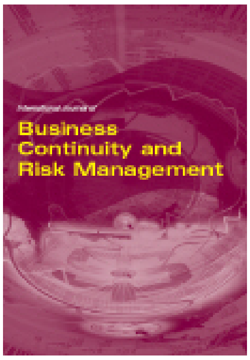

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Calculating the business continuity value by considering several destructive events and co-occurrence of risk factors

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Calculating the business continuity value by considering several destructive events and co-occurrence of risk factors

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Abstract: In the event of any disruption or interruption in the organisation's activities, methods and frameworks related to business continuity value management should be used to reduce damages. Considering the occurrence of destructive events and the existence of risk factors causing an interruption in business activity and their impact on the business and thus the damage to the organisation, it is necessary to measure the business continuity value (BCV) to adopt appropriate business decisions for its continuity and prevent these effects. This paper presents a formula to calculate the value of business continuity in the conditions of the co-occurrence of risk factors. The results illustrated the calculation of the business continuity value by considering the risk assessment and the co-occurrence of these factors. In the conditions of the co-occurrence of risk factors, the amount of the business continuity value is more reduced than in the conditions of non-co-occurrence of risk factors.

Keywords: business continuity value; BCV; co-occurrence of risk factors; destructive event; risk assessment.

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1 Introduction

Natural and man-made disasters can cause cash losses, destruction, and psychological consequences for the business. In order to minimise the loss caused by such disasters, it is necessary to develop and implement effective programs in the business continuity (BC)[1] that can deal with unnatural conditions. Humanity is witnessing growth in the face of natural and technological disasters to the extent that each day has to fix it before the disaster or it has been prepared for later. In some cases, it is necessary to have Simultaneous responses to different types of disasters (Momani, 2010). Nowadays, due to the competitiveness of businesses, such as businesses working with internet space or supply chain networks, there is a dire need for strong infrastructure to respond to probable problems. In this uncertainty is the most important task of preserving and increasing capital. Therefore, in case of any disruption[2] or interruption in organisational activity, methods, and frameworks related to BC management[3] should be used to reduce damage.

The main point is the continuous assessment of the BC to ensure the organisation can cope with the disaster. Also, by measuring the BC value, the organisation will always be at a desirable level of response. In the years, different approaches have been applied to calculate the BC value. Among these methods, the method of interview, questionnaire, consultation, and quantitative calculation are mentioned. Some BC indicators are used indirectly to determine the BC value. Torabi et al. (2014) determined the continuity parameters, including MTPD[4] and MBCO[5] from important functions using a new algorithm.

$$\sum_{i=1}^{n} \frac{(\alpha_i - MBCO_i)}{\alpha_i} \times \frac{MTPD_i}{DD_i - FT_i} \times W_i = K \tag{1}$$

i key product index

α_i normal performance level

W_i relative importance of key product i

DD_i date when the product is expected to be delivered

FT_i total processing time of all key activities required by the key product i

K the risk appetite of the whole organisation, which is determined based on the strategic views of the organisation, which can be a percentage of total performance.

Rezaei Soufi et al. (2019) have also used the formula (1) to compute these indices and originally to achieve key organisation products. In recent years, researchers have studied and evaluated the BC value from a quantitative perspective. Zeng and Zio (2017) introduced the formula (2) to calculate BC value.

$$BCV = 1 - \frac{L_T}{L_{tol}} \tag{2}$$

The L_{tol} parameter is the maximum loss that the organisation can tolerate and the loss caused by the disruptive accidents that occur in [0, T] is denoted by L_T. Also, Xing et al. (2019) have introduced a simulation-based framework for calculating the criterion of continuity of time-dependent trade. Of course, the use of developed numerical BC (Zeng and Zio, 2017), which is defined as more integrated is capable of covering the entire process (Xing et al., 2019).

$$DBCV([t, t+T]) = 1 - \frac{L([t, T+t])}{L_{tol}(t)} \tag{3}$$

$DBCV([t, t, +T])$ denotes the BC value that is evaluated at time t, for a given horizon T. Show potential losses in $[t, t, +T]$. $L_{tol}(t)$ indicates the maximum loss that the company can bear in t (Xing et al., 2019). Ostadi et al. (2021) proposed a hybrid model to evaluate BC and crisis recovery with the aim of maximising the value of BC with a fuzzy approach (Ostadi et al., 2021). For this purpose, they chose the article model (Sahebjamnia et al., 2015) as the main model. The second objective function of this paper (Sahebjamnia et al., 2015) has been changed and the minimisation of recovery time is modified to maximise the value of continuity of BC (Zeng and Zio, 2017).

$$BCV = 1 - \sum_{SEN} \sum_{S} prob^{sen} w_s \left(\frac{RTO_{s,sen}}{MTPD_s} \right) \tag{4}$$

s key product index

sen index of scenarios

$prob^{sen}$ probability scenario

w_s importance of key product s

$RTO_{s,sen}$ retrieval time for the key product s in the *sen* scenario

$MTPD_s$ maximum disruption tolerable time for key product s.

Therefore, the last quantitative formula regarding the BC value is formula (4), which is the risk[6] factors in organisations, risk assessment[7], co-occurrence of risk factors (also assessment and co-occurrence of destructive events) and the rest of the parameters has not considered in the BC value that were obtained by the studies that should be included in the calculation of the BC value.

So, in this article, first, by reviewing the literature, parameters related to BC value were discovered, then by examining these parameters with other parameters in formula (4), they were added to the formula. After that, the risk assessment was added to the formula along with the co-occurrence of risk factors and the destructive events assessment, and the correctness of the BCV formula was proved by sensitivity analysis. In Section 2, the literature review in the field of BC is discussed. According to the studies, this chapter is divided into three parts of BC management, business continuity management system (BCMS), and BC value, which are reviewed in each section of the literature and related articles. In Section 3, under the title of research methodology, the topic of the research is described in detail, and all the cases that were used in the formulation of the BC value formula, with the scientific reason for using those parameters through the literature review in the BCV formula, the detailed steps of the description given. By adding them, an algorithm for determining the input parameters and calculating the BC value is stated. In Section 4, which is a numerical example of this research, input data and a detailed description of the steps to calculate the amount of BC is given as a numerical example. Then in Section 5, the results are analysed, that is, after the implementation of the proposed algorithm code in MATLAB software, the BCV value calculated in different positions was obtained and the results were analysed to validate the results of the analysis. The sensitivity of the parameters used. Finally, in Section 6, the conclusion of this paper is discussed.

2 Literature review

In this section, the definition of terms in BC management is presented.

