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A DECISION SUPPORT FRAMEWORK FOR PLANNING AND PRIORITIZING URBAN SUSTAINABLE DEVELOPMENT STRATEGIES UNDER UNCERTAINTY CONDITIONS: A CASE STUDY

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ABSTRACT. The study addresses decision-making under conditions of uncertainty regarding the development of public policies and sustainable development strategies in an urban region in Brazil. Based on the case study, a decision support framework for planning and prioritizing urban sustainable development strategies (SDS) under uncertainty conditions is developed. In the framework social, economic and environmental factors have been considered using a fuzzy multi-criteria comprehensive evaluation approach in order to analyze and select SDSs. Critical factors and sub-factors for SDS are identified with the active participation of a committee of experts and representatives from different sectors of civil society. As a result, a set of urban sustainable development strategies are prioritized using the Fuzzy VIKOR Method that will help local authorities to improve their decisions. The decision support-framework illustrates the combination and application of Operations Research Methods in solving a complex problem related to decision-making in public management.

Keywords: urban sustainable development, decision support framework, fuzzy comprehensive evaluation, fuzzy VIKOR method.

1 INTRODUCTION

Currently, more than 50% of the world's population live in urban areas and it is expected to reach 66% by 2050 (United Nations, 2014). Urban Sustainable Development (SD) aims to change be-

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havior through a more rational and efficient management of all resources with less pressure and impact on the environment (Holden et al., 2014). The United Nations 2030 Agenda for SD specified cities as the drivers of SD and made sustainable cities a part of the Sustainable Development Goals (SDGs) (United Nations, 2015). The SDGs provides a guide and reference for countries and institutions to design their policies and actions and cover all aspects of SD, i.e. social, economic, and environmental dimensions (Shulla et al., 2020). Efforts to eradicate poverty require strategies that can work on economic growth, ensuring environmental protection and managing a range of social needs (Miola & Schiltz, 2019). However environmental issues are broad and difficult to capture and sustainability is a wide and complex research field which has several applications in different disciplines (Ding, 2008; Klopp & Petretta, 2017; Olawumi & Chan, 2018). SD is the complex base for supporting decision-making and policy in a broad environmental, economic and social context, and transcends a purely technical/scientific evaluation (Sala et al., 2015).

Sustainability was analyzed and assessed on quantitative and qualitative indicators at different spatial scales, e.g., assessment structures, analytical evaluation approach and the sustainability metrics (Dizdaroglu & Yigitcanlar, 2014; Fernandes et al., 2018; Kaur & Garg, 2019; Sharifi, 2021; Benítez & Liern, 2021; Puchol-Salort et al., 2021). In the analytical approach most of the studies related to priority alternatives in urban sustainability have been performed by common methods, such as factor analysis and models based on weighting and scoring procedures (Pohekar & Ramachandran, 2004; Ding et al., 2016; Dias et al., 2017; Zinatizadeh et al., 2017; Ali-Toudert & Ji, 2017). Multi-Criteria decision Analysis (MCDA) methods are ideal for managing decision problems in the context of sustainability (Anastasiadou & Gavanas, 2023). An analysis of the potentials of MCDA methods to conduct sustainability assessment can be found in (Cinelli et al., 2014). A good overview on the use of MCDA in the context of sustainability can be found in (Huang et al., 2011; Herva & Roca, 2013; Diaz-Balteiro et al., 2017; Lindfors, 2021).

However the practical measurability of urban sustainability are still unsolved (Ali-Toudert & Ji, 2017). Defining and formulating strategies to promote urban sustainable development is a very complex process, given the multidimensionality that is intrinsic to the concept of sustainability and the need to think across disciplinary boundaries (Krause & Hawkins, 2021). It is a challenge for decision makers and public policy makers to decide what actions should be taken in an attempt to make society more sustainable.

The decision-making involving sustainability strategies must evaluate several conflicting factors in the optimization process (Edjossan-Sossou et al., 2020). SD is a long-term journey, involving significant uncertainties and immense complexities (Malekpour et al., 2020). Furthermore, some aspects add even more complexities such as vagueness, inaccurate, incomplete and uncertain information, conflicting purposes, economic, technological and several other limitations. To assess urban sustainability and then planning actions, a comprehensive, holistic and accurate method is required (Zinatizadeh et al., 2017; Assunção et al., 2020). We believe that strategies and policies that promote sustainable urban development need to be prioritized, which implies the need to develop tools that help decision makers to face scenarios characterized by conditions of uncer-

tainty. In this context, a decision-support framework (DSF) can support and guide management decisions for public policy development. A DSF provides a structured and systematic approach to decision-making in complex situations characterized by multiple decision-makers, conflicting views and objectives (Chitaka et al., 2018).

In this setting, the case study addresses the challenge related to decision making in the development of public policies related to sustainable development strategies in an urban region. The study refers to decision making under conditions of uncertainty in prioritizing development strategies for a city in Brazil. Based on the case study, a decision-support framework for planning and prioritizing urban sustainable development strategies under uncertainty conditions is constructed. The framework integrates a comprehensive fuzzy assessment method and a group multi-criteria method to prioritize strategies to improve quality of life and well-being. A comprehensive fuzzy evaluation approach is used to assess the SD of the city and then a set of development strategies is prioritized by using Fuzzy Vikor Method (FVIKOR). Although other fuzzy multi-criteria methods could be applied, in the current study we adopted FVIKOR method based on the major advantage of this method, i.e., the trade off between the maximum group utility of the majority (the aggregation of all criteria) and the minimum individual regret of the opponent (each of criteria), and because it uses a simple and straightforward computation procedure that allows simultaneous considerations of the closeness to ideal and anti-ideal solution (Aghajani Bazzazi et al., 2011).

The contributions of this case study are summarized as follows: i) this paper provides a decision-support framework for planning and prioritizing urban sustainable development strategies under conditions of uncertainty; ii) social, economic and environmental factors are established in a holistic approach; iii) the framework can help decision-makers and policymakers to improve their decision-making choices in prioritizing and developing public policies; iv) the study illustrates the combination and application of Operations Research Methods in solving a complex problem related to decision-making in public management.

Besides the introduction the remainder of this paper is organized as follows. Section 2 presents the research design, subsection 2.1 presents the case study area and the subsection 2.2 describes the data collection and the methodological steps for its analysis. Section 3 presents the results of applying the decision-support framework. Section 4 presents the discussion of the results. Finally, conclusions are given in Section 5.

2 RESEARCH DESIGN

This study was conducted as a single case study where the focus and the case is a region that has a strategic location. Case studies capture information about the how and why of a complex situation. As stated by Yin (2005) the case study research method can be defined as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used. Furthermore, in understanding of Tasci et al. (2020), even though a

simple real situation can be the focus of a case study, its advantages are better realized in studying the complex phenomena that are fuzzy, dynamic, with a specific context for the researcher(s) to be involved for true understanding of diverse variables and their relationships. In conducting the case study, we basically followed the guidelines described by Yin (2005) namely: case study design, preparation for data collection, evidence collection, analysis of collected data and report the case study.

2.1 Case study background

Our study area is the Garuva city in the State of Santa Catarina in the southern region of Brazil. It is located in the Atlantic Forest biome region near the tropics and between two major cities Curitiba and Joinville. The permanent preservation area is approximately 65% of the territory, totaling approximately 12% of the remnant of the Atlantic Forest in the territory of Santa Catarina State. The GDP of the Garuva city is derived from industrial and services activities. The Municipal Urban Development Index (HDI-M) is 0.725 points, which shows a good human development index (IBGE, 2010). Garuva is close to the main highways for cargo transport, commerce and tourism. This southern region has intense economic activity highlighting industrial, metallurgy, metal-mechanics, chemistry, plastics, textiles, manufacturing, software development, agriculture and livestock products to name a few. The city of Garuva has access to the coast of Paraná and the municipality of Itapoá, important tourist and transshipment centers for maritime cargo transport. In recent years, due to its proximity to large consumer centers, Garuva has become a major attraction for large companies. The expansion of port logistics companies in the city of Garuva is expected in the coming years due to the growth of port activities.

2.2 Data collection and analysis

First, a list of four experts who conducted this study was defined. The four experts habitually adopted linguistic terms to express their assessments throughout this study. For the data collection phase, semi-structured interviews were conducted with representatives of key organizations and members of civil society to collect information on the city's sustainable development. At this stage, the interviews were carried out in the form of face-to-face meetings in which the interviewees expressed their opinions in linguistic terms. Thereafter, we analyzed the information collected in the interviews to evaluate, in a first stage, the sustainable development of the city in the understanding of the different actors of the civil society, and later for the prioritization of the necessary strategies for the improvement of the sustainable development of the city. In this regard, a five-step approach was adopted (see Figure 1).

