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OPTIMAL RESOURCE ALLOCATION MODEL IN DISASTER SITUATIONS FOR MAXIMIZING THE VALUE OF OPERATIONAL PROCESS RESILIENCY AND CONTINUITY

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Abstract. Organizations need to apply resilience and business continuity in industry to protect themselves against the crises and destructive events. Also, the growing expansion of competition in the global market and the increasing crisis in the world have increased the importance of optimal resource allocation. With the optimal resource allocation, huge losses and damages to organizations are prevented. The problem of resource allocation can be raised alongside the criteria of process resilience and continuity. Therefore, organizations change their perspective from focusing solely on reducing vulnerability to increasing resilience and continuity against to accidents in crises and destructive situations. The objective of this paper is proposed a mathematical model for optimal resource allocation with the aim of minimizing the lack of process resilience and maximizing the process continuity. So, the organization can continue to operate with available resources in times of crisis and lack of resources. Also, main activities and processes are not interrupted by crises and destructive events. After solving the model using a case study (textile industry), the results of the model were described and it was found that destructive events were recovered before the tolerance threshold and crisis and destructive events did not interrupt activities and processes.

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1. Introduction

Since process optimization leads to the achievement of organizational objectives and facilitates the execution of organizational missions in an efficient and effective manner, so it will be of particular importance. In addition, the customers of the organization will benefit from the advantage of receiving better products or services in a shorter time and at a lower cost. On the other hand, the same customers will cause the growth and development or even save the organization, so the process optimization should be done with more focus on customers. Especially in spite of the bad economic conditions prevailing in some organizations or even countries that are actually trying to survive, the problem of process optimization is more important than ever.

Keywords. Resource allocation, risk management, process optimization, resiliency, business continuity.

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Process optimization is one of the best methods for organizations that are technically known and use complex processes to achieve the best productivity and performance. Almost all optimization applications attempt to improve factory profitability or return on investment immediately by direct measurement methods. Due to the increasing risks, which in some cases lead to a major disaster, the society needs a business continuity plan to prevent the cessation of activities in the society by identifying existing crises. In the event of such interruptions, society incurs enormous and irreparable costs. In fact, when a destructive event occurs, resilience manages it, which can ultimately reduce the duration of the disruption or reduce its impact on system performance [23]. Also, when a destructive event occurs, the business continuity causes the production or service activities not to stop and continue to operate [28]. In order to identify risks and reduce their impact on the activities of organizations, there is a comprehensive approach, *i.e.* business continuity management, which the problem of product recovery after a destructive event and the allocation of resources is one of the important aspects of this field [18]. Among the methods used to measure resilience in the articles are: neural network, conceptual frameworks, optimization model, simulation models, fuzzy logic model, structural equation modeling and fuzzy cognitive map. Also, to measure the business continuity, the methods of optimization model, conceptual framework and event tree and fault tree model have been used. In this paper, a quantitative model is proposed to allocate resources of minimizing the lack of process resilience of organizations and maximizing the process continuity of organizations. There is a fundamental assumption in this paper that there is a lack of resources in at least one of the available resources due to the excessive amount of outputs and services or products. To solve the proposed model, the ε-constraint method was used. Finally, the proposed model is validated through application to a real case study (textile industry). The main contributions of this paper can be outlined as follows:

- Modeling the concept of stock portfolio optimization to determine the percentage of resource allocation to process output or related activities. Therefore, the desired portfolio is a percentage of each resource that is allocated to a product or activity. There are different scenarios of these percentages, which the proposed model finds the optimal portfolio.
- Proposing an indicator to measure process resilience and continuity.
- Modeling the resource allocation at the activities level in operational processes.
- Determining the percentage of resource allocation based on resources in two categories of activity-oriented and output-oriented.
- Modeling resource allocation according to the nature of operations and activities and considering the assumptions of prerequisite and synchronization of activities.
- Providing a mathematical formula for process resilience index and process continuity.
- Considering the index of resilience and continuity in processes in the conditions of lack of resources and considering different combinations of resource allocation as an example of an investment portfolio.

Also, the research questions of this paper can be outlined as follows:

- How can the resources needed in operational processes be optimally allocated during the life cycle of the processes in such a way that the process has optimal and acceptable performance?
- How can determine the percentage of resource allocation based on resources in two categories of activity-oriented and output-oriented?
- What are the optimization parameters in process performance?
- What is the appropriate mathematical model for the optimal resource allocation in operational processes and how can benchmark the concept of stock portfolio optimization for this reason?

The article are structured as follows: Section 2 reviews the studied articles. Section 3 proposes the research method and the proposed model. In Section 4, a case study proposes to prove the applicability of the proposed model. Finally, Section 5 describes concludes.

2. Literature review

Process analysis is closely related to process optimization and is actually a set of methods and tools that are used to examine the intermediate results of processes and help the decision-making process in the organization. Organizations typically analyze processes to inform managers, stakeholders, and process executives about the efficiency and effectiveness of processes, and this analysis is often considered as an input to process optimization, or is sometimes used to measure the compliance of an organization's performance with predetermined rules. In the optimization path, the discussion of resources has a major role and the problem of resource allocation can be relevant to the efficiency and effectiveness of resources. As we know, resources are a fundamental component of various organizations, departments and centers, and without resources, not only do they have no meaning, but their management will not be possible. Among the various organizational resources, human resources are the most valuable resource of organizations, especially in organizations such as service and health organizations and hospitals that are dependent on their human resources, is more evident. Optimal resource allocation helps organizations to ensure the status of their resources, surplus resources, lack of resources in different sectors or their balance. In general, the issue of resource allocation is raised due to limitations in the use of resources. Allocating the resources needed to execute strategies is fundamental to strategic management [2,6,8]. Alongside the main role of resources, process indicators and other organizational problem are raised. The problem of resource allocation can be raised alongside the criteria of process resilience and process continuity. In fact, due to the increasing risks, which in some cases lead to a major disaster, the society needs a business continuity planning to identify existing crises to prevent the interruption of activities and the resources allocation due to their lack in critical condition. In the event of such interruptions, society incurs enormous and irreparable costs. In such circumstances, the society is always trying to be prepared for disasters by using different approaches in the field of business continuity management, such as risk management, crisis management or creating a state of resilience. Also, one of the important aspects in the field of business continuity management is the discussion of product recovery after a destructive event and the resources allocation for this purpose. In processes based on the different outputs that exist, how the available resources can be optimally allocated so that higher priority outputs are selected and considered. Therefore the process must be continuous. So here is a concept called process continuity. Also in different conditions (normal state or with many inputs and requests in a process) the process can have different modes of its own resilience. So with this view, we can enter into a concept called resilience. Actually, in normal state there is a service-oriented process in which the client requests a service and exits after the operation. Now in critical conditions where excessive input is allowed, the process must be able to respond to service requests, which can be measured by process continuity and process resilience. In the propose paper, which considers the resources allocation at the process level, there are a series of activities and resources in these processes, whose function is based on the resources allocation. Each resource has a minimum and maximum amount and available and external resources. If the process has too much input, it will usually have to source from external resources. Also, activities and resources are also associated with risk. Therefore, it is necessary that resources are allocated in such a way that the process has its optimal performance in different conditions. In these different situations, there can be risks that the basis of process performance should be based on process resilience and process continuity. There are several challenges in processes, and that is that some processes face high workloads for critical reasons or due to high input requests. Therefore, the process may be challenged, so different conditions need to be considered. Therefore, the process must be able to respond to service requests, which this ability can be measured by the process continuity value and process resilience. For example, in the event of a crisis in a hospital, if there is one cashier which is considered as a resource of manpower, three more cashiers can be added to propose services and prevent congestion, that this is called business continuity. Therefore, when the number exceeds a certain limit or a process face a disruption, it may be difficult to continue and it may not be able to continue that service or business. One of the things they do in these situations is called business continuity planning. It must also be estimated to what extent the process can resilience by very high inputs or very low outputs. Resilience focuses on how much tolerate that process is, that this resilience is dependent on resources. Now we want to know in critical condition, given the level of operation that exists, how much resource can be allocated to each activity in the process so that the process can be expected to be resilient and process continuous at a reasonable level?