2.1 BC management

BC management is a continuity management process that should be directed to the important business processes of the organisation to ensure BC. BC management with preventive characteristics reduces the damage caused by disruptive business events (Smit, 2005). Definitions of BC management from 1995 to 2005 are the same management process that is comprehensive and its goal is to prevent disruption of jobs and protect the organisation. However, the definitions since 2005 with greater detail and include stakeholders, reputation, brand names, and activities that create value (Zhang and McMurray, 2013). In the absence of an acceptable standard of BC management, different organisations are using various ways of managing BC in order to ensure the continuity of their activities. This has often resulted in unreliable and inefficient business plans. Publication of the BCM standard – BS 25999 – by the British Standards Institution helped organisations to adopt a comprehensive BCM global approach. BC management should be integrated into the organisation as an integrated management process (Tammineedi, 2010). According to ISO BS25999-1 (2006), BC management is a business-driven process, as well as a strategy tailored to the purpose and creates a specific operational framework for BC plans[8] that:

- Previous to the discontinuation, will improve the organisation's flexibility against interruption of activities that will be established in the organisation's key activities in order to supply products or services.
- Give a method tested to repair the organisation's capability to a level of pre-acceptance and the specified time when the incident occurs in the supply of products and services.
- It provides a proven ability to manage a business interruption and support the reputation of the organisation.

Blos et al. (2015) define BC management as a comprehensive management process that identifies potential impacts that threaten an organisation, provides a framework for resisting them, and the ability to an effective response that protects the interests of its main stakeholders, reputation, brand, and activities that create value. BC management provides a framework for faster recovery of the organisation by identifying internal and external risks and their impact on business processes (Blos et al., 2015).

Musumali and Qutieshat (2022) reviewed the literature related to BC management for small and medium-sized companies in developing countries by searching articles in this field from 2012 to 2020 with keywords to identify issues that prevent the use of BC and work in them can be identified. They found that SMEs in developing countries face low implementation of BC management due to low prioritisation, limited resources, knowledge, and capacity. Also, few research has been done on BC in small and medium enterprises.

Because of the disruptions in organisations, Ostadi et al. (2023) and Ebrahimi-Sadrabadi et al. (2023) felt the need to pay attention to the issue of resilience, BC, and risk, as well as the need to investigate and find the relationship between them for better management in organisations. So they reviewed the literature. The purpose of the research (Ostadi et al., 2023; Ebrahimi-Sadrabadi et al. (2023) was to provide a classification and a conceptual framework in the fields of BC, flexibility, and risk. By studying 90 articles, they divided them into three categories: 'maximising the value of BC and flexibility', 'maximising process safety' and 'minimising risk'. Finally in total three conceptual frameworks are presented in this article.

2.2 BC management system

Today's competitive environment persuades any organisation to use a BCMS to deal with incidents such as earthquakes, terrorist attacks, etc. to ensure the continuity of the organisation's main products or services, a BC management plan should be established in a BCMS. Business impact analysis (BIA)[9] and risk assessment are the main steps of a BCMS that should be done during the creation of this system. BIA and risk assessment as the main steps of the BCMS, respectively, identify the main products of the organisation and the disruptions that threaten the timely delivery of key products (Rezaei Soufi et al., 2019). The BCMS is a well-known management system that is created to ensure the continuity of the organisation's key products in different conditions and causes the organisation flexible (Kildow, 2011). Among the framework and model of the main processes that have to be done when designing and creating a BCMS can be mentioned BIA. Torabi et al. (2014) presented a new framework for conducting BIA in the organisation based on some multi-attribute combination decision-making techniques (MADM) and by conducting a case study, confirmed the proposed framework and showed its usefulness. BIA is an important part of the BCMS in which the organisation's key products or services are determined along with their important functions and indices related to BC, i.e., the maximum tolerable period of disruption (MTPD) and minimum business continuity operation (MBCO). The structure of the proposed BIA framework (Torabi et al., 2014) is such that has prepared a new BIA framework in four separate stages in an organisation. Torabi et al. (2016) proposed an advanced risk assessment framework within the BCMS framework while enumerating the specific steps and requirements of a BCMS, that uses the well-known four-step framework of identifying, analysing, assessing, and responding to risks (Torabi et al., 2016). Kosmowski et al. (2022) considering safety and security for companies that use advanced technologies, given that many disruptions, including problems in systems or cyber-attacks from this kind of thing, can happen to them and they need an integrated approach, a diagram that provided the relationship between the BCM framework and the ones mentioned. This BCM diagram includes risk analysis, BIA, and disaster recovery plan (DRP) (Kosmowski et al., 2022).

Due to the increase in complexity and frequency of cybercrimes, when a cyber-attack occurs, to maintain business operations, it is necessary to take a comprehensive approach to IT risks and create a plan for system continuity (Assibi, 2023). Therefore, Assibi (2023) reviewed the literature on how enterprise risk management (ERM) and BC interact and concluded that ERM and BC are critical components of cyber resilience and can help organisations identify, assess, and manage disruption risks.

2.3 BC value

In an organisation, different disruptive events such as technological disruptions, natural disruptions, and social disruptions may occur that can jeopardise its continuation (Zeng and Zio, 2017). Studies in this field model the value of BC in different ways. In this section, the articles that have been worked on in this field are divided based on the type of model (i.e., the BC value quantitatively or qualitatively) and the type of tools. Accordingly, the articles are included in the following categories:

- statistical models and simulation
- use of questionnaires and consultation
- use of standard models
- use of conceptual models
- use of mathematical models.

Zeng and Zio (2017), who have quantitatively modelled and evaluated BC value, have defined four quantitative criteria for BC, based on potential losses from events. They then developed an integrated modelling framework for modelling the entire business process. In the integrated model, the protection, reduction, and emergency steps are modelled by event tree models. The recovery period is modelled by Markov model. Xing et al. (2019) also introduced a simulation-based framework for calculating time-dependent BC metrics. However, it uses numerical BC indicators developed in Zeng and Zio (2017), which are defined in a more integrated sense that are able to cover the entire process.

Ostadi et al. (2021) have presented a quantitative model in the field of BC that is adapted from the model of Sahebjamnia et al. (2015). The model presented in their research is a complex integer programming model. In the model presented in their research, changes have been made compared to the model of Sahebjamnia et al. including considering the actions of the organisation in the face of destructive events and considering the counter-intensifying effects of destructive events in a fuzzy way that brings the model closer to reality. Ostadi et al. (2021) proposed a hybrid model to evaluate BC and crisis recovery with the aim of maximising the value of BC with a fuzzy approach. In their study, the second objective function of this paper (Sahebjamnia et al., 2015) has been changed and the minimisation of recovery time is modified to maximise the value of continuity of BC (Zeng and Zio, 2017). In principle, Ostadi et al. (2021) have implemented a BC plan. Solving the model was based on the scenario in such a way that each scenario has a specific coefficient. The model presented in GAMZ software has been solved by the Epsilon constraint method.

