]	[0.0723,0.1200]

Source: Zhang, et al. [31]

Consequently, meta-weights for the formulation of the holistic acceptability indexes include:

$$\alpha^{12} = \left(1.00, 0.69, 0.54, 0.44, 0.36, 0.30, 0.25, 0.20, 0.16, 0.13, 0.10, 0.07, 0.05, 0.02\right). \tag{18}$$

As a result, using the open-source software described by Heydari, et al., [42], it is possible to solve the SMAA-2 model efficiently.

NORMAL DISTRIBUTION

It has been assumed that interval data $\left[LS_i^k, US_i^k\right]$ have a normal distribution. Their variance and mean are introduced $\mu_i^k = \frac{LS_i^k + US_i^k}{2}$ $\left(\sigma^2\right)_i^k = \frac{US_i^k - LS_i^k}{6}$

Table 3 and Figure 1 present outputs obtained for rank acceptability and holistic acceptability indexes extracted from the SMAA-2 method.

Table 3. Normal distribution of holistic acceptability index and rank acceptability indices

Project	b^1	b^2	b^3	b^4	b^5	b^6	b^7	b^8	b^9	b^{10}	b^{11}	b^{12}	b^{13}	b^{14}	a^h
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.35	0.64	0.0307
2	0.01	0.01	0.00	0.01	0.02	0.03	0.03	0.02	0.04	0.04	0.08	0.11	0.27	0.33	0.0960
3	0.00	0.25	0.46	0.23	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5392
4	0.00	0.00	0.00	0.00	0.00	0.09	0.47	0.38	0.07	0.00	0.00	0.00	0.00	0.00	0.2311
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.55	0.37	0.03	0.0607
6	0.91	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.9708
7	0.07	0.24	0.16	0.16	0.21	0.12	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.5128
8	0.03	0.24	0.18	0.26	0.17	0.06	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.5035
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.10	0.59	0.27	0.01	0.00	0.0962
10	0.02	0.17	0.17	0.26	0.31	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.4833
11	0.00	0.00	0.00	0.01	0.03	0.08	0.13	0.12	0.22	0.29	0.10	0.01	0.00	0.00	0.1798
12	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.13	0.31	0.39	0.14	0.03	0.00	0.00	0.1464
13	0.01	0.00	0.01	0.05	0.09	0.28	0.14	0.20	0.16	0.06	0.01	0.00	0.00	0.00	0.2630
14	0.00	0.01	0.01	0.02	0.12	0.25	0.13	0.12	0.16	0.11	0.05	0.03	0.00	0.00	0.2426

Source: Zhang, et al. [31]

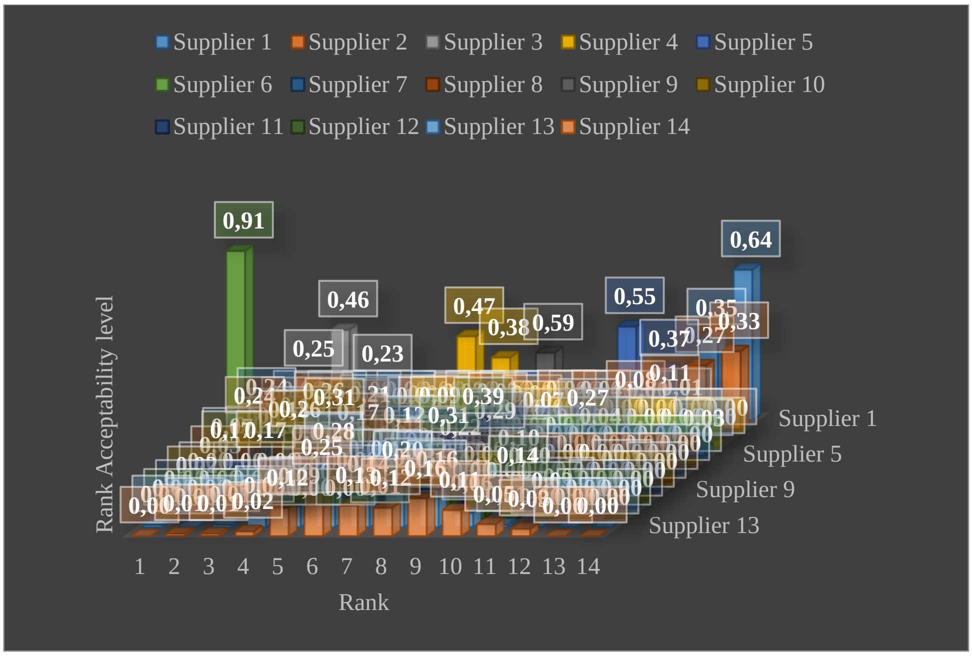

Figure 1. Normal distribution of rank acceptability index. Source: Zhang, et al. [31].

