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Decision-Making Algorithm for the Analysis of the Development Process of A New Asphalt Mixture

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Abstract
The paper explores the sensitivity of the Laplace and Hurwicz algorithms to the estimated "performance indicator," evaluated through working alternatives (Ai) and performance scenarios (Sj). This sensitivity underscores the need for accurate data and well-founded assumptions in the decision-making process. The Laplace algorithm identifies the best alternative by maximizing expected performance, assuming equal probability across all scenarios. On the other hand, the Hurwicz algorithm incorporates an optimism coefficient (α), allowing for flexible decision-making by assigning different values to alternatives, particularly in areas like reducing manufacturing and transport costs, and CO2 emissions, per tonne of novel asphalt mixture. The study's key contributions lie in the development of modified decision optimization strategies that consider the varying significance of different alternatives by applying weighted coefficients to each performance scenario. These algorithms utilize a utility function tied to the performance indicators, providing a robust framework for analyzing such complex problems. It is shown that the final decision is shaped not only by the chosen algorithm but also by the weighting of performance scenarios, which reflect their relative importance in the decision process.

Keywords: Modified decision-making algorithm, novel asphalt mixture, performance indicator.

JEL classification: O320.

Context and optimization patterns

In innovative product development, performance indicators are crucial for assessing efficiency and success, often used in rankings and reports on innovation and competitiveness. Analyzing product development requires a multidisciplinary approach, combining expertise to enhance decision-making (DM) and address innovation complexities. Early decisions on technology and marketing strategies should rely on objective evaluations based on reliable data and diverse expertise. However, there is often a gap between initial research and final market launch, which can be mitigated by utilizing these evaluation methods early on.

However, the commercialization of innovative products often faces challenges due to the lack of objective evaluation methods. In this context, optimization strategies, such as those introduced by Laplace and Hurwicz, become essential. These mathematical frameworks support decision-making under uncertainty by assessing risks and opportunities in product development. Such strategies help avoid the risks associated with subjective or incomplete data, offering a more reliable foundation for critical business decisions.

Integrating these strategies enables a systematic approach to DM, from research and development to commercialization. Stage-specific performance indicators help track progress and adjust strategies to increase the likelihood of success in a competitive market. Furthermore, they allow for continuous realignment of the development process, ensuring that evolving market conditions and new insights are accounted for throughout the product lifecycle.

Various techniques, including SWOT analysis, market analysis, Stage-Gate, feasibility studies, Delphi method, cost-benefit analysis, Design Thinking, Lean Startup, PESTEL analysis, and impact assessments, offer valuable insights into product development. However, a decision-making algorithm with a solid mathematical foundation is critical for managing complexity and uncertainty. Algorithms like those of Laplace and Hurwicz provide objective risk assessments using mathematical and statistical principles.

While traditional methods provide useful insights, only a robust mathematical DM algorithm can comprehensively evaluate options, quantify risks and opportunities, and support informed decision-making, essential for successful product development. The paper "Integrated Approach to Multi-Criteria Decision Making for Sustainable Product Development" (Soota, 2014) highlights the need for multi-criteria analysis to assess technical, economic, environmental, and social attributes when planning product development, balancing conflicting qualitative and quantitative criteria.

The multi-criteria decision-making (DM) methodology, known as Multiple-Criteria Decision-Making (MCDM), has become an indispensable tool in research, development, and innovation, particularly in scenarios with "conflicting" objectives. MCDM, a key branch of operations research, focuses on developing mathematical and computational tools to identify the best alternative based on clearly defined criteria, whether the decision is made by an individual or a group.

In innovative product development, MCDA provides methods like MADM (Alinezhad & Khalili, 2019) and MODM for evaluating options based on objectives, assigning weights, and integrating findings into solutions. Techniques such as AHP, MAUT, ELECTRE, and PROMETHEE are commonly used for systematic evaluations, helping identify the best alternatives by integrating quantifiable variables and uncertainties (Mardani et al., 2015).

The paper "Fostering Product Development Using Combination of QFD and ANP" (Soota et al., 2011) emphasizes the importance of multicriteria methods like QFD, AHP, ANP, and Pugh selection in new product development. ANP, an advanced version of AHP, is useful for complex problems that can't be hierarchically organized, offering solutions that consider intricate interactions between criteria and alternatives. Combined with QFD, ANP optimizes engineering features and prioritizes key criteria in product development.