In the newest research on the use of questionnaires and consultation, (Galbusera et al., 2021) implemented the European Reference Network for Critical Infrastructure Protection (ERNCIP) survey on COVID-19 emergency and BC to strengthen critical infrastructure. The topics covered in their study include assessing the state of BC and evaluating aspects of emergency management and disaster recovery, which are examined from the perspectives of different departments, types of organisations, and respondents' personal perceptions. They observed that the continuity of business across society depends largely on the ability to prevent disruption of vital systems such as the health system, water and energy resources, public management and security, communications, and so on. Thus, the effectiveness of actions taken in occupations can affect BC (Galbusera et al., 2021). As mentioned, the outbreak of COVID-19 in 2019 disrupted all businesses, especially small and medium-sized organisations. In this regard, Le and Nguyen (2022) conducted a study on the effects of this disorder on the BC of small and medium organisations, which came to this conclusion by analysing the answers to questions by the managers of these companies. This disorder (COVID-19) will certainly reduce BC, but corporate governance principles (CGP) can play a moderating role in this regard (Le and Nguyen, 2022).

In using conceptual models, Margherita and Heikkilä (2021) examined the responses of the world's 50 leading companies to the COVID-19 emergency situation and integrated them into a descriptive framework. They used data available online which was information shared by organisations about their reactions to the COVID-19 emergency situation, and by performing content analysis on web pages and social media posts, extracted 77 actions related to 13 sub-domains and integrated them into a five-level framework that includes operations, customer, workforce, leadership, and community-related responses, thus contributing to the existing BC literature (Margherita and Heikkilä, 2021).

With the outbreak of the COVID-19 pandemic, its economic impact on small and medium-sized companies has been felt due to its strategic position in the economy (Sulaeman et al., 2023). Also, small businesses have been among the most affected by the COVID-19 crisis: many of them have temporarily closed their businesses and are mostly facing cash flow constraints. The purpose of their study is to investigate the impact and role of ERM in BC during the COVID-19 pandemic and its impact on policy-making by key stakeholders in small and medium enterprises in Indonesia as an intervening variable. Their research is of a quantitative type and uses a sample of 133 respondents; as a result, Sulaeman et al. (2023) found that company risk management (ERM) has a positive and significant effect on BC. Because ERM has a positive and significant effect on the policy-making of organisations and implements human resource management policies that affect the recruitment, promotion, reward, training, and evaluation of the performance of each employee and finally policy-making has a positive and significant effect on the continuity of business and has worked.

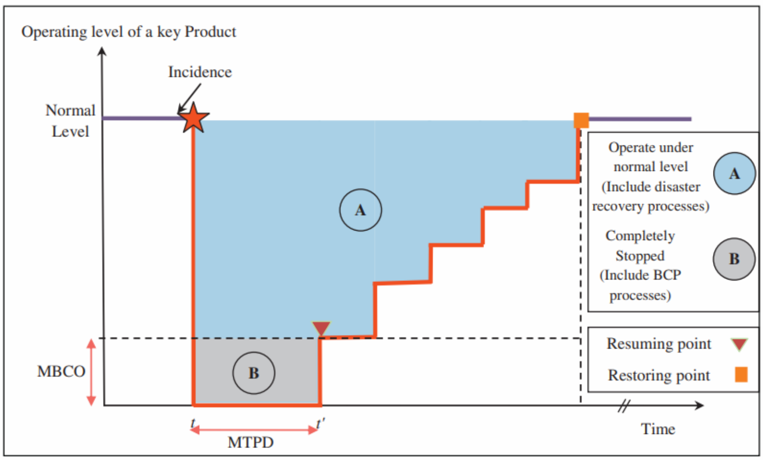
In the wake of the COVID-19 pandemic, Fakhoury and Fakih (2023) conducted a study to investigate the extent of BC in Jordan and Morocco regarding small and medium-sized organisations from the World Bank's COVID-19 organisational follow-up dataset. Fakhoury and Fakih (2023) divided the variables related to BC into three parts: business response, government intervention, and sector. The business response section includes the variables of online activity, online sales, remote work, convert, and workforce share working remotely. The government intervention section includes government grants, government measures, and expected government measures. The sector includes the Sector retail and sector manufacturing. By examining 943 cases and relying on probit regressions, their findings showed that businesses that considered flexibility strategies such as creating an online presence and manufacturing conversion had more BC, while companies that adopted remote work They have less BC, which could be due to the lack of preparation of companies and the unavailability of technology in Jordan and Morocco. Also, the variables of government measures and online sales have not shown a statistically significant effect on BC. They also announced that the companies that expected government support will have very low BC and close the company.

Due to the importance of BC in government organisations, due to the importance of providing services to citizens (Lutz et al., 2021) conducted research on risk management and BC in the public sector (Western Cape Government of South Africa). For this purpose, they used a qualitative approach by interviewing the government departments of that region and concluded that risk management and BC processes in government organisations are not fully understood and the necessity of BC as a They emphasised the preventive program for correct management against facing disruptions and risk reduction in government organisations.

3 Research methodology

In the article, (Ostadi et al., 2021), although several destructive events and their interaction effects have been considered, the co-occurrence of risk factors has not been considered. In the real world, the occurrence of multiple risks exacerbates or reduces the effects of risks. Thus, co-occurrence of risks leads to a decrease or intensification of intensity in any source of uncertainty (Ostadi and Abbasi Harofteh, 2023). But in traditional methods of risk assessment, the co-occurrence of risk factors was not considered, but Ostadi and Abbasi Harofteh (2023) considered that in risk assessment. Also, other factors and factors of BC criteria can be effective in calculating the BC value formula that has not been seen in the research of Ostadi et al. (2021). In the following, the relationship between these criteria and the BC value is proposed and proved. The goal is to build and develop a formula for calculating the BC value. This is important because organisations can use a formula to calculate their BC value and make subsequent decisions for their organisation accordingly. Therefore, the BC value formula can be developed with the above considerations. For this purpose, in this research, the basic formula (Ostadi et al., 2021), which is itself defined using the formula (Zeng and Zio, 2017), will be considered as the basic formula. From the perspective of BC, with the occurrence of any disruptive events, it is necessary to resume important processes or activities (Torabi et al., 2014). In manufacturing or service organisations, one of the goals is to deliver key products or services. To do this, you must identify the key activities that lead to the production of those key products or services. The important thing is that these activities require resources. Resources such as manpower, energy, equipment, and so on. One of the factors affecting the BC value is the operational level. Each destructive event reduces the operational capacity of the entire organisation by reducing the level of availability of some resources in the organisation (Ostadi et al., 2021). For this purpose, criteria are needed that reflect this operational level. In this section, MBCO (minimum level of BC operation) and RPO [the level of capacity recovered at the end of the resumption or recovery period (Rezaei Soufi et al., 2019)], which are the criteria for BC, are considered. In the article (Torabi et al., 2014), a new framework for BIA to determine key products, key activities, and their BC indicators, MTPD and MBCO is determined. Figure 1 provides a graphical form of the BIA criteria proposed by Torabi et al. (2014).