According to the literature on resource allocation, various mathematical methods have been used to allocate resources, which include: system dynamics, goal Programing, heuristic approaches, linear programming, multiple-criteria decision analysis, data envelopment analysis models, fuzzy logic, discrete event simulation model, dynamic planning model and colored Petri nets. The resource allocation model is rooted in research conducted by Bower in 1970 and extended by Burgelman in 1983. This research has inspired a rich array of field studies, from large organizations to small companies and entrepreneurial startups. Radually, other studies began to explore the limits of the resource allocation model. In these studies, questioning the conditions under which the model is prescriptive or descriptive, as exemplified by Eisenmann and Bower's studies in 2000 [19].

In 1999, Cook and Kress made the first attempt to allocating fixed cost using the DEA approach. Then in 2003 Beasely proposed an alternative cost allocation approach by maximizing the average efficiency and adding constraints and models for unique cost allocation [1]. In 2004, Lozano *et al.* first introduced resource allocation models. They used the data envelopment analysis model for glass recycling operations in Spanish cities. The purpose of their research is to allocate glass containers to each city in such a way that the total number of recycled glass is maximized [12]. Joglekar *et al.* [11] used system dynamics and simulation to allocate resources for product development. According to them, proper allocation will reduce the time of product development projects [11]. Belfars *et al.* [3] used the Tabu Search and Pareto optimization to solve multi-objectives resource allocation problems with time window constraints. The results showed that this method improved the allocation of resources without changing the plan schedule [3]. In 2007, a model was proposed to evaluate the impact of the resource allocation in public hospitals with the aim of minimizing mortality rates using the probabilistic approach [25]. If destructive events occur during resource allocation, the organization must respond to destructive events by proposing an appropriate level of organizational resilience. Therefore, with the emergence of issues such as the importance of being resilient of processes, research in the field of resilience also became relevant. It is noteworthy that in the event of destructive events, the operational capacity of the entire organization decreases with decreasing the level of availability of some resources of the organization. In these circumstances, residual resources must be allocated to recover disrupted critical operations in order to continue the business. The concept of business continuity has its roots in research into disaster recovery planning in the 1970s. In the last decade, BCM has attracted the attention of many organizations [27]. In 1973, Haling conducted research on the concept of resilience, entitled "Resilience and Sustainability of Environmental Systems", which concept of resilience is rooted in his research. Haling's research forms the basis for subsequent studies on the concept of resilience [4]. For first time, Bruneau *et al.* introduced a mathematical formula to measure the amounts of resilience lack [5]. In the field of resource allocation with the aim of increasing the resilience and business continuity, Sahebjamnia *et al.* in 2015 proposed a mathematical model of resource allocation to determine the resources needed to deal with destructive events. In this model, simultaneous allocation of internal and external resources is planned with the aim of minimizing the weighted sum lack of resilience of key products over time and also minimizing the weighted sum of recovery times of all key products. This article also assumes that the amount of required resources are less than internal and external resources [21]. Faturechi *et al.* [7] deal with the optimal allocation of limited resources to response capabilities and the preparedness actions that facilitate them. It addresses the problem of maximizing the airport's runway and taxiway network resilience under several damage-meteorological scenarios [9]. Torabi *et al.* proposed a new method to provide the required resources to continue key functions after happened risk. They also propose a formula for calculating the minimum necessary resources after a risk occurs [24]. In 2018, Xu *et al.* presented a mathematical model for the optimal allocation of resources in the field of logistics under uncertainty. They have also used a heuristic algorithm to solve it [26].

In 2018, following the research of Sahebjamnia *et al.* [21], a multi-objective optimization model for the optimal resource allocation in the event of a disaster with the objective of minimizing the lack of resilience and maximizing the value of business continuity in organizations is presented. In this model, assumptions such as considering the interaction of destructive events, the organization's reactive actions after the destructive events are added, and also discusses how resources are allocated to critical activities in the event of destructive events [18].

In 2018, Sahebjamnia *et al.* following their research in 2015, proposed a multi-objective optimization model for planning the allocation of internal and external resources with minimal restoration time, resumption time and loss in the operational level of critical functions. The proposed model is a business continuity model and disaster recovery planning model for organizational resilience that includes 3 objective functions: minimizing the weighted sum of the operational level loss of critical functions, minimizing the recovery time by maximizing the number of post-disruption periods during which the operational level of critical function is more than MBCO and minimizes the weighted sum of recovery times after the occurrence of destructive incidents [22].

In another article in 2021, Ostadi *et al.* model the optimum number of required equipment and manpower for operational processes in the textile industry. According to the results of the proposed model, more comprehensive and accurate information is proposed under uncertain conditions that can be used to make appropriate decisions to revise the unused capacity, reduce the cost of idle resources and increase the efficiency and productivity of the industry [17].

Also, among the works that have been done in the field of mathematical modeling of resource allocation in processes, we can mention the article by Ostadi *et al.* [15]. Which has done activity-based costing for hospital services with a fuzzy approach is used and the proposed model is used in a sample related to the hospital laboratory section [16]. In order to minimize the lack of resilience in the key products of the organization and to minimize the total cost of the business continuity plans in 2019, a model was proposed. In this model, the amount of resources is considered constant during the period of the disruption and is not reduced. Also, the maximum amount of data that the organization is willing to lose depends on the amount of available resources, which are defined in different modes to determine it [20]. In Mokhtarian Daloie and Ostadi [13], a discrete-event simulation model is introduced to improve the quality of services of the urology unit at a kidney center, which optimally assigns technicians to shifts. Among the results of this model were the reduction of waiting time, patient's cancellation rates and also the increase of efficiency of Extracorporeal Shock Wave Lithotripsy (ESWL) processes [13]. In 2020, a model for optimal budget allocation to the infrastructure components was introduced to increase system resilience, which a power generation unit with a series of possible characteristics is considered that reduces the recovery time of the generator by improving each characteristic or subset of them. Therefore, due to budget limit, the subset of all sets should be selected in such a way as to achieve a higher level of resilience for the system [14]. In 2021, following the research of Sahebjamnia *et al.* [21], an objective optimization model at the level of organization for the optimal resource allocation in the event of a disaster to maximize the value of resilience and business continuity was presented. In this model, assumption such as considering the interaction of destructive events is added. Also it discusses how resources are allocated to critical activities in the event of destructive events [18]. Also, in another article, following the research of Mokhtarian Daloie and Ostadi [13], technicians are assigned to weekly shifts using the Markowitz model. In this article, when allocating resources, the risk is minimal and the return is maximized [18]. Considering that in critical situations due to the disruptions caused after the disaster, there is a need to manage the situation in order to reduce the impact of the disruption on the society and allocate resources optimally, Jain and Bharti [10] proposed a model to solve the situation that use meta-heuristic algorithms for resource allocation [10].