Similarly, "Uncertain Quality Function Deployment Using a Hybrid Group Decision-Making Model" (Wang et al., 2016) highlights QFD's role in incorporating customer requirements throughout product development. QFD uses the "House of Quality" matrix to translate customer needs into design requirements, supporting group decision-making (DM) in cross-functional teams. Incorporating fuzzy techniques enhances flexibility and adapts to uncertainties, optimizing product designs while balancing technical and financial constraints.

In construction, innovations like reclaimed asphalt pavement (RAP) and recycled materials reduce greenhouse gas emissions and ecological impact. These materials, including plastic and glass, are repurposed in asphalt mixes, reducing waste and conserving resources. Such practices align with international environmental standards, such as ISO 14001 and Life Cycle Assessment (LCA) regulations.

Littar®, a new asphalt mixture, repurposes plastic and glass waste, improving mechanical properties, reducing emissions, and cutting transport costs. The study develops a DM algorithm to evaluate performance indicators, like reductions in production and transport costs and CO_2 emissions per ton of asphalt, considering different economic scenarios (Linjie et al., 2024). This data-driven approach supports informed decision-making in product development.

Innovative companies must adapt their business models to evolving customer demands and economic uncertainties. In this context, decision-making (DM) methods like Bellman-Zadeh, along with optimization strategies (Laplace & Hurwicz), can address uncertainty in DM (Bellman & Zadeh, 1970). Group DM, involving experts from different fields, helps mitigate subjectivity and ensures optimal decisions. Robust DM strategies, like Laplace & Hurwicz algorithms, handle uncertainty and incomplete data.

This paper also explores the development of a DM algorithm to analyze performance indicators like production cost reductions, transport cost reductions, and CO_2 emission reductions, considering optimistic, pessimistic, and neutral scenarios. Using a decision support matrix, the algorithm evaluates the influence of various parameters on performance outcomes (Guler & Petrisor, 2021). The Laplace & Hurwicz strategies help overcome evaluation challenges in real-world commercialization processes (Stoilova, 2020).

Laplace and Hurwicz decision-making algorithms, adapted and modified for the evaluation of innovative product development scenarios, were guided by three main considerations: their suitability for decision-making under uncertainty, their ability to capture different managerial attitudes toward risk, and their relative transparency and interpretability for practitioners. We considered alternative algorithms (e.g., Maximin, Minimax Regret, Bellman–Zadeh fuzzy models), but these were excluded because they require more complex data inputs not available in our case. The Laplace–Hurwicz pair thus offered an appropriate balance between methodological rigor and simplicity of practical applicability.

1. Modified Laplace and Hurwicz algorithms in decision optimization for Littar® development in the logic of the performance evolution "scenarios" corresponding to the choice of working "alternatives"

In the decision-making (DM) process, options are evaluated by optimizing a utility function, also known as a "performance indicator". This process involves the analysis of different alternatives: Ai = {A1, A2,…, Am}, in the context of various scenarios: Sj = {S1, S2, …, Sn}. To deal with conditions of uncertainty, decision algorithms using specific criteria are applied.

Consequently, the decision models used in the present study are formulated as presented below. For a group decision-making (DM) model, based on a modified Laplace algorithm, when all possible scenarios are considered equally likely, this approach involves computing a set of "performance indicators", i.e. expected outcomes R (notation derived from the word "Random") , for each alternative ($R_{i,j}^{(ie=1\div3)}|_{i=1\div3} - see\ formula$ (1)), and the selection of the option with the best value (best $EV_{i,j}^{(ie=1\div3)}$(Ai$|_{i=1\div3}$) $- see\ formula$ (2)), corresponding to each evaluation of the three decision-making (DM) expertise involved (Eie (ie=1÷3)). Performance indicators (expected results $R_{i,j}^{(ie=1\div3)}|_{i=1\div3}$) are calculated by using a procedure for applying the SIMUS fuzzy method, known from the specialized literature (Stoilova & Munier, 2021).