Step 1: *Appoint the expert committee*. A committee of experts is appointed to conduct the activities in this study.

Step 2: *Establish the main factors and sub-factors for sustainable development assessment.* A comprehensive evaluation index system is proposed in order to evaluate the SD. Factors and subfactors are defined in three levels for the assessment of the city's SD. The first-level corresponds

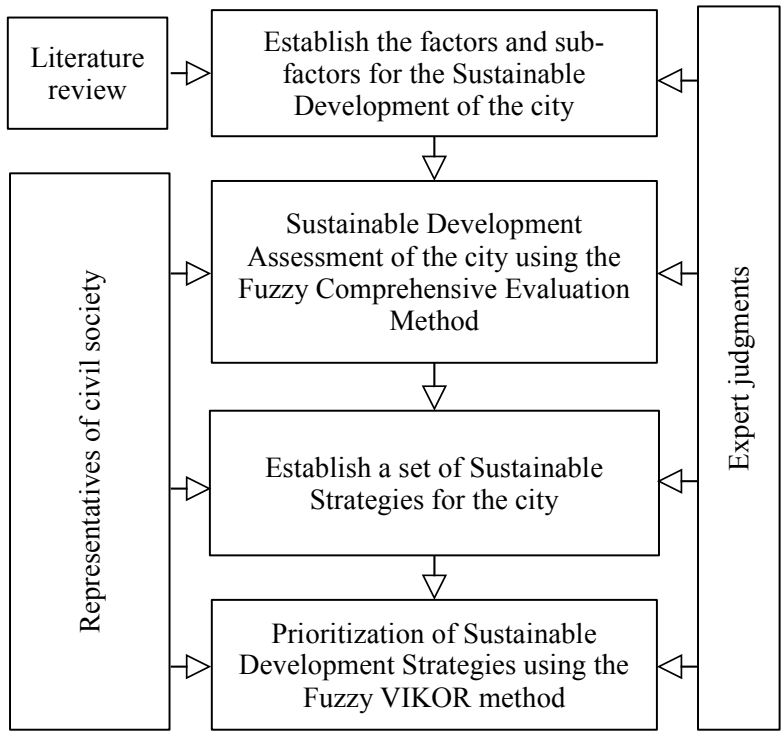

Figure 1 – Research design for the present work.

to the economic, social and environmental perspectives which are defined respectively as elements of a set $U = \{u_1, u_2, u_3\}$. The second-level layer contains the factors of each perspective u_i defined as $u_i = \{u_{i1}, u_{i2}, \ldots, u_{im}\}$. The set of sub-factors for each factor u_{ij} is defined in the third level layer as $u_{ij} = \{u_{ij1}, u_{ij2}, \ldots, u_{ijn}\}$.

Step 3: *Fuzzy comprehensive evaluation (FCE) of the city's sustainable development.* Critical factors and sub-factors for the SD of the city are identified and the FCE approach is adopted using linguistics evaluations. Fuzzy set theory offers a mathematical architecture to describe linguistic terms (Wang et al., 2006; Javanbarg et al., 2012; Zadeh, 1965; Wang et al., 2018a; Zadeh, 1975a,b; Fan et al., 2018; Pei & Zheng, 2017). In this study triangular fuzzy numbers (TFN) are preferred to represents linguistic variables (LV) expressed as a triplet (l, m, u) which $l \leq m \leq u$:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-l}{m-l} & l \leq x \leq m \\ \frac{u-x}{u-m} & m \leq x \leq u \\ 0 & otherwise \end{cases} \tag{1}$$

The FCE method is based in the maximum membership principle to make an evaluation from a holistic perspective of all relevant factors with ambiguity and uncertainty through four steps: i) establish an evaluation index system U; ii) define the evaluation set V; iii) construct the fuzzy

evaluation matrix R, and iv) establish the fuzzy comprehensive evaluation model (Du et al., 2019; Liu et al., 2019; Yang et al., 2018). The evaluation index system $U = (u_1, u_2, u_3, ...u_n)$ represents the affecting factor of evaluation object and the judgment set $V = (v_1, v_2, v_3, ...v_m)$, is the collection of evaluations defined as five remarks levels V = {"*excellent*", "*very good*", "*good*", "*fair*", "*poor*"} where v_i represents the decision maker's assessment of the city's sustainable development (Loh et al., 2017; Guo et al., 2009). Respondents express their opinions using words (TFNs on the fuzzy scale of 1 to 9) as summarized in Table 1.

Table 1 – Fuzzy linguistic variables of remarks levels.

Intensity	Linguistic variables	Membership function
1	Poor (PO)	(1,1,3)
3	Fair (FA)	(1,3,5)
5	Good (GO)	(3,5,7)
7	Very good (VG)	(5,7,9)
9	Excellent (EX)	(7,9,9)

To denote the relative importance of factors, a normalized set Z of index weights is defined as $Z = (z_1, z_2, z_3, ...z_n)$, $\sum_{i=1}^{n} z_i = 1.0$ and $0 \leq z_i \leq 1 \ \forall i = 1, 2, \ldots, n$ (Li et al., 2015; Jiao et al., 2016; Wei et al., 2010; Feng et al., 2014; Xie et al., 2017). The relationship between the evaluation indexes U and the evaluation set V is established by a membership function r_{ij} in a evaluation matrix R (Li et al., 2015). In this way, r_{ij} represents the grade of membership of factor u_i aiming at the evaluation v_j (Chen et al., 2015; Shen et al., 2005; Haiyan, 2002; Wei et al., 2015):

$$R = \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1m} \\ r_{21} & r_{22} & \ldots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \ldots & r_{nm} \end{bmatrix} \tag{2}$$

The conclusion of the comprehensive evaluation is obtained by the maximum membership principle (Chen et al., 2015; Zeng et al., 2017). The fuzzy comprehensive evaluation vector B is obtained as $B = Z \otimes R = (b_1, b_2, b_3, ..., b_n)$ (Zheng et al., 2019). Finally, the committee of experts establishes a set of factors and sub-factors with low evaluation, i.e. all that presents membership of poor and fair evaluations greater than 50%, that is, the sum of their membership degree greater than or equal to 0.50.

Step 4: *Establish the sustainable development strategies.* A set A of k strategies for the sustainable development of the city is formulated. At least five strategies for each sub-factor with low evaluation are initially proposed by the committee of experts.

Step 5: *Prioritize the sustainable development strategies.* The set of strategies are prioritized taking into account a set of criteria using the fuzzy Vikor (FVIKOR) method. This method determines a compromise solution for a problem using a ranking index based on measure of closeness

to the ideal solution L_p-*metric* as an aggregation function (Po, 1973; Opricovic, 1998; Tadić et al., 2014; Liao & Xu, 2013).:

$$L_{p,k} = \left\{ \sum_{j=1}^{m} \left[w_j \left(f_j^* - f_{kj} \right) / \left(f_j^* - f_j^- \right) \right]^p \right\}^{1/p} \tag{3}$$

where $1 \leq p \leq \infty$, *k=1,2,..,n*, w_j are the criteria weights, $f_j^* = \underset{k}{max}\ f_{kj}$ and $f_j^- = \underset{k}{min}\ f_{kj}$ are the best and worst values of strategy *k*. The fuzzy ratings of decision makers are described by TFNs (Opricovic & Tzeng, 2007; Opricovic, 2011). The fuzzy performance matrix and weight vector are be expressed as (f_{ij} and $\tilde{w}_i$ are TFNs.):

$$\tilde{D} = \begin{array}{r} \\ A_1 \\ A_2 \\ \dots \\ A_n \end{array} \begin{bmatrix} C_1 & C_2 & \dots & C_m \\ f_{11} & f_{12} & \dots & f_{1m} \\ f_{21} & f_{22} & \dots & f_{2m} \\ \dots & \dots & \dots & \dots \\ f_{n1} & f_{n2} & \dots & f_{nm} \end{bmatrix} \quad \text{and} \quad \tilde{w} = \begin{bmatrix} \tilde{w_1} & \tilde{w_2} & \dots & \tilde{w_n} \end{bmatrix} \tag{4}$$