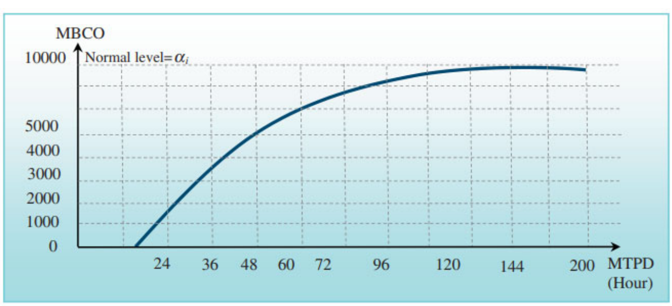
Figure 1 Graphic definition of BIA actions (see online version for colours)



Source: Proposed by Torabi et al. (2014)

According to the research of Torabi et al. (2014), the calculation of MTPD and MBCO of key products by equation (1) is obtained using the algorithm presented in Torabi et al. (2014). For each amount of risk appetite, they plotted a level with different combinations of MTPD and MBCO values for key products, and by determining the amount of risk appetite; they obtained a final score for MTPD for each MBCO (Torabi et al., 2014).

Figure 2 A sample bent for MTPD and MBCO (see online version for colours)

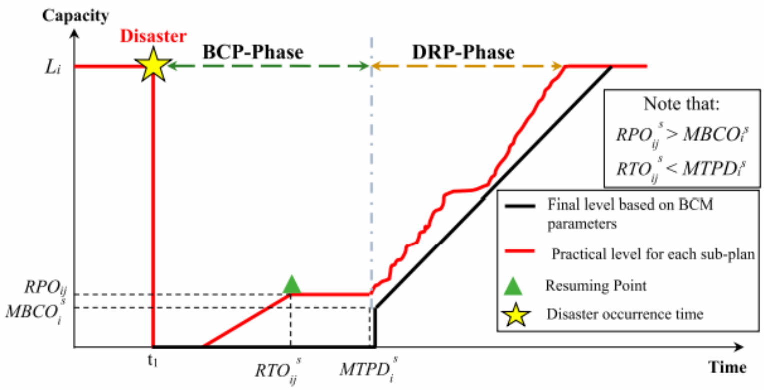


Source: Provided by Torabi et al. (2014)

Therefore, there is a direct relationship between MTPD and MBCO indices. Also, Rezaei Soufi et al. (2019) presented a conceptual model for defining the required BCPs as shown in Figure 3. That paper deals with BC planning modelling. As shown in

Figure 3, it is the MTPD and MBCO that limit candidate BCPs. So RTO[10] should be less or equal to MTPD and RPO should be more or equal to MBCO (Rezaei Soufi et al., 2019).

Figure 3 A showcase of BCP and DRP and their parameters (see online version for colours)



Source: Proposed by Rezaei Soufi et al. (2019)

Therefore, the need for MBCO and RPO, in addition to being a factor that reflects the operational level, is the relationship between them with MTPD and RTO and the use of MTPD and RTO in the formula of BC value. Hence, logically and according to Figure 3, the higher the level of recovered capacity (RPO), the higher the business continuity and BCV must be higher. So, adding this item to the formula should be such that this item is considered. On the other hand, L_s is the normal performance level for the s product. Given the above limitations and the conceptual Figure 3 proposed by Rezaei Soufi et al. (2019) if the distance between it with the minimum operational level of continuity of the target business is divided by to level of recovered capacity, i.e., some of this distance that the organisation has been able to recover has been obtained (it can be said that is a kind of efficiency). Therefore, the model is developed in the form of a formula (5).

$$BCV = 1 - \sum_{SEN} \sum_{S} prob^{sen} \times w_s \times \left(\frac{RTO_{s,sen}}{MTPD_s} \right) \times \frac{L_s - MBCO_s}{RPO_{s,sen}} \tag{5}$$

Indices and parameters:

s key product index

sen index of scenarios

$prob^{sen}$ probability scenario *sen*

w_s importance of key product *s*

$RTO_{s,sen}$ retrieval time for the key product *s* in the scenario *sen*

$MTPD_s$ maximum disruption tolerable time for key product *s*

L_s normal performance level for key product *s*

$RPO_{s,sen}$ the level of capacity recovered at the end of the resumption period (retrieval) for the key product s in the scenario *sen*

$MBCO_s$ the minimum operational level of target BC for key product s.

The next innovations is considering several destructive events and co-occurring risk factors in the BC value formula. Organisations face different types of disruptions that can occur individually or simultaneously (Wunnava, 2011). According to BS EN ISO 22301: 2019, disruption is an accident, either unforeseen or foreseen, that has an unplanned cause, causing negative destruction (deviation) from the expected delivery of products and services in accordance with the organisation's main purpose. And according to BS EN ISO 22301: 2019, the risk is uncertainty about goals. Therefore, according to the concepts of risk and Disruption, these two concepts are considered separately. Thus, there are a series of external factors that are divided into two categories of destructive events (disruption) and risk factors. For example, earthquakes, and pandemics (such as the spread of diseases such as COVID-19, influenzas, etc.) are part of the category of destructive events, and inflation rate, price, etc. are part of the risk factors. First, the risk factors and how it is added to the BC value formula will be examined. In this part, the goal is to see the co-occurring risk factors in the BC value formula. For this purpose, after identifying the risk factors according to the method used by Torabi et al. (2016), according to equation (6) presented by Ostadi and Abbasi Harofteh (2023), the risk assessment will be performed.

$$Risk_j = P_j \times S_j \times (1 \pm w_{ij}) \times (1 \pm w_{kj}) \times (1 \pm w_{mj}) \times (1 \pm w_{sj}) \times (1 \pm w_{nj}) \times (1 \pm w_{oj}) \qquad (6)$$

i, j, k, m, n, o, s risk indices

P_j the probability of risk j

S_j the severity of risk j

W_{ij} the coefficient of co-occurrence of risk i and the risk j.

Therefore, each risk has a probability of occurrence and severity (Ostadi and Abbasi Harofteh, 2023). The co-occurring risk factors in that study are determined by experts and finally, the formula is simulated by the Monte Carlo method. Because according to (Ostadi and Abbasi Harofteh, 2023) the output of this numerical formula is between 0 and 1, logically and based on the concept of BC, when a disruption or risk factor occurs, it causes interference in the normal course of business. Therefore, this should be seen in the BC value formula that if there is no risk factor or scientifically had very little impact on BC, it will not affect the outcome of the BC value formula and if there is a risk factor, causes reducing the BC value. And the higher the probability and severity of the risk, as well as the coefficient of occurrence of the risks, the BC value will more decrease. Although destructive events and risk have separate definitions and concepts, the same formula can be used to calculate and see the effect of these two items on the BC value formula. For this purpose, by defining separate indexes for the assessment of destructive events and the assessment of risk factors, the formula presented by Ostadi and Abbasi Harofteh (2023) is used for both cases (separately). Since destructive events cause more disruption to systems, this must be added somehow to the formula to have a greater impact on the BCV calculation in the event of a destructive event. So both risk factors assessment and destructive events assessment will be added as follows. Proof that this section has been added correctly is that the amount of BCV is ∈ (–1, 0). Hypothetically if the calculated amount of the risk factor assessment or destructive events assessment, which are numbers between 0 and 1, is very small and is negligible and close to 0, the power changes to 1 and the BCV amount will not change much. But if the calculated amount of the risk factor assessment or destructive event assessment is high and close to 1, the power changes to 0. If a number reaches the power of 0, it becomes 1. This is as expected from the developed BCV formula. Therefore, the BC value formula is developed and rewritten as follows.