3. Resource allocation model formulation in crises and destructive situations

The main assumption used for formulation of the resource allocation problem are as follows:

There is a lack of resources in at least one of the available resources due to the excessive amount of outputs and services or products.

$$\exists \sum_{o=1}^{O} \widehat{X}_{oks} > \mathrm{ROI}_{ks} + \mathrm{ROE}_{ks} \qquad \forall k, s \tag{1}$$

$$\exists \sum_{o=1}^{O} \sum_{i=1}^{m} \sum_{j=1}^{n_i} \widehat{X}_{jiotk's} > \mathrm{RAI}_{k's} + \mathrm{RAE}_{k's} \qquad \forall k', s. \tag{2}$$

So:

Sets

O	Set of outputs $(o = 1, 2, \ldots, O)$
K	Set of output-oriented resources type $(k = 1, 2, \ldots, K)$
k'	Set of activity-oriented resources type $(k = 1, 2, \ldots, K')$
T	Set of times $(t = 1, 2, \ldots, T)$
I	Set of processes $(i = 1, 2, \ldots, m)$
J	Set of activities $(j = 1, 2, \ldots, n_i)$
L	Set of operational levels $(l = 1, 2, \ldots, L)$
S	Set of scenarios $(s = 1, 2, \ldots, S)$

Parameters

prob^s	The probability of scenario s
γ_{jios}	MTPD for the jth activity j in the ith process for the oth output in scenario S
γ_{os}	MTPD for the oth output in scenario S
λ_{jios}	MBCO for the jth activity j in the ith process for the oth output and in scenario S
BG	Existing organization budget under critical condition (unexpected)
w_o	Weight for output o
w_k	Weight for kth resource
P_o	The demand for the oth output
r_{oks}	The consumption rate of kth output-oriented resources for oth output in scenario S
$r_{jiok'ts}$	The consumption rate of k'th activity-oriented resources for oth output at time t in scenario S
ROE_{ks}	The total amount of the external kth resource in scenario S for output-oriented
ROI_{ks}	The total amount of the internal kth resource in scenario S for output-oriented
$\mathrm{RAE}_{K's}$	The total amount of the external K'th resource in scenario S for activity-oriented
$\mathrm{RAI}_{K's}$	The total amount of the internal K'th resource in scenario S for activity-oriented
$\widehat{X}_{oks}$	The amount of the kth required output-oriented resources allocated to the oth output and in scenario S
$\widehat{X}_{jiotk's}$	The amount of the k'th required activity-oriented resources allocated to the jth activity of the ith process of the oth output at time t and in scenario S
CE_k	External resource cost k output-oriented
$\mathrm{CE}_{k'}$	External resource cost k activity-oriented
Z_{jio}	If the jth activity from the ith process in the output o is active will be one, otherwise zero

Variables

Y_{jitsol}	If operational level (ijo) at time t and scenario S is equal to l it will be one; otherwise zero
M_{jiot}	If the jth activity from the ith process related to the output o at time t is active will be one, otherwise zero
XI_{Oks}	The amount of the kth output-oriented internal resources allocated to the oth output in scenario S (in the critical condition)
XE_{Oks}	The amount of the kth output-oriented external resources allocated to the oth output in scenario S (in the critical condition)
$\mathrm{XI}_{jiotk's}$	The amount of the kth activity-oriented internal resources allocated to the jth activity of the ith process in the oth output at time t in scenario S (in the critical condition)
$\mathrm{XE}_{jiotk's}$	The amount of the kth activity-oriented external resources allocated to the jth activity of the ith process in the oth output at time t in scenario S (in the critical condition)

W_{jiots}	The planned operational level for the jth activity of the ith process in the oth output at time t in scenario S
W_{os}	The planned operational level for the oth output in scenario S
ϑ_{jios}	The recovery time for the jth activity of the ith process in the oth output at time t in scenario S
ϑ_{os}	The recovery time for the oth output in scenario S

Therefore, the process resilience and process continuity model for dealing with the resource allocation problem in critical conditions is as follows:

$$\text{Min } R = \sum_{s=1}^{S} \text{prob}^s \sum_{t=1}^{T} \sum_{o=1}^{O} w_o \sum_{i=1}^{m} \sum_{j=1}^{n_i} M_{jiot} * (L - W_{jiots}) + \sum_{s=1}^{S} \text{prob}^s \sum_{o=1}^{O} w_o * (L - W_{os}) \tag{3}$$

$$\text{Max } CA = \frac{\sum_{i=1}^{m} n_i - \sum_{s=1}^{S} \text{prob}^s \sum_{o=1}^{O} w_o \sum_{i=1}^{m} \sum_{j=1}^{n_i} \left(\frac{\vartheta_{jios}}{\gamma_{jios}} \right)}{\sum_{i=1}^{m} n_i} \tag{4}$$

$$\text{Max } CO = 1 - \sum_{s=1}^{S} \text{prob}^s \sum_{o=1}^{O} w_o * \left(\frac{\vartheta_{\text{os}}}{\gamma_{\text{os}}} \right) \tag{5}$$

$$\sum_{o=1}^{O} \text{XI}_{Oks} \leq \text{ROI}_{ks} \qquad \forall k, s \tag{6}$$

$$\sum_{o=1}^{O} \text{XE}_{Oks} \leq \text{ROE}_{ks} \qquad \forall k, s \tag{7}$$

$$\text{XE}_{Oks} + \text{XI}_{Oks} \geq \alpha \times \widehat{X}_{oks} \qquad \forall o, k, s \tag{8}$$

$$\text{XE}_{Oks} + \text{XI}_{Oks} < \widehat{X}_{oks} \qquad \forall o, k, s \tag{9}$$

$$\sum_{t=1}^{T} \sum_{o=1}^{O} \sum_{i=1}^{m} \sum_{j=1}^{n_i} \text{XI}_{jiotk's} \leq \text{RAI}_{K's} \qquad \forall k', s \tag{10}$$

$$\sum_{t=1}^{T} \sum_{o=1}^{O} \sum_{i=1}^{m} \sum_{j=1}^{n_i} \text{XE}_{jiotk's} \leq \text{RAE}_{K's} \qquad \forall k', s \tag{11}$$

$$\text{XI}_{jiotk's} + \text{XE}_{jiotk's} \geq \alpha \times M_{jiot} \times \widehat{X}_{jiotk's} \qquad \forall j, i, o, t, k's \tag{12}$$

$$\text{XI}_{jiotk's} + \text{XE}_{jiotk's} < M_{jiot} \times \widehat{X}_{jiotk's} \qquad \forall j, i, o, t, k's \tag{13}$$

$$\sum_{l=1}^{L} \sum_{o=1}^{O} Y_{jitsol} = 1 \qquad \forall j, i, s, t \tag{14}$$

$$\sum_{t=1}^{T} \sum_{l=1}^{L} l * Y_{jitsol} \geq \lambda_{jios} \qquad \forall j, i, o, s \tag{15}$$

$$\sum_{k=1}^{K} \text{CE}_K \sum_{o=1}^{O} \text{XE}_{oks} + \sum_{k'=1}^{K'} \text{CE}_{K'} \sum_{t=1}^{T} \sum_{o=1}^{O} \sum_{i=1}^{m} \sum_{j=1}^{n_i} \text{XE}_{jiotk's} \leq \text{BG} \qquad \forall s \tag{16}$$

$$\sum_{l=1}^{L} l Y_{jitsol} \geq W_{jiots} \qquad \forall j, i, o, s, t \tag{17}$$