The fuzzy best value $f_i^* = (l_i^*, m_i^*, u_i^*)$ and fuzzy worst value $f_i^o = (l_i^o, m_i^o, u_i^o)$ are defined as $\tilde{f}_i^* = \underset{j}{MAX} \tilde{f}_{ij},\ \tilde{f}_i^o = \underset{j}{MIN} \tilde{f}_{ij},\ for\ i\ \varepsilon\ B$ and $\tilde{f}_i^* = \underset{j}{MIN} \tilde{f}_{ij},\ \tilde{f}_i^o = \underset{j}{MAX} \tilde{f}_{ij},\ for\ i\ \varepsilon\ C$, where B is the benefit criteria and C the cost criteria (Rostamzadeh et al., 2015; Liu et al., 2015). The fuzzy difference $\tilde{d}_{ij}$ between $\tilde{f}_{ij}$ and fuzzy best value f_i^* or fuzzy worst value f_i^o is computed as (Opricovic & Tzeng, 2007; Opricovic, 2011):

$$\tilde{d}_{ij} = \frac{(\tilde{f}_i^* - \tilde{f}_{ij})}{(u_i^* - l_i^o)} \quad for\ i\ \varepsilon\ B \tag{5}$$

$$\tilde{d}_{ij} = \frac{(\tilde{f}_{ij} - \tilde{f}_i^*)}{(u_i^o - l_i^*)} \quad for\ i\ \varepsilon\ C \tag{6}$$

The separation $\tilde{S}_j$ of strategy A_j from the fuzzy value f_i^* and the separation $\tilde{R}_j$ of strategy A_j from the fuzzy f_i^o can be obtained as : $\tilde{S}_j = \sum_{i=1}^{n} (\tilde{w}_i \otimes \tilde{d}_{ij})$ and $\tilde{R}_j = \underset{i}{MAX} (\tilde{w}_i \otimes \tilde{d}_{ij})$ (Wang et al., 2018b). The compromise value $\tilde{Q}_j$ of every strategy can be calculated as:

$$\tilde{Q}_j = \frac{\nu(\tilde{S}_j - \tilde{S}^*)}{(S^{ou} - S^{*l})} \otimes \frac{(1-\nu)(\tilde{R}_j - \tilde{R}^*)}{(R^{ou} - R^{*l})} \tag{7}$$

where $\tilde{S}^* = MIN_j \tilde{S}_j$, $S^{ou} = MAX_j S_j^u$, $\tilde{R}^* = MIN_j \tilde{R}_j$, $R^{ou} = MAX_j R_j^u$, and $\nu = (n + 1/2n)$, i.e. the weight for the strategy of "the majority of criteria" (or "the maximum group utility"). Here, $(1-\nu)$ represent the weight of the individual regret. If $\nu > 0.50$ then make decisions in order to maximize the group interests, if $\nu = 0.5$, then make decisions based on a balanced compromise, and if $\nu < 0.5$ then make decisions in a way that minimizes individual regrets (Tian et al., 2019).

The final step ranks the strategies by sorting the values of S, R and Q in descending order resulting in three ranking list. The compromise solution of alternative $A^{(1)}$ is the best-ranked by the measure Q(minimum) if two conditions are satisfied: acceptable advantage and acceptable stability in decision making (Kim & Chung, 2013; Chang, 2014).

3 RESULTS

The committee of experts, that conducted the research, was made up of four members with professional experience of more than ten years. An overview of the interviewed experts'profiles is provided in Table 6 in Appendix A. This committee adopted a set of main factors and sub-factors (summarized in Table 2) to be used in economic (e.g. Singh et al. (2012), Holden et al. (2014), Dizdaroglu & Yigitcanlar (2014), Dias et al. (2017), Kaur & Garg (2019), da Silva Rocha Paz et al. (2021)), social (e.g. Singh et al. (2012), Zinatizadeh et al. (2017), Dias et al. (2017), Shulla et al. (2020), da Silva Rocha Paz et al. (2021)) and environmental (e.g. Haiyan (2002), Singh et al. (2012), Ding et al. (2016), Dias et al. (2017), Ali-Toudert & Ji (2017), Chitaka et al. (2018), da Silva Rocha Paz et al. (2021)) contexts.

Semi-structured interviews were conducted with representatives of the main organizations and members of civil society to collect information on the sustainable development of Garuva city, e.g, governmental and non-governmental institutions, local industry, entrepreneurs, the services sectors, academics, technicians, and members of the port sector (see the profiles of the interviewees in Table 7 in Appendix A). The conducted interviews were in the form of face-to-face meeting and where the respondents expressed their opinions by filling out a questionnaire using the words shown in Table 1 (see Table 8 in Appendix B the questionnaire used to collect information regarding the sustainable development of the city). Therefore, after collecting the information from the respondents, the following index evaluation matrix was performed as defined by Eq. 2:

$$R_{11} = \begin{bmatrix} 0.067 & 0.067 & 0.333 & 0.533 & 0.000 \\ 0.000 & 0.067 & 0.133 & 0.267 & 0.533 \\ 0.000 & 0.133 & 0.400 & 0.333 & 0.133 \end{bmatrix}$$

$$R_{12} = \begin{bmatrix} 0.000 & 0.400 & 0.400 & 0.200 & 0.000 \\ 0.133 & 0.400 & 0.267 & 0.200 & 0.000 \\ 0.000 & 0.133 & 0.467 & 0.333 & 0.067 \\ 0.000 & 0.067 & 0.400 & 0.533 & 0.000 \end{bmatrix}$$

$$R_{13} = \begin{bmatrix} 0.067 & 0.200 & 0.267 & 0.200 & 0.267 \\ 0.067 & 0.200 & 0.200 & 0.200 & 0.333 \end{bmatrix}$$

$$R_{21} = \begin{bmatrix} 0.067 & 0.000 & 0.600 & 0.333 & 0.000 \\ 0.000 & 0.067 & 0.133 & 0.533 & 0.267 \end{bmatrix}$$

$$R_{22} = \begin{bmatrix} 0.000 & 0.000 & 0.267 & 0.667 & 0.067 \end{bmatrix}$$

$$R_{23} = \begin{bmatrix} 0.000 & 0.000 & 0.200 & 0.600 & 0.200 \\ 0.000 & 0.067 & 0.000 & 0.667 & 0.267 \\ 0.000 & 0.133 & 0.000 & 0.400 & 0.467 \end{bmatrix}$$

Table 2 – Factors and sub-factors for sustainable development assessment.

Perspective	Factor	Sub-factor
(u_1) Economic	(u_{11}) Services	(u_{111}) Electricity service
		(u_{112}) Natural gas service
		(u_{113}) Logistics services
	(u_{12}) Infrastructure	(u_{121}) Port access
		(u_{122}) Access to highways
		(u_{123}) Access to other modal ways
		(u_{124}) Telecommunication services
	(u_{13}) Taxes	(u_{131}) Tax breaks
		(u_{132}) Tax exemption periods
(u_2) Social	(u_{21}) Basic services	(u_{211}) Health services
		(u_{212}) Collective transport services
	(u_{22}) Welfare	(u_{221}) Leisure and sports areas
	(u_{23}) Training and education	(u_{231}) Qualification of labor
		(u_{232}) Technical education centers
		(u_{233}) Higher education institutions
	(u_{24}) Labor	(u_{241}) Job opportunity
		(u_{242}) Availability of labor
		(u_{243}) Qualification of workforce
		(u_{244}) Labor cost
	(u_{25}) Housing	(u_{251}) Availability for acquisition
		(u_{252}) Rental availability
	(u_{26}) Human development	(u_{261}) Human development index
		(u_{262}) Welfare
(u_3) Environmental	(u_{31}) Hydric resource	(u_{311}) Water availability
		(u_{312}) Water Quality
		(u_{313}) Potable water distribution network
		(u_{314}) Water treatment
	(u_{32}) Effluents	(u_{321}) Wastewater network
		(u_{322}) Wastewater treatment
	(u_{33}) Solid waste	(u_{331}) Collect
		(u_{332}) Formal destination / treatment
		(u_{333}) Recycling
	(u_{34}) Environmental programs	(u_{341}) Environmental education
		(u_{342}) Monitoring programs

$$R_{24} = \begin{bmatrix} 0.000 & 0.000 & 0.467 & 0.467 & 0.067 \\ 0.000 & 0.000 & 0.267 & 0.733 & 0.000 \\ 0.000 & 0.067 & 0.133 & 0.600 & 0.200 \\ 0.067 & 0.133 & 0.400 & 0.333 & 0.067 \end{bmatrix}$$

$$R_{25} = \begin{bmatrix} 0.067 & 0.133 & 0.467 & 0.267 & 0.067 \\ 0.067 & 0.333 & 0.200 & 0.333 & 0.067 \end{bmatrix}$$

