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Pre-production of an educational serious game on coordinated Business Continuity Management

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Abstract (English)

Natural catastrophes have grown increasingly in past few years, posing a threat to economic operations. People have learned that natural catastrophes may have major consequences not just for humans, but also for the national, regional, and global economies. Disaster risk reduction is signified by each enterprise's Business Continuity Management which may decrease losses and speed up the recovery process after a business disruption. However, many tragedies demonstrated that in the case of a large-scale natural catastrophe, organizations' ability to deal with the catastrophic event is restricted without the collaboration between public and private sector partners in those areas. Regardless of how much individual work is put by a company, it struggles to stay in operation, due to transportation infrastructure failures, shortages of essential services like water, electricity, and disrupted supply chains. This makes dealing with disasters incredibly difficult. As a result, establishing an area Business Continuity Management with collaboration from all associated partners is becoming increasingly crucial.

The objective of this study is to develop a pre-production of an educational serious game on coordinated Business Continuity Management in an earthquake-prone area which contains interdependent public and private organizations. The pre-production consists of the development of the main concepts and ideas, creating a storyline and the game flow, designing player tasks and building a Simulink model to simulate players business continuity plans performance. The game is primarily intended for students, to provide them with an understanding of the concepts related to Area Business Continuity Management (Area BCM), and the importance of coordination when developing business continuity plans, through a hands-on exercise. The study will focus on developing a serious game to be used for developing Area BCM for Carware manufacturing company.

The study starts by developing the general flow of the serious game and identify which data will be given to users and which data and decisions will be provided by them. Then, a fictional case study for a manufacturing company will be developed. This fictional case study is loosely based on real events, organizations and people, in order to have a realistic game, but do not utilize real people's or organization's names. It investigates the case in which the area of the manufacturing company was hit by an earthquake, and some of the external providers of the company, electricity and logistics providers which are located in the same area, were disrupted. Then, Simulink model is developed to model the business processes of manufacturing company by modeling internal interdependencies between business functions within the company, and external interdependencies between the company and its external providers in the area. This simulation model will be used as the back engine of the educational serious game. Then, this model was tested by assuming an earthquake scenario to validate the outcomes of the model and test its performance. Finally, some of the recovery strategies options for manufacturing company were selected based on the outcomes of the assumed earthquake scenario. These strategies were applied to the case in order to investigate the impact of recovery strategies on the business continuity of the manufacturing company.

The finding of this study is that the presented simulation model is ready to be used for different earthquake scenarios and with different recovery strategies. Carware company can use this simulation model to choose appropriate combinations of recovery strategies for different earthquake scenarios to be prepared for any earthquake scenario. Using this simulation model to prepare for earthquakes will save time and money compared to traditional methods, and it will provide more accurate results. This simulation model is ready to be used as a back engine for the Area BCM educational serious game.

Key words: Business Continuity Management, Serious Gaming, Simulation, Interdependencies, Area Business Continuity Management, Business Continuity Planning, Collaboration.

Abstract (Italiano)

Le catastrofi naturali sono aumentate sempre di più negli ultimi anni, ponendo minacce alle operazioni economiche. Le persone hanno compreso che le catastrofi naturali possono avere gravi conseguenze non solo per gli esseri umani, ma anche per le economie nazionali, regionali e globali. La riduzione del rischio di catastrofi è rappresentata dalla Business Continuity Management di ciascuna azienda, che può ridurre le perdite e accelerare il processo di ripristino dovuto ad una interruzione dell'attività. Tuttavia, molte tragedie hanno dimostrato che nel caso di una catastrofe naturale su larga scala, la capacità delle organizzazioni di affrontare l'evento catastrofico è limitata senza la collaborazione con il settore pubblico e privato in quelle aree. Indipendentemente dalla quantità di lavoro individuale svolta da un'azienda, diventa faticoso rimanere operativi, a causa di guasti alle infrastrutture di trasporto, carenza di servizi essenziali come acqua, elettricità e catene di approvvigionamento interrotte. Questo rende molto difficile affrontare i disastri. Di conseguenza, sta diventando sempre più cruciale istituire un'area Business Continuity Management con la collaborazione di tutti i partner associati.

L'obiettivo di questo studio è sviluppare una pre-produzione di un gioco educativo sulla gestione coordinata della Business Continuity Management in un'area soggetta a terremoti che contiene organizzazioni pubbliche e private interdipendenti. La pre-produzione consiste nello sviluppo dei concetti e delle idee principali, nella creazione di una trama e del flusso di gioco, nella progettazione delle attività dei giocatori e nella creazione di un modello Simulink per simulare le prestazioni dei piani di continuità aziendale dei giocatori. Il gioco è destinato principalmente agli studenti, per fornire loro una comprensione dei concetti relativi all'area Business Continuity Management (Area BCM) e l'importanza del coordinamento nello sviluppo di piani di continuità aziendale, attraverso un esercizio pratico. Lo studio si concentrerà sullo sviluppo di un gioco serio da utilizzare per lo sviluppo di un'area BCM per l'azienda produttrice di Carware.

Lo studio inizia sviluppando il flusso generale del gioco e identifica quali dati verranno forniti agli utenti e quali dati e decisioni dovrebbero essere forniti da loro. Quindi, verrà sviluppato un caso di studio fittizio per un'azienda manifatturiera. Questo caso di studio fittizio è basato su eventi, organizzazioni e persone reali, al fine di avere un gioco realistico, ma non utilizza i nomi di persone o organizzazioni reali. Indaga sul caso in cui l'area dell'azienda manifatturiera è stata colpita da un terremoto e alcuni dei fornitori esterni dell'azienda, fornitori di energia elettrica e logistica che si trovano nella stessa area, sono stati disagiati. Quindi, il modello Simulink viene sviluppato per modellare i processi aziendali dell'azienda manifatturiera modellando le interdipendenze interne tra le funzioni aziendali all'interno dell'azienda e le interdipendenze esterne tra l'azienda ei suoi fornitori esterni nell'area. Questo modello di simulazione verrà utilizzato come ruota motrice del gioco educativo. Quindi, questo modello è stato testato considerando uno scenario sismico per convalidare i risultati del modello e testarne le prestazioni. Infine, sono state selezionate alcune delle strategie di ripristino per l'azienda manifatturiera sulla base degli esiti dello scenario sismico ipotizzato. Tali strategie sono state applicate al caso al fine di indagare l'impatto delle strategie di ripristino sulla continuità operativa dell'azienda manifatturiera.

Il vantaggio di questo studio è che il modello di simulazione presentato è pronto per essere utilizzato per diversi scenari sismici e con diverse strategie di ripristino. L'azienda Carware può utilizzare questo modello di simulazione per scegliere alcune combinazioni appropriate di strategie di recupero, per diversi scenari sismici da preparare per qualsiasi scenario sismico. L'uso di questo modello di simulazione per prepararsi ai terremoti farà risparmiare tempo e denaro rispetto ai metodi tradizionali e fornirà risultati più accurati. Questo modello di simulazione è pronto per essere utilizzato come ruota motrice per il gioco educativo Area BCM.

Parole chiave: Business Continuity Management, Serious Gaming, Simulation, Interdependencies, Area Business Continuity Management, Business Continuity Planning, Collaboration.

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1. Introduction

1.1 Background of the Study

Natural catastrophes have grown increasingly palpable in past few years, posing a threat to economic operations. People have learned that natural catastrophes may have major consequences not just for humans, but also for the national, regional, and global economies. The Great earthquake and tsunami that hit Japan in 2011 caused tremendous pressure on the country's economy, as well as having worldwide ramifications through industrial supply chains: for example, the supply of Japanese car parts to automotive assembly facilities all over the world was significantly affected [1].

Given the latest increase in financial losses caused by catastrophes, and the recognition of the private market as a participant and partner in crisis management, Baba et al. [2] stated that the Global Platform for Disaster Risk Reduction, under the auspices of the United Nations, concluded the Fourth Session. This session seeks to promote resilience and generates novel opportunities for collaborations between public and private organization as part of a massively better risk governance. It also emphasized priorities such as the private industry's gradual alignment of risk mitigation efforts and the development of business procedures.

The most meaningful impact of the private industry to disaster risk reduction is signified by each enterprise's Business Continuity Management which may decrease losses and speed up the recovery process after a business disruption. The BCP has been defined as ISO22301 and is used by a large number of businesses all over the world [2]. However, for comparably small commercial organizations, especially in the developing countries where many industrial agglomerated regions are positioned in natural disaster-prone locations, the BCM has yet to be designed and implemented in the majority of local businesses [2]. Furthermore, even if business continuity plans are prepared, firms have limited power to minimize losses and sustain operations individually, as was the case with latest large-scale catastrophes.

Baba et al. [2] mentioned that it is critical to conduct collaborative risk assessments at an appropriate size and develop scenario-based emergency plans in order to mitigate damage in the area and to reduce economic consequences or losses in the case of large-scale catastrophes that damage key infrastructure in specific regions. Furthermore, having strategic coordinated business continuity managements and incorporated resource management between both private and public sectors can assist each company's Business Continuity Management.

Furthermore, Dunaway and Shaw [3] cited that throughout a crisis, major private business partners must be included in the local disaster decision-making procedure or have a direct connection with major local emergency managers. In fact, without effective collaborative relationships between private and public sectors, communities cannot successfully deal with or recover from catastrophes.

According to several studies, more study on area business continuity management is needed. According to Warren [4], a substantial majority of public sector agencies are not developing integrated business continuity plans. The influence on properties, the responsibility of the public sector management in identifying risks, the strategy to build the coordinated framework, and to reduce the consequences of natural catastrophes and extreme disasters are all areas where further study is needed.

Recently, the awareness of the importance of using game-based simulations in the field of Business Continuity Management has increased [5]. Game-based simulations can be used to educate learners on best practices in business continuity management in a quick, efficient, and cost-effective manner. The reason is that these games place learners in scenarios that are close to real life, and the learners become in an environment where it is safe to make mistakes, and that aids in the learning process. In addition, Game-based simulations can be used to ensure that a Business Continuity Management is implemented successfully by assessing if the business continuity plans will perform as intended in a real circumstance since these games are the closest to actual execution. Furthermore, Game-based simulations can be used to test, and regular update business continuity plans to assure that they are effective and to guarantee that corporate activities do not come to a standstill in the event of unforeseen events.

In game-based simulations, the team is given a scenario and is instructed to follow the processes outlined in the business continuity plan and to allocate the resources to cope with the scenario. This sort of test should reveal any employees' concerns about their function and nature of their tasks, any resources that are missing or inadequate, and any omissions or mistakes in the business continuity plan. Because the major goal of testing is to assess the efficiency and identify limitations of the business continuity plans, it is critical to do a comprehensive debriefing after each test to interpret the results, including what went well, what did not, and any user concerns. Following that, the business continuity plans should be updated accordingly.

1.2 Statement of Problems

Natural disasters have become more common in recent years, posing a hazard to economic operations. People have learned that natural catastrophes may have major consequences not just for humans, but also for the national, regional, and global economies. Suez Canal blockage, that happened on 23 March 2021 by the container ship Ever Given which blocked the canal because of strong storm, caused tremendous pressure on the country's economy, as well as industrial supply chains [6]. According to Lee [6], over 400 ships in the West-East and East-West routes are expected to sail through the Canal. The utilization of routes and timetables presented a problem for such vessels. Ships planned to arrive at and pass through the Canal, consignees, shippers, ship owners, ship operators, and container stations were among the other victims of this crisis. Amounts ranging from $15 to $17 billion have been held up [6]. Another natural disaster caused tremendous pressure on the countries' economies and industrial supply chains worldwide is COVID-19 pandemic. COVID-19 first affected China, which is at the heart of many global value chains, causing worldwide supply chain disruption [7].

Business continuity management is about establishing solid business practices which offer the necessary direction during a disaster and guarantees that critical problems are not ignored [8]. However, The COVID-19 epidemic highlighted how vulnerable a big number of firms were [8]. According to research done in 2020 by Economic Times, 51% of businesses worldwide lack a business continuity strategy [8]. As a consequence, 100,000 businesses in the United States were forced to close due to the pandemic because they did not have business continuity plans [8].

Many tragedies demonstrated that, in the case of a large-scale natural catastrophe, organizations' ability to deal with the catastrophic event is restricted without the collaboration between public and private sector partners in those areas. Regardless of how much individual work is put by a company, it struggles to stay in operation, due to transportation infrastructure failures, shortages of essential services like water, electricity, and disrupted supply chains [9]. In fact, individual business continuity management concentrates on keeping the business going for individual organizations without taking into account the resilience of businesses and enterprises in the area altogether.

Watanabe [10] stated that in today's connected society, it is extremely unusual for services and products to be given by a single entity. Through supply chains, most of the procedures for developing and delivering services and products are split horizontally and vertically. In normal circumstances, this is efficient and functional social structure, but it also contains a large variety of interdependencies inside the social system, that can result in wide-area product and service chain interruptions in crisis scenarios. In today's increasingly interdependent society, it is nearly impossible for an organization to operate with significant resilience using individual Business Continuity Management for its own restricted scope [10].

According to Vakil [11], the ripple impacts of manufacturer disruption or damage could be felt quickly in any supply chain catastrophe. As a result, there are large supplier details which are considered as blind spots and that would have been experienced immediately after the event of a supply chain catastrophe. Supplier manufacturing sites, subcontractor interdependence, and business recovery strategies are all examples of information black holes [11]. Most businesses are unaware of their suppliers' or partners' business continuity policies and recovery strategies. Vakil [11] mentioned that, according to the 2010 BCI Survey, just 7% of organizations have been successful in convincing suppliers to undertake business continuity planning. Only half of these businesses have persuaded suppliers to share information about their business continuity plans. This makes dealing with disasters incredibly difficult. As a result, establishing an area Business Continuity Management with collaboration from all associated partners is becoming increasingly crucial. However, and according to several studies, more study on area business continuity management is needed.

Not testing nor updating business continuity management procedures and business continuity plans is another issue. Klosterman [12] mentioned that if a company never implemented and tested its Business Continuity Plan, it will be difficult to be convinced that the plan is going to be adequate and sufficient when a disaster takes place. The capability to effectively recover from different circumstances, such as a natural catastrophe or a communications interruption, may be improved over time through testing the business continuity plan. Furthermore, Gardner [13] stated that ignoring to test a company's business continuity plan might result in the discovery of weaknesses in the framework when it is put into action. Gardner [13] added that non-existent or infrequent testing of business continuity plan of a company puts that company at risk. The main reason behind that is the frequent changes in the company which lead to having flaws in these plans. Examples of these changes are recruitment and dismissal of employees, adding and removing services or products, and adding new systems. To better understand the strengths and limitations of business continuity plans, companies should aim to test their BCPs to find flaws in these plans and discover how it may be improved. The most comprehensive way for testing and updating BCPs is to use a game-based disaster simulation in which the organization completely mimics a disaster, and then learners will have to deal with that disaster to get the systems running [13]. However, and according to several studies, more study on developing serious games- based simulations in area business continuity management is needed.

1.3 The Objectives of the Study

The overall objective is to develop a pre-production of an educational serious game on coordinated Business Continuity Management in an earthquake-prone area which contains interdependent public and private organizations. It is primarily intended for students, to provide them with an understanding of the concepts related to Business Continuity Management (BCM), and the importance of coordination when developing business continuity plans, through a hands-on exercise. The overall idea is to design the serious game based on three interdependent organizations in the same area and these organizations are manufacturing company, electricity provider and logistics provider which is a seaport. The team of students who will play this educational serious game will act as the BCM team of the manufacturing company. The team firstly has to perform a Business Impact Analysis (BIA) for the manufacturing company. Before deciding upon the recovery strategies for the Business Continuity Plan, the team will receive information form the other two organizations which it depends on. Information is about their business continuity plans and recovery parameters, including Maximum Tolerable Period of Disruption (MTPD), Recovery Time Objectives (RTO) and possibly Recovery Level Objective (RLO). After exchanging this information between the organizations, BCM team in the manufacturing company has to adjust its business continuity plan accordingly since the three organizations are interdependent. In the final step, an earthquake scenario is simulated to evaluate the performance of the manufacturing organization BCP.

The further step, which is not part of this study, is to simulate the use of the Cosmetecor technology of in the game to enhance BC planning in earthquake scenarios. The Cosmetecor technology for early detection of earthquakes will be used to improve the coordinated BCM between the three organizations for the earthquake scenario. The technology may provide information about upcoming earthquakes like the timing, location and severity of an earthquake, so that players will have an opportunity to adjust their coordinated business continuity plans accordingly and be prepared for the earthquake. Then, players could evaluate how this technology can improve the entire risk management and business continuity management

The objective of this study is to focus on manufacturing company and build a Simulink model to simulate the internal and external interdependencies and recovery strategies of this organization. This will be a first step in building the back engine of the serious game.

The aim of this educational serious game is to educate students in Business Continuity Management best practices in a fast, effective and cost-efficient manner. Furthermore, to prove the importance of Area Business Continuity Management to deal with large-scale disasters like earthquakes.

1.4 The Expected Outcomes of the Study

The expected outcome of this study is to have the framework of an educational serious game based on one large case study where three interdependent organizations and involved in an earthquake scenario. These organizations are located in the same area. Although this case is fictional, it is still realistic in sense that information from real cases from different sources were used to build this fictional case study. This study will provide the fictional case first, and then will provide the general flow of the educational serious game that will be used to investigate Area BCM of the three organizations. Furthermore, this study will provide a Simulink model for manufacturing organization. This simulation model will simulate the external interdependencies between the manufacturing company and the other two organizations, namely electricity and logistics provider. Furthermore, the model will simulate internal interdependencies between business functions within manufacturing organization. In addition, the application of recovery strategies within manufacturing organization will be modeled and simulated using the Simulink model. This Simulink model is a part of large model which will be used as a back engine of the educational serious game that will be built later.

1.5 Significance of the study

Business continuity throughout time is the only way to ensure a stable economy. Furthermore, establishing an Area Business Continuity Management with collaboration from all associated partners in the same area is becoming crucial in order to deal with large-scale disasters like earthquakes. As a result, the study's greatest value is its contribution to area business continuity management practices in today's business environment specially with natural disasters which have become more common in recent years. Furthermore, this study contributes to develop a serious game that educates students about the importance of Area Business Continuity and allow them to practice and apply theoretical concepts. In addition, and due to the scarcity of studies that develop educational serious games in the field of area business continuity, this study is considered as one of the first studies to contribute to design of this type of serious games. This study will open the door to interdependent companies that are located in the same earthquake-prone area to develop their own game-based simulation to enhance and improve their area business continuity managements and to simulate earthquake scenarios to investigate their performances and readiness.

1.6 Definitions of Terms

In this section, terms used in this study are defined and theses terms include:

Business Continuity: is defined as the continuous availability of all critical resources sustaining core business processes [14].

Business Continuity Management: it ensures that important functions and resources are available to guarantee that critical objectives are achieved [14].

Business Continuity Planning: it refers to the actions connected with preparing documents to ensure the continuing availability of people, assets, and property [14].

Business Continuity Plan: A set of information and practices that is designed, assembled, and maintained in case of a catastrophe or emergency [14].

Business Impact Analysis (BIA): is a managerial analysis that determines the consequences of a corporation's loss of resources. The BIA assesses the impact of resource losses and rising losses with time in order to offer reliable information for senior management to make continuity planning decisions and to mitigate risks [14].

Business Interruption: any event that disturbs the normal flow of business operations at a company site, whether predicted, like a strike in public service, or unpredicted, like a blackout [14].

Disaster: When an incident overcomes management's ability to respond, control begins to slip away, and the situation is labeled a disaster. External organizations are frequently called in to manage disasters [14].

The Maximum Tolerable Period of Disruption (MTPD): is the time needed for negative consequences to become intolerable as a result of not providing a product, service or conducting an activity [14].

Recovery Time Objective (RTO): the time period following an accident during which a service or product should be restored, an activity should be restored, or resources should be recovered, and it is commonly used to define priorities and design plans [14].

Recovery Level Objective (RLO): the level at which information required by an operation must be recovered in order for the operation to be resumes normally [14].

Stakeholders: people and organizations that may affect or be affected by event, activity or decision or including anyone with an influence and interest in the community or organization, including the Board of Directors, workers, management, local communities, citizens, suppliers, customers, regulators, government and others [14].

Organization's business functions: pivotal business functions which an organization cannot operate for long time. If a vital business function is unavailable, the company may face significant legal, financial, or other losses or penalties [14].

2. Review of the state of the art on Business Continuity Management and Serious Gaming

This chapter reviewed preceding major textbooks and publications that were relevant to this study. The first section of this chapter shows the methodology used to review the state of the art. The second section reviewed the definition, components, standards and benefits of Business Continuity Management. Then the definition, identified stockholders, implementation and benefits of Area Business Continuity Management was reviewed in the third section of this chapter. The fourth section of this chapter reviewed the concept, advantages and applications of Serious Games, and the usage of Serious Games for testing business continuity.

2.1 Methodology

As observed, in the number of papers concentrating on business continuity management, area business continuity management, and serious gaming has been continuously increasing in recent years. The study's research methodology is as follows; the search keywords were defined firstly. Secondly, academic databases such as Emerald, IEEExplore, Metapress, ProQuest, ScienceDirect, Springer, and Wiley were used to find journal articles. No limitations have been imposed on the list of journals in order to guarantee that every relevant study was captured, regardless of the journal in which it was published. At this stage, 120 publications were collected. Thirdly, a set of criteria was established and utilized to filter the articles. These criteria are as follows:

- The article had to contain at least one or more of the subjects that are under investigation, which are Business Continuity Management, Area Business Continuity Management, and Serious Gaming.
- The article has to include at least one or more of the applications of serious game in Business Continuity Management.

The abstracts of the papers were investigated to check if they included one or more of these criteria. If an article did not fulfill the filtration criteria, it was removed. Then, the reference lists of the nominated papers were evaluated to confirm that no additional relevant publications had been overlooked throughout the search. Finally, the number of articles after the filtration decreased to 77, each article's content was assessed to ensure that it fits within at least one of the focus subjects. Figure 1 shows the methodology used to prepare the state of the art of this study.

