APPLICATION OF EXACT METHODS FOR FINDING THE OPTIMAL SOLUTION OF ORGANIZATIONAL RESILIENCE IMPROVEMENT

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Abstract: *This paper investigates the application of branch and bound algorithms to determine the optimal solution for enhancing organizational resilience. Faced with an increasingly dynamic and uncertain business environment, organizations seek effective methods to fortify their resilience against disruptions. Our study focuses on identifying a set of management methods that can improve key resilience factors while considering constraints such as execution time and costs. Through rigorous analysis, the branch and bound algorithm efficiently navigates the vast solution space, yielding a curated set of methods including Flowchart (generic), Mind map, Stakeholder analysis, Brainstorming, Brainwriting, 5W2H, and Importance–performance analysis. These methods offer diverse approaches to resilience enhancement, each with its unique strengths. By incorporating time and cost constraints, our approach ensures practical feasibility for real-world implementation. It can be concluded that leveraging branch and bound algorithms provides valuable insights for organizations to proactively adapt to challenges and seize opportunities in an ever-evolving landscape of disruptions.*

Keywords*: organizational resilience, heuristic algorithm, optimization*

1. INTRODUCTION

In the contemporary landscape of business operations, the imperative of organizational resilience stands out as a critical determinant of sustained success (Kerr 2016). Defined by its capacity to adapt, withstand, and recover from disruptions, organizational resilience encapsulates a multifaceted array of factors, including adaptability, agility, robustness, and recovery capabilities. In response to this imperative, organizations increasingly seek strategies to fortify their resilience posture through targeted interventions (Tasic et al. 2020).

A prevailing approach involves the implementation of diverse management methods aimed at fortifying specific resilience factors (RFs). Yet, the challenge persists: how can organizations optimize the allocation of resources to maximize resilience enhancements, particularly when faced with constraints such as limited budgets and varying applicability of management methods?

In response to this challenge, this paper introduces a novel approach leveraging the branch and bound algorithm for optimizing organizational RF improvement. The objective function of the algorithm is to maximize the integration of management methods aimed at enhancing RFs, with constraints including a predefined budget and the applicability of each management method. The input data for the calculation is provided by Decision Makers (DMs).

The branch and bound algorithm, a classic optimization technique, offers a systematic approach to exploring the solution space of combinatorial optimization problems (Lawler & Wood 1966). By iteratively partitioning the solution space into smaller subspaces and bounding the objective function within each subspace, the branch and bound algorithm efficiently identifies the optimal solution or proves optimality within a given tolerance.

This paper contributes to the burgeoning literature on organizational resilience by proposing a novel application of the branch and bound algorithm to address the complex optimization problem of RF improvement. By harnessing the computational power of the branch and bound algorithm, organizations can gain insights into optimal resource allocation strategies for enhancing resilience while navigating resource constraints and method applicability considerations.

The subsequent sections of this paper are organized as follows: Section 2 provides an overview of related work in the fields of organizational resilience and optimization algorithms. Section 3 outlines the methodology employed in developing and applying the branch and bound algorithm for RF improvement. Section 4 presents the experimental setup and results of applying the proposed algorithm to a real-world case study. Finally, Section 5 offers conclusions and avenues for future research.

2. LITERATURE REVIEW

Organizational resilience has attracted attention in both academic and practical domains in recent years. This section provides an overview of pertinent literature spanning organizational resilience and heuristic optimization, laying the groundwork for the development and application of heuristic algorithms in optimizing RF improvement.
Organizational resilience is a multifaceted concept that encompasses an organization's capacity to anticipate, prepare for, respond to, and recover from disruptions while maintaining essential functions and adapting to changing circumstances (Hollnagel 2010). Resilience factors, such as awareness, preparedness, flexibility, and redundancy, play a crucial role in determining an organization's ability to withstand and thrive amidst adversity (Macuzić et al. 2016).
Scholars have emphasized the dynamic and interconnected nature of RFs, highlighting the need for holistic approaches that consider the interplay between organizational structures, processes, culture, and external environments (Vogus & Sutcliffe 2007). Various frameworks and models have been proposed to conceptualize and assess organizational resilience (Shirali & Nematpour 2019).

Optimization algorithms offer valuable tools for addressing the complex resource allocation challenges inherent in enhancing organizational resilience. While a variety of optimization techniques exist, the focus here is on the branch and bound algorithm, a classic method for solving combinatorial optimization problems (Little et al., 1966).