$$R_{26} = \begin{bmatrix} 0.000 & 0.200 & 0.400 & 0.400 & 0.000 \end{bmatrix}$$

$$R_{31} = \begin{bmatrix} 0.733 & 0.133 & 0.067 & 0.067 & 0.000 \\ 0.533 & 0.200 & 0.200 & 0.000 & 0.067 \\ 0.133 & 0.400 & 0.200 & 0.267 & 0.000 \\ 0.200 & 0.267 & 0.133 & 0.200 & 0.200 \end{bmatrix}$$

$$R_{32} = \begin{bmatrix} 0.000 & 0.200 & 0.333 & 0.200 & 0.267 \\ 0.000 & 0.067 & 0.333 & 0.267 & 0.333 \end{bmatrix}$$

$$R_{33} = \begin{bmatrix} 0.067 & 0.067 & 0.667 & 0.133 & 0.067 \\ 0.067 & 0.067 & 0.267 & 0.267 & 0.333 \\ 0.000 & 0.067 & 0.067 & 0.600 & 0.267 \end{bmatrix}$$

$$R_{34} = \begin{bmatrix} 0.000 & 0.000 & 0.133 & 0.467 & 0.400 \\ 0.000 & 0.000 & 0.200 & 0.400 & 0.400 \end{bmatrix}$$

Low-rated factors and sub-factors are perceived, which suggests that it is precisely at these points that sustainable development strategies are needed. A set of factors and sub-factors with poor and fair evaluations greater than 50% were established (i.e. the sum of their membership degree greater than or equal to 0.50, Table 3 shows the list).

In order to improve the city's SD, the following A_{ij} strategies were established for each subfactor u_{ij}.

A_1: Natural gas service: *i)* expand the natural gas network; *ii)* develop a policy for natural gas service; *iii)* increase supply and access to natural gas use; *iv)* promote ventures that require natural gas as raw material; *v)* disseminate and update information on the availability of local and regional services.

A_2: Electricity service: *i)* expand the electricity coverage service; *ii)* create differentiated policy for sustainable use of electricity; *iii)* research with service providers, increased demand and improvements in service provision; *iv)* create a different policy to promote alternative sources of energy generation (renewable energies); *v)* expand and modernize the electricity distribution system.

A_3: Telecommunications infrastructure: *i)* extend telecommunication service; *ii)* foment the installation of new communication services; *iii)* expand and modernize telephone and inter-

Table 3 – Factors and sub-factors for sustainable development that obtained low evaluation.

Perspective	Factor	Sub-factor
(u_1) Economic	(u_{11}) Services	(u_{111}) Electricity service
		(u_{112}) Natural gas service
	(u_{12}) Infrastructure	(u_{124}) Telecommunication services
	(u_{13}) Taxes	(u_{132}) Tax exemption periods
(u_2) Social	(u_{21}) Basic services	(u_{211}) Collective transport services
	(u_{22}) Welfare	(u_{221}) Leisure and sports areas
	(u_{23}) Training and education	(u_{231}) Qualification of labor
		(u_{232}) Technical education centers
		(u_{233}) Higher education institutions
	(u_{24}) Labor	(u_{241}) Job opportunity
		(u_{242}) Availability of labor
		(u_{243}) Qualification of workforce
(u_3) Environmental	(u_{32}) Effluents	(u_{322}) Wastewater treatment
	(u_{33}) Solid waste	(u_{332}) Formal destination / treatment
		(u_{333}) Recycling
	(u_{34}) Environmental programs	(u_{341}) Environmental education
		(u_{342}) Monitoring programs

net networks; *iv)* provide internet access and telephony for all citizens; *v)* create mechanisms that facilitate the attraction of new ventures that develop innovative technologies in the telecommunications sector.

A_4: Taxes: *i)* improve the investment incentive model by taking advantage of the opportunities available in the city; *ii)* update public policies related to economic and fiscal incentives; *iii)* encourage an incentive policy to attract new investors; *iv)* foment public tax policies for activities with low environmental impact and that promote sustainability; *v)* create differentiated public policies for the technology and innovation sector.

A_5: Basic services (transportation services): *i)* institutionalize urban and rural mobility plans; *ii)* foment, through differentiated public policies, the expansion of new ventures related to logistic modalities; *iii)* establish urban and rural public transport system; *iv)* create differentiated public policy for enterprises that develop innovative and sustainable collective and individual transport technologies; *v)* encourage the use of environmental friendly and energy efficient means of transport.

A_6: Wellness (recreation and sports areas): *i)* insert in the "Multiannual Plan" the destination of resources for the implantation of leisure and sports spaces; *ii)* institute in the form of Municipal Law the need for leisure and sports practices as means to promote physical and mental wellbeing; *iii)* encourage the development of sports, leisure and cultural practices through public and private partnerships; *iv)* invest and develop educational activities for children and adolescents related to

sports; *v)* create and develop educational projects to encourage afforestation and conservation of green areas and leisure spaces.

A_7: Training/education (qualification of manpower): *i)* invest heavily in youth and adult education; *ii)* invest in workforce education and technical training projects; *iii)* formalize partnerships with professional, institutions and associations to meet the demand of the city; *iv)* promote and strengthen actions provided for in Municipal Law No. 2122/2019 - Establishes the "Pro-Woman Work Program" and qualification of female labor; *v)* create a differentiated tax incentive policy to attract entities that offer labor training.

A_8: Labor (availability, job opportunity): *i)* use the available means of communication to promote local economic development and increase the supply of jobs; *ii)* create a citizen service center to facilitate access to job offers; *iii)* develop a broad communication channel to publicize job openings; *iv)* foment the development of "Individual Entrepreneurs" and "Individual Microentrepreneurs - MEI"; *v)* encourage and promote local artisans and entrepreneurs to strengthen the city's brand and products, increasing the supply of jobs for the population.

A_9: Effluents: *i)* carry out a survey of the current conditions of the city (coverage network and effluent treatment station, alternative and individual systems); *ii)* raise funds and/or formalize partnerships to implement wastewater treatment systems; *iii)* develop a differentiated policy for the implementation of individual wastewater treatment systems (septic tank and anaerobic filter, root treatment systems), with the help of the public authorities; *iv)* increase the demands and oversight of companies, industries and service providers regarding the treatment of wastewater produced in the execution of their respective activities; *v)* develop and apply the guidelines provided by Municipal Law 1987/2017-Establishes the Municipal Plan for Basic Sanitation.

A_{10}: Solid Waste (treatment and final destination): *i)* encourage research, development and implementation of new techniques for the management, collection, treatment and final disposal of solid waste; *ii)* reduce operational and final disposal costs in the treatment of solid waste; *iii)* control and supervise solid waste generation processes; *iv)* eliminate and inhibit the illegal dumping of waste by the population; *v)* expand service provision to maintain full coverage for collection, transportation and final disposal of household waste.

A_{11}: Solid Waste (recycling): *i)* ensure social inclusion in the selective collection program, ensuring the participation of recyclable and reusable material collectors; *ii)* raise funds and/or formalize partnerships for the implementation of a selective collection system and organic composting; *iii)* encourage the recycling industry and the use of raw materials and inputs derived from recyclable and/or recycled materials; *iv)* establish goals and procedures to increase the production of recyclables and composting organic waste, in order to minimize waste; *v)* encourage, promote and supervise the execution of reverse logistics.

A_{12}: Environmental programs (environmental education): *i)* promote actions and projects with municipal schools for the reuse of recyclable waste and its proper disposal; *ii)* encourage and promote projects for the reforestation of urban and rural flora; *iii)* develop educational practices for conservation and maintenance of the Babitonga Bay marine biome; *iv)* encourage rural and

green tourism by promoting green trails and corridors; *v)* encourage scientific and technological studies regarding traditional customs, striving for the orderly use and protection of natural resources.

A_{13}: Environmental Programs (management and monitoring): *i)* implementation of the guidelines and objectives of the Municipal Environmental Policy, Law No. 1906/2015; *ii)* implementation of the guidelines contained in the Municipal Plan of Basic Sanitation - Integrated Program of Solid Waste Management - PGRS, Law No. 1987/2017; *iii)* implementation of the guidelines contained in the Municipal Sanitation Policy, Law No. 2007/2017; *iv)* maintenance of the Municipal Environmental Licensing Program, Complementary Law 073/2013; *v)* implementation of the Municipal Code of Solid Waste, Law No. 1920/2015.