Figure 1 Review methodology

2.2 Business Continuity Management (BCM)

The numerous community-wide accidents, along with the exceptional calamities that have befallen enterprises, organizations, municipalities, and governmental organizations in the last dozen or so years, have demonstrated that disaster recovery planning alone is insufficient. The continuity of the business should be the aim of all organizations [15]. Crises strike for a variety of reasons, both ordinary and extraordinary, and BCM should consider every element of business [16]. A crisis is therefore not limited to natural disasters including tsunamis and storms, but it might also encompass any occurrence that has a significant impact on an organization's operations, like human incorrect data input or deliberate acts such as the September 11th tragedy in 2001 [17].

Government organizations and businesses are increasingly susceptible to hazards that threaten productivity or the capacity to offer timely and consistent service to their consumers [18]. Multiple societal and economic events and trends, such as increased centralization, automation, globalization, offshoring, terrorism, networking and outsourcing, all contribute to these risks [18]. Disasters can have a substantial impact due to the increasing complexity of business operations and their increasing reliance on information technology and external service providers; hence it is critical to have plans that ensure business continuity [18].

This section reviewed the definition, components, standards and benefits of business continuity management.

2.2.1 What is BCM?

Business Continuity (BC) is concerned with the continuance of operations in the event of a disaster. People, procedures, varied assets, goods, and services make up a business. Any event that disrupts any of these entities, such as a market crash, pandemic illnesses, natural catastrophes, technology failures, human mistakes, cyber assaults, fraud, or terrorism, can have a short- or long-term impact on business continuity [19].

Since the 1970s, BCM has grown as an operational and technical response to risks and disruptions, and it contributes to resilience of the organization defending the interests of stakeholders [20].

Corrales-Estrada et al. [21] cited that Business Continuity Management is a comprehensive management process that determines potential vulnerabilities and threats that could face a company and the impact of those vulnerabilities and threats on business operations if realized and offers a framework for developing organizational resilience with the ability of an efficient response that protects the interests of key stakeholders, brand, reputation and value-creating operations. Knowledge management and dynamic abilities are linked to BCM, which improves performance of the organization during disasters [22]. Dynamic business continuity skills might be viewed as a socio-technical capability to deal with and recover from disasters [23], and also to assure prevention form losses and to respond to systemic catastrophe risk [24].

Furthermore, business continuity management, according to Gibb and Buchanan [25], is a technique that may be used to increase confidence in the products of processes and services in the presence of hazards. It is concerned with determining and dealing with potential risks that threaten to interrupt critical functions and related services, reducing the consequences of such risks, and guaranteeing that a process or service can be recovered without causing major business disruption.

According to Dey [19], Business Continuity Management is the process of predicting disruptions, assuring prevention or fewer likelihood of occurrences, and reacting to any such crisis in a prepared and practiced manner in order to recoup losses and restore the business. Disruptions can occur without warning or with warning, and the outcomes might be predictable or unpredictable. Furthermore, according to Dey [19], the terminology Disaster Recovery Planning (DRP) is more commonly used, yet it is essentially a component of the larger BCM framework. DRP is often responsible for ensuring the availability of information technology (IT) systems and is often technical in nature. Krell [26] mentioned that Disaster Recovery used to be based on information technology (IT) departments. These first efforts were largely focused on restoring data, hardware and software following a disruption. Business continuity planning activities nowadays are widely considered as requiring a cross-company approach and thus should not be limited to the IT department [26]. Nonetheless, catastrophe recovery efforts in the IT domain during the last decade have yielded plenty of excellent continuity strategies [26]. More recently, disaster recovery has been renamed "Business Continuity Planning", a terminology that originally meant moving continuity activities beyond the IT function and weaving them across the enterprise [26]. The term "Business Continuity Management" and "Business Resiliency" have lately become more popular, highlighting the proactive character of contemporary continuity operations [26].

In the case of an incident or catastrophe, a firm's business continuity plan is defined as set of actions designed by or for the company to safeguard people's lives and ensure effective recovery and continuity of operations [26]. For an organization's business continuity plan to be efficient, it must be created and executed far ahead of time. Business Continuity Management is a framework for maintaining and managing business continuity plans. Each business requires a Business Continuity Plan to deal with any potential interruptions and keep its operations functioning with minimal downtime. Protecting human lives, minimizing reputational and financial losses, continuing to serve consumers, and adhering to legal rules and regulations are the goals of BCM.

According to Glenn [27], there are two factors that must be considered in order to fully understand business continuity planning. First, it should be assured that an organization can carry on with business as normal, or at a minimum, in the aftermath of a calamity. Second, it should be returned to the state it was in prior to the incident.

2.2.2 Components of BCM

Previous works have suggested various BCM development cycles, each of which focuses on distinct elements of BCM. Gibb and Buchanan [25] presented a comprehensive framework of BCM that incorporates the phases listed below (some of which overlap):

1. Program initiation:

According to the framework suggested by Gibb and Buchanan [25], it is critical to design a program of business continuity measures during the program initiation stage, which is the first stage in the framework, and the CIO may play a vital role in supporting this cause and assisting in the identification and dissemination of recommended practice. A senior management, typically at the director level, should be in charge of a BCM program and supervise the formulation of a BCM charter. A charter is a high-level strategy document that establishes the context for specific efforts as well as delivery criteria. The mapping of business processes and related resources, the development of guidelines, and the establishment of suitable monitoring and control systems are all important elements in producing the charter [25]. The organization will have to design a program plan once the program charter has been determined [25]. Within the framework of the charter, this program plan will detail how, what, and when particular BCM initiatives will be launched, as well as how they will be funded and who will lead them. To determine where expenditures should be made, the company will have to examine the criticality of certain functions [25].

2. Project initiation:

Gibb and Buchanan [25] mentioned that following the definition of the program, the prioritized projects can be started using normal project management procedures. In order to begin each project plan, a considerable quantity of background information and data would need to be obtained, just as it did for the program charter. Background information about the service or process, as well as the resources required to deliver it, will be required. To improve access to data at the desktop and when the business continuity management crew is in the field, the construction of a portal that consolidates this information must be explored [25].

3. Risk analysis:

There are three steps of risk analysis: identification of risk, risk evaluation, and business impact analysis (BIA) [25]. This necessitates the BCM team identifying occurrences, determining their reasons, and calculating the repercussions of these events. Gibb and Buchanan [25] mentioned that A risk registry, as well as any evaluations and mitigation measures related with it, should be created by the company. This will assist to maintain uniformity of approach between projects within the program, as well as save effort and time when it comes to determining realistic risk metrics. Then, individual risks must be estimated and evaluated for their possibility of occurrence, expected occurrence frequency, and business impact. This will necessitate the project team assessing how technical assets are designed and positioned, analyzing building plans and area maps, and examining how applications are setup and accessible in order to identify possible sources of failure [25]. The next stage is to determine the risk event's effects and consequences. A risk's effects are the potential harm or loss to a service or process, whereas a risk's impacts are the commercial implications. In many circumstances, the impact is just a short failure to meet service standards with no long-term ramifications. Any protracted loss of continuity, on the other hand, is likely to result in financial loss, reputational damage, and legal action [25]. After estimations for the frequency of hazards and their implications have been developed, it will be feasible to scale and categorize these risks in order to determine investment priorities [25].

4. Selecting risk mitigation strategies:

According to Gibb and Buchanan [25], this stage focuses on finding and weighing the options for addressing the risks mentioned in the preceding phase. These techniques may be classified into two categories: those that deal with risk proactively by transferring, reducing, absorbing, or pooling it, and the ones that deal with risk occurrences by implementing disaster recovery plans. There might be one or more mitigation options for each risk. To estimate the impact of the solution and the value it will provide in cost savings or preserved earnings, an option evaluation will be required.

5. Monitoring and control:

Gibb and Buchanan [25] mentioned that to guarantee that the plan's needs are turned into action, the BCM strategy requires an efficient communication, command, and control framework. The control and monitoring phase ensures that current staff have been trained properly, new staff have been incorporated into the relevant BCM practices, testing has been completed to the agreed-upon levels, risk mitigation measures have been implemented, and effective emergency reporting including both successful and unsuccessful risk management has been implemented.

6. Implementation:

This stage, according to Gibb and Buchanan [25], focuses on implementing any changes to operational procedures, infrastructures, security, and other areas that might assist transfer, minimize, or absorb the risks of services and processes being compromised. This stage must guarantee that BCM is integrated into the development life cycle of the system at the point where new projects are launched. This stage also includes continued evaluation of any recovery strategies that have been fully operationalized. Other tasks include securing insurance coverage and assuring that BCM plan paperwork is updated and accessible.

7. Testing:

Disaster recovery plans and risk mitigation strategies should be thoroughly tested on a regular basis to ensure that they are still relevant and achievable. Gibb and Buchanan [25] mentioned that plans must be tested within three months of development at the very least, and then on an agreed-upon period of no more than one year. Testing can be done at a workstation, with technology, or as a process or service. In all circumstances, a report must be produced that assesses the efficacy of the tested plan components and emphasizes aspects which need to be addressed, along with practical recommendations.

8. Education and training:

This phase is focused with ensuring that the BCM strategy's advantages and objectives have been conveyed to the workforce, as well as ensuring that the objectives can be met through education and training. All stakeholders must be informed of their tasks and responsibilities; therefore, communication is essential [25]. Gibb and Buchanan [25] mentioned that there will be a necessity to give training for certain personnel in connection to specific procedures and services, in addition to educating workers about the purpose, nature, and their engagement in BCM. New employees should get BCM training as part of their onboarding, and current employees should receive re-orientation training regularly, especially when new systems and processes are installed [25]. Certification mechanisms and s elf-assessment should be considered for essential processes.

9. Review:

Gibb and Buchanan [25] mentioned that the goal of this stage is to ensure that the BCM system is adaptable to changing company needs. New procedures, applications, technologies, and individuals all introduce new risks and needs, therefore it's critical that the company doesn't fall into complacency and stop updating its BCM protocols. Operational data, such as incident reports, must be used to inform the assessment, which should highlight best practices, achievements, and failures. Modifications in the business climate, company priorities, and new initiatives must all be maintained up to date. The program and project managers, in addition to managers responsible for the day-to-day operation of services, must get feedback from the review phase.

In the case of an incident or catastrophe, a firm's business continuity plan is defined as set of actions designed by or for the company to safeguard people's lives and ensure effective recovery and continuity of operations. For an organization's BCP to be efficient, it must be created and executed far ahead of time. Business Continuity Management (BCM) is a framework for maintaining and managing business continuity plans [25].

According to Dey [19], risk analysis and its impact on business are critical components of BCP. It's also necessary to prioritize and categorize time-sensitive sectors or operations of the business, as well as their resources. Business Impact Analysis (BIA) is the process of analyzing current and prospective risks to all important business activities and evaluating the impact of these functions being unavailable for a maximum amount of time (Maximum Tolerable Downtime, MTD) and their Mean Time to Recovery (MTTR) in each situation.

When a disruption happens, the company must quickly know how to address the problem. This is referred to as crisis management. After the crisis has been brought under control, the other business continuity procedures will take whatever steps are necessary to ensure that goods and services are delivered to the end user only within acceptable and previously agreed-upon 'Service Level Agreement' (SLA). The final phase will be to recoup any losses or damages and return the operation to its previous state [19].

The primary components of Business Continuity Planning include Business Impact Analysis (BIA), Risk Management, Incident Handling, Disaster Recovery and Restoration. As illustrated in Figure 2, all of them are integrated into an end-to-end system including planning, analysis, design, training, implementation, review, maintenance, audit, and documentation, which covers the whole cycle of Business Continuity Management [19].

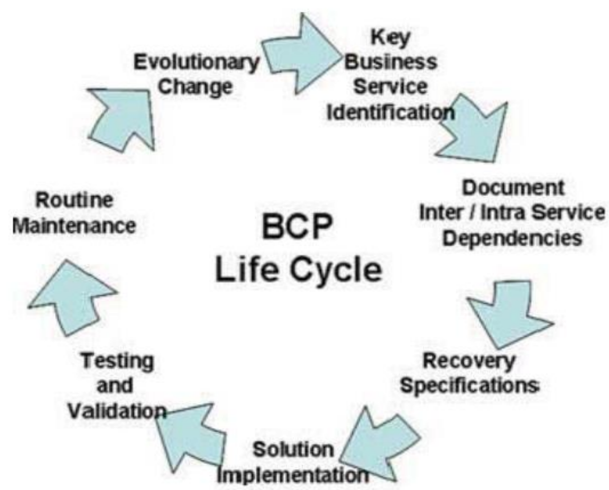


Figure 2 BCP Lifecycle [19]

The BCP process is a thorough, logical planning procedure that may help a company respond effectively to a variety of disruption hazards. The dynamic nature of both local and global surroundings, as well as the changing expectations of the company and its stakeholders, must be reflected in the BCP. According to Gibson and Love [14], the BCP process is broken down into nine steps, which are:

1. Commencement: Business continuity plans are adopted inside enterprises to focus on the long-term sustainability of critical business goals, as well as the development of a thorough awareness of and commitment to BCP.

2. Risk and vulnerability analysis: The organization's risks and threats are identified, as well as how these elements might cause business disruption risks and the organization's vulnerabilities to these risks.

3. Business impact assessment (BIA): The possible organizational consequences of disruptions are evaluated, as well as the resources necessary to maintain business operations in the aftermath of disruptions.

4. Disruption strategies: Recovery and continuity strategies along with emergency response are designed to effectively manage priority disruption risks.

5. Interdependencies and resources: Resource requirements from throughout an enterprise are collected and organized according to priorities, and internal and external interdependencies are detected and handled.

6. Plan documentation: Using the data gathered and established during the BCP process to generate plans which can be implemented practically.

7. Disruption communication: Prior to an accident happening, the company should communicate with internal and external stakeholders and inform them about difficulties relating to recorded plans and planned measures.

8. Maintenance: The company keeps improving BCP abilities to guarantee that plans are relevant and updated.

9. Activation and development: The company must ensure that plans are properly executed and maintained.

2.2.3 Business Continuity Standards

Enterprises should follow already defined criteria and principles to guarantee that a business continuity framework is useful and completely comprehensive in addressing all areas of business continuity in present and future circumstances of uncertainty. These standards provide such a structured management strategy for implementing best practice controls, quantifying the degree of risk appetite, and implementing suitable measures for business continuity and recovery, thus safeguarding the organization and the interests of stakeholders [19]. the goal of business continuity standards is to assist businesses in developing and maintaining good business continuity competencies, as well as to determine the quality and effectiveness of a company's business continuity program. Various standards issuing organizations from all around the globe created business continuity standards. In 2003, the British Standards Institute (BSI) and the Business Continuity Institute (BCI) released Publicly Available Specification 56, the first BCM standard (PAS 56) [28].

Beginning July 2006, PAS 56 was superseded by British Standard (BS) 25999 [28]. The terminology, process, and principles of business continuity management are defined in this standard [29]. The goal of this Standard is to offer a foundation for comprehending, establishing, and executing business continuity in a company, as well as to provide other companies and customers confidence in the firm's interactions [29]. According to Bethany [28], the first part of British Standard (BS) 25999, namely BS 25999-1, was published in 2006 and was titled Business Continuity Management Code of Practice. It provided general guidelines and recommended practices on an effective Business Continuity Management System (BCMS) [28]. The second part of British Standard (BS) 25999 was BS 25999-2 [28]. It was released in 2007 and was titled Specification for Business Continuity Management, and it explained how to establish, run, audit, and enhance a Business Continuity Management System in order to get compliance certification [28].

Bethany [28] mentioned that, in 2005, the Singapore Technical Reference (TR) 19 defined standard for BC. However, in 2008 TR 19 was superseded by Singapore Standard (SS) 540. Then, SS 540 has been superseded by ISO 22301 [28], which will be addressed subsequently. In 2007, the National Fire Protection Association (NFPA) issued NFPA 1600: (2007) which is revised and updated e very three years [28]. The most recent edition of the NFPA standard on BC Programs is NFPA 1600: (2013) [28].

Canada produced its own form of standardized business continuity planning with the publication of the Canadian Standards Association (CSA) standard Z1600: (2008), named Emergency Management and Business Continuity Programs [28]. The Canadian specification was based on the NFPA 1600 standard, which was widely used in the United States. In 2007, the United States Congress, through the Department of Homeland Security (DHS), started developing PS-Prep, a certification and accreditation program aimed at the private sector. The program's goal was to help firms identify and execute the procedures needed to set up and maintain a complete management system that addressed, organizational resilience, business continuity and emergency and catastrophe management [28].

Bethany [28] mentioned that realizing the need of establishing a worldwide standard for BCM, the International Standards Organization (ISO) produced ISO 22301: (2012), named Societal Security—Business Continuity Management Systems—Requirements. In September 2014, the Singapore standard, SS 540, was superseded by the ISO 22301: (2012) standard, which superseded the British standard, BS 25999 [28]. ISO 22301: (2012) specifies standards for establishing and operating an efficient Business Continuity Management System (BCMS) [28].

The ISO 22301: (2012) standard is divided into ten sections: Scope, Normative references, Terms and Definitions, Organizational Context, Leadership, Planning, Support, Operation, Performance evaluation and Improvement [28]. In the Operation section, standard mandates that enterprises execute and document risk assessment and business impact assessment procedures, define a BC strategy, determine resource needs to execute BC strategies, and evaluate risk protection and mitigation measures [28]. Organizations must have an emergency response framework, warning and communication protocols, and business continuity plans in order to comply with the ISO 22301:2012 standard [28].

2.2.4 Benefits of BCM

Business continuity management is about establishing solid business practices. BCM's risk and governance objectives give confidence to customers, partners, shareholders, workers, and the market. This guarantees that business is done in the best interests of all stakeholders, including investors and customers, who both require assurance that risks will be controlled to reasonable standards [30]. According to a Mckinsey study published in Business Continuity Online, "nearly 80% of shareholders might pay 18% extra for shares in a well-governed organization” [30].

Furthermore, Devargas [31] mentioned that in terms of describing an organization's overarching objective, which is "to live long and flourish”, determining the advantages of business continuity management is relatively straightforward. It's similar to insurance of liability in that it gives a definite level of confidence that if a catastrophic crisis strikes, the organization will not be ruined financially. Nevertheless, insurance of liability does not guarantee the organization's activities will continue, and it may not be sufficient to pay for the countless losses of business during the disruption or for business which never resumes.

Therefore, Business continuity Management offers the necessary direction during a disaster and guarantees that critical problems are not ignored. A thorough strategy, when properly prepared, will successfully lead even unskilled employees in assisting the company's recovery. The mere presence of a plan can serve as proof that the corporation did not disregard disaster preparedness in its management responsibilities [31].

Supriadi and Pheng [26] mentioned that while BCM may assist businesses in preparing for large disruptions that could threaten their operations, the Business Continuity Institute determined that there are other advantages to adopting BCM as a management discipline in an enterprise. To begin, BCM will assist the company in addressing certain important risks and achieving compliance. Second, by demonstrating "customer care," BCM may be leveraged as a competitive advantage to win new clients and boost profitability. Finally, a complete assessment of the business using Business Impact Analysis (BIA) can reveal weaknesses and focus on objectives that would not have been discovered otherwise. In addition, businesses that provide services or commodities understand that maintaining consumers by delivering a more consistent service is less expensive than attempting to entice deserters back after a disruption. Other research has discovered a variety of advantages to using BCM in a company [26].

Devargas [31] mentioned some additional benefits associated with developing a comprehensive BCM which are: reducing possible financial losses, minimizing legal liability, minimizing disruption to organizations' operations, guaranteeing organizational stability, guaranteeing orderly recovery, reduced insurance costs, maintaining the safety of employees and customers, conformance with regulatory and legal requirements, reducing decision-making during a disaster, avoiding ambiguity and mistakes, offering training resources for new personnel, minimizing the dependence on some key personnel and operations, reducing potential exposures, decreasing the possibility of occurrence, preserving the organization's resources, reducing production disturbances, reducing the impact on customer loss of confidence, and decreasing the likelihood of invoice/order losses.

Business Continuity Management is being used by a wide range of companies in a variety of industries. For this concept, international standards and regulations have been devised, as well as methodologies for measuring the amount of BCM readiness. Various forces are now supporting the need for BCM, and while there are certain problems in putting the concept into practice, the benefits of BCM are worth highlighting.

2.3 Area Business Continuity Management (Area BCM)

The major contribution of the private sector to catastrophe risk reduction is signified by each enterprise's Business Continuity management (BCM), which may assist limit damages and speed up business interruption recovery. Therefore, BCM is used in a variety of businesses all across the world [32]. However, for comparably small commercial organizations, especially those in developing countries where several industrial agglomerated regions are located in natural disaster-prone locations, the BCM has yet to be designed and implemented in the majority of local businesses [32]. Furthermore, even if Business continuity plans are prepared, the business organizations have limited capability to reduce losses and sustain operations by their own efforts, as was the case with recent large-scale crisis [32].

It is critical to conduct risk assessments at an appropriate size and develop scenario-based recovery plans for area damage mitigation in order to reduce economic consequences or losses in the case of large-scale catastrophes that disturb key infrastructure in specific regions. Furthermore, having integrated resource management and strategic contingency plans that can support each enterprise's BCM efforts in collaboration with government initiatives is critical [32].

With this background, Baba et al. [2] stated that since February 2013, Japan International Cooperation Agency (JICA) has been working on a project titled "Natural Disaster Risk Assessment and Area Business Continuity Plan Formulation for Industrial Agglomerated Areas in the ASEAN Region" in collaboration with the ASEAN Coordination Centre for Humanitarian Assistance on Disaster Management (AHA Centre). The study presented the principle of Area BCM and validated its implementation.

This section reviewed the definition, Stakeholders, methods of implementation and benefits of area business continuity management.

2.3.1 What is Area BCM?

The interruption of corporate operations because of disasters results in significant financial losses. Meechang et al. [33] mentioned that the floods in Thailand in 2011 are an evident example of a localized disaster that has had a worldwide impact. It took a long time for things to go back to normal. It showed that many businesses were unprepared for unforeseen situations. Destroyed equipment, lost supplies, ruined transportation routes, and other factors all contribute to it [33]. Several industrial complexes have been located nearby rivers and coasts due to logistics and transportation, leaving them vulnerable to natural catastrophes like as floods, tsunamis, and coastal erosion [33]. As a result, risk and crisis management are essential. Business Continuity Management may help to improve resilience by allowing for a more effective catastrophe response. The framework offers instructions on how to deal with and recover from a disaster for each organization [33]. In particular, it seeks to ensure business continuity in the organization by taking into account the priority business' operations and necessary resources [34]. Despite this, the outcomes of deploying BCM indicated that losses were decreased, and company operations were quickly restored [32]. They have attracted the attention of a limited number of private organizations. Individual BCM could be effective to sustain the functionality and resources if there are no external threats [33]. On the other hand, effects on public utilities, routes of transportation, infrastructure, and other factors, are beyond the control of any individual organization [33]. As a result, and according to Meechang et al. [33], BCM may become inadequate.