The branch and bound algorithm systematically explores the solution space of an optimization problem by partitioning it into smaller subspaces and bounding the objective function within each subspace. Through a process of iterative refinement and pruning, the algorithm efficiently identifies the optimal solution or proves optimality within a specified tolerance. This makes it particularly well-suited for optimization problems with discrete decision variables and complex constraints, such as those encountered in resilience enhancement efforts.

Recent research has demonstrated the potential of the branch and bound algorithm in optimizing resource allocation for organizational resilience improvement. By formulating the resilience enhancement problem as a combinatorial optimization problem and applying the branch and bound algorithm, organizations can identify optimal strategies for allocating resources to maximize RFs while adhering to constraints such as budgetary limitations and method applicability.

While the literature on the integration of the branch and bound algorithm specifically for organizational resilience optimization is relatively scarce, studies in related fields such as project scheduling, portfolio optimization, and resource allocation provide valuable insights into the efficacy and applicability of the algorithm (Pardalos et al. 2013). These studies highlight the versatility and effectiveness of the branch and bound algorithm in addressing complex optimization problems across diverse domains.

The literature reviewed herein underscores the critical importance of organizational resilience and optimization algorithms in contemporary business contexts. Building upon this foundation, the subsequent sections of this paper introduce a novel application of the branch and bound algorithm for optimizing organizational RFs improvement, offering a practical and effective approach for organizations seeking to enhance their resilience capabilities in the face of uncertainty and disruption.

3. THE PROPOSED MODEL AND ALGORITHM

In this section, the proposed methodology is presented. It is used to evaluate the suitability of the method whose application leads to the improvement of RFs, which is further propagated to increase the resilience of the company. Assessment of the method suitability for the RFs enhancement is presented as a fuzzy group decision-making problem. DMs use pre-defined linguistic expressions which are modeled by TFNs. The time and costs of applying the method are assessed by the Operations manager who forms the opinion on the personal competence, experience, and evidence data. The rest of the DM’s team could consist of different senior management members, such as the manager of the production process, quality manager, or top manager according to the specific characteristics of the treated enterprise.

In order to make the proposed Algorithm easier to understand, the notation of variables is given in Table 1.

Table 1 Notation

Notation	Description	Notation	Description
J	The total number of RFs	$\tilde{x}_{jm}^{e}$	Fuzzy rating of the method's suitability $m, m = 1,.,M$ for unapređenje RF $j, j = 1,..,J$ at the level of DM $e, e = 1,..,E$
$j, j = 1,..,J$	Index of RF	$\tilde{x}_m$	The aggregated values of method's suitability $m, m = 1,.,M$ for the RFs enhancement
M	the total number of methods used for the RFs enhancement (Tague 2023)	T	The total amount of time needed for the enhancement of RFs
$m, m = 1,..,M$	index of the management method for RFs enhancement	t_m	The amount of time needed for the execution of the management method $m, m = 1,.,M$
E	the total number of DMs	$\mathcal{G}$	The total planned budget needed for the enhancement of RFs
$e, e = 1,..,E$	index of DM	γ_m	The costs of the management method execution $m, m = 1,.,M$

3.1. Linguistic terms for describing the methods' suitability for the RFs enhancement

It is widely acknowledged that DMs find it more intuitive to express their evaluations using linguistic expressions rather than conventional measurement scales. The conceptual framework of fuzzy sets, pioneered by Dubois and Prade (1980) and further refined by Zimmermann (2010), has provided a robust mathematical foundation for representing these linguistic expressions in a quantitative manner. This framework facilitates the modeling of linguistic expressions through fuzzy numbers, characterized by key attributes such as membership function, granularity, and domain.

Numerous studies in literature advocate the efficacy of Triangular Fuzzy Numbers (TFNs) in capturing uncertainties and imprecisions inherent in natural language without necessitating complex mathematical computations. TFNs offer a pragmatic approach to addressing linguistic uncertainties, effectively bridging the gap between qualitative assessments and quantitative analyses.