For the prioritization of strategies, five criteria were defined:

i) Budget criterion (BUC).

ii) Positive long term impact (LTI).

iii) Rate of return to the municipality (RTM)

iv) Attractiveness for new business (ANB)

v) Impact on local Human Development Index (HDI)

All criteria will be considered equally important and their weights were defined as TFN with parameters (1,1,1). In order to evaluate the ratings of the proposed strategies with respect to each criterion, semi-structured others interviews were conducted with representatives of leadership organizations and members of civil society directly engaged in the development of the city. Eight interviews were conducted in the form of face-to-face meeting where the respondents expressed their opinions by filling the questionnaires using linguistic variables (TFNs on the fuzzy scale of 1 to 9)) as summarized in Table 4.

Table 4 – Fuzzy scale of relative importance.

Linguistic variables	Membership function
Very low (VL)	(1,1,3)
Low (L)	(1,3,5)
Fair (F)	(3,5,7)
High (H)	(5,7,9)
Very High (VH)	(7,9,9)

The fuzzy individual preferences were then aggregated into group preferences. An aggregated fuzzy matrix is constructed by using the geometric mean method (Chang et al., 2013). Tables 9 and 10 show de results. The fuzzy best value and fuzzy worst value of all criterion function and the differences are then calculated. It is to pointed out that this research aims to minimize *BUC*

and maximize *LTI*, *RTM*, *ANB* and *HDI* criteria. The committee of experts establishes that the strategy of the maximum group utility (v) can be selected with "voting by majority" ($v > 0.50$), "by consensus" ($v = 0.50$) or "with veto" ($v < 0.50$). In this sense, the committee of experts assumed $v = 0.60$ for compromise solution in the "voting for majority" modality.

The separation $\tilde{S}_j$ of strategic A_{ij} from the fuzzy best value $f_i^* = (l_i^*, m_i^*, u_i^*)$, the separation $\tilde{R}_j$ of strategic A_{ij} from the fuzzy worst value $f_i^o = (l_i^o, m_i^o, u_i^o)$ and the index $\tilde{Q}_j$ were calculated. Tables 11 and 12 summarizes these fuzzy values for all strategies. These TFNs $\tilde{S}$, $\tilde{R}$ and $\tilde{Q}$ are then defuzzified into crisp numbers. The results are presented in Table 5.

According to these defuzzified values the strategies were ranked by sorting the crisp Q as shown in the last column of the Table 5. Finally the conditions are tested showing that the condition of acceptable advantage is satisfied. The strategy A_{85} is in the first position of the ranking lists that are constructed considering S and R values. Therefore, the condition of acceptable stability is also satisfied.

4 DISCUSSION

The analysis of the results shown in Table 5 made it possible to identify critical elements related to the sustainable development strategies for the Garuva city. As an example, we focus the analysis on the first three strategies.

The first strategy was A_{85}: *Encourage and promote local artisans and entrepreneurs to strengthen the city's brand and products, increasing the supply of jobs for the population*. The residents of the city of Garuva have in their essence the behavior of valuing the local production and the local native culture. The city has a very rich culture, due to its colonization next to Babitonga Bay. It is a privileged place for its natural beauty and the miscegenation of the people. This region provides a mix of attractions in different segments, for example, transport and logistics, gastronomy, tourism, handicrafts, metal mechanics, auto parts, drinks, sweets, bananas, rice, palm, canned foods, among others. The population sees in its own culture a way that can contribute to local development.

Although large enterprises make a difference and leverage the development of the region and contribute in the short and medium term to the development of the families, it is important to support small sources of income, such as artisans, individual entrepreneurs, micro entrepreneurs, in this way there will be a balance between large and small companies. In addition, this vision will create a supply chain, whose stability in the face of economic turbulence will be more constant. It also shows a feeling stamped on the local culture, in short, the great result will be in the sum of the small sources that generate income. The second strategie (A_{83}) reflect the demand of the first strategy (A_{85}), since all native production and culture must be widely publicized facilitating the access to information for all producers and consumers of products and services. The third strategy (A_{44}) aims to promote local development and sustainability through a differentiated taxation policy for small entrepreneurs and activities with low environmental impact. In this way, sustainable development can be encouraged in people's economic activities.

Table 5 – Defuzzified $\tilde{S}$, $\tilde{R}$, $\tilde{Q}$ and strategies ranking.

Strategy	S	R	Q	Ranking by Q	Strategy	S	R	Q	Ranking by Q
A_{11}	0.82	0.33	0.09	10	A_{81}	0.58	0.31	0.06	4
A_{12}	1.05	0.35	0.12	26	A_{82}	1.82	0.47	0.23	63
A_{13}	1.02	0.34	0.11	21	A_{83}	0.52	0.21	0.03	2
A_{14}	1.18	0.47	0.17	51	A_{84}	0.83	0.26	0.07	5
A_{15}	1.61	0.62	0.25	65	A_{85}	0.38	0.18	0.00	1
A_{21}	0.87	0.46	0.13	32	A_{91}	1.26	0.44	0.17	49
A_{22}	0.80	0.35	0.09	12	A_{92}	1.28	0.42	0.16	44
A_{23}	1.03	0.33	0.11	19	A_{93}	1.68	0.52	0.23	62
A_{24}	1.36	0.41	0.16	47	A_{94}	1.31	0.43	0.17	50
A_{25}	0.85	0.55	0.16	40	A_{95}	1.32	0.43	0.17	48
A_{31}	0.97	0.47	0.15	37	A_{101}	0.99	0.35	0.11	23
A_{32}	0.86	0.27	0.08	7	A_{102}	1.50	0.45	0.19	56
A_{33}	1.17	0.59	0.20	57	A_{103}	1.61	0.49	0.21	60
A_{34}	1.00	0.55	0.17	53	A_{104}	1.28	0.41	0.16	42
A_{35}	0.97	0.33	0.10	16	A_{105}	1.62	0.45	0.20	59
A_{41}	0.92	0.31	0.09	14	A_{111}	1.11	0.31	0.11	24
A_{42}	0.94	0.35	0.11	18	A_{112}	1.22	0.34	0.13	33
A_{43}	1.05	0.44	0.14	36	A_{113}	0.87	0.25	0.07	6
A_{44}	0.66	0.23	0.04	3	A_{114}	0.99	0.27	0.09	9
A_{45}	0.96	0.31	0.10	15	A_{115}	1.07	0.33	0.11	22
A_{51}	1.14	0.36	0.13	28	A_{121}	1.08	0.39	0.13	31
A_{52}	1.35	0.41	0.16	46	A_{122}	1.10	0.38	0.13	30
A_{53}	1.50	0.61	0.24	64	A_{123}	1.60	0.52	0.22	61
A_{54}	1.23	0.37	0.14	35	A_{124}	0.96	0.28	0.09	11
A_{55}	1.32	0.43	0.17	52	A_{125}	1.60	0.45	0.20	58
A_{61}	1.56	0.39	0.18	55	A_{131}	1.31	0.42	0.16	45
A_{62}	0.97	0.42	0.13	29	A_{132}	1.25	0.42	0.16	41
A_{63}	0.91	0.36	0.11	17	A_{133}	1.22	0.35	0.13	34
A_{64}	1.32	0.45	0.17	54	A_{134}	1.35	0.37	0.15	38
A_{65}	0.91	0.38	0.11	25	A_{135}	1.35	0.39	0.16	43
A_{71}	1.02	0.38	0.12	27					
A_{72}	1.10	0.45	0.15	39					
A_{73}	1.05	0.32	0.11	20					
A_{74}	0.89	0.32	0.09	13					
A_{75}	0.89	0.28	0.08	8					

Our results showed that the structure developed is quite flexible, allowing the inclusion of social, economic and environmental factors in aiding decision-making in conditions of uncertainty and incomplete information. Considering that in public management, planners and decision makers must systematically consider a series of factors, criteria, scenarios, objectives and restrictions when prioritizing sustainable development strategies, the proposed framework can be very useful as a decision-making support tool in the planning and prioritization of public policies and strategies related to sustainable urban development. Finally, although the success of the framework application depends on the mathematical and computational resources for its implementation, the decision support framework presents a simple and straightforward computation procedure.

5 CONCLUSION

The case study addresses decision-making under conditions of uncertainty in the development of public policies and sustainable development strategies in an urban region in Brazil. Based on the case study a decision-support framework for planning and prioritizing urban sustainable development strategies is provided.