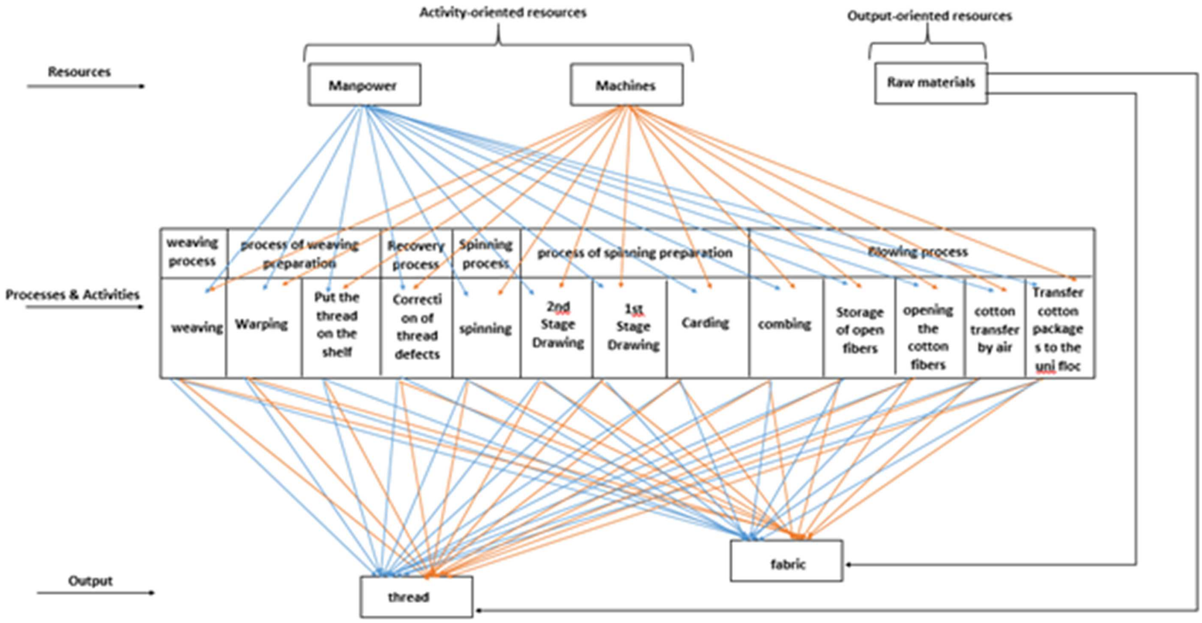

FIGURE 1. Outline of resource allocation to activities and products.

$$\left(T-\sum_{t=1}^{T}\sum_{l=1}^{L}Y_{ijtsol}+1\right)\leq \vartheta_{jios} \qquad \forall j,i,o,s \tag{18}$$

$$\vartheta_{jios}\leq \gamma_{jios} \qquad \forall j,i,o,s \tag{19}$$

$$\vartheta_{os}\leq \gamma_{os} \qquad \forall o,s \tag{20}$$

$$\sum_{t=1}^{T}M_{jiot}=1 \qquad \forall j,i,o \tag{21}$$

$$M_{jiot}-M_{j'iot}=0 \quad j\neq j' \qquad \forall j,i,o \tag{22}$$

$$M_{jiot}\leq M_{j''iot} \qquad \forall j,i,o \tag{23}$$

$$M_{jiot}+M_{j''iot}=1 \quad j\neq j'' \qquad \forall j,i,o \tag{24}$$

$$Y_{ijtsol},M_{jiot}\in\{0,1\} \qquad \forall i,j,o,l,t,s \tag{25}$$

$$\mathrm{XE}_{Oks},\mathrm{XI}_{Oks},\mathrm{XE}_{jiotk's},\mathrm{XI}_{jiotk's},W_{jiotks},W_{os},\vartheta_{jios},\vartheta_{os}\geq 0 \qquad \forall o,i,j,k,t,s. \tag{26}$$

The first objective function minimizes the weighted sum of the lack of resilience, in effect minimizing the distance between the planned operational level (the level of operation of a product reduced by a destructive event) and the level of normal operation (which is the maximum level of operating of the product). Resilience is the operational level of product, that the lowest level of operation is equal to the value of MBCO, and below that means failure and non-production.

TABLE 1. The activities required to produce output.

Output	Blowing process ($i = 1$)					Process of spinning preparation ($i = 2$)			Spinning process ($i = 3$)	Recovery process ($i = 4$)	Process of weaving preparation ($i = 5$)		Weaving process ($i = 6$)
	Transfer cotton packages to the uni floc machine ($j = 1$)	Cotton transfer by air flow ($j = 2$)	Opening the cotton fibers ($j = 3$)	Storage of open fibers ($j = 4$)	Combing ($j = 5$)	Carding ($j = 6$)	1st Stage Drawing ($j = 8$)	2nd Stage Drawing ($j = 8$)	Spinning ($j = 9$)	Correction of thread defects ($j = 10$)	Put the thread on the shelf ($j = 11$)	Warping ($j = 12$)	Weaving ($j = 13$)
Thread ($O = 1$)	1	1	1	1	1	1	1	1	1	1	0	0	0
Fabric ($O = 2$)	1	1	1	1	1	1	1	1	1	1	1	1	1

TABLE 2. Values related to the required and available resources to prove the assumption of the problem.

$S = 1$		$S = 2$		$S = 3$	
$\sum_{o=1}^{O} \widehat{X}_{oks}$	$\mathrm{ROI}_{ks} + \mathrm{ROE}_{ks}$	$\sum_{o=1}^{O} \widehat{X}_{oks}$	$\mathrm{ROI}_{ks} + \mathrm{ROE}_{ks}$	$\sum_{o=1}^{O} \widehat{X}_{oks}$	$\mathrm{ROI}_{ks} + \mathrm{ROE}_{ks}$
195 000	$4000 + 81\,000 = 85\,000$	162 500	$5000 + 82\,000 = 87\,000$	97500	$5000 + 85\,000 = 90\,000$

TABLE 3. The demand, weight, consumption rate and amount of kth output-oriented resources for the oth output in 3 week.