Determining the appropriate granularity for linguistic expressions remains an open question, devoid of universal guidelines or directives. Typically, the selection of linguistic expressions is contingent upon the intricacy of the problem at hand. Notably, a prevalent convention observed in scholarly discourse involves the utilization of seven linguistic expressions (Lootsma 1988). The predefined linguistic expressions, along with their corresponding TFNs, are elucidated as follows:
extremely low applicability-$V1 = (1,1,2.5)$
very low applicability -$V2 = (1,2,3)$
low applicability -$V3 = (1.5,3,4.5)$
medium applicability -$V4 = (3.5,5,6.5)$
high applicability-$V5 = (5.5,7,8.5)$
Very high applicability -$V6 = (8,9,10)$
extremely high applicability -$V7 = (8.5,10,10)$

Domains of defined TFNs are presented on real line into interval $[1 - 10]$ as in referent literature (Saaty 2013). A value of 1 indicates that the applicability of the method is almost negligible. On the other hand, a value of 10 indicates that the applicability of the method certainly leads to the improvement of RFs.

3.2 The proposed Algorithm

The proposed Algorithm can be realized through the following steps, which are further detailed.

Step 1. Let us construct the matrix for suitability analysis of management methods for enhancement of each RF:

$$\left[\tilde{x}_{jm}^{e}\right]_{JxM}$$

The values of this matrix, $\tilde{x}_{jm}^{e}$ can have value 0 if DM $e, e = 1, \ldots, E$ believes that there makes no sense to use that method for the RF enhancement, or those values can be described by using one of seven pre-defined linguistic expressions, where:

$$\tilde{x}_{jm}^{e} = \left(a_{jm}^{e}, b_{jm}^{e}, c_{jm}^{e}\right)$$

Step 2. Let us determine the aggregated value of the method suitability $m, m = 1, .., M$ at the level og each RF $j, j = 1, \ldots, J$ by applying the operator of fuzzy square mean, $\tilde{x}_{jm}$:

$$\tilde{x}_{jm} = \left(\sqrt[E]{\prod_{e=1,..,E} a_{jm}^{e}}, \sqrt[E]{\prod_{e=1,..,E} b_{jm}^{e}}, \sqrt[E]{\prod_{e=1,..,E} c_{jm}^{e}}\right) = \left(a_{jm}, b_{jm}, c_{jm}\right)$$

Step 3. Let us determine the total suitability of the method $m, m = 1, .., M$, $\tilde{x}_{m}$:

$$\tilde{x}_{m} = \left(\frac{1}{J} \cdot \sum_{j=1,..,J} a_{jm}, \frac{1}{J} \cdot \sum_{j=1,..,J} b_{jm}, \frac{1}{J} \cdot \sum_{j=1,..,J} c_{jm}\right) = \left(a_{m}, b_{m}, c_{m}\right)$$

Step 4. The representative scalar TFN $\tilde{x}_{m}$, x_{m}, is obtained by applying center gravity method (Wang & Luoh, 2000), so that:

$$x_{m} = a_{m} + \frac{c_{m} - a_{m} + b_{m} - a_{m}}{3}$$

Step 5. The choice of the optimal set of methods to be applied in order to improve RFs is set as a classic model of combinatorial optimization:

Fitness function:

$$\max_{m=1,..,M} x_{m}$$

Subject to:

$$\sum_{m=1,..,M} t_{m} \leq T$$

$$\sum_{m=1,..,M} \gamma_{m} \leq \mathcal{G}$$

4. CASE STUDY

This paper advances the state-of-the-art in organizational resilience research by introducing a novel approach that leverages the branch and bound algorithm for optimizing RFs improvement. Through empirical validation and case study analysis, we demonstrate the efficacy and practical applicability of the proposed approach in aiding organizations in their pursuit of enhanced resilience capabilities.

The proposed algorithm is tested in a complex international company that operates at different locations worldwide. The company is an international leader in high-precision equipment for quality management in industry. The input data is obtained through the interview with the DMs team. As mentioned in the section explaining the methodology, the DMs' team can consist of the different managers. In the treated company, it is decided that the DMs' team consists of (e=1) manager of integrated management systems, (e=2) operations manager, and (e=3) maintenance process manager.
The proposed Algorithm (Step 1 to Step 2) is illustrated for RF $(j = 3)$ at the level of the method $(m = 1)$. Fuzzy rating of method's suitability $(m = 1)$ is assessed by DMs in a following way:

$$V3, V3, V4$$

The aggregated value of the method's suitability calculated:

$$\tilde{x}_{31} = \left(\sqrt[3]{1.5 \cdot 1.5 \cdot 4.5}, \sqrt[3]{3 \cdot 3 \cdot 5}, \sqrt[3]{4.5 \cdot 4.5 \cdot 6.5}\right) = (1.99, 3.56, 5.09)$$

Each method's suitability is calculated in a similar manner for each RFs.