Considering the complexity of decision-making in public management, aggravated by imprecise, incomplete and uncertain information, conflicting purposes, economic and technological limitations, among others, the proposed framework considers, for the assessment of sustainable development, a set of factors and sub-factors from three perspectives, namely economic, social and environmental variables. A fuzzy comprehensive evaluation approach was adopted and representatives from different sectors of civil society participated in this study, i.e., governmental and non-governmental institutions, local industry members, entrepreneurs, services sector, academics, technicians, and members of the port sector. Of the set of critical factors and subfactors analyzed, 17 were classified as low. Based on this result, five strategies for each sub-factor were proposed in order to improve the sustainable development of the city. These strategies were then prioritized using the Fuzzy Multi-criteria VIKOR method.

The results indicated as a priority strategy “Encourage and propagate local artisans and entrepreneurs to strengthen the brand and products from the city, thus increasing the supply of jobs and population”. The city of Garuva has a very rich culture that can explain this result. The residents of the city have in their essence behavior of valuing the local production, the local native culture. The city is located at a privileged place for its natural beauty and the miscegenation of the people. This region provides a mix of attractions in different segments: transport and logistics, gastronomy, tourism, handicrafts, metal mechanics, auto parts production, drinks, sweets, bananas, rice, palm, canned foods, among others. Thus, the perception of the actors represents a form of local development that is intrinsic to the “Garuvense” culture, even with the great demand for the development of the logistics and transport segment, influenced by the Port of Itapoá. The population sees in its own culture a way that can contribute more to local sustainable development. Thus, the results of this study allowed to validate the proposed framework for planning and prioritizing urban sustainable development strategies. The application of the proposed

framework allowed to identify a priority set of strategies that can contribute to the management in order to improve the sustainable development of the municipality of Garuva.

The decision support framework is very flexible to help decision making under conditions of uncertainty and incomplete information, it presents a simple and straightforward computational procedure and can be adopted in other cities as a decision support tool in the management of development strategies that enable better living conditions in a fully sustainable perspective. Finally, this case study illustrates the combination and application of Operations Research Methods in solving a complex problem related to decision-making in public management.

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Appendix A PROFILE OF THOSE WHO PARTICIPATED IN THE INTERVIEWS

Table 6 – Profile of experts.

Code	Organization	Job position	Experience [years]
A	University	Research professor PhD	> 25
B	University	Research professor PhD	> 25
C	City Hall	Secretary of administration and finance	> 15
D	Consulting firm	Manager	> 12

Table 7 – Profile of civil society members that participated in interviews.

Code	Organization	Job position	Experience [years]
A	City Hall	Shipping and Invoicing Supervisor	> 7
B	City Hall	Secretary of Social Development and Housing	> 8
C	Law firm	Advisor	> 6
D	City Hall	Secretary of Administration and Finance	> 5
E	City Hall	Financial Controler	> 6
F	City Council	President	> 3
G	City Hall	Cabinet advisor	> 3
H	Industrial company	Entrepreneur	> 25
I	Commercial and Industrial Association	President	> 5
J	Furniture industry	Entrepreneur	> 20
K	Port company	Occupational Health and Safety Supervisor	> 15
L	Real estate agency	Advisor	> 8
M	Metallurgical sector	Entrepreneur	> 26
N	Architecture and urbanism firm	Architect	> 32

Appendix B QUESTIONNAIRE FOR INTERVIEWS

The following questions are about the sustainable development of the city. In your opinion and considering the economic, social and environmental perspectives, for each item indicate whether it is excellent, very good, good, fair or poor (one answer for each item).

Table 8 – Assessment of the city's sustainable development.

Perspective	Factor	Sub-factor	Excellent	Very Good	Good	Fair	Poor
Economic	Services	Electricity service					
		Natural gas services					
		Logistic services					
	Infrastructure	Port access					
		Access to other modal ways					
		Telecommunication services					
	Taxes	Tax breaks					
		Tax exemption periods					
Social	Basic Services	Health services					
		Collective transport services					
	Welfare	Leisure and sports areas					
	Training and education	Qualification of labor					
		Technical education centers					
		Higher education institutions					
	Labor	Job opportunity					
		Availability of labor					
		Qualification of workforce					
		Labor cost					
	Housing	Availability for acquisition					
		Rental availability					
	Human development	Human development index					
		Welfare					
Environmental	Hydric resource	Water availability					
		Water quality					
		Potable water distribution network					
		Water treatment					
	Effluents	Wastewater network					
		Wastewater treatment					
	Solid waste	Collect					
		Formal destination/treatment					
		Recycling					
	Environmental programs	Environmental education					
		Monitoring programs					

Appendix C MATHEMATICAL CALCULATIONS.

Table 9 – Aggregated rating of strategies as TFNs: $A_{11} - A_{75}$.

	BUC	LTI	RTM	ANB	HDI
A_{11}	(3.00;5.32;7.07)	(4.59;6.64;8.45)	(5.55;7.61;8.72)	(5.05;7.37;8.36)	(5.10;7.15;8.72)
A_{12}	(1.32;2.59;4.79)	(3.63;5.67;7.69)	(3.60;5.79;7.85)	(4.59;6.64;8.45)	(4.59;6.64;8.45)
A_{13}	(1.93;4.17;6.10)	(4.49;6.57;8.19)	(4.59;6.64;8.45)	(4.64;6.92;8.36)	(4.04;6.10;7.94)
A_{14}	(2.05;3.79;5.91)	(4.49;6.57;8.19)	(4.64;6.92;8.36)	(4.64;6.03;7.85)	(3.52;4.99;7.14)
A_{15}	(1.51;2.41;4.68)	(4.00;5.43;7.60)	(3.75;5.21;7.37)	(3.84;5.26;7.6)	(2.41;4.08;6.36)
A_{21}	(4.13;6.17;8.19)	(5.05;7.37;8.36)	(5.21;7.3;8.45)	(5.32;7.37;8.72)	(5.32;7.37;8.72)
A_{22}	(1.61;2.51;4.83)	(5.05;7.37;8.36)	(4.49;6.57;8.19)	(4.59;6.64;8.45)	(3.84;6.04;8.10)
A_{23}	(2.88;5.15;7.07)	(4.79;6.85;8.45)	(5.00;7.00;9.00)	(4.59;6.64;8.45)	(4.00;6.23;8.10)
A_{24}	(2.21;3.87;5.97)	(3.20;5.54;7.30)	(4.31;6.37;8.19)	(3.75;5.97;7.85)	(3.75;5.97;7.85)
A_{25}	(4.84;7.14;8.36)	(5.92;7.94;9.00)	(5.1;7.15;8.72)	(4.99;7.07;8.45)	(5.67;7.69;9.00)
A_{31}	(4.31;6.37;8.19)	(5.10;7.15;8.72)	(4.59;6.64;8.45)	(5.10;7.15;8.72)	(5.44;7.45;9.00)
A_{32}	(2.12;4.31;6.37)	(5.10;7.15;8.72)	(4.00;6.23;8.10)	(5.10;7.15;8.72)	(4.79;6.85;8.45)
A_{33}	(5.32;7.37;8.72)	(4.99;7.07;8.45)	(4.49;6.57;8.19)	(5.10;7.15;8.72)	(5.10;7.15;8.72)
A_{34}	(4.99;7.07;8.45)	(5.21;7.30;8.45)	(4.99;7.07;8.45)	(4.79;6.85;8.45)	(5.79;7.85;8.72)
A_{35}	(2.35;4.04;6.16)	(4.79;6.85;8.45)	(4.04;6.10;7.94)	(5.32;7.37;8.72)	(4.21;6.30;7.94)
A_{41}	(2.46;4.17;6.16)	(4.89;6.93;8.72)	(3.67;5.91;7.61)	(5.67;7.69;9.00)	(4.49;6.57;8.19)
A_{42}	(1.72;3.00;5.32)	(4.17;6.43;8.10)	(3.91;6.16;7.85)	(5.55;7.61;8.72)	(3.91;6.16;7.85)
A_{43}	(2.26;3.91;6.16)	(4.21;6.30;7.94)	(4.59;6.64;8.45)	(5.67;7.69;9.00)	(3.30;5.49;7.37)
A_{44}	(2.21;3.87;5.97)	(5.32;7.37;8.72)	(4.31;6.37;8.19)	(5.44;7.45;9.00)	(5.32;7.37;8.72)
A_{45}	(1.97;4.21;6.30)	(4.59;6.64;8.45)	(4.49;6.57;8.19)	(4.89;6.93;8.72)	(4.31;6.37;8.19)
A_{51}	(1.46;2.79;4.94)	(4.31;6.37;8.19)	(3.14;5.43;7.53)	(3.38;5.55;7.61)	(4.79;6.85;8.45)
A_{52}	(1.93;3.63;5.73)	(3.07;5.37;7.30)	(3.38;5.55;7.61)	(4.49;6.57;8.19)	(4.13;6.17;8.19)
A_{53}	(5.44;7.45;9.00)	(4.00;6.23;8.10)	(3.30;5.49;7.37)	(4.31;6.37;8.19)	(5.79;7.85;8.72)
A_{54}	(1.99;4.39;6.23)	(3.52;5.73;7.61)	(3.41;5.44;7.45)	(5.1;7.15;8.72)	(4.59;6.64;8.45)
A_{55}	(1.40;2.70;4.94)	(3.34;5.72;7.30)	(3.75;5.97;7.85)	(2.10;4.39;6.50)	(4.99;7.07;8.45)
A_{61}	(2.70;4.31;6.43)	(3.83;6.10;7.61)	(3.07;5.37;7.30)	(2.88;5.15;7.07)	(3.96;6.42;7.77)
A_{62}	(1.40;2.35;4.63)	(4.17;6.43;8.10)	(3.56;5.97;7.53)	(2.10;4.39;6.50)	(6.71;8.72;9.00)
A_{63}	(1.73;2.94;5.21)	(4.79;6.85;8.45)	(3.91;6.16;7.85)	(2.57;4.88;7.00)	(6.17;8.19;9.00)
A_{64}	(2.51;4.21;6.36)	(4.54;6.85;8.10)	(2.79;5.20;7.00)	(1.97;4.21;6.30)	(6.17;8.19;9.00)
A_{65}	(1.61;3.30;5.49)	(5.21;7.30;8.45)	(3.91;6.16;7.85)	(2.41;4.68;6.78)	(6.17;8.19;9.00)
A_{71}	(4.00;5.43;7.60)	(5.21;7.30;8.45)	(4.26;6.56;7.85)	(3.20;5.54;7.30)	(6.44;8.45;9.00)
A_{72}	(4.00;6.23;8.10)	(5.21;7.30;8.45)	(4.26;6.56;7.85)	(3.07;5.37;7.30)	(6.44;8.45;9.00)
A_{73}	(2.41;4.68;6.78)	(4.79;6.85;8.45)	(3.41;5.78;7.53)	(3.75;5.97;7.85)	(5.92;7.94;9.00)
A_{74}	(2.19;3.95;6.10)	(4.79;6.85;8.45)	(3.52;5.73;7.61)	(3.84;6.04;8.10)	(6.44;8.45;9.00)
A_{75}	(2.19;4.53;6.50)	(4.79;6.85;8.45)	(3.75;5.97;7.85)	(4.00;6.23;8.10)	(6.44;8.45;9.00)