Furthermore, Watanabe [10] stated that in today's connected society, it is extremely unusual for services and products to be given by a single entity. Through supply chains, most of the procedures for developing and delivering services and products are split horizontally and vertically. In normal circumstances, this is efficient and functional social structure, but it also contains a large variety of interdependencies inside the social system, that can result in wide-area product and service chain interruptions in crisis scenarios. In today's increasingly interdependent society, it is nearly impossible for an organization to operate with significant resilience using individual Business Continuity Management for its own restricted scope [10].

To increase the local and global economy's resilience, a new terminology named Area Business Continuity Management (Area BCM) was developed by JICA and the ASEAN Coordinating Centre for Humanitarian Assistance (AHA Centre) [32]. The focus is on organizational continuity and early recovery in the case of a disaster. BCM concentrates on the business continuity for individual businesses. Area BCM, on the other hand, focuses on enhancing the overall resilience of the area's enterprises. BCM and Area BCM are inextricably linked, and both increase the business continuity of individual enterprises and the resilience of the area's businesses [9].

The area BCM of individual companies are intertwined and interactive. It is possible to access information specified in Area BCP, such as the region's catastrophic events, other stakeholders' methods and capacities for disaster risk mitigation, and a mutual and agreed-upon direction of steps for disaster risk mitigation in the area, through Area BCM. However, as part of the Area BCM process, each company will be asked to give information that will serve as the foundation for its BCP and emergency management strategy. An organization's measures should be solidified, according to Area BCM. Repetition of the Area BCM cycle might enhance both Area BCP and individual BCPs, as well as their connectivity and integrity [9].

As defined by Baba et al. [2], the Area BCM is a structure and approach for crisis risk management by stakeholders. Individual businesses, industrial regional managers, local governments, and infrastructure managers are among the stakeholders who must work together to keep the industrial agglomerated area running. The Area BCM's geographical extent is determined by the local context or the amount of stakeholder coordination, and it can cover an industrial park, an industrial agglomerated area, or even a whole nation.

The Area BCM must be integrated with each candidate's BCM so that it offers complementary information for calculating losses and sharing company resources by both governmental and non - governmental organizations. Each BCM might relate to the Region BCM to identify restrictions in the area, as well as assess the business resources' Recovery Time Objective (RTO) and prepare recovery plans [32].

Another definition of Area Business Continuity Management (Area BCM) is a cyclic method of exchanging risk data or effect estimation, identifying the strategy, developing the Area business continuity plan, developing preparedness measures and effective recovery activities, and tracking to continuously develop the Area BCM system, in cooperation among partners, in order to enhance the area's ability to maintain effective business continuity [32].

2.3.2 Stakeholders of Area BCM

As Area BCM is a collaborative effort including all of the area's stakeholders, the first stage in Area BCM is to define them. They come from the governmental and commercial sectors, as well as a variety of other fields [9].

According to Sapapthai et al. [35], it is clear that individual firms will struggle to complete a project without collaborating with others. As a result, key decision-making groups were identified and requested to join the initiative as partners. To establish the stakeholders significant to the project being done, detailed criterion should be devised for many situations [36]. It's important to identify potential bottlenecks, like stakeholders that take a very long time to make decisions [35].

Individual actions of stakeholders are critical to improving the resilience of the area's businesses. Furthermore, government and non - governmental players must work together since they are in the same boat when a massive natural crisis hits the area. When crisis occurs, it has major consequences for all stakeholders in the region. Many stakeholders, including national government ministries and agencies, local governments, operators of transportation infrastructure and lifeline utilities, businesses and industrial estates, governmental research centers, industrial organizations, and others, are involved in ensuring business continuity in the area [9].

According to [9], the area's stakeholders are defined, and they are urged to take part in Area BCM. Stakeholders are assigned to one of three roles: leader, member, or supporter. The leader is in charge of promoting Area BCM as well as developing and maintaining Area BC plans. The leader shows the supporters and members how to lead, encourages them to engage, and prepares them to execute Area BCM. The leader's leadership is critical to the success of Area BCM. The leader can be a person, a group, or an enterprise with the power and capability to lead members and supporters.

Members take part in Area BCM to help build Area BC plans. The members share data for Area BCM as well as enhance their own organization's crisis management procedures and BCM. For example, local governments, town councils, emergency crews, regional representatives of the federal government, traffic infrastructure and lifeline utility providers, industrial estates, private companies, local chambers of commerce and industries, local universities, communities, and others [9].

The supporters back Area BCM, which is being executed by the leader and members. They provide as organizational or technical advice to the leader and members to ensure that Area BCM is implemented smoothly. They must also supply risk and hazard data, as well as professional assistance such as hazard and risk assessments. The supporters are supposed to act as catalysts in the promotion of Area BCM around the nation [9].

2.3.3 How to Implement Area BCM

The governance of the Area BCM framework with ownership and leadership by the leader is critical for the execution of Area BCM because it is the collaborative effort of the area's stakeholders. Supporters and members require the same level of support and understanding from senior management [9].

According to [9], an advisory committee and a working group should be formed as a governing entity to ensure that Area BCM is implemented successfully. Members of the advisory committee should come from important stakeholder management. The working group will be directed by the committee, and the working group's conclusions will be approved by the committee. The leader will plan and convene meetings of the committee. The working group is made up of area stakeholders and serves as an extension of the advisory committee for the implementation of Area BCM. The leader is in charge of Area BCM tasks such as meetings, seminars, research, and other essential tasks. To oversee the tasks, the leader's staff should choose a coordinator. If a suitable individual is not accessible, the work might be delegated to a member or outsourced person.

The method of Area BCM's continuous actions is built by the leader. The management cycle depicted in Figure 3 is used to execute the Area BCM. Because it is difficult to obtain a satisfactory level at the initial phase of the approach, the process of Area BCM will be gradually enhanced by repeating the cycle [9].

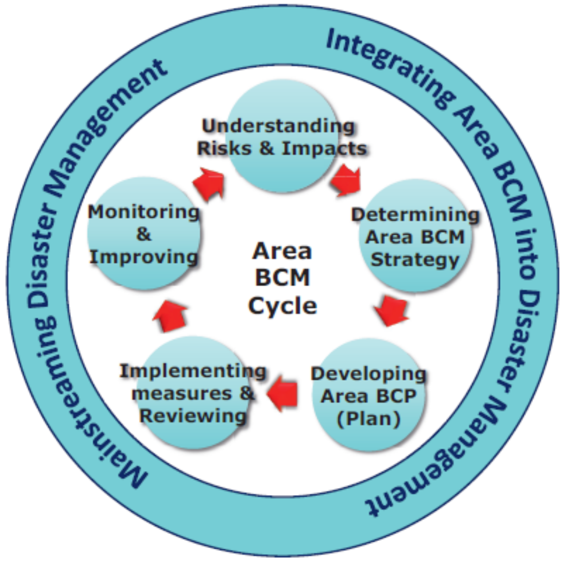


Figure 3 Area BCM cycle [32]

The leader hosts workshops that follow the stages of the cycle, allowing stakeholders to debate topics connected to Area BCM and the formation of Area BC plans. In the workshops, discussion-based activities and/or table-top exercises can be employed. Before every workshop, the leader sets up the subjects to be covered as well as the workshop agenda. Furthermore, prior to each workshop, homework should be distributed to stakeholders, and their replies should be summarized in order for the session to go well [9].

Furthermore, Baba et al. [32] mentioned the core steps of the Area BCM formulation, which are:

a) Hazard, Vulnerability, and Risk Analysis: This begins with the recognition of the most significant potential source of loss in the industrial agglomerated region, which is accomplished by probabilistic analysis of numerous hazards. The risks in the area are simulated with high probabilities of occurrence. In this analysis, we used a return time probability of 100 to 200 years for extreme situations of all sorts of hazards.

b) Infrastructure and Business Resource Assessment: In order to be prepared for the risk scenario in the target region, we assessed the catastrophe resilience of infrastructure and business resources, and also present supply chain circumstances. The resilience and vulnerability of the aspects associated to the area's business continuity were then analyzed.

c) Risk Scenario and Business Impact Analysis: The foregoing examination and assessment resulted in a superimposed risk of business disruption and broad repercussions. The creation of a risk scenario was the prerequisite for stakeholders to debate risk management strategies and actions in the following stage.

d) Area BCM Formulation: This step includes reviewing current measures and private sector Business continuity plans for natural catastrophes, developing an Area BCM plan, and drafting the Area BCM. The strategy should address a variety of challenges, including security solutions, integrated disaster management and response, rapid damage recovery, supply chain collaboration, monitoring Area BCM efforts for feedback, and other procedures to follow.

2.3.4 Benefits of Area BCM

According to Baba, H. et al. [37], The Area BCM process brings together the activities of area stakeholders, focuses them on a similar purpose, and enables the area to recover and rebuild swiftly, effectively, and efficiently. The variety of measures – such as the approach chosen – may assist each business continuity manager think about how to protect the necessary business resources. They also assist in the development of new methods of collaborating via improved contact with other partners and information exchange among connected parties in the region, as well as each enterprise's clientele. In addition, these factors may facilitate increased collaboration with many other industrial agglomerated zones as well as other strategically important regions. The preparation of an alternate supply chain network also improves supply chain coordination.

The increased responsibility that came with the formation and integration of Area BCM, according to Baba, H. et al. [37], benefited each organization's efforts. Even businesses who do not already have a BCM can begin to establish one. Furthermore, cross-industry collaboration arising from Area BCM can boost collaboration across line industries even more, since the idea of Area BCM is naturally distributed to other regions. Another advantage of Area BCM is that it may provide a motivation for private companies to set plans for each phase of the crisis management cycle, including prevention and mitigation, preparedness and response, restoration and rehabilitation, rather than the more common practice of only preparing plans for a response due to financial constraints and insufficient experience [37].

Baba, H. et al. [37] mentioned that private entities will be more involved in the design of structural risk reduction measures on a regional scale. In catastrophe risk mitigation, for instance, it is recognized that some degree of duplication in procedures and operations is required in order to adopt effective backup procedures and alternative solutions. The area's resilience will be enhanced through a combination of diverse programs under Area BCM, which include pooling resources and developing in strategies to limit catastrophe consequences while shifting risks. The government is also encouraged to develop and build a more durable infrastructure. Because the restoration of local jobs, the rebuilding of people's residential environments, and the regularization of socioeconomic activities are all necessary for the earliest possible recovery of a community, it is critical for both governmental and non - governmental partners to enhance their capacities in disaster-prone areas. Area BCM possibilities can increase strategic operations in normal enterprises to prevent unanticipated business risks and contribute effectively to catastrophe avoidance as well as sustained development for all partners involved by connecting the individual contributions of firms and public organizations [37].

Participating in Area BCM is a great way to establish or improve the organization's individual BCM and/or catastrophe risk reduction strategies. Some of Area BCM's operations are similar to those of BCM. During the implementation of the Area BCM, the information gathered, and conversations held in "Understanding the Area" and "Developing Area BCP" may be immediately used to individual BCPs and disaster risk management strategies. This is especially critical for small and medium-sized businesses, who often lack the knowledge and ability to conduct risk assessments [9].

Although it is rather early to assess the whole benefits of Area BCM, the increased resiliency may attract additional businesses to relocate their businesses to the target area, which has lower catastrophe risks than other places [37]. According to Baba, H. et al. [37], the area's greater resilience might be reflected in total asset value in the business environment, perhaps lowering local businesses' catastrophe insurance premiums. If costs are reduced as a result, the sector will attract increased involvement. As a consequence of the improved business continuity in the area, the national economy and jobs might grow, which might have a tremendous influence on the country. Improved business continuity in the area might lead to the development of a thriving economy, that can benefit the entire country. The Area BCM process encourages all involved partners to become aware of their interconnections and assists the private market in developing well-balanced and regulated plans for all phases of the crisis management cycle [37].

2.4 Serious Gaming

The concept of playing games extends back to antiquity and is considered a fundamental feature of all cultures. Laamarti et al. [38] mentioned that dice, for instance, seems to be one of the first human games; the earliest known example is a 3000-year-old game found in south Iran. Several of these games had a "serious" use; for instance, Mancala (a game created approximately 1400 BC) was utilizes as a tool for accounting and it was used for trading food and animals [38]. Nevertheless, about all of the games were built on the idea that the game includes and discloses information that would otherwise be hidden from the player [38]. Today's "serious games" is considered as serious business; as mentioned by the co-founder of the Serious Games Initiative, Ben Sawyer, the market of the serious games is already worth $20 million, and video games is a $10 billion per year sector that is predicted to increase over next century [39].

Tarja et al. [40] mentioned that serious games can be used in a variety of sectors, including government, military, educational, business, and medical. When talking about serious games, one of the most important questions to ask is what the term "serious game" truly implies. A very important meaning is that serious games are digital games which are utilized for objectives other than pure amusement. Another point of interest, according to Tarja et al. [40], is the purported good impacts of such games, as well as implementations from related and often conflicting fields like edutainment, eLearning, digital game-based learning and game-based learning. In addition, serious games, according to Corti [41], could have good effects on the players' development of a variety of abilities, in addition to apparent benefits such as helping learners to experience scenarios that are difficult in the real life for reasons of safety, cost, time, and so on.

This section reviewed the concept, advantages and applications of serious games. Then it reviewed the usage of serious game for testing BCM.

2.4.1 The Concept of Serious Gaming

The expression "serious gaming" is getting increasingly prevalent these days. Serious games are games which are meant to operate on video game consoles or personal computers and are used for practice, advertising, simulations, or learning [40]. Game-based learning or serious games, according to Corti [41], are all about harnessing the power of video games to capture and involve end-users for a particular purpose, such as developing new information and skills. According to Zyda [42], serious game is a conceptual competition performed with a computer in line with certain regulations that employs amusement to enhance governmental or business training, health, education, strategic communication and public policy objectives. Zyda [42] said that serious games are more than merely story, graphics, and software when comparing them to computer games. The inclusion of pedagogy (practices that teach or guide, hence transferring information or skill) elevates games to the level of seriousness.

Hardcore games players, on the whole, seek the most immersive experience possible from their games. However, for serious games the ability to use the model or simulation to address an issue is much more crucial than offering "rich experiences" like those demanded by hardcore gamers. Furthermore, for serious games, it is critical that the most key aspects of training are emphasized, as well as that the assumptions required to make a simulation viable are right; otherwise, the game will impart the incorrect skills [40]. On the other hand, entertainment games permit users to concentrate on the enjoyable aspects while using a variety of approaches (arbitrary numbers, time compression, and so forth) to facilitate simulation operations. Tarja et al. [40] propose that in serious games, it may be necessary to reconsider the usage of such simplifying strategies. Serious games, for instance, must respond to players' deliberate decisions rather than chance, thus volatility may be unsuitable. Another example is communication in entertainment games, which is frequently faultless (i.e., with no lateness or misunderstandings), yet serious training applications must represent the fact that communication is rarely perfect.

Tarja et al. [40] claimed that 3D is crucial in games because it allows players to encounter genuinely replicated events that are difficult to encounter in the real life. People also gain an instinctive sense that a 3D application that replaces a certain real-world task might be of instant use. Several firms, according to Tarja et al. [40], are seeking for 3D solutions to tackle business issues rather than games per se. Nevertheless, the recent enthusiasm in 3D technology has misled game designers and developers, and when businesspeople say "game," they are most often referring to a "3D application." But even so, not even all 3D applications based on contemporary game technology are called "games," and they shouldn't have to be entertaining or include any training or reward systems [40]. Given these ambiguities and gray areas, Tarja et al. [40] proposes that serious games be divided into the following categories:

• Games: applications that emphasize education, simulation, and entertainment.

• 3D applications: apps that tackle business challenges using 3D game technology and approaches.

However, these two categories are considered to overlap in the sense that there are 3D applications that aren't games, 3D applications that are games, and games that are just not 3D applications [40].

Tarja et al. [40] also point out that several serious gaming websites focus primarily on the game side, rather than the technological transfer to 3D applications. As a result, the author recommends the following definition: Serious Games" refers to the use of gaming technology, technique, and design to solve issues in organizations and businesses. Serious games encourage the exchange of game design expertise and technologies in normally non-game areas such as teaching, invention, sales, and advertising [40].

2.4.2 Advantages of Serious Games

Serious games already provide a number of advantages, which are likely to grow in popularity as demand grows and technology becomes more advanced. Simulated systems and environments allow users to explore circumstances that would be impossible in the actual world due to safety, cost, or time constraints [41]. Studies have been done throughout the years which consistently indicate that serious games help users to learn [39]. One of the advantages of serious games is mentioned by Azadegan et al. [43] which is that serious games can be used in a company training. The corporate training sector is a significant one nowadays. Employees must be trained in order to increase their knowledge and skills. Serious Games can be useful in training specially when the learning content is technical or tedious, or when the learning goals are challenging [43]. Furthermore, serious games offer a quantum leap in training since they shift the trainee's function from passive to active. In addition, serious games have shown to be an effective instrument for assisting learning and training in schools, colleges, as well as vocational training in the organizations [43]. Azadegan et al. [43] added that serious Games, which make use of IT-based methodologies, are helping businesses to enhance training programs by involving people more dynamically and measuring their knowledge of the content presented. Games may be used as basic corporate training tools, or they could be customized for a specific business. Video games have resulted in a more productive employee. Workers are taught how to solve issues in non-conventional ways, such as via trial and error, through gaming. Gamers can also learn valuable business skills [43]. Furthermore, Workers who practice with video games are better at "multi-tasking, taking decisions and assessing risk, agile in facing changes, and tend to consider failures as opportunities to try again" than non-gamers [43].

In addition, and according to Clark [44], serious games and simulations are potential tools for motivating learners of all ages to participate in the substantial, long-term training required to adjust, automate, and transmit difficult capabilities after direct directive is done. Furthermore, serious games are excellent motivators for learners to practice and receive reformative feedbacks. Game-based training could take place in a continuously interactive atmosphere where contextual clues, issue complexity, and novelty could be changed depending on individual and group progress. Games are also a great way for groups or teams to practice problem solving and analysis [44].

Clark [44] mentioned that, in business, military and government contexts, the objective of knowledge transmission and integration is critical. Workers who have been trained in the workplace typically may not have an instant chance to put what they have learned into practice until weeks or even months after they have completed training. If knowledge gained during training is not employed on a regular basis, it will quickly deteriorate. In professional educational contexts, where sophisticated knowledge should be continually incorporated as conceptual frameworks and other types of conceptual understanding are formed by learners, continuous practice is crucial. And such practice can be done through serious games.

2.4.3 Applications in Multiple Areas

This section reviewed some modern instances of applicable serious game implementations in several fields, such as academia, training, health care, well-being, advertising, cultural legacy, and communication.

a) Education and Training: Many academic efforts are aimed at getting the benefit of video games' popularity and applying it to the educational sector. Laamarti [38] mentioned that the addictive aspect of playing games and players' obsession with videogames are being considered to be exploited to enhance players' learning. According to Laamarti [38], Quest to Learn, a school in New York City that established in 1999 2009, is entirely centered on a game-like learning concept, since an increasing number of teenagers spend many hours playing video games. Learners at this school spend most of their time learning by developing and playing games.

Some instructional games are designed for school usage, and the subjects they cover might be rather diverse. Skills Arena [45], which was created expressly for school usage, is an example of such a game. Abilities Arena is a game that teaches pupils math skills at various degrees of difficulty using the Nintendo Gameboy. Research involving primary school learners indicated that playing a technology-based game improved learners' math’s ability. Making History is also another case of educational serious games utilized in the school [46]. It was put to the test to see how beneficial it was in teaching high school pupils about WWII. That case study was done in a history lecture where the teacher utilized the game instead of standard learning techniques to cover this topic. Students became more participatory and interested in the learning experience as a consequence of the experiment [46]. Computer science lecturers can utilize another instructional serious game to teach programming language abilities to college pupils [47]. It's a cooperative strategy serious game aimed at assisting participants in overcoming the numerous challenges they confront when studying programming.

Other instructional games are more frequently utilized for self-study. An excellent example is the field of learning languages. Lost in the Middle Kingdom [48], for example, assists users in learning a new language. Roma Nova [49] is a game that uses haptic technology for teaching users regarding artefacts. It's a multimedia serious game that makes use of the Novint Falcon, an inexpensive off-the-shelf haptic system that lets participants to feel features of the 3D game world including texture and artefact forms. Some instructional serious game development efforts are also focused on the healthcare field. A serious training game was created for surgical residents with the goal of teaching and educating them on total knee replacement [50]. For added authenticity, the game incorporates a background sound recorded during an actual knee replacement operation. Data games, that helps to learn from and explore actual data, are also another form of educational serious games to explore. Foldit [51], a puzzle serious game which lets students to learn about proteins as well as participate in scientific research by folding proteins in novel methods, is an example of such an educational serious game.

b) Well-Being: Sedentary behavior is a known contributor to overweight, as well as a variety of chronic diseases including diabetes and cardiovascular diseases. Increasing physical exercise can help to prevent these issues. Serious games for well-being are designed to encourage users to engage in physical activity through exciting and engaging game play [38]. Chen et al. [52] investigated how players' intentions can influence how they gain from the workout game. They utilized a famous Xbox Kinect game and discovered that users who were prepared to be using the game mainly for health advantages and who obtained healthcare feedback during playing the game played the workout game for prolonged durations of time than those who were not.