On the other hand, for a group decision-making (DM) model based on a modified Hurwicz strategy, where α is the optimism coefficient, with 0< α <1 (the coefficient α =0 corresponding to an environment considered to be completely hostile, α =0.5 characterizes a neutral environment (neither hostile nor friendly), and for α =1, the context being the most favorable), this approach also involves the calculation of a set of "performance indicators ", i.e. expected results H (notation derived from the word "Hurwicz"), for each alternative

($H_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) - see\ formula\ (3)$), and selecting the option with the highest probability (best $H_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) - see\ formula\ (4)$), corresponding to each evaluation of the three decision-making (DM) expertise involved (Eie (ie=1÷3)).

$$R_{i,j}^{(ie=1\div3)}|_{i=1\div3} = \lambda^{(ie)} * \sum_{j=1\div3} R_{i,j}^{(ie)} \tag{1}$$

$$\text{best } EV_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) = (max_{j=1\div3} R_{i=1\div3,j}^{(1)} + max_{j=1\div3} R_{i=1\div3,j}^{(2)} + max_{j=1\div3} R_{i=1\div3,j}^{(3)})/3 \tag{2}$$

$$H_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) = \alpha * max_{j=1\div3} R_{i=1\div3,j}^{(ie)} + (1-\alpha) * min_{j=1\div3} R_{i=1\div3,j}^{(ie)} \tag{3}$$

$$\text{best } H_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) = \max_{i=1\div3}\left(H_{i,j}^{(ie=1\div3)}(Ai|_{i=1\div3})\right) \tag{4}$$

In relations (1) ÷ (4), $\lambda^{(ie)}$ represent weights, respectively $\lambda^{(ie)}$ (ie = 1÷3), for the "degrees of contribution" of the performance evolution "scenarios".

In our study, we suppose three alternatives Ai (i=1÷3), i.e. A1 means increasing level of Technological Readiness Level (TRL), A2 is associated with the same tendency of Market Readiness Level (MRL), and A3 presumes increasing together other levels, i.e. Regulatory Readiness Level (RRL), Acceptance Readiness Level (ARL), Organizational Readiness Level (ORL), and Commercial Readiness Index (CRI) (Boanță et al., 2023).

Note: In the logic of the performance evolution "scenarios" corresponding to the choice of some working "alternatives", the summation in relation (1) is done according to the index "j" of the scenarios Sj = {S1, S2, ..., Sn}, with the meaning of "cumulation" the result of applying the Laplace or Hurwicz decision algorithms. This operation (summation) gives the character of "modification" of the Laplace and Hurwicz algorithms, proposed in our study, reflecting the idea of cumulating the values of the "performance indicators" from the proposed performance evolution "scenarios", for which the optimal solution will be determined more likely depending on the alternatives chosen. The reason for this summation is that we aim, through the modified decision algorithm, to obtain optimal solutions, for each proposed performance evolution "scenario", by arithmetically averaging the maximum values among those calculated by the amounts in question, not as in the classic algorithms, in which these calculation aspects do not exist. Therefore, the individualization of the options in the calculation table (algorithm), aims to reach a "unique" decision optimization solution, when the "performance indicators" ("KPIs", included in a "utility function") have the same meaning (unit of measure) (Borissova & Dimitrova, 2021). In our study, the "performance indicators" are different, with the same unit of measure (%), but with different meanings and ranges of variation, a problem that will be solved in the following development of the study, by a normalization (scaling) operation.

For these modified Laplace and Hurwicz algorithms, using relations (1) ÷ (4), a decision mechanism is proposed starting from the choice of alternatives Ai (i=1÷3) with the aim of determining the optimal (Laplace) / the most probable (Hurwicz) scenarios Sj (with j=1÷3), for "performance indicators" evolution, being different both in meaning and ranges of variation, as mentioned above, their consideration in the analysis being taken individually / independently.

We will also analyze two data modules of two cases each, regarding the weighted "degree of contribution" allocated to three performance evolution "scenarios" (production costs, transport costs, CO_2 emissions per ton, of new asphalt mixture), presented as follows. The quantitative evaluation of these "degrees of contribution" can be determined by applying an analytical hierarchy method ("Analytic Hierarchy Method" - AHP), which calculates the weight of each possibility according to a series of specific options of the analyzed process (Leal, 2020; Saaty, 2013).