So if $\left(\frac{RTO_{s,sen}}{MTPD_s}\right)\times\left(\frac{L_s - MBCO_s}{RPO_{s,sen}}\right)$ is less than 1:

$$BCV = 1 - \sum_{SEN}\sum_{S} prob^{sen} \times w_s \times \left[\left(\frac{RTO_{s,sen}}{MTPD_s}\right)\times\left(\frac{L_s - MBCO_s}{RTO_{s,sen}}\right)\right]^{\left((1-DE_s)^2\times(1-ER_s)\right)} \quad (7)$$

So if $\left(\frac{RTO_{s,sen}}{MTPD_s}\right)\times\left(\frac{L_s - MBCO_s}{RPO_{s,sen}}\right)$ is greater than 1:

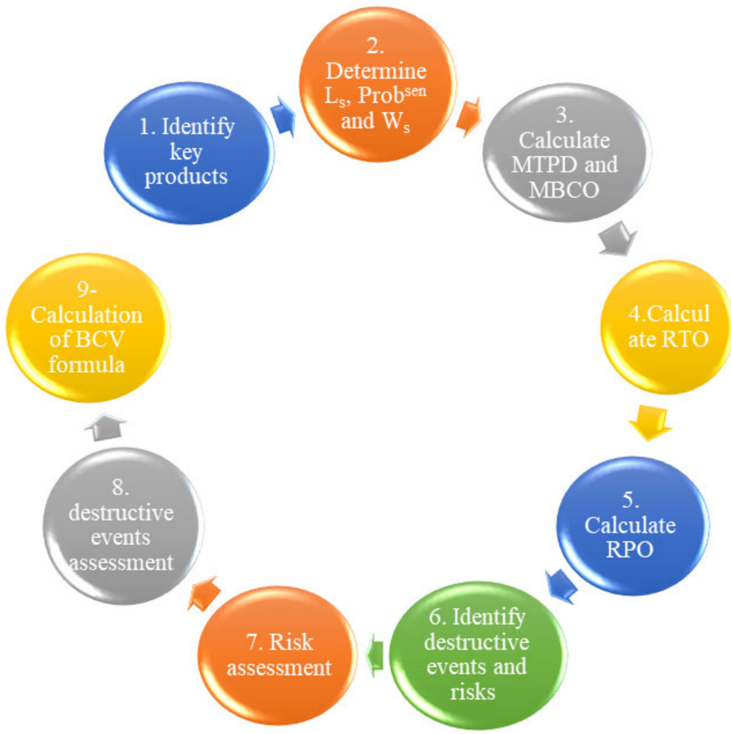
$$BCV = 1 - \sum_{SEN}\sum_{S} prob^{sen} \times w_s \times \left[\left(\frac{RTO_{s,sen}}{MTPD_s}\right)\times\left(\frac{L_s - MBCO_s}{RTO_{s,sen}}\right)\right]^{\left((1+DE_s)^2\times(1-ER_s)\right)} \quad (8)$$

Indices and parameters:

s	key product index
sen	index of scenarios
$prob^{sen}$	probability scenario *sen*
w_s	importance of key product *s*
$RTOs,sen$	retrieval time for the key product *s* in the scenario *sen*
$MTPD_s$	maximum disruption tolerable time for key product *s*
L_s	normal performance level for key product *s*
$RPO_{s,sen}$	the level of capacity recovered at the end of the resumption period (retrieval) for the key product *s* in the scenario *sen*
$MBCO_s$	the minimum operational level of target BC for key product *s*
DE_s	the amount of destructive events assessment related to the product *s*
ER_s	the amount of assessment of risk factors related to the product *s*.

Then an algorithm is defined to determine the input parameters and calculate the BC value.

Figure 4 Proposed algorithm for calculating the value of BC (see online version for colours)



4 Numerical example

In this section, to test the developed formula, the previous available data are used. For this purpose, the required data have been extracted from the research of Torabi et al. (2014). Their research is about an industrial company that manufactures some auto parts. Due to the importance of continuity in the delivery of products of this organisation in any situation, BCMS is being implemented in it. Considering the developments that similar models have had, the required additional data on other stages of the development of this model have also been extracted from the research of Ostadi et al. (2021), Ostadi and Abbasi Harofteh (2023) and Seifi (2018). From now on, the details of the proposed method will be described step by step. The input parameters determined in steps 1, 2 and 3 are extracted from Torabi et al. (2014) and the Probsen parameter is extracted from Seifi (2018).

4.1 Step 4: calculate RTO

At this stage, the time data required for the scenario *sen* to start delivering the key product *s*, as well as the time required to move equipment and set up activities in scenario *sen* for the key product *s* (Rezaei Soufi et al., 2019) must be determined and according to the data, the RTO calculated for each key product in each scenario with equation (9).

$$RTO_{s,sen} = t^1_{s,sen} + t^2_{s,sen} + 1 \tag{9}$$

At this stage, to analyse different scenarios and calculate the RTO, different data are assumed that can cover different conditions. In different analyses, usually, three states are considered for scenarios, which include realistic, optimistic, and pessimistic scenarios. To perform and calculate the RTO, are tried to consider these scenarios for each key product and the amount that covering the different situations of these scenarios are considered.

Table 1 Time required to start delivering key products in each scenario

$t^1_{s,sen}$	*Optimistic scenario*	*Realistic scenario*	*Pessimistic scenario*
BDP1	0.5	1	1
BDP2	1.5	1.5	2
BDP3	0.5	1	1.5

Table 2 Time required to move equipment and set up activities for key products in each scenario

$t^2_{s,sen}$	*Optimistic scenario*	*Realistic scenario*	*Pessimistic scenario*
BDP1	1.5	1.5	1
BDP2	2	1	0.5
BDP3	1	1	1

4.2 Step 5: calculate RPO

To calculate the RPO value of each key product in each scenario, can consider the level of available resources (Rezaei Soufi et al., 2019). For the level of available resources, three scenarios are mentioned in different analyses and the amount that covering the different situations of these scenarios are considered.

$$RPO_{s,sen} = \text{Percentage level of resources available} \tag{10}$$

Table 3 Levels of resources available for key products in each scenario

$RPO_{s,\ sen}$	*Optimistic scenario*	*Realistic scenario*	*Pessimistic scenario*
BDP1	1,400	1,350	1,300
BDP2	650	600	550
BDP3	1,000	950	900

4.3 Step 6: identify destructive events and risks

As mentioned, to calculate the value of BC, it is necessary to identify the risks and destructive events that occur in the business. According to the tables of identification of risk factors and destructive events presented in Torabi et al. (2016), the nature and subject matter, cost, manpower and inflation rate as risk factors and earthquakes, corona pandemics and fires as destructive events effective are considered in BC management.