Davis et al. [53] referred to another workout serious game which is Heartlands in which users walk around a zone of their choice while carrying a heart-rate wearable monitor as well as a Pocket computer with GPS. As the player walks around, a landscape appears on the screen of the Pocket compute. The image that results is a depiction of both the player's cardiovascular condition and his location. In Fish'n'Steps, another massively multiplayer online serious game, players have on a pedometer that records their steps every day. As a strategy to keep the players motivated, the game could be played both collaboratively and competitively. A study for fourteen weeks found out that p layers improved healthier daily exercise routines [54].

c) Advertisement: Advergames [55] are serious games intended for sales promotion that try to promote a certain product, service or brand to customers as they play the game. Business advergames include those sponsored by NFL, Pepsi, 7 Up, Burger King and Formula One [38]. Although serious games that are used by America's Army are primarily military training games, they also aim to increase recruiting for the US Army and hence could be classified as advertisement serious games [55]. In a controlled experiment of automotive racing games, Grace and Coyle [56] discovered that 35% of users can recall marketed brands, boosting advertising inside the game itself. For example, in the 2011 computer game FIFA, an Adidas banner appears in the forefront during the match, also the electronic board "Panasonic" is shown with every goal scored.

d) Cultural Heritage: Real-time interactive simulation of realistic virtual legacy settings, like reproductions of historical ruins and virtual exhibitions, is now possible because to advancements in gaming technology like smart phones or computers. While games for cultural legacy include some cultural teaching, they vary from other educational games in that they are designed to aid in the conservation and replication of artifacts. They additionally raise cultural knowledge and allow for item appreciation [38]. Storytelling and folktales are used in cultural presentations to teach players about heritage, beliefs, and societal values [38]. Nusran and Zin [57], for example, introduces the development and design of m- MyTale, a smartphone game based on classic Malaysian folktale like "The Princess of Mount Ledang" to encourage children's cultural and historical education. Another serious game introduced by Neto et al. [58] attempts to raise culture and heritage knowledge while visiting a museum. The name of this game is Solis Curse, and it is a game that employs multimedia interactions (video, audio, 3D images, and so forth) and provides a set of questions with increasing difficulty levels, with the player's result being tallied and compared to a universal ranking ladder.

e) Interpersonal Communication: In many facets of life, excellent communication skills are essential. People communicate constantly, and the effectiveness with which they communicate has a significant impact on their success, whether in their professional lives or in their personal relationships. In the research, there are a variety of cultural learning methods that make use of serious games. Furthermore, BiLAT (Advanced Learning Environments for Bilateral Discussions with new Technologies) is a serious gaming fully immersive platform that educates the management, implementing, and understanding bilateral meetings in a sociocultural context [59].

SimParc [60] is also another managerial game that facilitates interpersonal connections. It's a game version aimed at promoting biodiversity discussions and social involvement through multicultural participatory management of preserved fields. Lane et al. [61] introduced a smart teaching system that relies on face-to-face interactions among users and virtual avatars to educate cultural social norms. Another instructional serious game is StoreWorld [62], which educates learners business fundamentals and investigates how social communications might enhance simulation in business serious games.

f) Biomedical and Health Care: Laamarti [38] confined health-care implications to a definition that necessitates the absence of disease or harm. However, a more general definition comprises well-being implications that were investigated previously in this section. The primary objective of health-care serious games is to impart skill and/or information to users while also serving a medical function by mimicking a condition in order to minimize risk, hazard, and financial constraints. As a result, Laamarti [38] divided serious games for healthcare into four groups: (1) detection and treatment, (2) rehabilitation, (3) therapeutic education and prevention and lastly (4) health monitoring.

In the literature, there are various serious games for health monitoring. Finkelstein et al. [63] introduced the Home Automated Telemanagement (HAT) system which is used to assist patients suffering congestive heart failure (CHF) in monitoring the symptoms, weight fluctuations, and life quality while also educating the patients about the disease's features. The system operates on the Nintendo Wii and needs an Internet connection in order to function. Furthermore, serious game research and development for the identification and treatment of numerous health issues has increased dramatically in recent years [38]. 21 Tally is a set of 2D serious games that are used to recognize fragmented attention invisibly, utilizing a serious game that requires users to pay attention to many dimensions at the same time to succeed [59]. In addition, serious games for healthcare are beneficial in the areas of therapeutic teaching and avoidance. Therapeutic learning serious games could teach patients or those around them about treatment options for a given ailment. Elude, a game aimed for family or friends of people suffering from depression, is one example mentioned by Laamarti [38]. This serious game is aimed to educate them about the disease and let them to participate in the patient's rehabilitation. Furthermore, rehabilitation is one of the healthcare sectors where serious games may have a significant positive influence. According to the National Institute of Neurological Disorders and Stroke (NINDS), neurological dysfunction impact approximately 50 million persons in the United States each year [38]. Many people with these conditions require therapy in order to restore control of their motor abilities. The use of serious games for rehabilitation has been shown to be an effective way to overcome the loss of motivation caused by the repetition of exercises in conventional physical therapy [64].

2.4.4 Serious game for testing Business continuity

Recently, the awareness of the importance of using game-based simulations in the field of Business Continuity Management has increased. Game-based simulations can be used to educate learners on best practices in business continuity management in a quick, efficient, and cost-effective manner since these games placed learners in a scenario that are close to real life, so they are in an environment where it is safe to make mistakes and that aids in the learning process. In addition, Game-based simulations can be used to ensure that a Business Continuity Management is implemented successfully by assessing if the business continuity plans will perform as intended in a real circumstance since these games are the closest to actual execution. Furthermore, Game-based simulations can be used to test, and regular update business continuity plans to assure that they are effective and to guarantee that corporate activities do not come to a standstill in the event of unforeseen events.

In game-based simulations, the team is given a scenario and is instructed to follow the processes outlined in the business continuity plan and to allocate the resources to cope with the scenario. This sort of test should reveal any employees' concerns about their function and nature of their tasks, any resources that are missing or inadequate, and any omissions or mistakes in the business continuity plan. Because the major goal of testing is to assess the efficiency and identify limitations of the business continuity plans, it is critical to do a comprehensive debriefing after each test to interpret the results, including what went well, what did not, and any user concerns. Following that, the business continuity plans should be updated accordingly.

Serious games are frequently used in complicated situations for teaching objectives, such as to demonstrate or illustrate a situation, a problem, or a procedure. Nevertheless, just a few serious gaming applications for BCM could be identified: Serious games, in this regard, could provide a test environment for ensuring decent performance in disaster situations, which frequently necessitate dynamic judgments under time constraints. Responding quickly and effectively can help to limit fatalities and injuries, as well as avert subsequent disasters and financial losses [65], [66]. Therefore, some earlier crisis management games have been built on simulation models [67]. The "Serious Human Rescue Game (SHRG)" designed by Ruppel and Schatz [68] is an example of these crisis management games. The major goal of this game is to examine the influence of building state on the behavior of the human during the process of emergency evacuation. It uses simulation models to give a simulated environment for designing rescue experiments in burning buildings. Furthermore, the "DRILLSIM game" uses a multifactorial simulation to evaluate each part in a building emergency evacuation crisis response procedure [65]. As previously mentioned, simulation-based models can also be used to evaluate different crisis management scenarios in order to teach companies. According to Arturo et al. [5], the Flu Pandemic

Game is an example of training serious games which is produced by the UK Department of Health to assist employees, managers, and non-profit organizations in developing their own business continuity plans. Its major goal is to teach users about the effect of a potential flu pandemic on their company by mimicking the effects of the flu on the company.

Serious games for Business Continuity Management have been established in both the services and manufacturing sectors, since BCM is currently used in a variety of scenarios. The so-called "CODE RED: Triage!" produced by Wouters, van der Spek, and Oostendorp is an example of Serious games for Business Continuity Management in the service sector. This game attempts to prepare medicinal first responder emergency professionals to do a triage following a blast in the subway [5].

Arturo et al. [5] proposed a framework for building a manufacturing-specific Business Continuity Game (BCG). The goal is to give manufacturing executives with recommendations for creating their unique BCG to promote a successful BCM process. Initial assessment, game design, and game execution are the three key stages that make up the framework. A brief description of each stage will be presented.

a) Initial assessment process: Game designers, Arturo et al. [5], must first do a thorough examination of the present circumstances affecting the business from a BCM standpoint. The primary goal of this stage is to assess and disseminate knowledge of the firm's BCM process throughout the whole company. The total game complexity will differ depending on the sort of company. Arturo et al. [5] suggested tools which can support the designers of BCG in promoting this stage. These tools include: (1) Examining the organizational chart to ensure the existence of defined responsibilities and roles from a BCM perspective (business continuity manager, business continuity teams, or emergency response teams); (2) Conducting direct interviews and surveys with a sample of the entire staff; (3) Examining documents related to BCM, such as business continuity plans, emergency procedures, and so on. Furthermore, the following two tasks must be conducted, according to Arturo et al. [5], in order to emphasize the most essential activities for the businesses: 1. Creating a documented risk assessment which detects and assesses the potential for disruptive occurrences. 2. Performing a Business Impact Analysis in order to determine products, examine functions, and determine the consequences of a potential disruption on them.

b) BCG design process: The suggested Business Continuity Game is a role play in which each person portrays his or her actual function inside the organization while making choices in a fictitious context. Figure 4 shows the BCG design approach suggested by Arturo et al. [5]. The first step in the BCG design process proposed by Arturo et al. [5] is to identify the triggering events, including accidental and incidental ones that initiate the disaster: these events are excluded from the preceding risk assessment step. After defining the triggering events, game developers should calculate the effects of the accidents on the company's operation, as well as the suspension of business operations, because all operations are recovered. The SOLUTION CARDS procedure may be designed using the outcomes of this stage. During the crisis and recovery procedures, these cards indicate how each player contributes to the completion of their unique mission [5]. Then the game design method introduces escalation parameters. Escalation factors and random events are the two types of escalation parameters. The escalating factor might be used by the game developer to influence the level of criticality of the game: by providing a large number of escalating incidents, users are required to deal with increasingly severe situations (for example, production disruptions), raising the simulation game's criticality level.

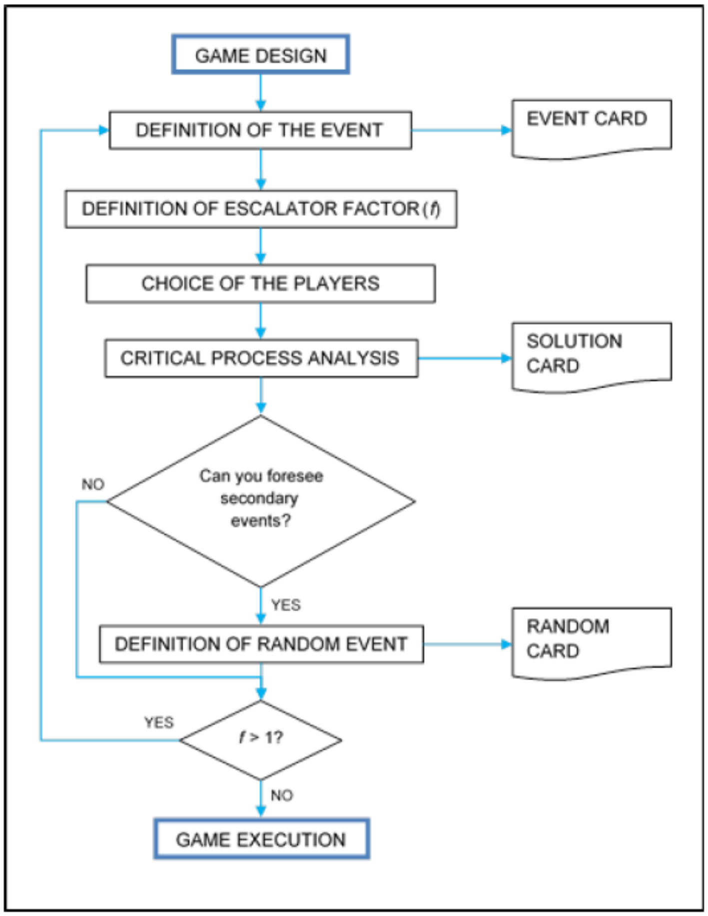


Figure 4 The proposed BCG design process [5]

c) Game execution: Arturo et al. [5] mentioned that a trial run, a pre-simulation step of the BCG that is not entirely functional, might be undertaken out to assess the BCG's initial practicality. The trial run must not be carried out by the same users who will be involved in the full-scale BCG implementation; instead, other users from different corporate sectors must be identified for this phase. Even during trial run, the game developer must keep an eye on things including: his or her own responsibility is to appropriately evaluate the results. If the trial run is deemed successful, the full-scale game might be eventually played. Alternatively, if the trial does not yield the desired outcomes, the game developer will have to make the appropriate modifications based on the input received. As a result, he or she must iterate on all aspects of the game designing process. After then, the game's implementation stage may begin. Eventually, after the completion of the game play, it would be beneficial to schedule a debriefing session for all participants to discuss their individual proposals and, more importantly, to make relative judgments about the firm's readiness to handle such unanticipated scenarios.

3. Study Methodology

3.1 Introduction

This chapter describes study methodology used to develop a pre-production of an educational serious game on coordinated Business Continuity Management in earthquake-prone area. The study methodology approaches considering the study objectives were using fictional case study as research choice and using the block diagram environment namely Simulink for modeling the case.

3.2 The fictional case study as research choice

There are two different kinds of case studies: factual case studies that reflect actual companies, people, and circumstances, and fictional case studies that are loosely based on real events, organizations and people but do not utilize real people's or organization's names [69]. According to Vira [70], fictive case studies based on organizations, situations and products are used typically as part of a course or training program to assist learners or trainees to better understand and contextualize certain concepts. Fictional case studies give learners insight into realistic scenarios in their field of study or work in sense that information from real cases from different sources were used to build these fictional case studies. As a result, these fictional case studies help learners develop the skills to deal with similar situations in the real life [70]. Since a case study is analytical in nature, it necessitates some investigation and research, even if it is fictitious. A detailed comprehension of the many aspects at play is required for the case study to be complete. This implies that most of the work involved in developing a case study is completed before the actual writing begins.

The study starts with building a fictional case study of three interdependent organizations located in the same area. The fictional case study is loosely based on real events, organizations and people, in order to have a realistic game, but do not utilize real people's or organization's names. The story investigates the case study of three organizations which were hit by an earthquake in an earthquake-prone area. These three organizations are a manufacturing company, which is central in the game, and two organizations providing services: an electricity provider and a logistics provider, which is a seaport. These organizations are interdependent as they exchange services along the same value chain and share similar risks since they are in the same geographical area. For building the case, the search keywords were defined first. Second, journal papers were collected using academic databases such as Emerald, IEEExplore, Metapress, ProQuest, ScienceDirect, Springer, and Wiley. No restrictions on the number of publications were placed on the list in order to ensure that every relevant study was included, regardless of the journal in which it was published. Fourth, a set of criteria was developed and applied to the articles in order to filter them.

The criteria are that the article has to include at least one organization in one of the following fields: auto-part manufacturing company, electricity provider, or logistics provider. Furthermore, the article has to include a case study of business disruption happen in one of the organizations due to a disaster. Paper abstracts were examined to see if they were relevant or not. The reference lists of the nominated articles were next scrutinized to ensure that no other relevant publications had been overlooked throughout the search. Then, the content of each article was evaluated to ensure that it fits within at least one of the focus subjects. Finally, using the collected information, a fictional case study about three organizations was built. During building the case, educated guesses were made in case of missing data to complete the case and provide all needed information to players, so they can better understand and contextualize certain concepts.

The fictive case should cover several points for each organization. First, each fictional organization should start with company description including general overview, main products/services, primary customers/stakeholders, main business functions, business process (including interdependencies between business functions), inputs to business functions (resources) and outputs, and existing resilience capabilities to mitigate impacts and support service continuity. Second, financial data for each case should be provided and that includes losses from business interruption, lost production/revenue, contractual penalties, regulatory fines, loss of customers and suppliers (reputational impact). Third, threat description, which is earthquake in this study, should be covered by each case study. Furthermore, each organization description has to cover vulnerability estimate based on magnitude and that includes damage to assets facilities, buildings, machinery, equipment, etc. In addition, each organization description should cover several proposed recovery strategies with their implementation and deployment costs.

3.3 Simulink Modeling

After building and completing the fictional case and covering all the determined information, and before developing the educational serious game, a Simulink model is needed to model external interdependencies between the three companies, in addition to internal interdependencies between business functions within manufacturing company. The model is also used to model the application of recovery strategies within manufacturing organization to investigate their impact on the performance of all business functions of the company with time. In this study, a Simulink model will be created to model internal interdependencies between business functions within manufacturing company in addition to external interdependencies between manufacturing company and both electricity provider and logistics provider. The created model will also be used to model the application of recovery strategies within manufacturing company.

Manufacturing organization can be modeled as a set of business functions with several internal interdependencies between them. These business functions are modeled on Simulink as blocks and the interdependencies, either physical, cyber or logical, are represented as arrows that link some of these business functions, within the manufacturing organization, together. Similarly, external interdependencies between manufacturing company and both electricity provider and logistics provider will be modeled as arrows connecting between different business functions (blocks) across different companies.

Simulink [71] is a commonly utilized tool for modeling dynamic systems, However, it is rarely utilized to simulate business processes. Simulink is capable of simulating any dynamic system that is built by users. Stateflow is an add-on tool in Simulink, and it is a graphical design tool, which it is used for modeling and simulating event-driven systems, often known as reactive systems. Event-driven systems are those that can switch from one state to another in response to certain events or situations. Stateflow allows hierarchical representation, which makes it easier and more effective to visualize more complicated systems. When an event is called, a Stateflow takes actions related with transitions and states. Stateflow diagrams or external sources, such as a Simulink model, can be used to produce events. Stateflow comes with all of the essential scheduling rules, which are more than enough to handle any indeterministic situation. The execution order of parallel states, for example, and the selection of a state's valid outbound transitions are always statically known. States and Transitions are the two fundamental components of a Stateflow model. A state in a Stateflow diagram denotes a mode. There are two types of states: active and inactive. A state's activity status can be adjusted dynamically in response to events and situations. There are five different sorts of acts that a state can do, which are: Entry actions, During actions, Exit actions, On event name actions, and Bind: events and data. Furthermore, a transition is the change from one state to another in a Stateflow diagram. A transition has a full label that includes a transition action, an event, a condition action, and a condition, in the following general structure.

4. General game flow and the case study

4.1 Introduction

The first step in designing the educational serious game is to set the general game flow and identify which data will be given to the user and which data and decisions will be provided by the user. Each player or group of players will be the business continuity manager or business continuity team of manufacturing company. Players face a series of choices to define the key business continuity planning strategies and parameters. These choices impact the performance in an earthquake scenario, and players are evaluated based on these outcomes. The simulation will calculate the financial performance, as the sum of losses from business disruption of lower-level performance, BCP setup costs, and BCP deployment costs.

For the purpose of developing the educational serious game on coordinated Business Continuity Management, one fictional case study for three interdependent organizations were built and used to base the game on. This fictional case study is loosely based on real events, organizations and people, in order to have a realistic game, but do not utilize real people's or organization's names. The story investigates the case study of three organizations which were hit by an earthquake in an earthquake-prone area. These three organizations are a manufacturing company, which is central in the game, and two organizations providing services: an electricity provider and a logistics provider, which is a seaport. These organizations are interdependent as they exchange services along the same value chain and share similar risks since they are in the same geographical area. Each fictive organization should cover several points. First, it should start with company description including general overview, main products/services, primary customers/stakeholders, main business functions, business process (including interdependencies between business functions), inputs to business functions (resources) and outputs, and existing resilience capabilities to mitigate impacts and support service continuity. Second, financial data for each case should be provided and that includes losses from business interruption, lost production/revenue, contractual penalties, regulatory fines, loss of customers and suppliers (reputational impact). Third, threat description, which is earthquake in this study, should be covered by each organization description. Furthermore, each organization has to cover vulnerability estimate based on magnitude and that includes damage to assets facilities, buildings, machinery, equipment, etc. In addition, it should cover several proposed recovery strategies with their implementation and deployment costs.

This chapter will present the general game flow and will present comprehensively the description of the manufacturing organizations, as well as descriptions for both external providers that manufacturing company relies on, which are an electricity provider and a logistics provider.

4.2 General game flow

As shown in Figure 5, the game starts with game instructions which will explain briefly the objectives and the sequence of the game, and what are the expected outcomes of the game. Then the next screen is the manufacturing company title screen. From that stage, the student or group of students will be the business continuity team of the manufacturing company. Then the next stage is a description of the manufacturing company, and this description will include the general overview of the company, main products or services provided by the company, primary customers or stakeholders of the company, main business functions, business process, internal interdependencies between business functions within the company, external interdependencies between company and external organizations, resources of business functions, and existing resilience capabilities to mitigate impacts and support service continuity. Then, company’s financial data will be provided to the BCM team, and this data include the losses from business interruption which includes lost revenue, contractual penalties, regulatory fines, and reputational impact which leads to losing customers and suppliers. After that, the team will be required to estimate the financial impact of the corresponding company, determine which are the critical assets and functions in the company, and define the recovery objectives for each business function in the company. The recovery objectives namely are Maximum Tolerable Period of Disruption (MTPD), Recovery Time Objectives (RTO), and Recovery Level Objective (RLO). Then, a description of the threat which is an earthquake will be provided to the team in the next step. Furthermore, vulnerability estimate for the company will be provided by the game to the team. The next stage of the game is the risk evaluation for each business function in the manufacturing company. In this stage, the team will receive automated inputs and recovery parameters from the other two external organizations which are electricity and logistics providers. These inputs must be considered when deciding on the manufacturing company coordinated BCP due to interdependency between the three organizations. The recovery parameters of the external providers include MTPD, RTO and RLO of the other two external providers. By doing so, manufacturing company will be informed with the recovery objectives of the external suppliers that it relies on, so the company can evaluate the risk of all business functions and take actions accordingly. Then, manufacturing company has to manage the risk of every business function by either accepting, reducing or transferring the risk for each business function within the company. If a team chooses to transfer the risk of a business function, they can insure the business disruption of this business function with an insurance cost. However, if a team chooses to reduce the risk, suggested recovery strategies will be provided to the BCM team to choose from. For each strategy, a strategy description, implementation cost, and deployment cost should be provided to the player. The next step is to perform an earthquake scenario simulation in the area and investigate the performance of each organization just after an earthquake. Finally, the game will show the results of the scenario simulation for the organization. The result includes and business functions performances in manufacturing company.

In the next iteration of this game, which is not included in this study, Cosmetecor technology for early detection of earthquakes will be used to improve the coordinated BCM between the three organizations for the earthquake scenario. The technology may provide information about upcoming earthquakes like the timing, location and severity of the earthquake, so that players will have an opportunity to adjust their coordinated business continuity plans accordingly and be prepared for the earthquake. Then, players could evaluate how this technology can improve the entire risk management and business continuity management processes.