The mentioned study modules are as follows:

a) Module I, referring to the combination of "degrees of contribution" with the highest weights, scenario S3 for case I.1, respectively scenario S2 for case I.2:

- Case I.1: $\lambda^{(1)} = 0.15$; $\lambda^{(2)} = 0.35$; $\lambda^{(3)} = 0.50$, their sum being 1.00;
- Case I.2: $\lambda^{(1)} = 0.20$; $\lambda^{(2)} = 0.60$; $\lambda^{(3)} = 0.20$, with the same observation as in case I.1; and

b) Module II, referring to the combination of "degrees of contribution" with the highest weights, scenario S3 for case II.1, respectively scenario S1 for case II.2:

- Case II.1: $\lambda^{(1)} = 0.15$; $\lambda^{(2)} = 0.35$; $\lambda^{(3)} = 0.50$, their sum being 1.00;
- Case II.2: $\lambda^{(1)} = 0.60$; $\lambda^{(2)} = 0.20$; $\lambda^{(3)} = 0.20$, with the same observation as in case II.1.

These two modules practically cover all possible performance evolution "scenarios", when from the point of view of the involvement of multidisciplinary teams, with different fields of specialization, respectively of experts, with different skills, they will contribute to the credibility of the specific process of implementing a group decision-making (DM) model.

More specifically, in module I, specialists with managerial expertise (RRL, ARL, ORL and CRI - case I.1) are involved in the decision-making (DM) process, respectively specialists with marketing expertise (MRL) for case I.2, while, in module II, being involved in the decision-making (DM) process mainly the group of specialists with managerial expertise (RRL, ARL, ORL and CRI - case II.1), respectively specialists with expertise in technological development (TRL) for case II.2.

As mentioned before, for a group decision-making (DM) model based on a modified Hurwicz strategy, the synthesis of some options chosen for our study is presented in Table 1. In this case, we are discussing the case of the maximum optimism coefficient (0.7) and the minimum pessimism coefficient (0.3), with unit sum, for the possibility with the highest probability of being prioritized, as implementation and manifestation / emergence, corresponding to (MRL).

The optimism coefficients applied (α = 0.4, 0.7, 0.15) were chosen to represent different managerial attitudes:
α = 0.4 corresponds to a moderately pessimistic stance, suitable for scenarios with high uncertainty or external constraints, in Table 1, being associated with specialists in technological development (TRL).
α = 0.7 reflects an optimistic outlook, often adopted when innovation is supported by strong market signals, in Table 1, being associated with specialists in the field of marketing (MRL).
α = 0.15 represents a highly conservative approach, relevant when resource constraints dominate decision-making, in Table 1, being associated with specialists with managerial expertise (RRL, ARL, ORL and CRI).
This combination of optimism coefficients was assumed in our study like a possible scenario, where the experts in marketing field brings the most optimistic approach, product manifesting strong marketing opportunities, the technological development capacity being moderate, while the ones with expertise in management refers to the most pessimistic scenario, the organization, developing the new asphalt, having limited managerial experience in transferring innovative products in a very competitive market.

Table 1. The pair of values for the coefficient of optimism / pessimism (α, 1- α)

	λ^(1) TRL	**λ^(2) MRL**	**λ^(3) RRL, ARL, ORL and CRI**
α	0.4	0.7	0.15
1-α	0.6	0.3	0.85
	1.00	1.00	1.00

2. Data analysis for the development of the innovative Littar® product to optimize decisions in the logic of the performance evolution "scenario" corresponding to the choice of working "alternatives"

In the context of the present study, we structured and analyzed the relevant data for some "performance indicators" targets / references, as follows:

- ✓ A1 - Reduction of production costs per ton of new asphalt mixture (5%)
- ✓ A2 - Reduction of transportation costs per ton of new asphalt mixture (18%)
- ✓ A3 - Reduction of CO_2 emissions per ton of new asphalt mixture (83%)

The three indicators—reduction of production costs, reduction of transport costs, and reduction of CO_2 emissions—were prioritized for their direct measurability, immediate relevance to sustainability, and availability of reliable data. While other criteria (e.g., durability of production equipment, recyclability of other plastics, or social impacts) are relevant, they were excluded at this stage due to data limitations. These values derive from previous research on Littar® asphalt mixtures, being validated by expert assessments (DEBIE et al., 2023). A1 and A2 reflect operational cost factors where moderate variability is expected, whereas A3 reflects environmental performance, which is significantly influenced by material substitution and thus carries the largest weight. This as a limitation and suggests future research should expand the set of criteria to capture broader sustainability dimensions.