4.4 Step 7: calculating risk assessment

According to the paper (Ostadi and Abbasi Harofteh, 2023), the risk factors assessment with formula (11) is calculated using the Monte Carlo simulation method.

$$ER_s = C_{r,s} \times P_r \times S_r \times \prod_{r,r1} \left(1 \pm w_{r,r1}\right) \tag{11}$$

r risk factors index

r_1 risk factors index

P_r the probability of risk r

S_r the severity of risk r

$C_{r,s}$ the correlation matrix between risk r with the key product s

$W_{r,r1}$ the coefficient of co-occurrence of risk r and the risk $r1$.

4.4.1 Step 7-1: Monte Carlo simulation

In this step, for each key product, Monte Carlo simulation will be performed to assess the risk. After identifying the risks, the distribution function of each risk will be determined by experts. In the next step, Monte Carlo simulation is used to generate the possible amount of uncertainty. Determining the probability and severity of risks is done in the next steps. Co-occurrence coefficients are then determined by experts. Finally, the proposed method of Ostadi and Abbasi Harofteh (2023) is used to assess the risks. In Ostadi and Abbasi Harofteh (2023), to calculate the severity of risks, the amount of each source of uncertainty about the severity of occurrence and the severity of the impact is measured. The severity of the risk is determined in order to determine S_r, which determines the severity of the risk, in accordance with Table 5.

Table 4 Risk distribution function

Risk	*Distribution function*
Cost	N(700, 15)
Manpower	N(386, 15)
Inflation rate	N(13, 1.2)

The Monte Carlo simulation output is classified as the severity of occurrence for each uncertainty based on the distance suggested by the experts, as shown in Table 5. The severity of any source of uncertainty is influenced by the severity of its occurrence (Ostadi and Abbasi Harofteh, 2023). The severity of the effect is then determined and finally, the severity of each risk is calculated according to equation (12) in Table 6 (Ostadi and Abbasi Harofteh, 2023).

$$S_r = \frac{severity\ of\ occurance(r) \times severity\ of\ impact(r)}{\sum \max(severity\ of\ impact) * severity\ of\ occurance} \tag{12}$$

Table 5 MCS output classification and severity of occurrence of risks determination

Risk	*Interval*	*Severity of occurrence*
Cost	x < 718	Low
	718–736	Medium
	x > 736	High
Manpower	x > 368	Low
	350–368	Medium
	x < 350	High
Inflation rate	x < 13.6	Low
	13.6–14.2	Medium
	x > 14.2	High

Source: Ostadi and Abbasi Harofteh (2023)

Table 6 Severity of occurrence and severity of impact of risks

Risk	*Severity of occurrence*	*Severity of impact*	S_r
Cost	Low(1)	8	0.0889
	Medium(3)	9	0.3
	High(5)	10	0.5556
Manpower	Low(1)	4	0.0444
	Medium(3)	6	0.2
	High(5)	8	0.4444
Inflation rate	Low(1)	1	0.0111
	Medium(3)	2	0.0667
	High(5)	3	0.1667

Source: Ostadi and Abbasi Harofteh (2023)

Table 7 Co-occurrence coefficients of risks

Risk	*Cost*	*Manpower*	*Inflation rate*
Cost	0	0.25	0.75
Manpower	0.25	0	0
Inflation rate	0.75	0	0

Source: Ostadi and Abbasi Harofteh (2023)

Formula (11) shows the direct effect or intensification of the effect of risks on each other with the + sign and the opposite effect with the – sign. Also, the numbers 0.75, 0.5, 0.25 and 0, respectively, indicate the strong, medium, weak and no effect of risks on each other (Ostadi and Abbasi Harofteh, 2023). Therefore, the coefficient of co-occurrence of risk factors is given in Table 7.

4.4.2 Step 7-2: recognising the relationship between the risk that occurred and the key products

After determining the severity of each risk, using the coefficients of the effect co-occurrence of risks on each other, the risk assessment amount of each key product is calculated according to Table 8. This step examines the relationship between risk and key products. This means that the occurrence of a risk may affect one or more key products, in which case the number 1 and otherwise the number 0 will be assigned to it. For this purpose, a matrix is completed whose rows are key products and the columns of which are risks. To solve the numerical example, the data in this section will be considered in the form of Table 8.

Table 8 The relation between the risk that occurred and the key products

Risk / *Key product*	*Cost*	*Manpower*	*Inflation rate*
BDP1	1	1	0
BDP2	1	1	0
BDP3	0	1	1

4.3 Step 8: calculating destructive events assessment

This step will follow the same as step 7, which was to calculate the risk assessment, except that in this step, destructive events are replaced. Therefore, according to the formula of the article (Ostadi and Abbasi Harofteh, 2023), the destructive events assessment with formula (13) is calculated using the Monte Carlo simulation method.

$$DE_s = C_{d,s} \times P_d \times S_d \times \prod_{d,d1} \left(1 \pm W_{d,d1}\right) \qquad \forall s \tag{13}$$

d destructive event index

d_1 destructive event index

P_d the probability of destructive event d

S_d the severity of destructive event d

$C_{d,s}$ the correlation matrix between destructive event d with the key product s

Wd, $d1$ the coefficient of co-occurrence of destructive events d and $d1$.

4.3.1 Step 8-1: Monte Carlo simulation

In this step, for each key product, Monte Carlo simulation will be performed to destructive events assessment. This section will be done according to step 7-1 (see 7-1). The severity of the occurrence of destructive events to determine the S_d, which determines the severity of the destructive event, is considered according to the equation (14).

$$S_d = \frac{severity\ of\ occurance(d) \times severity\ of\ impact(d)}{\sum \max(severity\ of\ impact) * severity\ of\ occurance} \tag{14}$$

Table 9 Destructive event distribution function

Destructive event	*Distribution function*
Earthquake	U(0.1, 0.2)
COVID-19 pandemic	U(0.5, 0.7)
Fire	U(0.35, 0.55)

Table 10 MCS output classification and severity of occurrence of destructive events determination

Destructive event	*Interval*	*Severity of occurrence*
Earthquake	x < 0.12	Low
	0.12–0.15	Medium
	x > 0.15	High
COVID-19 pandemic	x > 0.65	Low
	0.52–0.65	Medium
	x < 0.52	High
Fire	x < 0.37	Low
	0.37–0.5	Medium
	x > 0.5	High

Table 11 Severity of occurrence and Severity of impact of destructive events

Risk	*Severity of occurrence*	*Severity of impact*	S_d
Earthquake	Low(1)	8	0.0889
	Medium(3)	9	0.3
	High(5)	10	0.5556
COVID-19 pandemic	Low(1)	4	0.0444
	Medium(3)	6	0.2
	High(5)	8	0.4444
Fire	Low(1)	1	0.0111
	Medium(3)	2	0.0667
	High(5)	3	0.1667

Table 12 Co-occurrence coefficients of destructive events

Destructive event	*Earthquake*	*COVID-19 pandemic*	*Fire*
Earthquake	0	0.88	0.1
COVID-19 pandemic	0.88	0	0.26
Fire	0.1	0.26	0

4.3.2 Step 8-2: recognising the relationship between the destructive event that occurred and the key products

This step examines the relationship between the destructive event and key products. For this purpose, a matrix is completed whose rows are key products and whose columns are destructive events. To solve the numerical example, the data in this section will be considered in the form of Table 13.