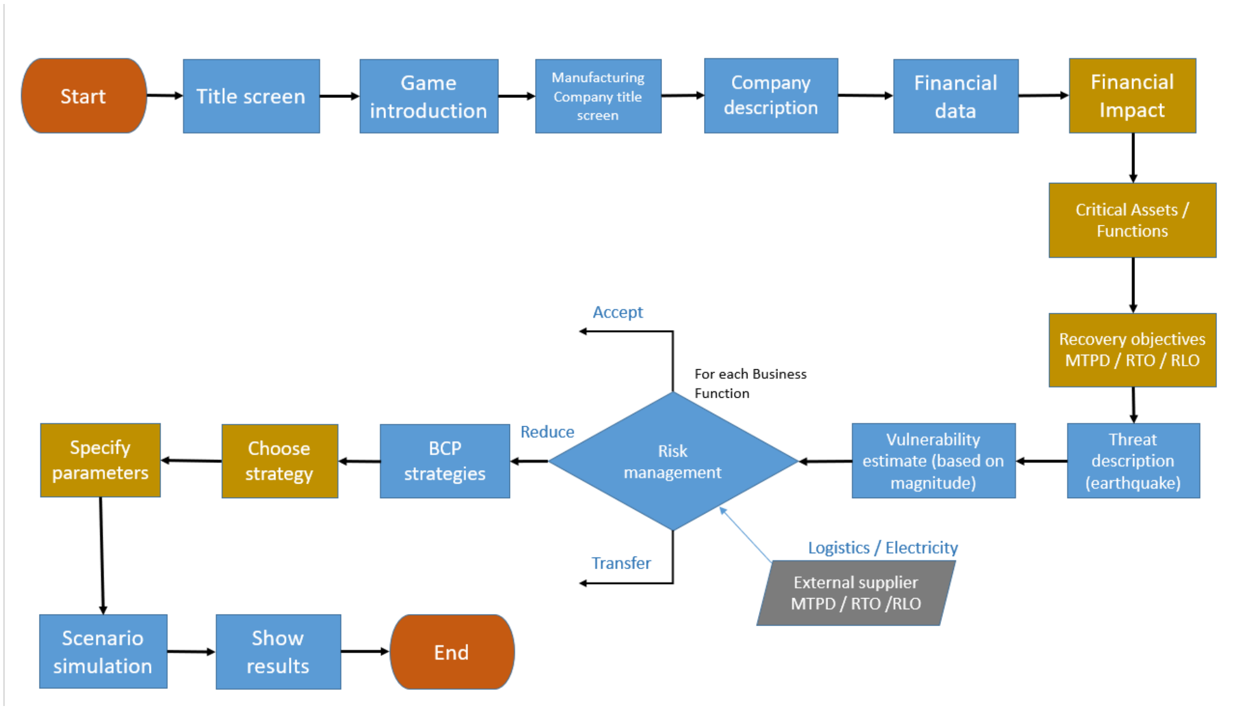


Figure 5 General game flow

4.3 Manufacturing company

The following part of the fictive case study serves as a case to base the educational serious game on, and it describes an auto-parts manufacturing company in central Italy. Source [72] has been utilized to help in building this case study.

4.3.1 Overview

Carware is an auto-parts manufacturing company which has 120 employees who work out of a single location in a light industrial area in central Italy. They manufacture and sell casted and machined aluminum auto-parts. The customers call in orders regularly. They also run a website that has seen sales grow significantly, so that Web sales are now equal to a quarter of total sales. Carware makes about €300 million a year in sales, about quarter of that online. As shown in Figure 6, Carware consists of three main facilities. The main one is a large space comprised mostly of manufacturing space and some office space. In addition, another facility which is the Warehouses in which there are four physical stocks which are Raw Material stock, Finished Products stock, Internal Parts stock and External Parts stock. The third facility is the Logistics Center, which is responsible for assembly, loading and unloading processes. They ship and receive packages daily for Web operations and they ship weekly for their non-Web customer orders.

The manufacturing plant in Carware operates on two 8-hour shifts, 7 days per week schedule, for 300 operating days per year. The warehouse can stock raw materials for a maximum 20 days of manufacturing without restocking, and the level of raw materials stock is decided on by the company. Furthermore, the warehouse space can stock 10 days of internal produced parts, and this can be used either as a buffer for assembly, or as an available storage space for manufactured parts if assembly or shipping is disrupted. In addition, the warehouse space can stock 10 days of imported external parts, and this can be used either as a buffer for assembly, or as an available storage space for shipping parts if assembly is disrupted. Finally, the warehouse space can stock 10 days of Finished products after assembly, and this can be used either as a buffer for shipping, or as an available storage space for assembly parts if shipping is disrupted. Stocking level is one of the strategic decisions that is decided by the company.

Another main process of Carware is the assembly process which operates on two 8-hour shifts, 6 days a week schedule, for 220 operating days a year. Carware uses Assemble-to-order (ATO) manufacturing strategy where products are assembled from components only once an order has been made. As a result, products are assembled quickly and are customizable to a certain extent. The basic parts of the product are already manufactured end imported but not assembled before an order. The time to assemble a product from components is negligible compared to the time required to produce the parts and sub-components, assembly takes place within the same day of the order. Moreover, Carware stocks up sub-assembly parts and inventories and assembles the parts into the final product when a customer places an order. The strategy of Carware relies on the ability of the company to assemble and deliver goods quickly. The aim of this case study is to create a BCP based on an earthquake scenario that assumes that the Carware and its service providers are disrupted due to an earthquake. The overall impacts on Careware are loss of revenues, repairing cost, reputation and market share.

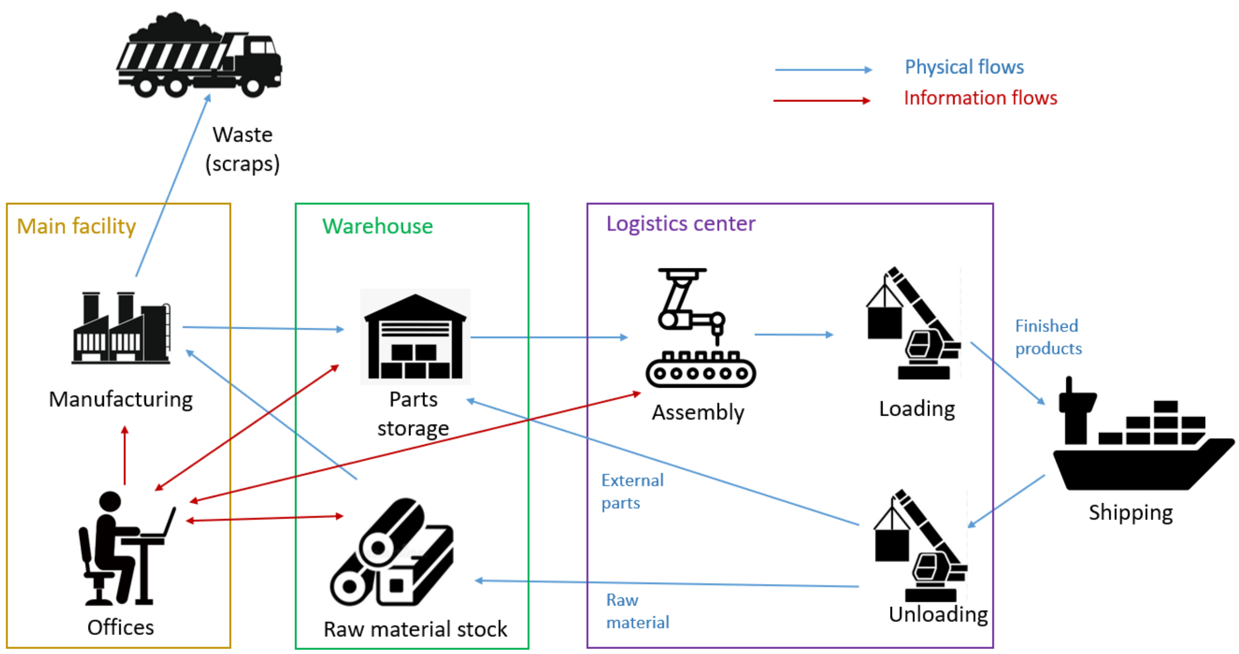


Figure 6 Carware operation process

4.3.2 Organization's Business Functions and resources:

The following business functions are the ones that the company cannot function for long without these functions. If one of these business functions is unavailable, the company may face significant legal, financial, penalties, or other losses. The business functions of Carware are:

1. Manufacturing: manages and controls all functions related to the productivity processes of Carware that produce the aluminum auto-parts.

2. Assembly: manages and controls all functions related to the assembly processes of finished products for delivery.

3. Marketing and Sales: covers promotion, selling, customer relation management, product management, marketing information management, pricing, financing and distribution.

4. Administration (Legal / Finance / HR): provides logistical assistance to the entire organization, human resources, takes care of the finance and rules/regulations related to legal aspects, security and safety management, asset management.

5. IT Systems: responsible for the architecture, hardware, software and networking of computers in the company. It covers installation and maintenance of computer network systems within Carware.

In addition, table 1 shows the resources including people, premises, equipment and providers for each business function of the Carware. Furthermore, table 2 shows the resilience and robustness of each business function in Careware to investigate the ability of the company to absorb disruptive events and retain operational integrity.

Table 1 Resources of the Carware business functions

Business functions	People	Premises	Equipment	Providers
Manufacturing	25	Manufacturing space (inside the main facility)	Production machinery Electricity Water Raw materials	Electricity (external provider) Maintenance (external provider)
Assembly	20	Logistics center	Assembly machinery Electricity	Electricity (external provider)
Marketing and Sales	20	Office space (inside the main facility)	IT equipment (hardware + software) Electricity Connectivity (Internet, Phone)	Electricity (external provider)
Administration (Legal / Finance / HR)	12	Office space (inside the main facility)	IT equipment (hardware + software) Electricity Connectivity (Internet, Phone)	Electricity (external provider)
IT Systems	8	Office space (inside the main facility)	IT equipment (hardware + software) Electricity Connectivity (Internet, Phone)	Electricity (external provider)

Table 2 Resilience (robustness) of business functions

Business functions	People	Premises	Equipment	Providers
Manufacturing	Minimum Staff: 10	No alternative facility	No backup electricity or reserve equipment	There are alternative raw material suppliers No alternative for logistics provider
Assembly	Minimum Staff: 10	No alternative facility	No backup electricity or reserve equipment	No alternative parts supplier No alternative for logistics provider of parts
Marketing and Sales	Minimum Staff: 5	No alternative facility	Electricity backup generator	No alternative electricity provider
Administration (Legal / Finance / HR)	Minimum Staff: 3	Administrative staff can work from home	Electricity backup generator	No alternative electricity provider
IT Systems	Minimum Staff: 2	No alternative facility	Electricity backup generator	No alternative electricity provider

4.3.3 Interdependencies

Internal **i**nterdependency can be defined as a linkage or connection between two business functions within an organization where the state of each business function influences the other. Whereas external **i**nterdependency can be defined as a linkage or connection between two organizations where the state of each organization influences the other.

Table 3 shows the internal interdependencies between business functions of Carware as well as the external interdependencies between Carware and other organizations. As shown in the table, losing some business functions or external provider can have an instant impact in some cases, and in other cases the impact will take some time to happen.

Table 3 Internal and external interdependencies for Carware

		1. Manufacturing	2. Assembly	3. Marketing and Sales	4. Administration (Legal / Finance / HR)	7. IT System
Internal	1. Manufacturing		1-20 days			
	2. Assembly	1-10 days				
	3. Marketing and Sales		32d			
	4. Administration (Legal / Finance / HR)					
	5. IT system	instant	instant	instant	instant	
External	Electricity supply	instant	instant	1d	1d	1d
	Maintenance	30 days				
	Inbound logistics – Raw materials delivery	1-20 days				
	Inbound logistics – External parts delivery		1-10 days			
	Outbound Logistics – finished products shipment (delivery)			1 day online / 7 days offline sales		

4.3.4 Physical flow and Information flow Diagram

Figure 7 shows the physical and informational flows between all business functions within Carware, and also shows the external flows that are necessary for Carware to function. Blue blocks represent the business functions of Carware which are Manufacturing, Assembly, Marketing and Sales, Administration and IT system. Furthermore, green blocks represent logical and physical stocks of Carware, and they are Orders stock, Raw material stock, Internal parts stock, External parts stock, and Finished products stock. Whereas the brown blocks represent the external services needed by Carware in order to operate and these services are provided by external providers.

Carware, and with the help of an external logistics provider, delivers raw material which used by manufacturing department, as well as the external parts used by assembly department. Furthermore, the provider also delivers finished products to customers. Raw material and imported parts are stored in raw material stock and external parts respectively. Whereas finished products are stored in finish products stock.

Manufacturing business function will receive inputs internally and externally. External inputs of manufacturing are electricity from an electricity provider, and maintenance from external service provider. However, internal inputs of manufacturing are from IT system, administration and raw material stock. The output of manufacturing will be stored in internal parts stock to be used later by assembly department. Assembly business function will receive inputs internally and externally. External input to assembly is electricity from an electricity provider. However, internal inputs to assembly are from administration, orders stock, internal parts stock, and external parts stock. The output of assembly will be stored in finished products stock to be shipped later through an external logistics provider. In addition, marketing and sales business function will receive external and internal inputs. External input of marketing and sales is electricity from an electricity provider. However, internal inputs of marketing and sales are from administration and IT system departments. The output of marketing and sales will be stored logically in orders stock to be used later by assembly department.

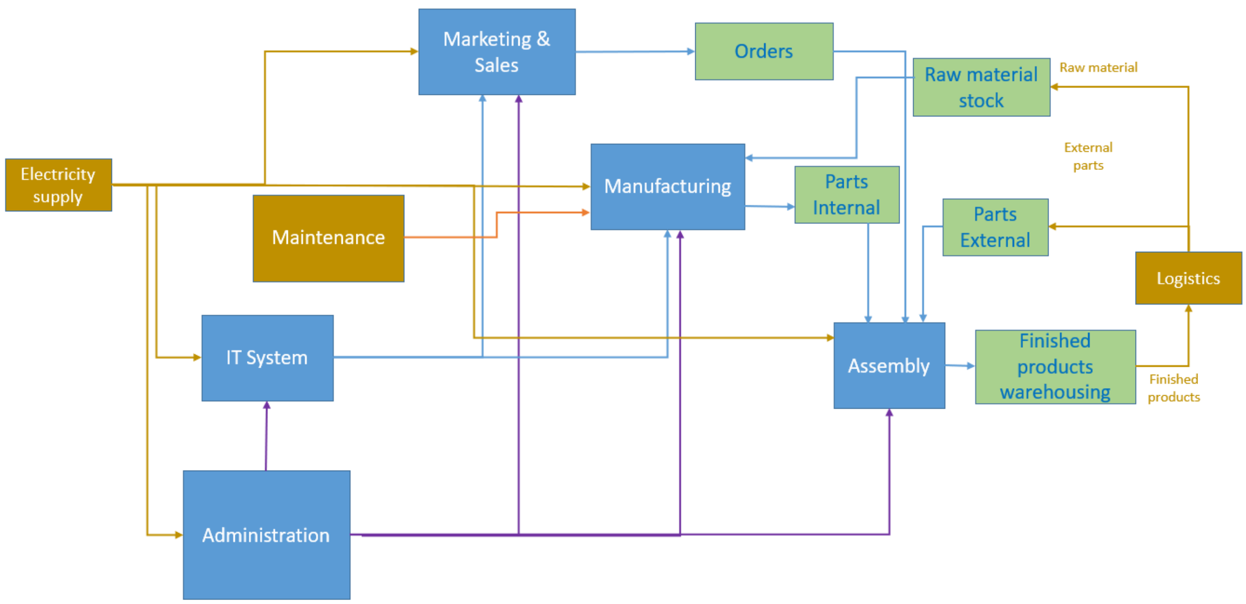


Figure 7 Physical flow and Information flow Diagram of Carware

4.3.5 Risk of earthquake

Risk sources which have a significant influence on Carware manufacturing company in central Italy district are fire, accident, terrorism and natural catastrophes which include storm, flood and earthquake. Even though these disasters are unlikely to occur, if they do, the consequences will be catastrophic. This case study will focus on the risk of an earthquake in the Carware area.

Figure 8 shows the modified Mercalli intensity scale of earthquake severity. An earthquake's intensity is a number that describes the strength of ground movement at a certain area by taking into account the impacts of the movement on humans, built structures, and the landscape [73]. The Modified Mercalli Intensity Scale has been used to measure intensity for decades. The scale contains parameters that allow a seismologist to assign a numerical value to the strength of ground movement in a region or portion of a region [73]. Since its inception in 1931, the MM scale has demonstrated that some criteria are more accurate than others as indicators of the amount of ground shaking [73]. The main scales levels of modified Mercalli intensity scale of earthquake severity and their effects descriptions are as follows [74]:

- **Intensity weak to light (M4-5):** felt by many indoors. No structural damage.
- **Intensity moderate (M5-6):** moderate damage. Cracks in many walls, fall of large pieces of plaster. Heavy furniture moves. Chimneys are damaged.
- **Intensity strong (M6-7):** substantial damage. Large cracks in the walls. Little damage to seismic resistant building. Severe damage to non-resistant structures.
- **Intensity major (M7-8):** serious damage. Serious cracks, partial collapses, most frame structures and their foundations destroyed. Landslides.
- **Intensity great (M8+):** complete collapse. Notable collapses affecting more than 50% of the structure. Wide cracks in ground.

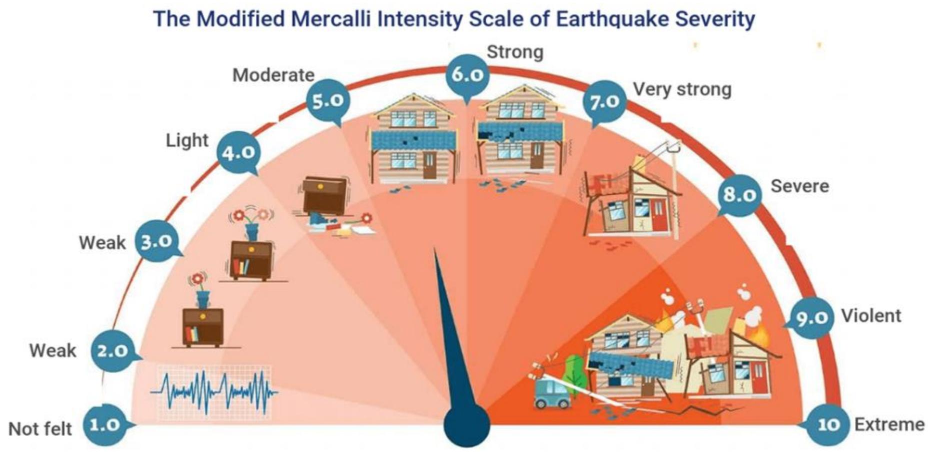


Figure 8 Modified Mercalli intensity scale of earthquake severity

Based on modified Mercalli intensity scale of earthquake severity, the earthquake vulnerability estimates of Carware are as follows:

Strength 5- : The manufacturing and assembly process would be stopped for a short time to assess the situation. No major physical damage/injury or life loss and all the processes can be restarted immediately after an earthquake.

Strength 5-6: The manufacturing and assembly processes would be moderately disrupted. The inventory in the warehouse (finished products) wouldn't be damaged and the ability to process inventory could be maintained. The factory is unaffected, and its networks' dependency is not critical. The office area and computer systems wouldn't be damaged or destroyed if furniture and its content are secured (brace to floor, secure to wall, latch to the desk).

Strength 6-7: The manufacturing and assembly processes would be substantially disrupted. Damage to the finished products and parts stocks (around 10% of lost inventory) if the storage is with unanchored roof system, or soft story construction or other building irregularities with unreinforced or unanchored brick elements in building structure or façade. Possible leakage of fluid in flanged joints. No release of the hazardous materials. No critical damage on large scale machinery, underground equipment and lifeline systems.

Strength 7-8: The manufacturing and assembly processes would be seriously disrupted. Destructive damage on industrial area. The manufacturing equipment would be seriously damaged. Breakage and pulling out of anchored structures. Damage to tanks, reservoirs, and numerous breaks in water pipelines which need to be repaired and would take 14 days. Networks' dependency is critical: damage on power stations, long-term stoppage of power and gas supply, damage on lifeline systems. Possible leakage of hazardous material. Blocked access routes due to landslides. Partial collapse of frame structures. The buildings would have to be inspected, approved for use and repaired. Damage to the finished products and parts stocks (around 50% of lost inventory).

Strength 8+: The factory is heavily affected, and its networks' dependency is the most critical. Notable collapses affecting more than 50% of the structures on industrial area. Denial access to the area due to destruction, inclination of structures, or flooding due to ground liquefaction. The manufacturing and assembly processes would be disrupted in long-term. Up to 80% of the parts stocks and finished products would be lost.

4.2.6 Impact of the disruption due to earthquake

There are several impacts of business disruption in Carware due to an earthquake. One of these impacts is loss of sales, either contracts, orders or online orders. Loss of sales comes from the opportunities missed, orders not taken or contracts that cannot be signed. Quarter of the sales is made online, and these cannot be recovered. Whereas Half of the sales are contractual partners with remaining contracts durations averaging 60 days. The remaining quarter are other offline sales where orders are taken for the following week, assembled and shipped weekly

Another impact is the contractual penalties. Contractual penalties happen in the case if the production or delivery is delayed. Knowing that half of the sales are contractual partners. According to service level agreement between the company and customers, contractual penalties are calculated as follows:

- If the production or delivery is delayed over 15 days, contractual penalties will equal 10% of the order value.
- If the production or delivery is delayed over 60 days, contractual penalties will equal 50% of the order value.
- If the production or delivery is delayed over 90 days, contractual penalties will equal 80% of the order value.

Another impact of an earthquake on the Carware is the uninsured loss of tangible assets including facilities, buildings, machinery, equipment and software. In addition, reduction in staff productivity is another impact of earthquake. It caused when manual workarounds and procedures are used instead due to damage caused by earthquake, or when staff is working from home. As a result, reduction in productivity by 30% would take place.

In case Marketing & Sales are disrupted for more than 45 days, it would cause a reduction in offline orders by 30% for every 45 days, and that will affect the competitiveness and market share of Carware. Moreover, the reputation of Carware would be damaged if the production or delivery is delayed for over 60 days, and as a result it would reduce overall sales by one third. As a result, Carware will lose some customers and clients due to the damaged reputation since some of its customers are working on tight timelines, and they will not wait for a delayed order from Carware, they will look elsewhere for these products. Also, there are other companies that are waiting for Carware to falter so they can swoop in and possess Carware's customers. In addition, if business (manufacturing, assembly or marketing) is disrupted for over 30 days, Carware will lose 15% of annual growth due to new ventures held up, delayed new products, and delayed entry into new markets.