The total method's suitability $(m = 1)$ is calculated by applying the proposed Algorithm (Step 3):

$$\tilde{x}_1 = \begin{pmatrix} \frac{1}{10} \cdot (1 + 4.07 + 1.99 + 1.14 + 1.14 + 1.31 + 6.23 + 1.14 + 8.18 + 1.99), \\ \frac{1}{10} \cdot (1.59 + 5.59 + 3.56 + 2.29 + 2.29 + 2.62 + 7.61 + 2.29 + 9.32 + 3.56), \\ \frac{1}{10} \cdot (2.82 + 7.11 + 5.09 + 3.43 + 3.43 + 3.93 + 8.97 + 3.43 + 10 + 5.04) \end{pmatrix}$$

$$\tilde{x}_1 = (2.82, 4.07, 5.33)$$

The crisp value of method's suitability $(m = 1)$ is given by center gravity method (Step 4 of the proposed Algorithm):

$$x_1 = 2.82 + \frac{5.33 - 2.82 + 4.07 - 2.82}{3} = 4.07$$

The values of other methods' suitability whose application may enhance the values of RFs are calculated in similar manner. The selection of methods to be applied is based on the following proposed KP problem:

Fitness function:

$$\max_{m=1,..,M} x_m$$

Subject to:

$$\sum_{m=1,..,49} t_m \leq 240$$

$$\sum_{m=1,..,49} \gamma_m \leq 190\,000$$

By applying the software solution (https://developers.google.com/optimization/cp/cp_solver), the optimal set of methods whose application will enhance the values of RFs is obtained. Simultaneously, the optimal set of methods satisfy constraints in terms of time and costs. The obtained solution is given after 0,01458 seconds. The obtained set of methods include: Flowchart (generic)$(m = 6)$, Mind map $(m = 9)$, Stakeholder analysis $(m = 15)$, Brainstorming $(m = 20)$, Brainwriting $(m = 21)$, 5W2H $(m = 23)$ and Importance–performance analysis $(m = 24)$.

5. CONCLUSION

In this paper, we have explored the application of branch and bound algorithms in determining the optimal solution for improving organizational resilience. Our objective was to identify a set of management methods that, when applied, would enhance the values of RFs. Through rigorous analysis and implementation of the branch and bound algorithm, we were able to effectively navigate the complex landscape of available methods and their associated costs and time requirements.

The results of our study reveal a curated set of methods that hold significant promise for bolstering organizational resilience. Among these methods are Flowchart (generic), Mind map, Stakeholder analysis, Brainstorming, Brainwriting, 5W2H, and Importance–performance analysis. Each of these methods brings unique strengths to the table, offering diverse approaches to addressing the multifaceted challenges of organizational resilience enhancement.

Furthermore, the authors consider the methods presented to be comparatively "easy" to implement in a business context. This is mainly due to the fact that they are already widely recognized in organizations and the necessary competences are either already available or can be developed quickly. This supports implementation in terms of organizational resilience - in which the speed of implementation can be an elementary key. Nevertheless, there should be a discussion as to whether the proposed methods are equally suitable for organizations in different sectors in treated company or how flexible they are in order to adapt to constantly changing market conditions and technologies. Are the methods also long-term enough to be able to map future scenarios.

By incorporating constraints related to both time and cost, we ensured that the identified methods are not only effective but also feasible within real-world organizational contexts. This dual consideration is crucial for practical implementation, as it allows decision-makers to make informed choices that align with their resource constraints and strategic objectives.

As we move forward, it is essential to recognize that the pursuit of organizational resilience is an ongoing journey rather than a finite destination. While the methods identified in this study represent valuable tools for improvement, they are by no means exhaustive. Continued research and innovation in this field will be paramount for staying ahead of evolving challenges and opportunities.

The application of branch and bound algorithms has proven instrumental in uncovering actionable insights for organizational resilience enhancement. By leveraging these insights, organizations can proactively adapt to disruptions, seize new opportunities, and thrive in an ever-changing environment. We hope that this research serves as a catalyst for further exploration and advancement in the vital domain of organizational resilience.

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