Table 13 The relation between the destructive event that occurred and the key products

Key product \ *Destructive event*	*Earthquake*	*COVID-19 pandemic*	*Fire*
BDP1	1	1	0
BDP2	0	1	0
BDP3	0	1	1

5 Result analysis

After executing the code of the proposed algorithm in MATLAB software, the BCV value calculated in different states was obtained as follows. Due to the random nature of the probabilities of occurrence in the third and fourth states, to assess the risk and destructive events, and to the authenticate of the results, 1,000 runs have been taken and their average is considered as risk assessment and destructive events assessment.

Table 14 $RTO_{s,sen}$ output

	1	*2*	*3*
1	2.5000	3.5000	3.5000
2	3	3.5000	5
3	2.5000	3	3.5000

Table 15 ER_s output by Monte Carlo simulation method

	1	*2*	*3*
1	0.1119	0.1119	0.0763

Table 16 DE_s output by Monte Carlo simulation method

	1	*2*	*3*
1	0.5235	0.0672	0.1479

Therefore, according to the input parameters, some of which have been collected through the literature and some of which have been calculated by the software, are given in Table 17. Then the BCV amount in different states is calculated according to the model inputs and is given in Table 18.

Table 17 Parameters of BCV calculation input

Parameter / *S* \ *Sen*	*Prob*			*w*	*RTO*			*MTPD*	*L*	*MBCO*	*RPO*			*DE*	*ER*
	1	*2*	*3*		*1*	*2*	*3*				*1*	*2*	*3*		
1	0.2	0.6	0.2	0.3523	2.5	3.5	3.5	5	1,650	300	1,400	1,350	1,300	0.52	0.11
2	0.2	0.6	0.2	0.3492	3	3.5	5	5	900	200	650	600	550	0.06	0.11
3	0.2	0.6	0.2	0.2985	2.5	3	3.5	5	1,200	400	1,000	950	900	0.14	0.07

Table 18 BCV calculation outputs in different states

Model / *BCV*	*Base model*	*Considering parameters that reflect the level of operation*	*Considering risk assessment*	*Considering destructive event assessment*
0.33	✓			
0.3102	✓	✓		
0.2877	✓	✓	✓	
0.1882	✓	✓		✓
0.1742	✓	✓	✓	✓

It was observed that after adding other parameters to the basic formula of BC value, its amount decreased. The interpretation of the results observed in Table 18 follows:

- As expected, the BCV has decreased by taking into account the parameters that reflect the operational level in calculating the BC value.
- After adding the risk assessment to the BCV formula, it is expected that the BC value will decrease, which can be seen in the implementation of the algorithm. Therefore, with the addition of risk factors assessment, the BC value decreased, and this indicates the correctness of the developed formula.
- Now the results of considering the destructive event assessment in the developed formula for calculating the BC value are analysed. Also by adding it, the BC value is expected to decrease. Because the destructive event assessment in the developed formula has a power of 2, this amount of reduction in BC value should be greater than the previous state (add risk assessment). As can be seen, after the implementation of the algorithm in the software, the BCV value is less than when the only risk assessment is considered.
- It is also observed that if both risk factors and destructive events are taken into account, the BCV reduction will be higher and this is in line with the expectations of the developed formula.

In the following, sensitivity analysis will be performed to validate the developed model. For this purpose, by increasing or decreasing the value of parameters such as RPO, risk assessment, destructive events assessment, and co-occurrence of risk factors, the performance of the proposed model and its correctness and validity will be examined.

5.1 RPO parameter sensitivity analysis

First, the sensitivity analysis of RPO value is investigated. Due to the fact that the higher the level of recovered capacity, the higher the BC value will be increased, the value of BCV should be increased by changing the data of this parameter, so the increased data is given in Table 19.

According to Table 20, by applying this change, the BCV value will increase from 0.1742 to 0.2079, and this is in line with what is expected from the developed formula of the BC value. Therefore, if the management approaches used in an organisation during the occurrence of destructive events or the presence of risk factors to increase the level of recovered capacity to a desirable extent with increasing the percentage of resources available, the organisation has been able to increase the amount of the BC value.

Table 19 Increasing values of resource levels available for key products in each scenario

$RPO_{s,sen}$	*Optimistic scenario*	*Realistic scenario*	*Pessimistic scenario*
BDP1	1,450	1,400	1,350
BDP2	700	650	600
BDP3	1,100	1,050	1,000

Table 20 Comparison of BCV results while increasing the RPO parameter

Developing BCV with increasing RPO value	*Developing BCV*	*BCV in the basic formula*
0.2079	0.1742	0.33

5.2 Risk assessment sensitivity analysis

The risk assessment sensitivity analysis will now be addressed. If the amount of that increases, the BC value should decrease. First, the output of ERs calculated by the Monte Carlo simulation method is shown in Table 21, which shows an increase in risk assessment (1.2 times higher than the risk assessment in the initial state).

Table 21 Output of increasing ERs

	1	*2*	*3*
1	0.1339	0.1339	0.912

According to Table 22, after increasing the amount of the risk assessment, the result decreases from 0.1742 to 0.1715. Therefore, by increasing the amount of risk assessment, the BC value decreases and this indicates the correctness of the developed formula. Therefore, if the management approaches used in an organisation when there are risk factors is that reduce the amount of risk assessment by reducing the severity of its effect, the organisation has been able to increase the of its BC value.

Table 22 Comparison of BCV results while increasing the ER_s parameter

Developing BCV with increasing risk assessment (1/2 times the risk assessment)	*Developing BCV*	*BCV in the basic formula*
0.1715	0.1742	0.33

In this section, the importance of co-occurrence of risk factors and its impact on risk assessment and, consequently, its impact on calculating the BC value will be discussed. If this item is removed from the risk assessment, according to the study of Ostadi and Abbasi Harofteh (2023), the amount of risk assessment will be less, and in fact, to consider the co-occurrence of risk factors is due to the fact that several risks may occur simultaneously and consideration co-occurrence of risk factors brings the outcome of the risk assessment closer to reality. Therefore, it is expected that by eliminating the co-occurrence of risk factors, the amount of risk assessment will decrease and finally the amount of BCV will increase. The output results of ERs are shown in Table 23 without considering the co-occurrence of risk factors.