Table 4 summarizes the impacts of losing Carware's business functions and the time needed for each impact to appear after losing each business function.

Table 4 The impacts of losing Carware's business functions

Business Process/Function	Reputation (Customer / Investor perception)	Legal Issues / Regulatory Impact	Competitive position	Market share	Contractual penalties	Impact on Employees
Manufacturing	60 days			45 days	15 days	
Assembly	60 days			45 days	15 days	
Marketing and Sales	7 days		30 days			
Administration (Legal / Finance / HR)		30 days				1 day
IT system	7 days			15 days		

4.3.7 Recovery strategy options

There are multiple recovery strategies options for recovery the business disruption in Carware after an earthquake. One of these strategies is to increase the stocking capacity of Finished Products. Carware could increase the levels of stocking of the finished goods to make sure it can satisfy the orders for longer periods, gaining more time to restart and recover the production. However, this would incur the costs of an additional warehouse. The estimated cost is 600,000 euro per 100 m^2 and this area is equivalent to one day of production at full capacity. Another recovery strategy is increasing the stocking capacity of one or more of the other stocks which include Raw Material stock, Internal Parts stock, and Internal Parts stock. Carware could increase the levels of stocking of the raw materials to make sure it can sustain production for longer periods, when the delivery of raw material by inbound logistics is disrupted. This would incur the costs of an additional warehouse that amounts to 200,000 euro per 100 m^2 and this area is equivalent to one day of raw materials supply. Furthermore, Carware could increase the levels of stocking of internal parts to make sure it can maintain assembly for longer periods, when manufacturing is disrupted. This would incur the costs of an additional warehouse that amounts to 500,000 euro per 100 m^2 and this area is equivalent to one day of internal parts used by assembly at the full capacity. In addition, Carware could increase the levels of stocking of external parts to make sure it can maintain assembly for longer periods, when the inbound logistics are disrupted. This would incur the costs of an additional 500,000 euro per 100 m^2 and this area is equivalent to one day of external parts used by assembly at the full capacity. However, the maximum available space for these strategies is 4000m^2.

Another recovery strategy is factory's partial transfer. Carware could split into two locations, and they should be far enough not to be impacted by the same earthquake. Then, Carware could run production activities in parallel. As a result, in the event of disruption at one location, the activities can continue at the alternate location. In that case, Carware will be operating at 50% of the full production capacity. However, setting up a new location and the partial transfer would cost 15 million euro.

Backup equipment is another recovery strategy in which Carware could duplicate the equipment which are used in machining and assembly processes, which are vulnerable to earthquakes, and keep it ready in a remote location. Then in case of distortion of current equipment because of an earthquake, the backup equipment can be delivered to the location of Carware and installed, so the production process can be restored in few days. However, this would incur the costs of additional duplicated equipment which costs five million euro to duplicate the Manufacturing equipment, and three million euro to duplicate the Assembly equipment. Backup Manufacturing equipment can be delivered in 2 days by train, or 5 days by trucks, and the manufacturing process can be restored 3 days later. And Backup Assembly equipment can be delivered in 2 days by train, or 7 days by trucks, and the assembly process can be restored 3 days later.

One of the recovery strategies is alternative shipping. Alternative modes of transportation can be used to deliver raw materials and external parts to Carware, and to ship finished products from Carware. Road and off-road transport are examples of alternative modes of transportation that can be used by Carware rather than sea freight. Furthermore, rail freight is an alternative mode of transportation that can be used to deliver raw materials and external parts, and to ship finished products rather than sea freight. An alternative mode of inbound transport, with maximum of 16 trucks combined, is as follows:

- The delivery of raw materials by road transport which costs 10,000 euro daily for each truck. It covers 10% of the original raw material logistics capacity.
- The delivery of external parts by road transport which costs 20,000 euro daily for each truck. It covers 7% of the original external parts logistics capacity.

Whereas, an alternative mode of outbound transport, which uses the same number of trucks used for inbound transport, is as follows:

- The shipment of finished products by road transport which costs 40,000 euro daily for each truck. It covers 5% of the original finished products shipping capacity.

Another recovery strategy is alternative (or emergency) maintenance provider in which Carware could deal with another maintenance provider for emergency cases, that is located far enough not to be impacted by the same earthquake. By doing so, Carware will be able to reduce the downtime of the maintenance after an earthquake, which will help the company to recover its performance faster.

4.4 Electricity provider

In the first version of the game, the following part of the fictive case study will be used to provide automated inputs (as recovery parameters) that must be considered when deciding on the manufacturing company coordinated BCP, due to the interdependencies. At this point, this part of the fictive case study contains only simplified descriptions and might be further developed into a full game choice in the future. The following part of the fictive case study describes an electricity provider in central Italy. Sources [14], [75] and [76] have been utilized to help in building this case study.

4.4.1 Overview

The Italian Regulatory Authority for Energy, Networks and Environment (ARERA) carries out regulatory and supervisory activities in several sectors, electricity is one of these sectors. ARERA regulates the generation, transmission, and distribution of energy in central Italy. Two major state-owned utilities dominate the market: Electricity Generating Authority (EGA), and Electricity Authority (EA).

The Electricity Generating Authority (EGA) is a government-owned organization that reports to the Ministry of Energy. It owns and operates power plants all throughout Italy, with a total installed capacity of 20,035 megawatts (MW) in 2020. The EGA acquires electricity from independent power producers (IPPs) and small power producers in addition to generating its own (SPPs). In 2020, IPPs and SPPs had 18,949 MW and 16,540 MW of installed capacity, respectively. The responsibilities of the EGA are: Electric power generation, operation, and transmission across the country; engaging in energy-related services businesses and expanding business and investment in electricity and other energy-related businesses; and selling electricity and related services to the EA, a number of direct consumers mandated by law, and neighboring countries.

The Electricity Authority (EA) is a state-owned utility in central Italy. The organization responsibility is to distribute electric power to the customers in central Italy covering 3,192 sq.km. Electricity Authority gets high-voltage electricity from the Italian Electricity Generating Authority, which is then reduced to low-voltage at distribution substations and supplied to users. Electricity energy sales bring in around € 400 million per year for EA. As shown in Figure 9, the Electricity Authority gets power at high voltages of 230 kV, 115 kV, and 69 kV buses of terminal stations from the Italian Electricity Generating Authority (EGA). At distribution substations, the voltages are decreased to 24 kV or 12 kV before being delivered to medium-voltage consumers and distribution transformers. Low-voltage users receive 416/240 V power via distribution transformers. The EGA is the primary buyer of bulk power, selling to the EA, as well as a handful of regulated direct customers and adjacent nations. The EA also purchases electricity directly from small and independent power providers.

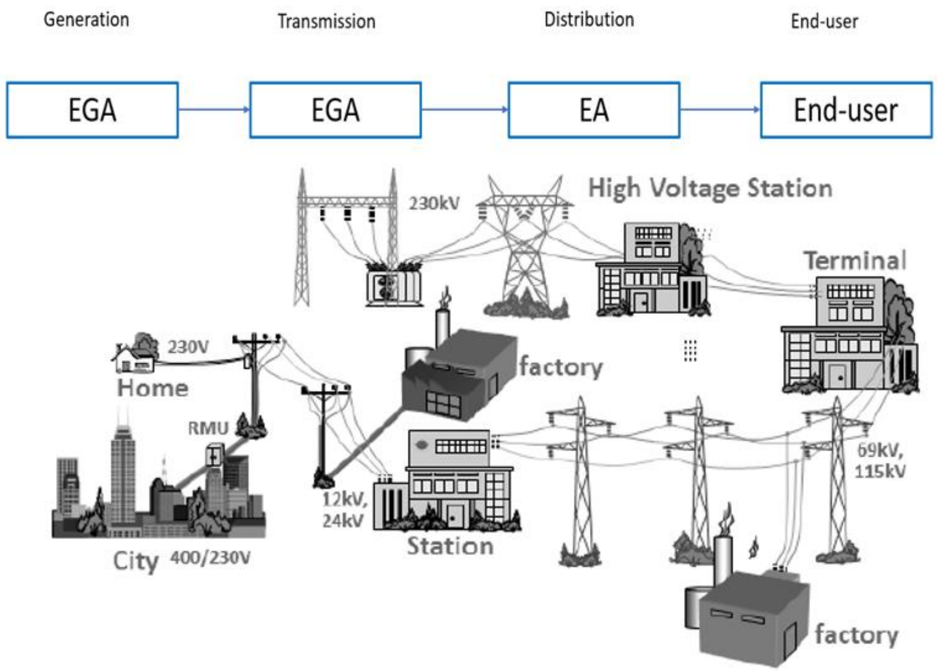


Figure 9 Power System of Electricity Authority [72]

The customers of the Electricity Authority are grouped into four groups. Group 1 includes 13 hospitals, group 2 includes 10 sites of public administrations, group 3 includes 13 pump stations for water and wastewater management, and group 4 includes industrial production site with 50 small and medium enterprises.

The aim of this case study is to create a BCP based on a scenario that assumes that the Electricity Authority in central Italy is widely destroyed. Major risks that face the Electricity Authority in central Italy may include risk of an earthquake in the area, risk of a storm in the area, risk of fire in the buildings, risk of terrorist (Bomb) in the area, and risk of an accident in the area. However, this case study will focus on the risk of an earthquake in the Electricity Authority area. In case of an earthquake, the power distribution system would be destroyed, and this will lead to a loss of power distribution system in central Italy. As a result, Electricity Authority cannot provide electricity for customers in central Italy.
The overall impacts on Electricity Authority, Customer and Nation are:
Electricity Authority: Loss of revenues, repairing cost, and reputation.
Customer: Loss of business operation and opportunity.
Nation: Deflation and Chaos.

4.4.2 Organization's Business Functions and resources:

The following business functions are the ones that the company cannot function for long without these functions. If one of these business functions is unavailable, the company may face significant legal, financial, or other losses or penalties. The business functions of the Electricity Authority are:

1. Power System Operation and Control: provide electricity for customers 24 hours, and control power distribution system using SCADA/EMS/DMS System.

2. Maintenance System: maintain the power distribution system, and repair or recover the power distribution system when a disruption happens.

3. Store Section: support equipment, tool, fuel and backup generators.

4. Fleet Management: support and supply vehicles, support maintenance to vehicles and supply drivers.

5. Public Relations and Customer Relations Department: communicate both internal and external organizations and receive and transmit information to customers.

In order to assign criticality scale for each business function, the recovery priority will be used for the criticality estimate as follows:

- The highest priority: Mission Critical Services.
- Essential Services: Vital.
- Necessary Services: Important.
- Desirable Services: Minor.

By using this criterion, table 5 shows the criticality scale for each business function in Electricity Authority.

Table 5 Criticality scale for the Electricity Authority business functions

Business Function	**Criticality**
Power System Operation and Control	Mission critical
Maintenance System	Vital
Store Section	Important
Fleet Management	Minor
Public Relations and Customer Relations Department	Important

Table 6 shows the resources including people, premises, equipment and providers for each business function of the Electricity Authority.

Table 6 Resources of the Electricity Authority business functions

Business functions	People	Premises	Equipment	Providers
Power System Operation and Control	12	Power System Management and Operation Division (POD) in Power System Control Department (PCD).	IT equipment and SCADA/EMS/DMS System (hardware + software) Connectivity (Internet, Phone)	SCADA/EMS/DMS System (External provider) Generated Electricity (external provider)
Maintenance System	59	Distribution System Service Division (DSD).	15 Poles. 40 Low/ High Voltage Accessories. 12 Transformers.	Store section (Internal provider)
Store Section	5	Distribution System Service Division (DSD).	IT equipment (hardware + software)	Provider of tools and Equipment (external provider)
Fleet Management	24	Distribution System Service Division (DSD). Office space (inside the main facility)	3 Hydra Lifts 35 Trucks 2 Cranes 1 Trailer	Truck supply and maintenance provider (external provider)
Public Relations and Customer Relations Department	13	Office space (inside the main facility)	Connectivity (Internet, Phone) 1 Public Relations Car	Internet and Phone (External provider)

4.4.3 Interdependencies:

Internal **i**nterdependency can be defined as a linkage or connection between two business functions within an organization where the state of each business function influences the other. Whereas external **i**nterdependency can be defined as a linkage or connection between two organizations where the state of each organization influences the other.

Table 7 shows the internal interdependencies between business functions of Electricity Authority as well as the external interdependencies between Electricity Authority and other organization. As shown in the table, losing some business functions or external provider can have an instant impact in some cases, and in other cases the impact will take some time to happen.

Table 7 Internal and external interdependencies for the Electricity Authority

		1. Power System Operation and Control Section	2. Maintenance System	3. Store Section	4. Fleet Management	5. Public Relations and Customer Relations
Internal	1. Power System Operation and Control Section					
	2. Maintenance System	1 day				
	3. Store Section		1-7 days			
	4. Fleet Management		15-30 days			
	5. Public Relations and Customer Relations	1 day				
External	Electricity Generating Authority (EGA)	instant				
	SCADA/EMS/DMS System provider and operator	instant				
	Provider of tools and Equipment (Cable, Pole, Insulator, Drop Fuse, Lightning Arrester)			1-7 days		
	Truck supply and maintenance provider				15-30 days	
	Communication provider (Internet, Phone)					instant

4.4.4 Physical flow and Information flow Diagram

Figure 10 shows that how information and equipment flow between all business functions of the Electricity Authority. Power System Operation and Control Section is the centralized business function in the organization, and it is responsible for providing electricity for customers 24 hours, and control power distribution process. It receives generated and transmitted electricity from Electricity Generating Authority (EGA), then it distributes electricity to the customers including the other two organizations that are in this study which are the manufacturing company (Carware) and the seaport. In addition, Power System Operation and Control receives and provides information from and to Public Relations and Customer Relations Department which is responsible for communicating with both internal and external organizations and receiving and transmitting information to customers. Furthermore, Power System Operation and Control receives maintenance service from Maintenance System business function which is responsible for maintain the power distribution system, and repair or recover the power distribution system when a disruption happens. However, Maintenance System business function receives physical flows from both Store Section and Fleet Management. Fleet Management provides Maintenance department with vehicles needed, supports maintenance to vehicles and supplies drivers for these vehicles. Furthermore, Store Section supports equipment, tool, and fuel needed by the maintenance department.

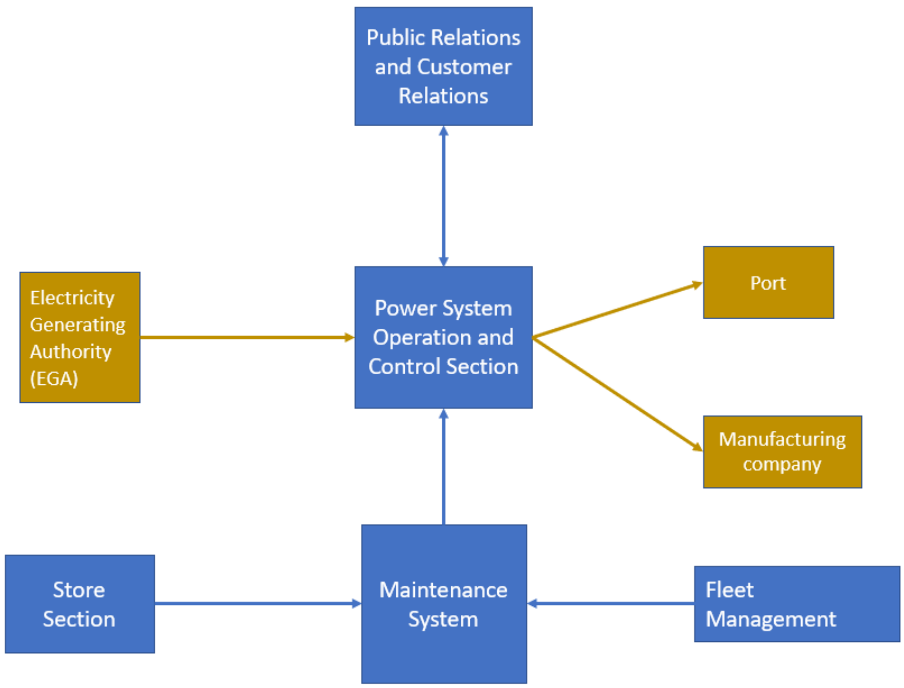


Figure 10 Physical flow and Information flow Diagram of Electricity Authority

4.4.5 Risk of earthquake

Risk sources which have a significant influence on power system operation and control and cause power distribution system loss in the central Italy district are fire, accident, terrorism and natural catastrophes which include storm, flood and earthquake. Even though these disasters are unlikely to occur, if they do, the consequences will be catastrophic. This case study will focus on the risk of an earthquake in the Electricity Authority area. In case of an earthquake, the power distribution system would be destroyed, and this will lead to a loss of power distribution system in central Italy. As a result, Electricity Authority cannot provide electricity for customers in central Italy.

Based on modified Mercalli intensity scale of earthquake severity, the earthquake vulnerability estimates of Electricity Authority are as follows:

Strength 5-: The Power System Operation and Control Section, and Public Relations and Customer Relations Department would be stopped for a short time to assess the situation. No major physical damage/injury or life loss and all the processes can be restarted immediately after an earthquake.

Strength 5-6: The Power System Operation and Control Section would be moderately disrupted. The Store Section and Maintenance Department wouldn't be damaged and the ability to process maintenance and supporting important customers with backup generators (if needed) could be maintained. The office area and computer systems wouldn't be damaged or destroyed.

Strength 6-7: The Power System Operation and Control Section would be substantially disrupted. 10% of Maintenance equipment would be damaged and would need a repair and checks. Possible leakage of fluid in flanged joints. No release of the hazardous materials. No critical damage on large scale machinery, underground equipment and lifeline systems.

Strength 7-8: The Power System Operation and Control Section would be seriously disrupted. The Maintenance equipment would be seriously damaged and would need a repair and checks. Cracks in walls and failure of individual non-structural elements (partition walls). The buildings would have to be inspected, approved for use and repaired, which would take 10 days. Possible denial of access to properties after an earthquake. Public Relations and Customer Relations Department would be disrupted, and EA will lose the contact with customers till they fix the problem and that could take 2 days. The repletion of EA will be impacted because of this loss of connection.

Strength 8+: Very heavy damage (heavy structural damage, very heavy non-structural damage). Serious failure of walls, partial structural failure of roofs and floors. Possible even collapse of building and warehouses. The Power System Operation and Control Section would be heavily disrupted. The equipment would be heavily damaged and would need to be replaced. Up to 80% of the equipment in Store Section and Maintenance Department would be lost.

Table 8 shows the organization's risk sources which are the possible disruption drivers and related factors that could affect the Electricity Authority. Furthermore, the table shows the risk assessment which is the evaluation of the outcomes of an event when it happens, the frequency of disruption, and the risk level associated with the outcome and frequency of that event.

Electricity Authority defined its recovery parameters in case of earthquakes, and these parameters are Maximum Tolerable Period of Disruption (MTPD), Recovery Time objectives (RTO), and Recovery Level Objectives (RLO). Maximum Tolerable Period of Disruption (MTPD) is the time needed for negative consequences to become intolerable as a result of not providing a product, service or conducting an activity. In this case study, MTPD of the Electricity Authority is defined as 45 days. In addition, Recovery Level Objective (RLO) is the level at which information required by an operation must be recovered in order for the operation to be resumes normally. In this case study, RLO of the Electricity Authority is defined as 50% of the normal performance. Recovery Time Objective (RTO) is the time period following an accident during which a service or product should be restored, an activity should be restored, or resources should be recovered, and it is commonly used to define priorities and design plans. In this case study, RTO of the Electricity Authority is defined as 25 days.

Table 8 Disruption Risk Register

Risk Sources	Risk	Risk Scenario	Risk Assessment		
			Consequence	Likelihood	Risk Rating
Natural disasters (earthquake, storm), fire, terrorist (bomb), or Accident.	Power distribution system was destroyed	Loss of power distribution system in central Italy	Catastrophic	Unlikely	High

Table 9 shows that when a disruption happens, Electricity Authority loses not just revenues, repair costs, and reputation, but clients also lose business operations and opportunities. Electricity Authority still has a BCP that is suitable for reconstructing a power distribution system that has been devastated in a small region, but not for a big area. As a result, Electricity Authority must update its Business Continuity Plan to account for significant calamities.

Table 9 Disruptive Scenario Register

Risk Scenario	Location(s)	Impact on Business Operations
Loss of power distribution system	Central Italy	Electricity Authority cannot provide electricity for customers in central Italy because the power distribution system is destroyed. Impacts include: **Electricity Authority:** Loss of revenues, repairing cost, and reputation. **Customer:** Loss of business operation and opportunity. **Nation:** Deflation and Chaos.

The customers of the Electricity Authority are grouped into four groups. Group 1 includes 13 hospitals, group 2 includes 10 sites of public administrations, group 3 includes 13 pump stations for water and wastewater management, and group 4 includes industrial production site with 50 small and medium enterprises. In case of business disruption due to an earthquake, the customer priority order, which was assigned previously by Electricity Authority, will be followed to make sure that electricity was supplied to important customers first. Table 10 shows the customer priority order of Electricity Authority.

Table 10 Customer priority

Major Customer/ Stakeholder	Priority
Group 1: Hospitals (13 hospitals)	1
Group 2: Public Administrations (10 sites)	2
Group 3: Water and wastewater Management (13 Pump Stations)	2
Group 4: Industrial Production site (50 SMEs)	3

4.4.6 Impact of the disruption due to earthquake

I. Financial impact:

For each business function, the types of impact are classified on a scale from 0 to 5. Scale 0 is the minimum threshold, and it refers to No Impact status which means that the business function does not have any economic losses. However, scale 1 refers to Very Low Impact status which means that the economic impact of the business function can be absorbed through normal operations. Furthermore, scale 2 refers to Low Impact status which means that the economic Impact of the business function can be absorbed but it requires an effort from management to absorb it. Scale 3 refers to Medium Impact status which means that the economic Impact of the business function can be absorbed but it requires an extraordinary involvement of management to absorb it. However, scale 4 refers to High Impact status which means that the economic impact of the business function requires a limited change of strategy to absorb it. Finally, scale 5, which is the maximum threshold, it refers to Very High Impact status which means that the economic impact of the business function requires a radical change of strategy to absorb it. Table 11 shows the financial impacts classification of the Electricity Authority with the ranges of economic losses and coded color for each scale.