As shown by the HAI in Table 3, a detailed rank of each project s: $6 \succ 3 \succ 7 \succ 8 \succ 10 \succ 13 \succ 14 \succ 4 \succ 11 \succ 12 \succ 9 \succ 2 \succ 5 \succ 1$ has been obtained. Therefore, the chosen project is 6, 3, 7, 8, and 10; the most desirable project is project 6, with an HAI of 97.08% and the first rank support of 91% of possibility. In contrast, the minimum profitable project is 1, the holistic rank indices, and finally, the last-rank support is 3.07 and 64% of potential.

EQUITABLE DISTRIBUTION

Consider that interval data have a uniform distribution. Based on the mentioned assumption, HAI and RAI are presented in Figure 2 and Table 4.

Table 4. Equitable distribution of HAI, RAI

Project	b^1	b^2	b^3	b^4	b^5	b^6	b^7	b^8	b^9	b^{10}	b^{11}	b^{12}	b^{13}	b^{14}	a^h
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.55	0.41	0.0362
2	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.07	0.23	0.56	0.0587
3	0.02	0.23	0.36	0.26	0.11	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5321
4	0.00	0.00	0.00	0.00	0.01	0.16	0.43	0.32	0.08	0.01	0.00	0.00	0.00	0.00	0.2365
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.14	0.61	0.20	0.02	0.0708
6	0.82	0.13	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.9359
7	0.10	0.19	0.17	0.16	0.17	0.12	0.04	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.5103
8	0.03	0.23	0.19	0.20	0.15	0.08	0.05	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.4813
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.17	0.55	0.19	0.01	0.00	0.1025
10	0.02	0.17	0.18	0.24	0.28	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.4717
11	0.00	0.01	0.01	0.02	0.05	0.10	0.12	0.14	0.19	0.24	0.09	0.02	0.00	0.00	0.1995
12	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.18	0.34	0.31	0.10	0.02	0.00	0.00	0.1592
13	0.01	0.01	0.03	0.05	0.11	0.22	0.16	0.16	0.14	0.10	0.01	0.00	0.00	0.00	0.2687
14	0.00	0.01	0.03	0.05	0.12	0.20	0.13	0.13	0.13	0.10	0.06	0.04	0.01	0.00	0.2495

Source: Zhang, et al. [31]

According to the figure, the sequence of the candidate projects using the SMAA-2 method based on the uniform distribution includes: $6 \succ 3 \succ 7 \succ 8 \succ 10 \succ 13 \succ 14 \succ 4 \succ 11 \succ 12 \succ 9 \succ 5 \succ 2 \succ 1$, and thus the chosen project s project s 6, 3, 7, 8, and 10, too. The above sequence has a minor difference from the one obtained from the normal distribution. Therefore, there is just one difference related to the rank solutions of projects 2, 5. However, the most profitable project 6's holistic rank indices have been 93.59% in detail. The first rank support equalled 82% of possibility, so that the two are lower than the average distribution. The last rank support and HAI the least favourable supplier 1 equalled 41% and 3.62%.

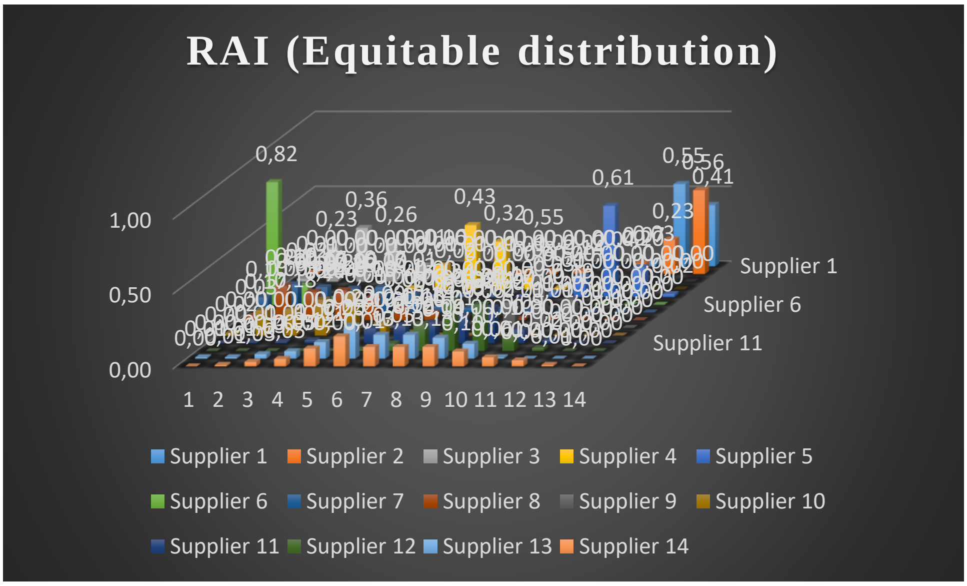

Figure 2. RAI (Equitable distribution). Source: Zhang, et al. [31]

It could be concluded that based on regular and uniform distribution assumptions, SMAA-2 possibly produces complete ranks with adequate discrimination power amongst each alternative. All experts have uncertain evaluations throughout the projects.