	P_o	W_o	$r_{oks}, \widehat{X}_{oks}$		
			$K = 1, s = 1$	$K = 1, s = 2$	$K = 1, s = 3$
$O = 1$	375 000 kg	0.6	$6, 91\,500$	$5, 76\,250$	$3, 45\,750$
$O = 2$	172 500 m	0.4	$3, 51\,750$	$5, 86\,250$	$6, 103\,500$

TABLE 4. The probability of scenario s.

prob^s	
$s = 1$	0.3
$s = 2$	0.5
$s = 3$	0.2

TABLE 5. External resources cost k output-oriented.

CE_k	
$k = 1$	15 000

TABLE 6. External resources cost k activity-oriented.

$\mathrm{CE}_{k'}$	
$k' = 1$	12 000
$k' = 2$	300 000

The second objective function maximizes the process continuity value for activity-oriented resources and the third objective function maximizes the process continuity value for output-oriented resources. If the value of process continuity is equal to one, it indicates that the disruption has not had effect on resources, if it is between zero and one, the disruption affects resources but they will be retrieved. If the value is negative, it means that after disruption, the organization was not able to retrieve its resources and the organization's activities were interrupted. Constraints (6) and (7), which are the maximum resource constraint for output-oriented resources, ensure that in the critical condition, the amount of the allocated output-oriented resource cannot be higher than the amount of total resource. Constraint of Minimum production (8) ensures that a minimum amount of output-oriented resource must be allocated to produce the product. Constraint (9), which is the constraint of production capacity, ensures that because a series of risks are imposed on the process, sometimes it is not possible to allocate the required amount to that process. Constraints (10) and (11), which are the maximum resource constraint for activity-oriented resources, ensure that in the critical condition, the amount of allocated activity-oriented resource cannot be higher than the amount of total resource. Constraint of Minimum production (12) ensures that a minimum amount of activity-oriented resource must be allocated to produce the product. Also, constraint (13) which is the constraint of production capacity for activity-oriented resource, ensures that because a series of risks are imposed on the process, sometimes it is not possible to allocate the required amount to that process. in other words, the allocation amount is less than the required amount. Constraint (14) ensures that just one operational level is assigned to each (IJO) at any given time. That's mean at time t, (IJO) cannot have multiple levels of operation simultaneously. Constraint (15) ensures that for times after MTPD, the (IJO) must be higher than the corresponding MBCO to prevent the activity from failing. Constraint (16) sets the scope of the budget to propose activity-oriented and output-oriented resources. Constraint (17) defines the planned operational level at any given time, *i.e.* the planned operational level as the output of the problem, the maximum can be as large as the level of operation of the product at that time where here the maximum level is equal to L. Constraint (18) sets the scope of the recovery time for each (ijo), which can vary from 1 to T. That's mean, in case of failure, the product can be recovered from 1 periods later to the T periods later. Constraint (19) sets the scope of the RTO for each (ijo), in fact ensuring that its value does not exceed the MTPD. Constraint (20) ensures that the RTO does not exceed the MTPD for each (o). Constraint (21), which is the constraint of being active an activity, ensures that each activity be active in the process a certain time $(t = 1, 2, \ldots, T)$. Constraint (22), which is called the synchronization constraint of activities, ensures that the two activities of j and j' of the process i are simultaneously active. Constraints (23) and (24), called activity prerequisite constraints, ensure that the prerequisite condition of activities is established. In this type of relationship, the condition for starting the activity is the completion of the prerequisite activity. As a result, activities must be planned in such a way that the required activities are performed. For this case we will have two constraints (23) and (24). Constraints (25) and (26) ensure that the decision variables are binary variables or non-negative.

TABLE 7. The consumption rate and amount of k'th activity-oriented resources allocated to the jth activity of the ith process for oth output at time t in scenario S.

	$r_{jiotk's}$			$\widehat{X}_{jiotk's}$		
	$t = 1, 2, 3$ $s = 1$	$t = 1, 2, 3$ $s = 2$	$t = 1, 2, 3$ $s = 3$	$t = 1, 2, 3$ $s = 1$	$t = 1, 2, 3$ $s = 2$	$t = 1, 2, 3$ $s = 3$
$i = 1, j = 1, o = 1, k' = 1$	20	17	15	84.7222	72.01389	63.54167
$i = 1, j = 1, o = 2, k' = 1$	20	17	15	123.6111	74.16667	92.70833
$i = 1, j = 2, o = 1, k' = 1$	15	12	10	63.54167	50.83333	42.36111
$i = 1, j = 2, o = 2, k' = 1$	15	12	10	92.70833	74.16667	61.80556
$i = 1, j = 3, o = 1, k' = 1$	16	13	11	67.77778	55.06944	46.59722
$i = 1, j = 3, o = 2, k' = 1$	16	13	11	98.88889	80.34722	67.98611
$i = 1, j = 4, o = 1, k' = 1$	13	10	9	55.06944	42.36111	38.125
$i = 1, j = 4, o = 2, k' = 1$	13	10	9	80.34722	61.80556	55.625
$i = 1, j = 5, o = 1, k' = 1$	80	70	60	338.8889	296.5278	254.1667
$i = 1, j = 5, o = 2, k' = 1$	80	70	60	494.4444	432.6389	370.8333
$i = 2, j = 6, o = 1, k' = 1$	70	65	60	296.5278	275.3472	254.1667
$i = 2, j = 6, o = 2, k' = 1$	70	65	60	432.6386	401.7361	370.8333
$i = 2, j = 7, o = 1, k' = 1$	120	100	90	508.3333	423.6111	381.25
$i = 2, j = 7, o = 2, k' = 1$	120	100	90	741.6667	618.0556	556.25
$i = 2, j = 8, o = 1, k' = 1$	150	140	130	635.4167	593.0556	550.6944
$i = 2, j = 8, o = 2, k' = 1$	150	140	130	927.0833	865.2778	803.4722
$i = 3, j = 9, o = 1, k' = 1$	600	500	450	2541.667	2118.056	1906.25
$i = 3, j = 9, o = 2, k' = 1$	600	500	450	3708.333	3090.278	2781.25
$i = 4, j = 10, o = 1, k' = 1$	230	210	200	974.3056	889.5833	847.2222
$i = 4, j = 10, o = 2, k' = 1$	230	210	200	1421.528	1297.917	1236.111
$i = 5, j = 11, o = 2, k' = 1$	11	9	8	718.75	575	479.1667
$i = 5, j = 12, o = 2, k' = 1$	70	65	60	6708.333	6229.167	5750
$i = 6, j = 13, o = 2, k' = 1$	140	110	90	10 252.083	10 020.83	10 001.67
$i = 1, j = 1, o = 1, k' = 2$	15	13	11	63.54167	55.06944	46.59722
$i = 1, j = 1, o = 2, k' = 2$	15	13	11	92.70833	80.34722	67.98611
$i = 1, j = 2, o = 1, k' = 2$	20	18	14	84.72222	76.25	59.30556
$i = 1, j = 2, o = 2, k' = 2$	20	18	14	123.6111	111.25	86.52778
$i = 1, j = 3, o = 1, k' = 2$	16	13	10	67.77778	55.06944	42.36111
$i = 1, j = 3, o = 2, k' = 2$	16	13	10	98.88889	80.34722	61.80556
$i = 1, j = 4, o = 1, k' = 2$	13	10	7	55.06944	42.36111	29.65278
$i = 1, j = 4, o = 2, k' = 2$	13	10	7	80.34722	61.80556	43.26389
$i = 1, j = 5, o = 1, k' = 2$	80	70	60	338.8889	296.5278	254.1667
$i = 1, j = 5, o = 2, k' = 2$	80	70	60	494.4444	432.6389	370.8333
$i = 2, j = 6, o = 1, k' = 2$	70	65	55	296.5278	275.3472	232.9861
$i = 2, j = 6, o = 2, k' = 2$	70	65	55	432.6389	401.7361	339.9306
$i = 2, j = 7, o = 1, k' = 2$	90	80	70	381.25	338.8889	296.5278
$i = 2, j = 7, o = 2, k' = 2$	90	80	70	556.0556	494.4444	432.6389
$i = 2, j = 8, o = 1, k' = 2$	140	130	115	593.0556	550.6944	487.1528
$i = 2, j = 8, o = 2, k' = 2$	140	130	115	865.2778	803.4722	710.76639
$i = 3, j = 9, o = 1, k' = 2$	300	250	220	1270.833	1059.028	931.9444
$i = 3, j = 9, o = 2, k' = 2$	300	250	220	1854.167	1545.139	1359.722
$i = 4, j = 10, o = 1, k' = 2$	130	110	90	550.6944	465.9722	381.25
$i = 4, j = 10, o = 2, k' = 2$	130	110	90	803.4722	679.8611	556.25
$i = 5, j = 11, o = 2, k' = 2$	40	35	20	1916.667	1677.083	958.3333
$i = 5, j = 12, o = 2, k' = 2$	18	165	145	8625	7906.25	6947.917
$i = 6, j = 13, o = 2, k' = 2$	260	240	220	12 458.33	11 500	10 541.67