The calculated data and assessments made will be used to draw conclusions and practical recommendations, thus facilitating the selection of the most effective option for optimizing the necessary allocations and reducing the ecological impact associated with the practical use of the new asphalt mixture.

2.1. The modified Laplace algorithm

For the application of the modified Laplace algorithm, we present the data analysis from only one situation, corresponding to Module I (cases I.1 and I.2), as already mentioned previously.

Table 2 – Data analysis for cases I.1 and I.2

		Performance ("reductions") Ri,j (%)			Formula Ri,j ^ (ie) (%)				Formula Ri,j ^ (ie) (%)				
DM expertise Eie (ie=1÷3)	Alternatives for "reductions" Ai (i=1÷3)	Scenarios for performance evolution Sj (j=1÷3)			S1	S2	S3	Case I.1	S1	S2	S3	Case I.2	
		S1	S2	S3	Ri,1 ^ (1)	Ri,2 ^ (2)	Ri,3 ^ (3)	Formula best EV(Ai)	Ri,1 ^ (1)	Ri,2 ^ (2)	Ri,3 ^ (3)	Formula best EV(Ai)	Alternatives for "reductions"
E1	A1	6,00	9,00	14,00	4,35	10,15	14,50	15,17	7,25	17,40	4,35	18,20	0,95
	A2	19,00	15,00	12,00	6,90	16,10	23,00	26,00	11,50	27,60	6,90	31,20	0,93
	A3	84,00	80,00	75,00	35,85	83,65	119,50	120,33	59,75	143,40	35,85	144,40	0,98
E2	A1	9,00	12,00	11,00	4,80	11,20	16,00		8,00	19,20	4,80		
	A2	22,00	14,00	18,00	8,10	18,90	27,00		13,50	32,40	8,10		
	A3	88,00	79,00	70,00	35,55	82,95	118,50		59,25	142,20	35,55		
E3	A1	11,00	7,00	12,00	4,50	10,50	15,00		7,50	18,00	4,50		
	A2	23,00	15,00	18,00	8,40	19,60	28,00		14,00	33,60	8,40		
	A3	90,00	76,00	80,00	36,90	86,10	123,00		61,50	147,60	36,90		

The data from Table 2, normally reveals that in case I.1, S3 is "dominant" (column in red), while in case I.2, S2 is "dominant" (column in red), in correlation with the assumed maximal values of $\lambda^{(ie)}$ (ie = 1÷3), i.e. $\lambda^{(3)} = 0.50$ for case I.1 and $\lambda^{(2)} = 0.60$ for case I.2.

Important is to mention that from data in column "Formula best EV(Ai)", in both cases, and calculating "Alternatives for "reductions"" from last column, the maximal value of 0,98 corresponds to working "alternative" A3 (reduction of CO_2 emissions per ton of new asphalt mixture) that is associated with the optimal solution for application the Laplace the decision-making (DM) procedure.

2.2. Modified Hurwicz algorithm

To apply the modified Hurwicz algorithm, we start from the set of values used in the application of the Laplace algorithm (see paragraph 7.3.1.), from which we take only case I.1 (in Module I), regarding the combination of "degrees of contribution" with the highest weights, respectively scenario S3 from case I.1: $\lambda^{(1)} = 0.15$; $\lambda^{(2)} = 0.35$; $\lambda^{(3)} = 0.50$, their sum being 1.00.

In essence, the Hurwicz algorithm introduces into the analysis the aspects regarding the use of a group decision-making (DM) model, based on a modified Hurwicz-type strategy. In our study, as already mentioned previously, we are discussing the case of the maximum optimism coefficient (0.7) and the minimum pessimism coefficient (0.3), with unit sum, for the possibility with the highest probability of being prioritized, as implementation and manifestation / emergence, corresponding to (MRL).