The multicriteria urban project selection problem in cooperating with a group of professionals is an issue that has been addressed mainly in the publications of supply chain management and decision science. Various professionals can present uncertain evaluation outputs for each project about the exact input data. Nonetheless, there is not enough information on this issue in the publications. Therefore, the present research dealt with this tremendous surge via initialising the interval values to optimise and innovative application of the SMAA-2 algorithm to catch the candidate project's overall rank.

Hence, it has been supposed that interval data are normally or smoothly distributed in the research. One of the meta-weight schemes for deriving the holistic rank indices has been elicitation from earlier studies. Finally, we re-examined one of the numerical examples from the current research to show our approach efficiency.

Therefore, this part of the research provided the DMs with more fantastic methodological choices and enriched the urban project selection problem's method and theory. Hence, additional investigations must determine unknown sets for DMs and investigate more function distributions over uncertainty.

CONCLUSION

Multicriteria urban project selection problem with A panel of experts has been broadly discovered in decision science and SCM context. Different experts might create uncertain assessment results for all projects given certain input data. However, the extant context has largely gone unnoticed on this subject.

This paper gets involved in this massive upsurge by first optimizing the interval values and then applying the SMAA-2 method in a novel way to catch an overall rank overall candidate project s. In this study, the interval data are assumed to be distributed normally or uniformly. A metal weight design to derive holistic rank indexes is obtained from the previous context.

A numerical instance for the current research was re-examined to denote the efficiency of the utilized algorithm. According to the gateways outlined above, PPPs' implementation might be impacted via governance issues, either forecasted ex-ante or ex-post. First, the project's overall effectiveness is on the line, at least once bribery occurs: the likely increase in expense efficiency of P3s – which is debatable because it is nearly impossible to evaluate ex-ante – when compared to traditional public provision, must not be offset by the costs of corruption [47]. As previously stated, increased transaction costs or a worse value for the project's money may be the result and a far lower possibility of a project being managed more efficiently as a 3P than through public procurement. This would supply the expected advantages from P3s and cause enhanced expenses compared to the current situation.

Second, and related to the first point, competition may be distorted: if the private sector effectively suppresses the market system through unethical actions, it becomes a price maker rather than a price taker, akin to the classic monopoly solution, even if it cannot exist in a competitive environment [54]. As a result, bribery exists. This is a specific sort of adverse selection in which an inefficient bidder becomes the competitive, winning bidder. In the case of the 3P shape data, inefficiencies can lead to increased expenses for the government (where payments are fixed) or non-optimal rates for customers (e.g., in all concession algorithms) and insufficient service provision.

Finally, nepotism or corruption in the public sector has the disadvantage of *"weak interest"* in the public section [41]: as with P3s, current principal-agent issues can be reshaped in the sense that – due to asymmetric data and financial leeway – political or public interest becomes less important than the business interests of oligopolistic market actors. As a result, biased P3s projects monopolise semi-open market solutions [54].

This problem is exacerbated because the public section is only constrained by political considerations and public legislation, which do not apply to the private section. In certain circumstances, responsibility in the traditional sense is not given; yet, the public interest may suffer as a result. Nonetheless, P3s have become a critical tool for the public sector to finance and administer much-needed urban infrastructure and services over the last few decades.

Independent of the potential benefits of these collaborations, unique challenges may arise that risk their long-term success and make them less appealing – in terms of effectiveness and performance – than the current scenario. Immoral behavior and corruption may be among the most difficult aspects of the paper, but they are only tangentially mentioned. Several aspects may be identified to aid in controlling these governance challenges, the most important of which is the appropriate mix of controlling and penalties [52-54].

They focus on the external dimension, which increases the chances of exposure, rather than the project-specific measurement of direct expenses and incomes. In this literature, increased transparency is critical, regardless of whether it is imposed due to legal framework changes or public attention. This holds at both the administrative and political levels. Ex-ante and ex-post audits, particular whistle-blower programs or job rotations, and the general utility of the *"four-eyes principle"* could all help reduce corruption by reducing *"discretion of arrangements authorities by making greater use of centrally recognized rules on contracts"* [12].

If such a practice is uncovered, both in terms of fines and incarceration, increasing the costs of specific, undesirable behavior through harsher penalties (for both public and private participants) has a similar effect. Furthermore, payment strategies for public management are discussed in this literature: If in the general area, life-long career mechanisms are no longer in place or securing life-long employment for an individual in a particular position becomes unlikely, the risk of bribery will be far higher than it is now. Overall, the P3 method's unique sensitivity to corrupt activities might be considered inherent and so difficult to eliminate. Suggested strategies to limit the risk of immoral behavior in P3 implementation can never eliminate it, but they can increase the expenses and diminish the benefits; however, reduce it in the long run, starting with adjusting the parameters of individuals DM [27-32, 54-62]. This paper provides the decision-maker with more methodological options and adds to the theory and method of the urban project selection problem. In future research, the designation of uncertain sets for decision-making will be considered and more practical distributions across the uncertainty.

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