Table 10 – Aggregated rating of strategies as TFNs: $A_{81} - A_{135}$.

	BUC	LTI	RTM	ANB	HDI
A_{81}	(2.88;5.15;7.07)	(5.32;7.37;8.72)	(5.92;7.94;9.00)	(5.55;7.61;8.72)	(5.32;7.37;8.72)
A_{82}	(2.51;3.67;5.97)	(3.49;5.09;7.29)	(3.27;4.88;7.06)	(2.85;4.58;6.77)	(3.64;5.26;7.29)
A_{83}	(1.99;4.39;6.23)	(5.67;7.69;9.00)	(4.68;6.78;8.19)	(4.99;7.07;8.45)	(6.44;8.45;9.00)
A_{84}	(2.35;4.04;6.16)	(4.59;6.64;8.45)	(4.59;6.64;8.45)	(5.32;7.37;8.72)	(4.79;6.85;8.45)
A_{85}	(1.56;2.91;5.10)	(4.79;6.85;8.45)	(5.21;7.22;9.00)	(5.55;7.61;8.72)	(6.17;8.19;9.00)
A_{91}	(3.07;5.37;7.30)	(5.55;7.61;8.72)	(2.62;4.99;6.78)	(2.76;4.99;7.07)	(6.04;8.10;8.72)
A_{92}	(3.83;6.10;7.61)	(4.35;6.63;8.10)	(4.04;6.10;7.94)	(3.3;5.49;7.37)	(5.79;7.85;8.72)
A_{93}	(3.30;5.49;7.37)	(4.49;6.57;8.19)	(2.88;5.15;7.07)	(1.85;3.52;5.73)	(5.21;7.30;8.45)
A_{94}	(1.93;3.17;5.37)	(3.60;5.05;7.37)	(4.31;6.37;8.19)	(2.59;4.79;6.85)	(4.84;7.14;8.36)
A_{95}	(3.64;6.03;7.77)	(5.10;7.15;8.72)	(3.38;5.55;7.61)	(2.57;4.88;7)	(5.92;7.94;9.00)
A_{101}	(1.97;3.67;5.91)	(4.89;6.93;8.72)	(3.75;5.97;7.85)	(2.7;4.94;6.85)	(6.17;8.19;9.00)
A_{102}	(3.17;5.32;7.37)	(5.10;7.15;8.72)	(4.49;6.57;8.19)	(2.35;4.04;6.16)	(3.41;5.78;7.53)
A_{103}	(1.61;3.30;5.49)	(4.13;6.17;8.19)	(2.97;5.10;7.15)	(2.12;3.75;5.97)	(3.75;5.97;7.85)
A_{104}	(1.99;4.13;6.17)	(4.59;6.64;8.45)	(3.75;5.97;7.85)	(2.19;4.53;6.5)	(4.99;7.07;8.45)
A_{105}	(4.04;6.10;7.94)	(3.67;5.91;7.61)	(3.52;5.73;7.61)	(2.88;5.15;7.07)	(4.99;7.07;8.45)
A_{111}	(2.76;4.99;7.07)	(4.17;6.43;8.10)	(4.17;6.43;8.10)	(3.27;5.6;7.53)	(5.92;7.94;9.00)
A_{112}	(2.26;4.49;6.57)	(4.49;6.57;8.19)	(4.79;6.85;8.45)	(3.2;5.54;7.3)	(3.91;6.16;7.85)
A_{113}	(1.85;4.04;6.10)	(4.79;6.85;8.45)	(4.79;6.85;8.45)	(4.35;6.63;8.1)	(4.64;6.92;8.36)
A_{114}	(1.61;3.30;5.49)	(4.49;6.57;8.19)	(4.31;6.37;8.19)	(3.6;5.79;7.85)	(4.79;6.85;8.45)
A_{115}	(1.99;3.60;5.79)	(4.59;6.64;8.45)	(4.31;6.37;8.19)	(4.04;6.1;7.94)	(4.00;6.23;8.10)
A_{121}	(1.51;2.41;4.68)	(3.49;5.84;7.77)	(3.52;5.73;7.61)	(2.59;4.79;6.85)	(6.30;8.36;8.72)
A_{122}	(1.99;3.60;5.79)	(4.26;6.56;7.85)	(4.21;6.30;7.94)	(2.53;4.74;6.64)	(5.79;7.85;8.72)
A_{123}	(2.05;3.30;5.54)	(3.27;5.60;7.53)	(3.63;5.67;7.69)	(1.51;3.63;5.67)	(4.49;6.57;8.19)
A_{124}	(2.12;4.31;6.37)	(4.45;6.70;8.36)	(3.75;5.97;7.85)	(4.49;6.57;8.19)	(5.55;7.61;8.72)
A_{125}	(1.61;3.30;5.49)	(3.34;5.66;7.77)	(2.57;4.88;7.00)	(2.41;4.68;6.78)	(4.08;6.36;7.85)
A_{131}	(2.59;4.17;6.43)	(4.59;6.64;8.45)	(3.38;5.55;7.61)	(2.28;4.4;6.44)	(5.44;7.45;9.00)
A_{132}	(2.51;4.21;6.36)	(4.49;6.57;8.19)	(4.13;6.17;8.19)	(2.28;4.4;6.44)	(5.32;7.37;8.72)
A_{133}	(2.53;4.13;6.23)	(4.31;6.37;8.19)	(4.31;6.37;8.19)	(2.79;4.89;6.93)	(4.99;7.07;8.45)
A_{134}	(1.73;3.38;5.55)	(3.56;5.61;7.45)	(3.63;5.67;7.69)	(3.45;5.67;7.37)	(4.31;6.37;8.19)
A_{135}	(3.17;4.64;6.92)	(4.31;6.37;8.19)	(3.52;5.73;7.61)	(2.43;4.59;6.64)	(5.67;7.69;9.00)

Table 11 – The values of $\tilde{S}$, $\tilde{R}$ and $\tilde{Q}$ for the proposed strategies A_{ijk}: $A_{11} - A_{75}$.