Table 3 – Data analysis for case Hurwicz 1

		Performance ("reductions") Ri,j (%)			Formula Ri,j ^ (ie) (%)			Case Hurwicz 1		
DM expertise Eie (ie=1÷3)	Alternatives for "reductions" Ai (i=1÷3)	Scenarios for performance evolution Sj (j=1÷3)			S1	S2	S3	S1	S2	S3
		S1	S2	S3	Ri,1 ^ (1)	Ri,2 ^ (2)	Ri,3 ^ (3)	α = 0.4, Formula Hi,j ^ (ie) (%)	α = 0.7, Formula Hi,j ^ (ie) (%)	α = 0.15, Formula Hi,j ^ (ie) (%)
E1	A1	6,00	9,00	14,00	4,35	10,15	14,50	8,41	11,46	5,87
	A2	19,00	15,00	12,00	6,90	16,10	23,00	13,34	18,17	9,32
	A3	84,00	80,00	75,00	35,85	83,65	119,50	69,31	94,41	48,40
E2	A1	9,00	12,00	11,00	4,80	11,20	16,00	9,28	12,64	6,48
	A2	22,00	14,00	18,00	8,10	18,90	27,00	15,66	21,33	10,94
	A3	88,00	79,00	70,00	35,55	82,95	118,50	68,73	93,62	47,99
E3	A1	11,00	7,00	12,00	4,50	10,50	15,00	8,70	11,85	6,08
	A2	23,00	15,00	18,00	8,40	19,60	28,00	16,24	22,12	11,34
	A3	90,00	76,00	80,00	36,90	86,10	123,00	71,34	97,17	49,82

The data from Table 3, normally reveals that in case I.1, S3 is "dominant" (column in red), as result of Laplace decision-making (DM) procedure application, while, introducing the optimism / pessimism coefficients, specific to Hurwicz algorithm, column S2 - performance evolution "scenario" - becomes "dominant" (also column in red), associated with the most probable character of the solution, specific to the application of Hurwicz decision-making (DM) procedure.

3. Modified Hurwicz algorithm in the optimization of decisions for the development of Littar®, in the logic of "alternatives" to fulfill the performance evolution "scenarios"

On modified Hurwicz algorithm, a decision mechanism is proposed with the aim of determining the necessary working alternatives Ai (i=1÷9), recommended for fulfilling the chosen performance evolution "scenarios" Sj (with j=1÷3). Because scenarios differ both in meaning and in terms of ranges of variation, it is necessary to make a "normalization / scaling" procedure, all values being brought to the same domain of variation, thus their consideration in the analysis being taken as a group, in a unitary and qualitatively undifferentiated way.

The calculation relationships respect the methodology regarding the evaluation of "performance indicators" (expected results, $R_{i,j}^{(ie=1\div3)}|_{j=1\div3}$), with the introduction into the calculation relationships of the "degrees of contribution", allocated to the three performance evolution "scenarios" (in production costs, transport costs, CO_2 emissions per ton, of new asphalt mixture), and the formulation of mathematical expressions are specific to the application of the modified Hurwicz algorithm, which were extensively developed in the paper titled "An Integrated Multi-Criteria Approach for Planning Railway Passenger Transport in the Case of Uncertainty" (Stoilova, 2020).

For a group decision-making (DM) model, based on a modified Hurwicz strategy, where α is the coefficient of optimism, with $0 < \alpha < 1$, this approach involves calculating a set of "performance indicators", i.e. expected results H (notation derived from the word "Hurwicz"), for each alternative ($H_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) - see\ formula$ (6)), and selecting the option with the highest probability (best $H_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) - see\ formula$ (7)), corresponding to each evaluation of the three performance evolution "scenarios" involved, by using the above mentioned three decision-making (DM) expertise (Eie (ie=1÷3)).

The difference from relation (1), from paragraph 2, is that "performance indicators" (the expected results $R_{i,j}^{(ie=1\div3)}|_{j=1\div3}$) are calculated with relation (5), in which the summation is done according to the working alternative index "i" (i=1÷3 , i=4÷6, i=7÷9, so in groups of three) not according to the performance evolution "scenario" index "j", in correlation with the groups of working alternatives: A1, A4, A7 - reduction of production costs per ton of asphalt mixture (%) ; A2, A5, A8 - reduction of transportation costs per ton of asphalt mixture (%) and A3, A6, A9 - reduction of CO_2 emissions per ton of asphalt mixture (%).