Table 8. Existing external and internal resource value in scenario S (output-oriented).

	$K=1$		
	$S=1$	$S=2$	$S=3$
ROE_{ks}	4000	5000	5000
	81 000	82 000	85 000

Table 9. Existing external and internal resource values in scenario S (output-oriented).

	$\mathrm{RAE}_{K's}$			$\mathrm{RAI}_{K's}$		
	$S=1$	$S=2$	$S=3$	$S=1$	$S=2$	$S=3$
$K'=1$	11 200	12 000	15 360	27 200	29 600	31 200
$K'=2$	0	0	480	32 400	37 440	46 800

Table 10. MTPD for the oth output in scenario S.

γ_{os}			
	$S=1$	$S=2$	$S=3$
$O=1$	3	3	3
$O=2$	3	3	3

Table 11. Weight for output o.

w_o	
$O=1$	0.6
$O=2$	0.4

4. Numerical example

In this section, we describe our case study and the data collection procedure which is used to evaluate the proposed model. The case study was conducted for a textile industry in Iran to show how to deal with possible disruptions. In this study, a model is proposed for the optimal resource allocation (manpower, Machines and raw materials) in critical conditions. Also, you can see in Figure 1 that there are a series of resources that want to be allocated to the product. Here, in order to increase the accuracy of the allocation, the activities are given, and the resources are allocated through the activities. There are two types of resource:

(1) Activity-oriented resources: some resources are based on the nature of the activity (activity time).
(2) Output-oriented resources: some are based on the number of outputs (such as materials).

Output-oriented resources are resources that are for each product and have nothing to do with the activity, it is spent in the activity but it is dependent on the product. In fact, output-oriented resources directly affect the outputs, but activity-oriented resources show their effect on the output through activities.

Figure 1 shows how to allocate activity-oriented and output-oriented resources. First, the process and its corresponding activities in the textile factory are identified. Also, Output is a combination of activities. That is, according to each output, a set of activities is performed, which may be from one process or several processes, which is shown in the matrix of Table 1. Table 1 shows the activities and processes required to produce the

TABLE 12. MTPD for the jth activity j in the ith process for the oth output in scenario S.

γ_{jios}	$S=1$	$S=2$	$S=3$
$i=1, j=1, o=1$	3	3	3
$i=1, j=1, o=2$	3	3	3
$i=1, j=2, o=1$	3	3	3
$i=1, j=2, o=2$	3	3	3
$i=1, j=3, o=1$	3	3	3
$i=1, j=3, o=2$	3	3	3
$i=1, j=4, o=1$	3	3	3
$i=1, j=4, o=2$	3	3	3
$i=1, j=5, o=1,$	3	3	3
$i=1, j=5, o=2$	3	3	3
$i=2, j=6, o=1$	3	3	3
$i=2, j=6, o=2$	3	3	3
$i=2, j=7, o=1$	3	3	3
$i=2, j=7, o=2$	3	3	3
$i=2, j=8, o=1$	3	3	3
$i=2, j=8, o=2$	3	3	3
$i=3, j=9, o=1$	3	3	3
$i=3, j=9, o=2$	3	3	3
$i=4, j=10, o=1$	3	3	3
$i=4, j=10, o=2$	3	3	3
$i=5, j=11, o=2$	2	2	2
$i=5, j=12, o=2$	2	2	2
$i=6, j=13, o=2$	2	2	2

outputs in green. In fact, in this matrix, according to the desired output, if an activity is involved in that process, the value will be one, otherwise it will be zero.

First, the assumption of the problem that there must be a lack of resources in at least one of the available resources (manpower or machinery or raw materials) due to critical conditions is examined. According to the surveys conducted in the resource of raw materials (cotton), there is a shortage. That is, according to the following relationship, the required amount of resources is greater than the amount of available internal and external resources, which are specified in Table 2. So the condition of the problem is satisfied.

According to the above, the value of the inputs, *i.e.* the amount of resource required in the critical conditions, consumption rate, the amount of demand and existing internal resources and external resources is given in the Tables 3–9. The probability of the scenario for pessimistic conditions is 0.3, realistic 0.5 and optimistic 0.2. Also, the weight of output 1 is equal to 0.6 and output 2 is equal to 0.4.