	$\tilde{S}$	$\tilde{R}$	$\tilde{Q}$
A_{11}	(-1.74;0.94;3.15)	(-0.21;0.39;0.75)	(-0.69;0.11;0.83)
A_{12}	(-1.67;1.20;3.45)	(-0.26;0.38;0.90)	(-0.70;0.13;0.91)
A_{13}	(-1.68;1.17;3.40)	(-0.19;0.40;0.76)	(-0.68;0.13;0.86)
A_{14}	(-1.45;1.36;3.45)	(-0.06;0.57;0.83)	(-0.62;0.20;0.88)
A_{15}	(-1.12;1.88;3.79)	(0.05;0.70;1.00)	(-0.55;0.29;0.97)
A_{21}	(-1.58;0.94;3.20)	(-0.07;0.50;0.89)	(-0.63;0.14;0.88)
A_{22}	(-1.74;0.88;3.20)	(-0.21;0.41;0.78)	(-0.69;0.11;0.85)
A_{23}	(-1.72;1.21;3.43)	(-0.21;0.38;0.76)	(-0.69;0.13;0.86)
A_{24}	(-1.37;1.49;3.81)	(-0.17;0.42;0.98)	(-0.64;0.17;0.96)
A_{25}	(-1.65;0.98;3.08)	(0.03;0.62;0.92)	(-0.61;0.18;0.87)
A_{31}	(-1.66;1.12;3.30)	(-0.04;0.52;0.89)	(-0.63;0.17;0.89)
A_{32}	(-1.81;1.01;3.25)	(-0.26;0.28;0.78)	(-0.71;0.08;0.85)
A_{33}	(-1.40;1.32;3.45)	(0.09;0.65;0.96)	(-0.57;0.22;0.92)
A_{34}	(-1.45;1.10;3.24)	(0.05;0.61;0.93)	(-0.59;0.19;0.89)
A_{35}	(-1.63;1.10;3.33)	(-0.19;0.37;0.77)	(-0.67;0.12;0.85)
A_{41}	(-1.69;1.05;3.28)	(-0.22;0.33;0.83)	(-0.69;0.10;0.87)
A_{42}	(-1.63;1.01;3.36)	(-0.17;0.39;0.81)	(-0.67;0.11;0.87)
A_{43}	(-1.59;1.17;3.43)	(-0.10;0.49;0.86)	(-0.64;0.16;0.89)
A_{44}	(-1.89;0.77;2.99)	(-0.30;0.24;0.73)	(-0.73;0.05;0.81)
A_{45}	(-1.76;1.13;3.35)	(-0.22;0.36;0.74)	(-0.70;0.12;0.85)
A_{51}	(-1.57;1.28;3.56)	(-0.25;0.39;0.91)	(-0.69;0.14;0.92)
A_{52}	(-1.41;1.51;3.79)	(-0.22;0.43;1.00)	(-0.66;0.18;0.97)
A_{53}	(-1.13;1.64;3.84)	(0.10;0.66;1.00)	(-0.54;0.26;0.97)
A_{54}	(-1.54;1.41;3.62)	(-0.24;0.39;0.92)	(-0.68;0.15;0.93)
A_{55}	(-1.33;1.41;3.77)	(-0.11;0.44;0.95)	(-0.62;0.17;0.95)
A_{61}	(-1.10;1.65;4.04)	(-0.16;0.40;0.92)	(-0.61;0.18;0.97)
A_{62}	(-1.50;1.00;3.36)	(-0.11;0.44;0.92)	(-0.64;0.13;0.90)
A_{63}	(-1.63;0.99;3.30)	(-0.18;0.37;0.86)	(-0.67;0.11;0.88)
A_{64}	(-1.24;1.40;3.74)	(-0.08;0.46;0.97)	(-0.60;0.17;0.95)
A_{65}	(-1.62;0.99;3.28)	(-0.15;0.40;0.88)	(-0.66;0.12;0.88)
A_{71}	(-1.37;1.05;3.36)	(-0.08;0.40;0.82)	(-0.62;0.12;0.87)
A_{72}	(-1.37;1.18;3.44)	(-0.08;0.50;0.88)	(-0.62;0.17;0.90)
A_{73}	(-1.61;1.17;3.46)	(-0.25;0.33;0.87)	(-0.69;0.11;0.90)
A_{74}	(-1.68;1.00;3.26)	(-0.26;0.34;0.85)	(-0.70;0.10;0.87)
A_{75}	(-1.72;1.01;3.26)	(-0.30;0.31;0.82)	(-0.72;0.09;0.86)

Table 12 – The values of $\tilde{S}$, $\tilde{R}$ and $\tilde{Q}$ for the proposed strategies A_{ijk}: $A_{81} - A_{135}$.

	$\tilde{S}$	$\tilde{R}$	$\tilde{Q}$
A_{81}	(-1.89;0.67;2.87)	(-0.23;0.36;0.75)	(-0.71;0.07;0.8)
A_{82}	(-0.92;2.07;4.06)	(-0.09;0.53;0.93)	(-0.57;0.26;0.97)
A_{83}	(-1.94;0.61;2.80)	(-0.34;0.26;0.67)	(-0.75;0.04;0.77)
A_{84}	(-1.79;0.97;3.19)	(-0.26;0.28;0.74)	(-0.71;0.08;0.83)
A_{85}	(-2.06;0.46;2.68)	(-0.35;0.18;0.71)	(-0.76;0;0.77)
A_{91}	(-1.30;1.36;3.63)	(-0.13;0.46;0.99)	(-0.63;0.17;0.95)
A_{92}	(-1.32;1.42;3.62)	(-0.10;0.49;0.82)	(-0.62;0.18;0.90)
A_{93}	(-1.01;1.84;4.03)	(-0.01;0.56;0.96)	(-0.56;0.25;0.98)
A_{94}	(-1.36;1.47;3.66)	(-0.16;0.49;0.91)	(-0.64;0.19;0.93)
A_{95}	(-1.39;1.48;3.70)	(-0.13;0.48;0.87)	(-0.63;0.19;0.92)
A_{101}	(-1.63;1.1;3.38)	(-0.16;0.37;0.84)	(-0.66;0.12;0.88)
A_{102}	(-1.21;1.67;3.88)	(-0.07;0.49;0.89)	(-0.60;0.21;0.94)
A_{103}	(-1.18;1.80;4.02)	(-0.04;0.53;0.94)	(-0.59;0.23;0.97)
A_{104}	(-1.45;1.43;3.71)	(-0.11;0.42;0.91)	(-0.63;0.16;0.93)
A_{105}	(-1.08;1.76;4.04)	(-0.08;0.49;0.90)	(-0.59;0.22;0.96)
A_{111}	(-1.55;1.23;3.55)	(-0.24;0.34;0.81)	(-0.68;0.12;0.89)
A_{112}	(-1.48;1.35;3.64)	(-0.17;0.39;0.77)	(-0.65;0.15;0.89)
A_{113}	(-1.76;0.99;3.27)	(-0.25;0.27;0.71)	(-0.70;0.08;0.83)
A_{114}	(-1.69;1.14;3.39)	(-0.26;0.28;0.76)	(-0.70;0.10;0.86)
A_{115}	(-1.64;1.21;3.48)	(-0.21;0.38;0.76)	(-0.68;0.13;0.87)
A_{121}	(-1.44;1.15;3.49)	(-0.16;0.39;0.93)	(-0.65;0.13;0.92)
A_{122}	(-1.42;1.17;3.48)	(-0.13;0.39;0.86)	(-0.64;0.13;0.90)
A_{123}	(-1.11;1.74;4.03)	(0.00;0.54;1.00)	(-0.57;0.23;0.99)
A_{124}	(-1.68;1.09;3.37)	(-0.30;0.31;0.82)	(-0.71;0.10;0.87)
A_{125}	(-1.20;1.74;4.12)	(-0.15;0.47;1.00)	(-0.62;0.21;1.00)
A_{131}	(-1.41;1.46;3.72)	(-0.10;0.44;0.90)	(-0.63;0.17;0.93)
A_{132}	(-1.42;1.39;3.63)	(-0.10;0.44;0.90)	(-0.63;0.17;0.92)
A_{133}	(-1.44;1.36;3.60)	(-0.17;0.37;0.83)	(-0.65;0.14;0.90)
A_{134}	(-1.36;1.50;3.76)	(-0.22;0.39;0.92)	(-0.66;0.16;0.94)
A_{135}	(-1.31;1.48;3.75)	(-0.13;0.41;0.88)	(-0.63;0.17;0.93)