$$R_{i,j}^{(ie=1\div3)}|_{j=1\div3} = \lambda^{(ie)} * \sum_{i=1\div3} R_{i,j}^{(ie)} \quad (5)$$

$$H_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) = \alpha * max_{j=1\div3} R_{i=1\div3,j}^{(ie)} + (1-\alpha) * min_{j=1\div3} R_{i=1\div3,j}^{(ie)} \quad (6)$$

$$\text{best } H_{i,j}^{(ie=1\div3)}(\mathrm{Ai}|_{i=1\div3}) = \max_{i=1\div3}\left(H_{i,j}^{(ie=1\div3)}(Ai|_{i=1\div3})\right) \quad (7)$$

In relations (5) ÷ (7), $\lambda^{(ie)}$ represent weights, respectively $\lambda^{(ie)}$ (ie = 1÷3), for the "degrees of contribution" of the performance evolution "scenarios", and (α) the optimism coefficients, respectively (1-α) the pessimism coefficients, from the Hurwicz modified algorithm.

Note: In the logic of necessary working alternatives Ai (i=1÷9), recommended for fulfilling the chosen performance evolution "scenarios" Sj (with j=1÷3), also meaning "cumulation" of the results of applying Hurwicz decision algorithms, but "opposite" to the study carried out in paragraph 2, when we proceeded in the logic of the recommended performance evolution "scenarios" corresponding to the choice of some working "alternatives". This operation (summation) gives the character of "modification" of the Hurwicz algorithms proposed in our study. Once more, the reason for this summation is that we aim, through the modified decision algorithm, to obtain the most probable solutions, for each possible work alternative, by arithmetically averaging the maximum values among those calculated by the sums in question, not as in the classical algorithms, in which these amounts do not exist. In our study, the "performance indicators" are different, with the same unit of measure (%), but with different meanings and ranges of variation, the problem being solved by a normalization (scaling) procedure, as mentioned above.

For the application of the modified Hurwicz algorithm considered in the analysis, we consider only one situation, for the "degrees of contribution" & coefficient of optimism α, as follows: S1 / $\lambda^{(1)}$ = 0,15 & α = 0,75; S2 / $\lambda^{(2)}$ = 0,35 & α = 0,4; S3 / $\lambda^{(3)}$ = 0,50 & α = 0,65.

The "normalization / scaling" of the "performance indicators", with relationships of the form $A_{i=1\div9}$ norm = 100 * $A_{i=1\div9}$ / $A_{i=1\div9}$ ref (ex. 120 = 100 * 6 / 5), with $A_{i=1\div9}$ ref having the values, as follows: A_1ref = 5, A_2ref = 18, A_3ref = 83, A_4ref = 5, A_5ref = 18, A_6ref = 83, A_7ref = 5, A_8ref = 18, A_9ref = 83, with original values of $A_{i=1\div9}$ from the three columns in the left part of Table 4, presented in the image below:

Table 4 – Original and normalized data evolution of performance indicators

A1	6,00	9,00	14,00	**A1 norm**	**120,00**	**180,00**	**280,00**
A2	19,00	15,00	12,00	**A2 norm**	**105,56**	**83,33**	**66,67**
A3	84,00	80,00	75,00	**A3 norm**	**101,20**	**96,39**	**90,36**
A4	9,00	12,00	11,00	**A4 norm**	**180,00**	**240,00**	**220,00**
A5	22,00	14,00	18,00	**A5 norm**	**122,22**	**77,78**	**100,00**
A6	88,00	79,00	70,00	**A6 norm**	**106,02**	**95,18**	**84,34**
A7	11,00	7,00	12,00	**A7 norm**	**220,00**	**140,00**	**240,00**
A8	23,00	15,00	18,00	**A8 norm**	**127,78**	**83,33**	**100,00**
A9	90,00	76,00	80,00	**A9 norm**	**108,43**	**91,57**	**96,39**

where:

A1, A4, A7 - reduction of production costs per ton of asphalt mixture (%)

A2, A5, A8 - reduction of transport costs per ton of asphalt mixture (%)

A3, A6, A9 - reduction of CO_2 emissions per ton of asphalt mixture (%)