Existing organization budget under critical condition (BG) are 50 000 000. According to the consumption rate and the amount of demand, the amount of required resources is obtained using relation (27) and (28). Also the consumption rate means how much $r^t_{ijok'}$ or r_{ok} of the resource is required for each output unit (Tabs. 10–13).

$$\widehat{X}_{oks} = P_o \times r_{oks} \qquad \forall o, k, s \tag{27}$$

$$\widehat{X}_{jiotk's} = P_o \times r_{jiok'ts} \qquad \forall i, j, o, k', t, s. \tag{28}$$

After solving the model in GAMS software, the model outputs are given in Tables 14–20. The model was solved in GAMS software and the weighted method was used to solve the model. In the textile factory did not have a lack of activity-oriented resources, therefore the amount of activity-oriented resources allocated is equal to the amount of required resources. But in output-oriented resources, because the amount of available

Table 13. MBCO for the jth activity j in the ith process for the oth output in scenario S

λ_{jios}			
	$S = 1$	$S = 2$	$S = 3$
$i = 1, j = 1, o = 1$	7	6	5
$i = 1, j = 1, o = 2$	7	6	5
$i = 1, j = 2, o = 1$	9	8	7
$i = 1, j = 2, o = 2$	9	8	7
$i = 1, j = 3, o = 1$	9	8	7
$i = 1, j = 3, o = 2$	9	8	7
$i = 1, j = 4, o = 1$	6	5	4
$i = 1, j = 4, o = 2$	6	5	4
$i = 1, j = 5, o = 1,$	6	5	4
$i = 1, j = 5, o = 2$	6	5	4
$i = 2, j = 6, o = 1$	7	6	5
$i = 2, j = 6, o = 2$	7	6	5
$i = 2, j = 7, o = 1$	8	7	6
$i = 2, j = 7, o = 2$	8	7	6
$i = 2, j = 8, o = 1$	6	5	4
$i = 2, j = 8, o = 2$	6	5	4
$i = 3, j = 9, o = 1$	5	4	3
$i = 3, j = 9, o = 2$	5	4	3
$i = 4, j = 10, o = 1$	9	8	7
$i = 4, j = 10, o = 2$	9	8	7
$i = 5, j = 11, o = 2$	8	7	6
$i = 5, j = 12, o = 2$	6	5	4
$i = 6, j = 13, o = 2$	5	4	3

Table 14. Objective function output.

Output	Process continuity		Process resilience
	Output-oriented resources	Activity-oriented	Activity-oriented and output-oriented resources
$O = 1$	0.667	0.338	4.434
$O = 2$			

Table 15. The amount of the kth activity-oriented external resources allocated to the jth activity of the ith process in the oth output at time t in scenario S (in the critical condition).

$\text{XE}_{jiotk's}$		
	$t = 1, s = 1$	$t = 1, s = 3$
$i = 2, j = 6, o = 1, k' = 1$		254.167
$i = 2, j = 7, o = 1, k' = 1$	416.667	
Others value	Null	

TABLE 16. The amount of the kth activity-oriented internal resources allocated to the jth activity of the ith process in the oth output at time t in scenario S (in the critical condition).

$\mathrm{XI_{jiotk's}}$									
	$t = 1$, $s = 1$	$t = 2$, $s = 2$	$t = 3$, $s = 3$	$t = 1$, $s = 1$	$t = 2$, $s = 2$	$t = 3$, $s = 3$	$t = 1$, $s = 1$	$t = 2$, $s = 2$	$t = 3$, $s = 3$
$i = 1, j = 1, o = 1, k' = 1$	84.722	72.014	63.542						
$i = 1, j = 1, o = 2, k' = 1$	123.611	74.167	92.708						
$i = 1, j = 2, o = 1, k' = 1$	63.542	50.833	42.361						
$i = 1, j = 2, o = 2, k' = 1$	92.708	74.167	61.806						
$i = 1, j = 3, o = 1, k' = 1$	67.778	55.069	46.597						
$i = 1, j = 3, o = 2, k' = 1$	98.889	80.347	67.986						
$i = 1, j = 4, o = 1, k' = 1$	55.069	42.361	38.125						
$i = 1, j = 4, o = 2, k' = 1$	80.347	61.806	55.625						
$i = 1, j = 5, o = 1, k' = 1$	338.889	296.528	254.167						
$i = 1, j = 5, o = 2, k' = 1$	494.444	432.639	370.833						
$i = 2, j = 6, o = 1, k' = 1$	296.528	275.347							
$i = 2, j = 6, o = 2, k' = 1$	432.639	401.736	370.833						
$i = 2, j = 7, o = 1, k' = 1$	91.667	423.611	381.25						
$i = 2, j = 7, o = 2, k' = 1$	741.667	618.056	556.25						
$i = 2, j = 8, o = 1, k' = 1$	635.417	593.056	550.694						
$i = 2, j = 8, o = 2, k' = 1$	927.083	865.278	803.472						
$i = 3, j = 9, o = 1, k' = 1$				2541.667	2118.056	1906.25			
$i = 3, j = 9, o = 2, k' = 1$				3708.333	3090.278	2781.25			
$i = 4, j = 10, o = 1, k' = 1$				974.306	889.583	847.222			
$i = 4, j = 10, o = 2, k' = 1$				1421.528	1297.917	1236.111			
$i = 5, j = 11, o = 2, k' = 1$							718.75	575	479.167
$i = 5, j = 12, o = 2, k' = 1$							6708.333	6229.167	5750
$i = 6, j = 13, o = 2, k' = 1$							6502.083	10 020.83	10 001.67
$i = 1, j = 1, o = 1, k' = 2$	63.542	55.069	46.597						
$i = 1, j = 1, o = 2, k' = 2$	92.708	80.347	67.986						
$i = 1, j = 2, o = 1, k' = 2$	84.722	76.25	59.306						
$i = 1, j = 2, o = 2, k' = 2$	123.611	111.25	86.528						
$i = 1, j = 3, o = 1, k' = 2$	67.778	55.069	42.361						
$i = 1, j = 3, o = 2, k' = 2$	98.889	80.347	61.806						
$i = 1, j = 4, o = 1, k' = 2$	55.069	42.361	29.653						
$i = 1, j = 4, o = 2, k' = 2$	80.347	61.806	43.264						
$i = 1, j = 5, o = 1, k' = 2$	338.889	296.528	254.167						
$i = 1, j = 5, o = 2, k' = 2$	497.444	432.639	370.833						
$i = 2, j = 6, o = 1, k' = 2$	296.528	275.347	232.986						
$i = 2, j = 6, o = 2, k' = 2$	432.639	401.736	339.931						
$i = 2, j = 7, o = 1, k' = 2$	381.25	338.889	296.528						
$i = 2, j = 7, o = 2, k' = 2$	556.25	494.444	432.639						
$i = 2, j = 8, o = 1, k' = 2$	593.056	550.694	487.153						
$i = 2, j = 8, o = 2, k' = 2$	865.278	803.472	710.766						
$i = 3, j = 9, o = 1, k' = 2$				1270.833	1059.028	931.944			
$i = 3, j = 9, o = 2, k' = 2$				1854.167	1545.139	1359.722			
$i = 4, j = 10, o = 1, k' = 2$				550.694	465.972	381.25			
$i = 4, j = 10, o = 2, k' = 2$				803.472	679.861	556.25			
$i = 5, j = 11, o = 2, k' = 2$							1916.667	1677.083	958.333
$i = 5, j = 12, o = 2, k' = 2$							8625	7906.25	6947.917
$i = 6, j = 13, o = 2, k' = 2$							7901.331	11 500	10 541.67

resources was less than the required resources, so the amount of allocated resources is less than the amount of required resources. Tables 15–17, which show the amount of allocated resources, were divided into two categories of external and internal resources. Table 17 are related to output-oriented resources, but due to the non-involvement of activities during the allocation and direct relationship of resources with outputs, the parameter t is not considered. The amount of the operating level is considered from 1 to 10, which can be seen in Tables 18 and 19.

Table 17. The amount of the kth output-oriented external and internal resources (in the critical condition).