Table 11 Financial impacts classification of the Electricity Authority

0	No Impact	No Economic loss	
1	Very Low	Economic loss < **€ 400k**	Economic Impact that can be absorbed through normal operations
2	Low	**€ 400k** < Economic loss < **€ 2M**	Economic Impact that can be absorbed but it requires an effort from management to absorb it
3	Medium	**€ 2M** < Economic loss < **€ 10M**	Economic Impact that can be absorbed but it requires and extraordinary involvement of management
4	High	**€ 10M** < Economic loss < € **50M**	Compromise the sustainability of the company – Economic impact that requires a limited change of strategy
5	Very High	Economic loss > € **50M**	Company not sustainable – Economic impact that requires a radical change of strategy

II. Other impacts:

Beside the loss of revenues due to loss of distribution process, there are additional impacts of business disruption in Electricity Authority. One of these impacts is the contractual penalties. Electricity Authority is providing electricity to four groups of customers which are 13 hospitals, 10 public administrations, 13 pump stations and one industrial production site with 50 small and medium enterprises. Electricity Authority have to maintain electricity continuity to satisfy all customers, and in case of long blackouts, there will be contractual penalties according to service level agreement between the company and customers. However, these penalties will not be enforced to public administrations, since Electricity Authority is a government-owned organization. In other words, three out of four groups of customers are contractual partners who are: 13 hospitals, 13 pump stations and one industrial production site with 50 small and medium enterprises. According to service level agreements, Electricity Authority have 2 days to restore electricity supply if it fails because of earthquakes. If the company fails to do so, €150 should be paid to the customer and a further €100 should be paid for each additional period of 1 day in which supply is not restored.

Another impact of an earthquake on the Electricity Authority is the loss of tangible assets including facilities, buildings, machinery, equipment and software. In addition, reduction in staff productivity is another impact of earthquake and it caused when manual workarounds and procedures are used instead due to damage caused by earthquake.

4.4.7 Recovery strategy options

Power disruptions are prevalent during and following severe earthquakes. Normally, electricity is disrupted during or shortly after a shaking. The earthquake epicenter region is impacted, although outages may also occur in nearby locations. The time period of any electricity disruption is determined by the extent of damage to the power lines and substations that service the area. Power is gradually restored following the earthquake. The duration of the blackout for most consumers might range from a few hours to months, depending on the severity of the ground motion and the extent of the damage.

Electricity distribution networks are very sensitive to seismic pressures, and significant earthquakes cause considerable damage to them, affecting many consumers across large areas. However, for three reasons, this form of damage is not a significant factor in the overall grid recovery time. First, grids are used to organize medium and low voltage distribution circuits. As a result, if few lines are lost, electricity may be diverted using a backup design. Repairing few key nodes may be enough to restore power in the event of more widespread damage. Second, spare parts and materials are far less costly than transmission system components. Distribution System Operators have backup supplies to perform more major repairs, while extra components can be ordered reasonably rapidly. Third, individual restorations require less time compared to repairs to transmission assets' components.

There are multiple suggested recovery strategies for recovery the disruption in Electricity Authority after an earthquake. One of these strategies is providing important customers with generators to provide electricity. Generators may be provided by the Electricity Authority to important clients in order to supply them with electricity. Hospitals, public administrations, and pump stations are all important customers, according to the priority order of Electricity Authority. Engineers will assess the impact on key customers and report to the Chief of Distribution System Maintenance Section, who will give the order to provide and install generators.

Another strategy is having spare equipment and material to be used to replace damaged equipment or parts. Availability spare parts are nearly entirely determined by cost versus benefit. Operators of distribution systems frequently keep tiny, cheap equipment on hand for emergencies and maintenance. The availability of these parts speeds up the repair of distribution substations and distribution lines.

One suggested recovery strategy for Electricity Authority after earthquake is providing alternative power supply routes. Interconnections improve resilience by offering alternate power supply lines, not by speeding up repairs. These typically make it easier to swiftly redirect electricity from other sources, reducing the period of blackouts while repairs are made. Electricity Authority may purchase electricity directly from independent power providers, small power producers, or neighboring countries.

4.5 Logistics provider: Seaport

In the first version of the game, the following part of the fictive case study will be used to provide automated inputs (as recovery parameters) that must be considered when deciding on the manufacturing company coordinated BCP, due to the interdependencies. At this point, this part of the fictive case study contains only simplified descriptions and might be further developed into a full game choice in the future. The following part of the fictive case study describes a logistic provider in central Italy which is a seaport. Source [77] has been utilized to help in building this case study.

4.5.1 Overview

The seaport that is owned and administered by the Italian government has two terminals: Terminal 1 which has two berths namely, berth 1 and berth 2, both are utilized for commercial ships, besides one area for fishing boat service; and Terminal 2 which also has two berths namely, berth 3 and berth 4, both are utilized for commercial ships. The port's core functions include the operations of multi-purpose terminal at berth 1 and 2, and the operations of container terminal at berth 3 and 4.

The port provides a "logistic center" service which is a complementary business to the business of the seaport. The logistic center also assists manufacturing industries by delivering imported materials to local businesses and transferring exported unit loads to the port terminal.

The customers of the seaport are grouped into six groups. Group 1 includes 24 industrial firms which are classified as importers, group 2 includes 16 industrial firms which are classified as exporters, group 3 includes 12 sites of public administrations, group 4 includes 18 shipping agencies and logistic companies, group 5 includes 2 mining companies, and group 6 includes 5 fisheries.

The aim of this case study is to create a BCP based on a scenario that assumes that the core functions in the seaport (Terminal N° 1, Terminal N° 2 and the logistic center) are widely destroyed. Major risks that face the seaport located in central Italy may include risk of an earthquake in the area, risk of a storm in the area, risk of fire in the buildings, risk of terrorist (Bomb) in the area, and risk of an accident in the area. However, this case study will focus on the risk of an earthquake in the seaport area. In case of an earthquake, the two terminals and logistic center would be destroyed. As a result, the seaport will not be able to provide its services for customers in central Italy. The overall impacts on the Seaport, Customer and Nation are:
Seaport: Loss of revenues, repairing cost, and reputation.
Customer: Loss of business operation and opportunity.
Nation: Deflation and Chaos.

4.5.2 Organization's Business Functions and resources

The following business functions are the ones that the company cannot function for long without these functions. If one of these business functions is unavailable, the company may face significant legal, financial, or other losses or penalties. The business functions of the seaport in this case study are:

1. Container/Multi-purpose terminal operation and Control: this business function is responsible for transshipped shipping containers among multiple transport vehicles for subsequent transportation. As a result, containerized merchandise is moved from land to sea and vice versa. Containers arriving by sea are frequently transshipped onto another mode of transportation, such as a truck or, increasingly, a train.

2. Fishing port operation: this business function is responsible for fishing boats services.

3. Logistic center operation: the logistic center consists of 10 warehouses, each 200 square meters, and equipped with a platform system, ultralight doors, lighting, and ramps. The operation of the logistic center is delivering the imported material or products to the local customers or transporting the exported material or products to the port terminal.

4. Maintenance System: maintaining the system of the seaport and repairing or recovering the system when a disruption happens.

5. IT Systems and Communications: in charge of the company's computer architecture, networking, software and hardware. It includes the maintenance and installation of computer network systems within the port.

6. Public Relations and Customer Relations Department: communicate both internal and external organizations and receive and transmit information to customers.

In order to assign criticality scale for each business function, the impact rating will be used for the criticality estimate. For each business function, impact ratings will be assigned based on defined criteria, and each rating has its weight. The summation of all weighted values of all impact ratings for each business function will result in a total score for this business function. Then based on that total score, criticality scale will be assigned to the business function as follows:

- Mission Critical Services: for a business function with total scores from 13 to 16.
- Vital: for a business function with total scores from 9 to 12.
- Important: for a business function with total scores from 5 to 8.
- Minor: for a business function with total scores from 0 to 4.

By using this criterion, Figure 11 shows the criticality scale for each business function in the seaport in central Italy.

Selection policy		Rating					
Criteria	**Specific impacts/risks of lossing business.**	Terminal operation and Control	Fishing port operation	Logistics center operation	Maintenance	IT Systems & Communications	Public Relations and Customer Relations
Sustainability and Environmental.	Negative impacts and environmental challenges incase of failures of certain systems.	A	B	B	B	C	C
Livelihood of people	Negative impact on the people's livelihood due to disruption event.	A	B	C	B	C	C
Legal and Regulatory requirements.	unablility to meet minimum legal and regulatory requirements in the event of certain business disruptions.	B	C	C	C	B	B
Credibility, Social and corporate image.	Negative impact on Credibility, Social and corporate image due to disruption event.	A	C	A	C	A	A
Operational.	Negative impacts on carrying out some of your operations	A	C	B	A	B	C
Port competitiveness and market share.	Risks of the terminals to lose out in competition with the rival ports and/or competing land surface transportations.	A	C	A	B	B	B
Financial.	Risks of the port operating entities to lose incomes and profit.	A	C	B	C	B	C
Loss/fine.	Risks of the port operating entities to incur penalty or compensation for port service disruption.	B	B	B	C	B	C
Total score		14	3	8	5	7	4
Inclusion or exclusion in BCP		Mission Critical	Minor	Important	Important	Important	Minor

BCP(Impact rating: A=high [2], B=Medium [1], C=low [0])	
• The highest priority (Mission Critical Services)	16 to 13
• Essential Services (Vital)	12 to 9
• Necessary Services (Important)	8 to 5
• Desirable Services (Minor)	4 to 0

Figure 11 Criticality scale for business functions of the seaport

Table 12 shows the resources including people, premises, equipment and providers for each business function of the seaport.

Table 12 Resources of Logistics Provider

Business functions	People	Premises	Facilities /Equipment	Providers
Container/Multi-purpose terminal operation and Control	40	Terminal Operation Station	Access channel, Anchorage, Tugboat, Apron, Turning basin, Quay wall, Quay crane, Service vessel, Rubber tyred gantry crane, Container chassis, Reefer Containers, Inspection and quarantine equipment, Electricity	Electricity (external provider) Water (external provider) Fuel (external provider)
Fishing port operation	18	Marine house	Access channel, Anchorage, Tugboat, Apron, Turning basin, Quay wall, Quay crane, Service vessel, Reefer Containers, Electricity	Electricity (external provider) Fuel (external provider)
Logistic center operation	20	Logistics center	Logistic equipment (hardware + software) Electricity Connectivity (Internet, Phone, Port radio) Terminal Operational system	Electricity (external provider) Telecommunication service (external provider)
Maintenance	25	Harbor building	Maintenance equipment (hardware + software) Electricity Connectivity (Internet, Phone, Port radio) Tugs and towing vessels	Electricity (external provider)
IT Systems & Communications	15	Port Authority Building	IT equipment (hardware + software) Port security system Connectivity (Internet, Phone, Port radio) Electricity	Electricity (external provider) Telecommunication service (external provider)
Public Relations and Customer Relations Department	15	Port Authority Building	Sea-NACCS system Port Management Information System Electricity Connectivity (Internet, Phone, Port radio)	Electricity (external provider) Telecommunication service (external provider)

4.5.3 Interdependencies

Internal **i**nterdependency can be defined as a linkage or connection between two business functions within an organization where the state of each business function influences the other. Whereas external **i**nterdependency can be defined as a linkage or connection between two organizations where the state of each organization influences the other.

Table 13 shows the internal interdependencies between business functions of the Seaport as well as the external interdependencies between Logistics provider and other organization. As shown in the table, losing some business functions or external provider can have an instant impact in some cases, and in other cases the impact will take some time to happen.

Table 13 Internal and External Interdependencies of the Port

		1. Container/Multi-purpose terminal operation and Control	2. Fishing port operation	3. Logistic center operation	4. Maintenance	5. IT Systems & Communications	6. Public Relations and Customer Relations Department
Internal	1. Container/Multi-purpose terminal operation and Control			2 days			
	2. Fishing port operation			10 days			
	3. Logistic center operation	2 days	10 days				
	4. Maintenance	30 days	30 days	30 days			
	5. 5. IT Systems & Communications	Instant	Instant	Instant			
	6. Public Relations and Customer Relations Department	45 days	45 days	45 days			
External	Electricity supply	Instant	Instant	Instant	Instant	1 day	
	Port Management Information System	Instant	Instant	Instant			
	Provider and Sea-NACCS system Provider	Instant	Instant	Instant			
	Communication provider (eg Internet, Phone)					Instant	Instant
	Infrastructure and roads	2 days	2 days	2 days			

4.5.4 Physical flow and Information flow Diagram

Figure 12 shows that how information and equipment flow between all business functions of the Port.

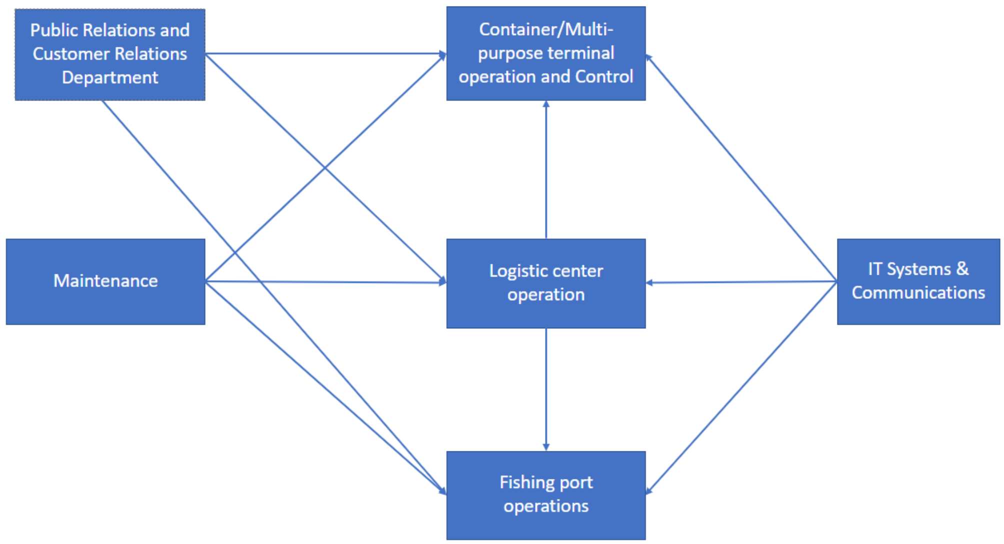


Figure 12 Physical flow and Information flow Diagram of the Port

4.5.5 Risk of earthquake

Risk sources which have a significant influence on seaport operations in the central Italy district are fire, accident, terrorism and natural catastrophes which include storm, flood and earthquake. Even though these disasters are unlikely to occur, if they do, the consequences will be catastrophic. This case study will focus on the risk of an earthquake in the seaport area. In case of an earthquake, Terminal N° 1, Terminal N° 2 and the logistic center would be destroyed. As a result, the seaport will not be able to provide services to the customers in central Italy. Table 14 shows the organization's risk sources which are the possible disruption drivers and related factors that could affect the seaport. Furthermore, the table shows the risk assessment which is the evaluation of the outcomes of an event when it happens, the frequency of disruption, and the risk level associated with the outcome and frequency of that event.

Based on modified Mercalli intensity scale of earthquake severity, the earthquake vulnerability estimates of the port are as follows:

Strength 5-: Container/Multi-purpose terminal operation and Control, Fishing port operation, Logistics center operation, and Public Relations & Customer Relations Department would be stopped for a short time to assess the situation. No major physical damage/injury or life loss and all the processes can be restarted immediately after an earthquake.

Strength 5-6: Container/Multi-purpose terminal operation and Control, Fishing port operation and Logistics center operation would be moderately disrupted. The Maintenance Department wouldn't be damaged and the ability to process maintenance (if needed) could be maintained. The office area and IT system wouldn't be damaged or destroyed.

Strength 6-7: Container/Multi-purpose terminal operation and Control, Fishing port operation and Logistics center operation would be substantially disrupted. 10% of equipment would be damaged and would need a repair and checks. Possible minor cracks in the port infrastructure. No release of the hazardous materials. No critical damage on large scale machinery, underground equipment and lifeline systems

Strength 7-8: Container/Multi-purpose terminal operation and Control, Fishing port operation and Logistics center operation would be seriously disrupted. The equipment would be seriously damaged and would need a repair and checks. cracks in walls and port infrastructure. The buildings in the port would have to be inspected, approved for use and repaired, which would take 10 days. Possible denial of access to properties after an earthquake. Public Relations and Customer Relations Department would be disrupted, and port authority will lose the contact with customers till they fix the problem and that could take 2 days. The reputation of port authority will be impacted because of this loss of connection.

Strength 8+: Very heavy damage (heavy structural damage). Serious failure of walls, partial structural failure in the port infrastructure. Possible even collapse of building and warehouses. Container/Multi-purpose terminal operation and Control, Fishing port operation and Logistics center operation would be heavily disrupted. The equipment would be heavily damaged and would need to be replaced. Up to 80% of the equipment would be lost.

The port defined its recovery parameters in case of earthquakes, and these parameters are Maximum Tolerable Period of Disruption (MTPD), Recovery Time objectives (RTO), and Recovery Level Objectives (RLO). Maximum Tolerable Period of Disruption (MTPD) is the time needed for negative consequences to become intolerable as a result of not providing a product, service or conducting an activity. In this case study, MTPD of the port is defined as 90 days. In addition, Recovery Level Objective (RLO) is the level at which information required by an operation must be recovered in order for the operation to be resumes normally. In this case study, RLO of the port is defined as 60% of the normal performance. Recovery Time Objective (RTO) is the time period following an accident during which a service or product should be restored, an activity should be restored, or resources should be recovered, and it is commonly used to define priorities and design plans. In this case study, RTO of the port is defined as 45 days.

Table 14 Disruption Risk Register

Risk Sources	Risk	Risk Scenario	Risk Assessment		
			Consequence	**Likelihood**	**Risk Rating**
Natural disasters (earthquake, storm), fire, terrorist (bomb), or Accident.	Terminal N° 1, Terminal N° 2 and the logistic center were destroyed	Port infrastructure and main facilities destroyed	Catastrophic	Unlikely	High

Table 15 shows that when a disruption happens, the seaport loses not just revenues, repair costs, and reputation, but clients also lose business operations and opportunities. All ports are required by Italian law to prepare emergency response plans, which include procedures for earthquake and tsunami catastrophes. Each plan outlines the steps to follow to safeguard the safety of the personnel, as well as the responsibilities to return to the port for preparatory activities. However, none of the plans include any potential courses of action or scenarios for returning to normal operations, which should be addressed with the BCP/BCM.

Table 15 Disruptive Scenario Register

Risk Scenario	**Location(s)**	**Impact on Business Operations**
Port infrastructure and main facilities destroyed.	Central Italy	Seaport cannot provide its services for customers because its infrastructure and main facilities was destroyed. Impacts include: **Seaport:** Loss of revenues, repairing cost, and reputation. **Customer:** Loss of business operation and opportunity. **Nation:** Deflation and Chaos.

The customers of the seaport are grouped into six groups. Group 1 includes 24 industrial firms which are classified as importers, group 2 includes 16 industrial firms which are classified as exporters, group 3 includes 12 sites of public administrations, group 4 includes 18 shipping agencies and logistic companies, group 5 includes 2 mining companies, and group 6 includes 5 fisheries. In case of business disruption due to an earthquake, the customer priority order, which was assigned previously by the port, will be followed to make sure that service will be supplied to important customers first. Table 16 shows the customer priority order of the seaport.

Table 16 Customer priority

Major Customer/ Stakeholder	**Priority**
Group 1: Industrial firms’ "importer" (24 Places)	1
Group 2: Industrial firms "exporters" (16 Places)	1
Group 3: Government/ State Enterprises (12 Places)	2
Group 4: Shipping agencies & Logistic companies (18 Places)	3
Group 5: mining companies (2 Place)	3
Group 6: fisheries (5 Place)	4

4.5.6 Impact of the disruption due to earthquake

I. Financial impact:

For each business function, the types of impact are classified on a scale from 0 to 5. Scale 0 is the minimum threshold, and it refers to No Impact status which means that the business function does not have any economic losses. However, scale 1 refers to Very Low Impact status which means that the economic impact of the business function can be absorbed through normal operations. Furthermore, scale 2 refers to Low Impact status which means that the economic Impact of the business function can be absorbed but it requires an effort from management to absorb it. Scale 3 refers to Medium Impact status which means that the economic Impact of the business function can be absorbed but it requires an extraordinary involvement of management to absorb it. However, scale 4 refers to High Impact status which means that the economic impact of the business function requires a limited change of strategy to absorb it. Finally, scale 5, which is the maximum threshold, it refers to Very High Impact status which means that the economic impact of the business function requires a radical change of strategy to absorb it. Table 17 shows the financial impacts classification of the seaport in central Italy with the ranges of economic losses and coded color for each scale.

Table 17 Financial impacts classification of the Electricity Authority

0	No Impact	No Economic loss	
1	Very Low	Economic loss < **€ 400k**	Economic Impact that can be absorbed through normal operations
2	Low	**€ 400k** < Economic loss < **€ 2M**	Economic Impact that can be absorbed but it requires an effort from management to absorb it
3	Medium	**€ 2M** < Economic loss < **€ 10M**	Economic Impact that can be absorbed but it requires and extraordinary involvement of management
4	High	**€ 10M** < Economic loss < € **50M**	Compromise the sustainability of the company – Economic impact that requires a limited change of strategy
5	Very High	Economic loss > € **50M**	Company not sustainable – Economic impact that requires a radical change of strategy

II. Other impacts:

Port Authority have to maintain delivering their services to satisfy all customers, and in case of long service disruption, there will be contractual penalties according to service level agreement between the company and customers. Contractual penalties due to long service outage is calculated as follows:

- If the delivery is delayed over 15 days, contractual penalties will equal 10% of the contract value.
- If the delivery is delayed over 30 days, contractual penalties will equal 50% of the contract value.
- If the delivery is delayed over 60 days, contractual penalties will equal 80% of the contract value.

Another impact is that the reputation, which is accompanied with loss of customers and clients, would be damaged in case of a service outage for over 60 days. It would reduce overall revenues by 25 percent.

Structural failures are a common occurrence during and after major earthquakes. The duration of the outages of port services is a function of the level of damage to the port infrastructure and facilities. After the earthquake, port operations are restored progressively. The duration of the service outage for customers depends on the intensity of ground motion and the level of damage. Earthquakes cause widespread structural damage to infrastructure and facilities. Structural failures may result from earthquake loading or be secondary to ground failure. Structural damage results from the response of structures and equipment to strong seismic ground motion.