Table 23 Output of ERs without co-occurrence of risk factors

	1	*2*	*3*
1	0.0896	0.0896	0.0761

According to Table 24, after eliminating the co-occurrence of risk factors, the result increases from 0.1742 to 0.1757. Thus, by eliminating the co-occurrence of risk factors, the amount of BC value increased, and this indicates that the presence of co-occurring factors brings the model closer to reality.

Table 24 Comparison of BCV results while without co-occurrence of risk factors (reduce the ER_s parameter)

Developing BCV without considering co-occurrence of risk factors (reduce risk assessment)	*Developing BCV*	*BCV in the basic formula*
0.1757	0.1742	0.33

5.3 Destructive events assessment sensitivity analysis

As the assessment of destructive events increases, the amount of BC value must be reduced. And because the destructive event has the power of 2, this amount of reduction in the BC value should be greater than the previous state (reduction of BCV by reduction of risk factor assessment). First, the DEs output calculated by the Monte Carlo simulation method is shown in Table 25, which shows an increase in the assessment of the destructive events.

Table 25 Output of increasing DEs

	1	*2*	*3*
1	0.6282	0.0806	0.1775

Table 26 Comparison of BCV results while increasing the DEs parameter

Developing BCV with increasing destructive events assessment (1/2 times)	*Developing BCV*	*BCV in the basic formula*
0.1565	0.1742	0.33

Thus, according to Table 26, the BC value decreased as the amount of destructive event assessment increased. This decrease was also greater than the decrease in the BC value by increasing the amount of risk factors assessment because the destructive event assessment in the formula has a second degree. So this situation shows the correctness of the developed formula of BC value. Therefore, if the management approaches used in an organisation when the occurrence of destructive events is to reduce the assessment of destructive events by reducing the severity of their effect, the organisation has been able to increase the BC value.

Table 27 shows the amount of BCV when both the risk assessment and destructive events assessment increase. In this state, the decrease in BCV will be greater than the decreasing it in states where the risk assessment or destructive events assessment alone increased.

Table 27 Comparison of BCV results while increasing ERs and DEs parameters

Developing BCV with increasing destructive events assessment (1/2 times)	*Developing BCV*	*BCV in the basic formula*
0.1541	0.1742	0.33

6 Conclusions

The main model of this article was obtained from reviewing the literature in the field of BC management. What was observed in the literature was the lack of articles on measuring the value of BC and especially the quantitative calculation of the BC value. After studies in this field, the BCV formula proposed by Ostadi et al. (2021) was chosen as a basic model for development. Although they have considered several destructive events and their interaction effects, the co-occurrence of risk factors has not been considered. In the real world, the occurrence of multiple risks exacerbates or reduces the effects of risks. Thus co-occurrence of risks leads to a decrease or intensification of severity in any source of uncertainty (Ostadi and Abbasi Harofteh, 2023). Therefore, one of the innovations of this article is considering other factors of BC criteria that were obtained by reviewing articles that are related to the parameters of the basic formula and can be effective in calculating the formula of BC value. The next innovation is to consider risk assessment and consequently, the co-occurrence of risk factors, as well as several destructive events and their assessment and consequently the co-occurrence of these destructive events in the formula for calculating the BC value. Finally, these items were integrated into the BC value formula. In the next step, a proposed algorithm for calculating the parameters used in the developed BC value formula is stated. Finally, this algorithm was implemented in MATLAB software and the results and sensitivity analysis were performed. It was shown that by considering the factors reflecting the operational level as well as risk assessment and destructive events, the BC value compared to the base state, has decreased and indicates the impact of these factors in calculating BCV as expected. If a business can find ways to analyse and evaluate the BC of an organisation, thus that business is capable and can pass better than the conditions that threaten its life. For this reason, the BC assessment of an organisation as a process of adopting strategic decisions can be a basis for the continuous improvement of business behaviour. Therefore, to facilitate this, it is necessary to have a formula that includes factors that are effective in the value of BC and provide the right result to the organisation in accordance with reality. In this paper, have tried to provide a formula for calculating the BC value by examining the parameters of continuity and their relationship and considering the assessment of risk factors and destructive and the co-occurrence of risk factors that were not considered in previous formulas. In order to maintain the BC value in an organisation, it must first pay attention to the key products or services of that organisation and identify them so that in the occurrence of a destructive event or risk factors, this value can be kept at an acceptable level. For this reason, it is necessary to pay enough attention to parameters such as RTO, RPO, MTPD and MBCO, Ls and the level of risk-taking of the organisation and be able to control them. Because these factors affect the BC value. According to the findings of this study, when a destructive event occurs, whatever the closer the level of recovered capacity of the key product (RPO), which is the result of the level of available resources, to the normal performance level of that key product (L_s), the BC value will increase. Therefore, it can be concluded that the organisation will have more ability to restore itself to normal by adopting an approach that further increases the level of resources available at the time of the interruption. Also, if an organisation can reduce the key product recovery time (RTO), relative to the maximum tolerable time for disruption by reducing a key product (MTPD), it is moving toward increasing its BC. According to the present study, it can be said that the higher the risk assessment and that risk is related to the key product of the organisation, the BC value decreases. If an organisation can mitigate the severity of the risk effect by adopting a suitable approach, it has actually helped to return to a normal situation in the event of risk occurrence and resume its activities.

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Notes

1 An organisation's strategic ability to respond appropriately at a pre-determined acceptable level in order to continue the organisation's activities in the face of events (ISO BS25999-1).

2 Disruption is an accident, either unforeseen or foreseen, that has an unplanned cause, causing negative destruction (deviation) from the expected delivery of products and services in accordance with the organisation's main purpose (ISO, 2019).

3 A general management process that identifies potential threats that target the organisation and the effects of those threats on the business, as well as provides a framework for effective response. Protects the interests of stakeholders, the reputation, brand of the organisation and key activities (Blos et al., 2015).

4 Maximum tolerable period of disruption: the time that after that the lifetime of the organisation is irrevocably threatened if the delivery of products and services fails (Rezaei Soufi et al., 2019).

5 MBCO: the minimum level of service or product delivery that is acceptable to the organisation in achieving its goals in the event of a disaster (Rezaei Soufi et al., 2019).

6 Something that may happen and its effects on achieving goals and missions (ISO, 2019).

7 The general process of risk identification, risk analysis and risk assessment (ISO BS25999-1).

8 A set of instructions that is prepared for the organisation to use in incident, in order to continue the activities at a predetermined acceptable level (ISO BS25999-1).

9 The process of analysing the activities and tasks of business and the effect that the interruption of business activities may affect them (ISO BS25999-1).

10 Recovery time operation: the time period after an incident in which the product or service is to be resumed or resources are to be recovered (Rezaei Soufi et al., 2019).