Table 5 – Data analysis for case Hurwicz 2

		Performance ("reductions") Ri,j (%)			Formula Ri,j ^ (ie) (%)			Case Hurwicz 2		
DM expertise Eie (ie=1÷3)	Alternatives for "reductions" Ai (i=1÷9)	Scenarios for performance evolution Sj (j=1÷3)			S1	S2	S3	S1	S2	S3
		S1	S2	S3	Ri,1 ^ (1)	Ri,2 ^ (2)	Ri,3 ^ (3)	α = 0,75, Formula Hi,j ^ (ie) (%)	α = 0,4, Formula Hi,j ^ (ie) (%)	α = 0,65, Formula Hi,j ^ (ie) (%)
E1	A1	120,00	180,00	280,00	163,38	179,86	218,51	204,73	185,43	199,22
	A2	105,56	83,33	66,67	98,03	107,92	131,11	122,84	111,26	119,53
	A3	101,20	96,39	90,36	65,35	71,94	87,41	81,89	74,17	79,69
E2	A4	180,00	240,00	220,00	204,12	206,48	202,17	205,40	203,89	204,97
	A5	122,22	77,78	100,00	122,47	123,89	121,30	123,24	122,34	122,98
	A6	106,02	95,18	84,34	81,65	82,59	80,87	82,16	81,56	81,99
E3	A7	220,00	140,00	240,00	228,11	157,45	218,19	210,44	185,71	203,38
	A8	127,78	83,33	100,00	136,86	94,47	130,92	126,27	111,43	122,03
	A9	108,43	91,57	96,39	91,24	62,98	87,28	84,18	74,28	81,35

The data, from Table 5, reveals that for the values of "degrees of contribution" & coefficient of optimism α, taken into calculation, where S1 is “dominant”, the recommended working “alternative” is A1, A4, A7 - reduction of production costs per ton of asphalt mixture, according to the application of Hurwicz decision-making (DM) procedure.

Conclusions regarding the application of Laplace and Hurwicz algorithms in the optimization of development decisions of the innovative Littar® product

The study highlights that the Laplace and Hurwicz algorithms, developed and applied here, are highly sensitive to the estimated values of the "performance indicator," which are evaluated based on some working “alternatives” (Ai) and performance evolution “scenarios” (Sj). This sensitivity emphasizes the critical importance of using accurate data and formulating correct assumptions in the decision-making (DM) process.

In terms of the decision logic, tied to specific performance evolution "scenarios" and their corresponding working "alternatives," as well as the reverse logic of working "alternatives" fulfilling performance evolution "scenarios", the Laplace algorithm determines the best alternative by maximizing expected performance, assuming all “scenarios” (S1, S2, or S3) are equally probable in the absence of additional information, thus the decision is made based on the equal distribution of probabilities across the mentioned “scenarios”.

Conversely, within the same logic of “scenarios” and “alternatives”, the Hurwicz algorithm introduces an optimism coefficient (α) to identify the most likely achievable “scenario”. This algorithm emphasizes the influence of the optimism coefficient on the final decision, allowing for flexibility in assigning different values to “alternatives” related to reduction of production costs, transport costs, and CO_2 emissions per ton of asphalt mixture. The role of this coefficient is crucial, as it directly affects the outcome of the decision-making (DM) process.

The study's key contributions involve the development of modified decision optimization strategies based on the Laplace and Hurwicz algorithms. These strategies account for the varying importance of different working “alternatives”, by assigning a weighted set of coefficients / "degrees of contribution" to each of three performance evolution “scenarios” (reduction of production costs, transport costs, and CO_2 emissions per ton of new asphalt mixture). Mentioned algorithms make use of a “utility function”, represented by the "performance indicator" / performance evolution “scenarios”, offering wide possibilities to analyze specific problems. It is shown that the final group decision is influenced not only by the choice of the algorithm but also by the weighting coefficients, which reflect the corresponding significance of the performance evolution “scenarios”, quality of data being essential, depending on the three-group decision-making (DM) expertise Eie.

In the future, we intend to complement the maturity evaluation criteria, like working “alternatives”, with other dimensions to assess the specific levels of maturity for any innovative product, such as 'Manufacturing Readiness Level', 'Demand Readiness Level', 'Investment Readiness Level', 'Economic Readiness Level'.

Also, it is needed to complete the used decision support algorithms with more elaborate and sophisticated techniques, in terms of mathematical calculation models, for more accurately capturing the presence of uncertainties and risk factors, and being validated through case studies, where recommendations, like those formulated in the current study, to be tested in practice, within finalized research-development-innovation projects, by using real data.

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