	XE_{Oks}			XI_{Oks}		
	$s=1$	$s=2$	$s=3$	$s=1$	$s=2$	$s=3$
$O=1, k=1$		3303.057		70 650	57 666.667	36 600
$O=2, k=1$				10 350	24 333.333	41 400

Table 18. The planned operational level for the jth activity of the ith process in the oth output at time t in scenario S.

W_{jiots}									
	$T=1$, $S=1$	$T=1$, $S=2$	$T=1$, $S=3$	$T=2$, $S=1$	$T=2$, $S=2$	$T=2$, $S=3$	$T=1$, $S=1$	$T=1$, $S=2$	$T=1$, $S=3$
$i=1, j=1, o=1$	10	10	10						
$i=1, j=1, o=2$	10	10	10						
$i=1, j=2, o=1$	10	10	10						
$i=1, j=2, o=2$	10	10	10						
$i=1, j=3, o=1$	10	10	10						
$i=1, j=3, o=2$	10	10	10						
$i=1, j=4, o=1$	10	10	10						
$i=1, j=4, o=2$	10	10	10						
$i=1, j=5, o=1$	10	10	10						
$i=1, j=5, o=2$	10	10	10						
$i=2, j=6, o=1$	10	10	10						
$i=2, j=6, o=2$	10	10	10						
$i=2, j=7, o=1$	10	10	10						
$i=2, j=7, o=2$	10	10	10						
$i=2, j=8, o=1$	10	10	10						
$i=2, j=8, o=2$	10	10	10						
$i=3, j=9, o=1$				10	10	10			
$i=3, j=9, o=2$				10	10	10			
$i=4, j=10, o=1$				10	10	10			
$i=4, j=10, o=2$				10	10	10			
$i=5, j=11, o=2$							10	10	10
$i=5, j=12, o=2$							10	10	10
$i=6, j=13, o=2$							6.342	10	10

Table 19. The planned operational level and recovery time for the oth output in scenario S.

	W_{os}			ϑ_{os}		
	$s=1$	$s=2$	$s=3$	$s=1$	$s=2$	$s=3$
$O=1$	7	8	8	1	1	1
$O=2$	1	2	8	1	1	1

TABLE 20. The recovery time and M_{jiot} value for the jth activity of the ith process in the oth output at time t in scenario S.

	ϑ_{ijos}			M_{jiot}		
	$S=1$	$S=2$	$S=3$	$t=1$	$t=2$	$t=3$
$i=1, j=1, o=1$	2	2	2	1		
$i=1, j=1, o=2$	3	3	3	1		
$i=1, j=2, o=1$	2	2	2	1		
$i=1, j=2, o=2$	3	3	3	1		
$i=1, j=3, o=1$	2	2	2	1		
$i=1, j=3, o=2$	3	3	3	1		
$i=1, j=4, o=1$	2	2	2	1		
$i=1, j=4, o=2$	3	3	3	1		
$i=1, j=5, o=1,$	2	2	2	1		
$i=1, j=5, o=2$	3	3	3	1		
$i=2, j=6, o=1$	2	2	2	1		
$i=2, j=6, o=2$	3	3	3	1		
$i=2, j=7, o=1$	2	2	2	1		
$i=2, j=7, o=2$	3	3	3	1		
$i=2, j=8, o=1$	2	2	2	1		
$i=2, j=8, o=2$	3	3	3	1		
$i=3, j=9, o=1$	2	2	2		1	
$i=3, j=9, o=2$	3	3	3		1	
$i=4, j=10, o=1$	2	2	2		1	
$i=4, j=10, o=2$	3	3	3		1	
$i=5, j=11, o=2$	1	2	2			1
$i=5, j=12, o=2$	1	1	1			1
$i=6, j=13, o=2$	1	1	1			1

The planned operational level for activity j of process i output o at time t in scenario s is equal to 10, because there is no lack of activity-oriented resources, and according to the relevant relationship for the planned operational level, all values of the planned operational level for activity-oriented resources have also been obtained as 10. Also, activities 1–8 are active in period 1, activities 9 and 10 in period 2, and activities 11–13 in period 3.

$$W_{jiots} = \left[L * \sum_{k'=1}^{K'} \frac{\mathrm{XI}_{jiotk's} + \mathrm{XE}_{jiotk's}}{\widehat{X}_{jiotk's}} \right] \qquad \forall i, j, o, t, s \tag{29}$$

$$W_{os} = \left[L * \sum_{k=1}^{K} \frac{\mathrm{XI}_{Oks} + \mathrm{XE}_{Oks}}{\widehat{x}_{oks}} \right] \qquad \forall o, s. \tag{30}$$

Due to the critical conditions and disruption, different amounts of the operating level have been obtained. Table 20 shows the recovery time scope for each (ijo), which can vary from 1 to 3. That's mean, in case of failure, the product can be recovered from 1 periods later to the 3 periods later.

If the value of business continuity is equal to one, it indicates that the disruption has no effect on resources, if it is between zero and one, the disruption affects resources but they are recovered. As the results of the process continuity objective function output show, the value of the objective function is between zero and one, indicating that the effects of the disruption are retrieved in less time than the MTPD, and the disruption affects resources but is retrieved.

5. Conclusion

In this article, a basic framework for optimizing process continuity and process resilience after an accident in a critical condition is proposed. In addition, the proposed framework includes a mathematical model of a novel resource allocation to determine the required resources in critical conditions. This model ensures that the organization can resume and restore the critical operations in destructive situations as quickly as possible with minimal resources. By adding resilience to the resource allocation model, it is possible to find out how resilient the process is in the event of a crisis and very high inputs or very low outputs, and in this case the organization's activities do not stop and resource allocation is done properly. And because this resilience is dependent on resources, therefore resilience is also seen in the resource allocation model. Results demonstrate that the proposed model is an applicable method for managing continuity, recovery and resilience plans in an organization. Also, the purpose of adding continuity to the resource allocation model is that if there are not enough resources at the time, the process can be maximized with the available resources. This means that the life cycle of the process continues. In fact, when a process face of disruptions, process continuity planning ensures that the activity continues and does not stop. Therefore, because we are facing a lack of resources in a critical situation, we expect activities and processes in the organization not to stop and disruption does not affect the processes, so it requires resilience of processes and continuity of activities and processes in the face of lack of resources.

Given that the resources used in the processes can have risks, in future research we can see the issue of risk alongside with the issue of resilience and continuity when allocating resources. In fact, paying attention to the risks in resource allocation helps to more accurate time planning on resource allocation. In future research, the internal resource cost parameter can be added to the model. Also, because the processes of organizations use a lot of resources to generate outputs, and due to other factors expected to be effective on processes, any scenario of combining resources to create risky outputs and returns commensurate with the intended outputs. Therefore, in this regard, the Markowitz model can be used to allocate resources with the aim of maximizing process resilience and process continuity and minimizing process risks.

For future research, researchers can use other formulas to evaluate resilience and continuity in the objective function. Or they can examine the impact of lack of resources and production decrease on customer satisfaction.

It is also possible to consider the time value of the monetary unit of resources (in terms of inflation, etc.) or market demand in the model or possible states in the constraints.

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