Another impact of an earthquake on the port is the loss of tangible assets including facilities, buildings, machinery, equipment and software. In addition, reduction in staff productivity is another impact of earthquake and it caused when manual workarounds and procedures are used instead due to damage caused by earthquake.

4.5.7 Recovery strategy options

There are multiple suggested recovery strategies for recovery the disruption in the seaport after an earthquake. One of these strategies is Repairing, rebuilding and reconfiguration. These activities will support the recovery of port by:

- Replacing destroyed port facilities with contemporary, fully match infrastructure required for the port's safety, effective, and efficient operation.
- Reconfiguring the Port to increase efficiency, maintain capabilities to fulfill future freight demand, and give community benefits.
- Improving the Port's resiliency.

Another strategy is having spare equipment and material to be used to replace damaged equipment or parts. Availability spare parts are nearly entirely determined by cost versus benefit. Operators of distribution systems frequently keep tiny, cheap equipment on hand for emergencies and maintenance.

Parallel traffic networks utilizing various modes of transportation and alternate routing are another recommended recovery approach, such that in the case of a specific or large-scale failure, one transport network can take over most of the tasks of the other.

5. Simulation model

5.1 Introduction

After developing the general game flow and constructing the fictional case study of the three interdependent organizations, the next step is designing the back engine of the serious game. This back engine will be a Simulink model that will model the internal interdependencies between business functions within manufacturing company and also external interdependencies between the three companies. The Simulink model also will measure the daily performance of each business function and based on that; daily losses can be calculated. Furthermore, the model can be used to test the application of recovery strategies and investigate the performance of each business function within Carware after applying recovery strategies.

This chapter will present the simulation model description that will be used as the back engine of this game. In addition, the chapter will present how recovery strategies van be applied and simulated in the model.

5.2 Simulation model description

This research utilizes a widely known scientific and engineering modeling tool which is MatLab Simulink. Figure 13 shows the overall system model of manufacturing company, which includes the main business functions of the company, the stocks of the company, the electricity input, which is supplied by an external provider, maintenance input which is provided by external service provider, and logistics service which is provided by external logistics provider.

The first main business function in the model of the Carware company is the Manufacturing. The inputs of the Manufacturing function in the model are as follows:

- Electricity.
- IT system.
- Maintenance.
- Infrastructure of the Manufacturing which includes building and equipment.
- Limit to Manufacturing performance coming from Internal Parts stock when the stock is gone (MxIP).
- Limit to Manufacturing performance coming from Raw Material storage when the stock is gone (MxRM).

Although Manufacturing depends on Maintenance as an input, the effect of losing Maintenance on Manufacturing is not instant since it will take some time for the impact to take place and this impact will not be constant with time, it will get worse if no action was taken with time. The impact of the lack of Maintenance on Manufacturing is modelled as shown in Figure 14. The performance of Manufacturing will start decreasing after 30 days without Maintenance. Until the Maintenance is not recovered, the Manufacturing performance will keep decreasing. It is assumed that the loss of performance is a bit faster than linear. It is approximated as a step function on every 30 days, with a 20% larger decrease compared to the previous step (Figure 14). With that being said, the performance of Manufacturing will be calculated using the following equation:

Manufacturing 1 = MIN (Manufacturing Infrastructure, Electricity, IT system) * (1-Mnt')

Where Mnt' is the inoperability due to missing maintenance.

Performance of Manufacturing = MIN (Manufacturing 1, MxRM, MxIP)

Another main business function in the model of the Carware company is the Assembly. The inputs of the Assembly function in the model are as follows:

- Electricity.
- IT system.
- Infrastructure of the Assembly which includes building and equipment.
- Limit to Assembly performance coming from External Parts stock when the stock is gone (AxEP).
- Limit to Assembly performance coming from Internal Parts stock when the stock is gone (AxIP).
- Limit to Assembly performance coming from Orders when the stock is gone (AxO).
- Limit to Assembly performance coming from Finished Products storage when the stock is gone (AxFP).

With that being said, the performance of Assembly will be calculated using the following equations:

Performance of Assembly = MIN (Assembly Infrastructure, Electricity, IT system, AxEP, AxO, AxIP, AxFP)

Other main business functions in the model are Inbound logistics and Outbound logistics. They have been split into two separate functions in the simulation model because they could operate in different levels due to various reasons. For example, if Raw Material stock and External Parts stock are full, the Inbound logistics would have to stop importing raw material and external parts, whereas the Outbound logistics can keep performing and delivering finished products. As a result, in order to be able to simulate these scenarios, Inbound logistics and Outbound logistics have been split into two separate functions in the simulation model. In addition, two internal variables are used for both Inbound logistics and Outbound logistics and these variables represent the performance of Inbound and Outbound logistics coming from the performance of the external logistics provider (Outbound x Logistics Provider) and (Inbound x Logistics Provider). The inputs of the Outbound logistics function in the model are as follows:

- Limit to performance of Outbound Logistics coming from the performance of Finished Products stock when the stock is gone (LxFP).
- The performance of Outbound logistics coming from the performance of the external logistics provider (Outbound x Logistics Provider).

Whereas the inputs of the Inbound logistics function in the model are as follows:

- Limit to performance of Inbound Logistics coming from the performance of External Parts stock when the stock is gone (LxEP).
- Limit to performance of Inbound Logistics coming from the performance of Raw Material Stock when the stock is gone (LxRM).
- The performance of Inbound logistics coming from the performance of the external logistics provider (Inbound x Logistics Provider).

With that being said, the performance of Outbound logistics and Inbound logistics will be calculated using the following equations:

Performance of Outbound logistics = MIN (Outbound x Logistics Provider, LxFP).

Performance of Inbound logistics = MIN (Inbound x Logistics Provider, LxEP, LxRM).

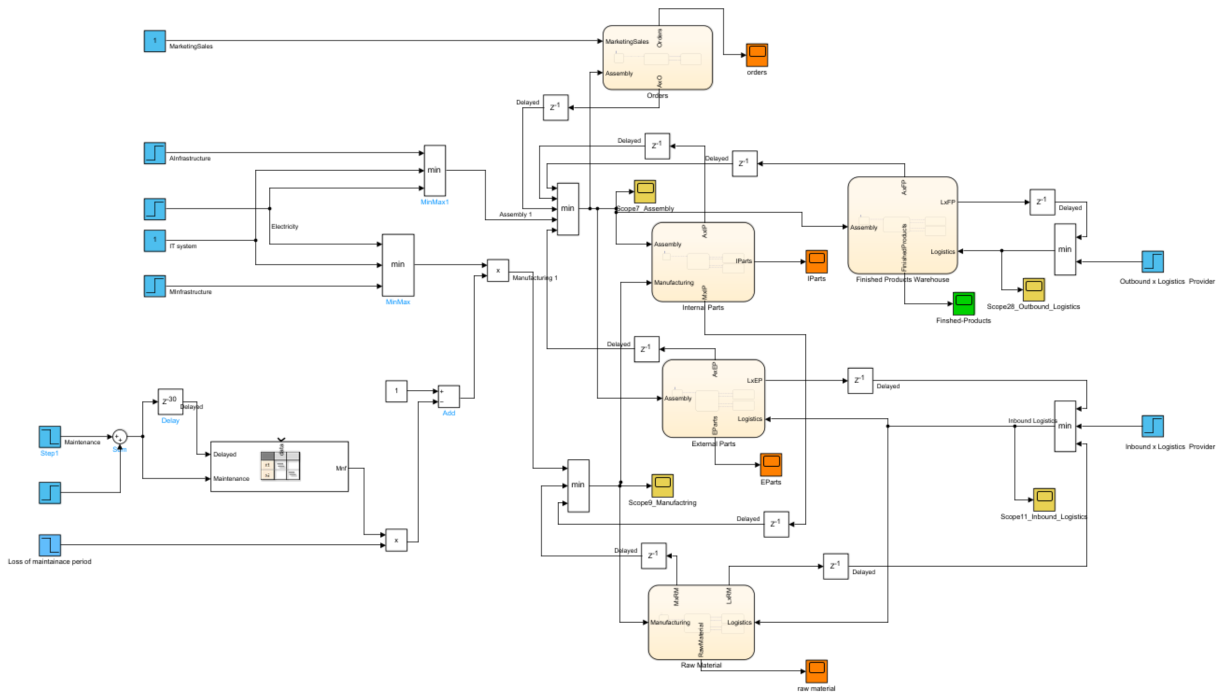


Figure 13 The overall system model of manufacturing company

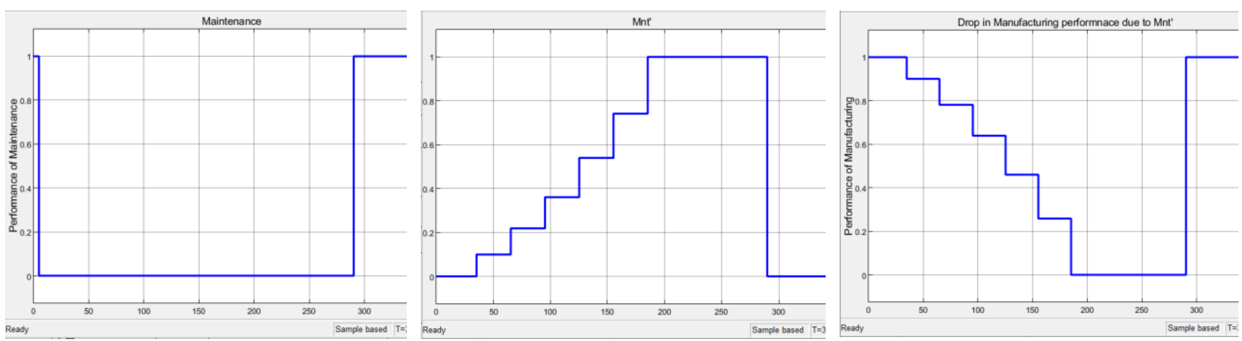


Figure 14 Effect of the disruption of Maintenance (left) and its propagated inoperability (Mnt' – middle) on Manufacturing (right)

There are four 'physical' stocks in the model, which are: Raw Material, Internal parts, External parts, and Finished products. Furthermore, there is one 'logical' stock in the model which is the Orders stock.

The finished products are assembled using a mix of internally produced parts and parts provided by external suppliers. For simplicity, we don't distinguish between different types of parts and assume equal usage of both parts in Assembly (Internal and External).

The five stocks of the model are:

Raw material

- Default size: 20 days (of manufacturing at full capacity)
- The initial (default) level of stock is chosen by the player
- The stock is consumed by *Manufacturing* (proportional to its performance)
- The stock is topped up by *Logistics (*performance of inbound logistics)

As shown in Figure 15, the stock is modelled using State Chart where four different states are defined:

- **Initiation** – where the initial values are defined, such as the initial level of stock and the default values of parameters representing limitations due to inoperability (1, as there is no inoperability in normal operation).
- **Update** – used for the period of normal operation where at each step the level of stock is updated by adding raw material coming from the Logistics performance and subtracting the raw material consumed by manufacturing process.
- **Full** – this is one extreme state, when the level of stock reaches its maximum value, i.e., it is full. This situation is not a limiting factor for Manufacturing (stock is available), but it is for Inbound Logistics of raw material, since there is no more available space to top up the stock. In this case, the inoperability propagates backward, meaning that while the stock is full the performance of Logistics is limited by the performance of Manufacturing (variable LxRM). In other words, Logistics can add only the amount of raw material consumed by Manufacturing. The stock remains in this state (full) until the Manufacturing performance becomes higher than Logistics.
- **Empty** – this is the other extreme state, when the raw material stock is fully consumed and drops to zero. This situation is not a limiting factor for Logistics (there is available space), but it is for Manufacturing, since there is no more raw material. In this case, the inoperability propagates forward, meaning that while the stock is empty the performance of Manufacturing is limited by the performance of Logistics (variable MxRM). Manufacturing can use only the amount of raw material provided by Logistics. The stock remains in this state (empty) until the Logistics performance becomes higher than Manufacturing.

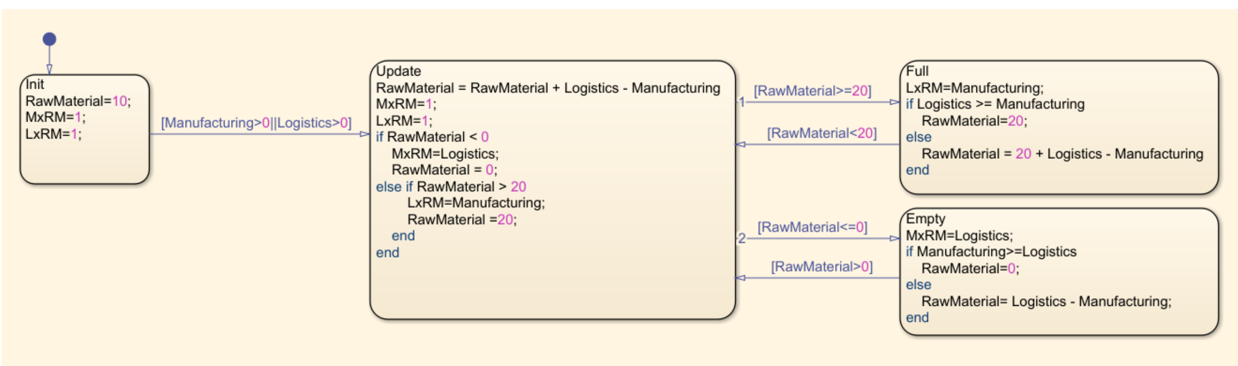


Figure 15 Raw Material Stock model

Variables:

- RawMaterial (Internal variable) – level of raw material stock (in days)
- Logistics (Input) – performance of Inbound Logistics function (external provider)
- Manufacturing (Input) – performance of Manufacturing
- MxRM (Output) – Limit to Manufacturing performance coming from Raw Material stock
- LxRM (Output) – Limit to Logistics coming performance from Raw Material stock

Internal parts

- Default size: 10 days (of manufacturing at full capacity)
- The initial (default) level of stock is chosen by the player
- The stock is consumed by *Assembly* (proportional to its performance)
- The stock is topped up by *Manufacturing (*proportional to its performance)

As shown in Figure 16, the stock is modelled using State Chart where four different states are defined:

- **Initiation** – where the initial values are defined, such as the initial level of stock and the default values of parameters representing limitations due to inoperability (1, as there is no inoperability in normal operation).
- **Update** – used for the period of normal operation where at each step the level of stock is updated by adding Internal parts based on the Manufacturing performance and subtracting the Internal parts consumed by Assembly.
- **Full** – this is one extreme state, when the level of stock reaches its maximum value, i.e. it is full. This situation is not a limiting factor for Assembly (parts are available), but it is for Manufacturing, since there is no more available space to top up the stock. In this case, the inoperability propagates backward, meaning that while the stock is full the performance of Manufacturing is limited by the performance of Assembly (variable MxIP). In other words, Manufacturing can add only the amount of Internal parts consumed by Assembly. The stock remains in this state (full) until the Assembly performance becomes higher than Manufacturing.
- **Empty** – this is the other extreme state, when the internal parts stock is fully consumed and drops to zero. This situation is not a limiting factor for Manufacturing (there is available space), but it is for Assembly, since there are no more Internal parts available. In this case, the inoperability propagates forward, meaning that while the stock is empty the performance of Assembly is limited by the performance of Manufacturing (variable AxIP). Assembly can use only the amount of Internal parts provided by Manufacturing. The stock remains in this state (empty) until the Manufacturing performance becomes higher than Assembly.

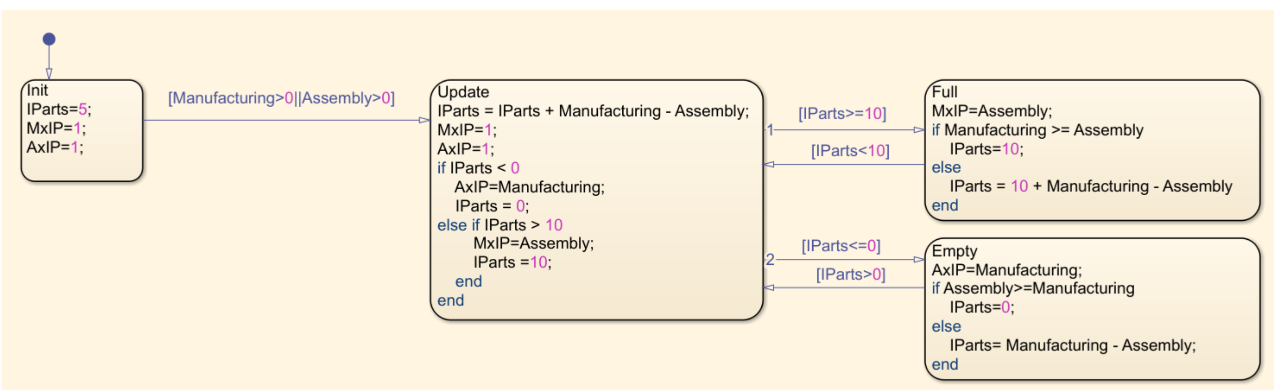


Figure 16 Internal Parts Stock model

Variables:

- IParts (Internal variable) – level of Internal Parts stock (in days)
- Assembly (Input) – performance of Assembly
- Manufacturing (Input) – performance of Manufacturing
- MxIP (Output) – Limit to Manufacturing performance coming from Internal Parts stock
- AxIP (Output) – Limit to Assembly performance coming from Internal Parts stock

External parts

- Default size: 10 days (of manufacturing at full capacity)
- The initial (default) level of stock is chosen by the player
- The stock is consumed by *Assembly* (proportional to its performance)
- The stock is topped up by *Logistics (*performance of inbound logistics)

As shown in Figure 17, the stock is modelled using State Chart where four different states are defined:

- **Initiation** – where the initial values are defined, such as the initial level of stock and the default values of parameters representing limitations due to inoperability (1, as there is no inoperability in normal operation).
- **Update** – used for the period of normal operation where at each step the level of stock is updated by adding External parts coming from the Logistics performance and subtracting the External parts consumed by Assembly.
- **Full** – this is one extreme state, when the level of stock reaches its maximum value, i.e., it is full. This situation is not a limiting factor for Assembly (parts are available), but it is for Logistics, since there is no more available space to top up the stock. In this case, the inoperability propagates backward, meaning that while the stock is full the performance of Logistics is limited by the performance of Assembly (variable LxEP). In other words, Logistics can add only the amount of External Parts consumed by Assembly. The stock remains in this state (full) until the Assembly performance becomes higher than Logistics.
- **Empty** – this is the other extreme state, when the External parts stock is fully consumed and drops to zero. This situation is not a limiting factor for Logistics (there is available space), but it is for Assembly, since there are no more External parts available. In this case, the inoperability propagates forward, meaning that while the stock is empty the performance of Assembly is limited by the performance of Inbound Logistics (variable AxEP). Assembly can use only the amount of External parts provided by Inbound Logistics. The stock remains in this state (empty) until the Inbound Logistics performance becomes higher than Assembly.

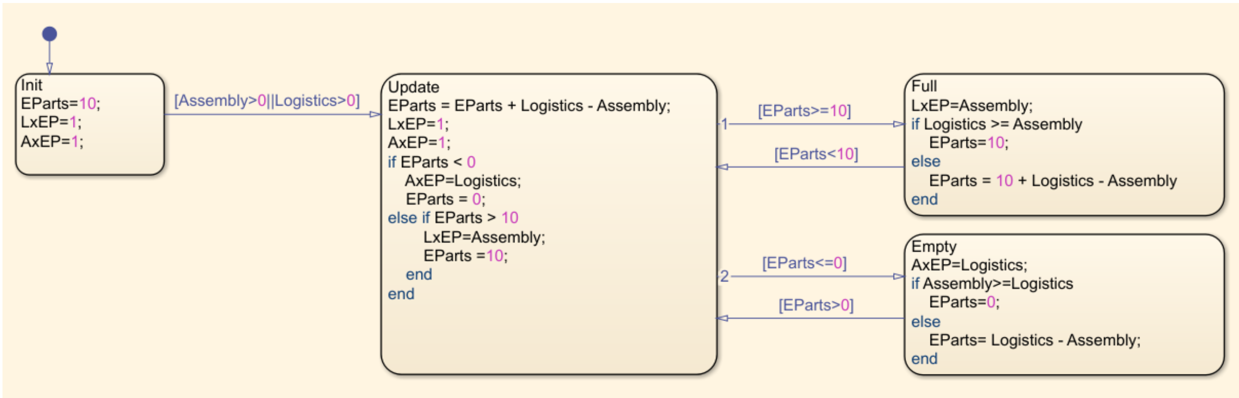


Figure 17 External Parts Stock model

Variables:

- EParts (Internal variable) – level of External Parts stock (in days)
- Assembly (Input) – performance of Assembly
- Logistics (Input) – performance of Inbound Logistics function (external provider)
- LxEP (Output) – Limit to Logistics performance coming from External Parts stock
- AxEP (Output) – Limit to Assembly performance coming from External Parts stock

Finished products

Carware uses Assemble-to-order strategy where finished products are assembled from components only once an order has been made. It means there is no stock of finished products (it is basically 1 day since what is produced in a day is immediately shipped the next day). Still, there is a warehouse space where finihed parts can be stored before they are shipped. This space is used as a buffer between Assembly and shipment to mitigate impacts of logistics disruption to the Assembly process.

- Default size: 10 days (of assembly at full capacity)
- The initial (default) level of stock is 1.
- The stock is consumed by *Logistics* (performance of outbound logistics)
- The stock is topped up by *Assembly* (proportional to its performance)

As shown in Figure 18, the warehouse storing finished products is modelled using State Chart where four different states are defined:

- **Initiation** – where the initial values are defined, such as the initial level of finished products stored (0) and the default values of parameters representing limitations due to inoperability (1, as there is no inoperability in normal operation).
- **Update** – used for the period of normal operation where at each step the level of stock is updated by adding Finished products coming from the Assembly performance and subtracting the Finished products taken away by Outbound Logistics.
- **Empty** – is a state, when all the Finished products are shipped. This situation is not a limiting factor for Assembly (there is available space), but it is for Outbound Logistics, since there are no more available Finished products to ship. In this case, the inoperability propagates forward, meaning

that while the warehouse is empty the performance of Outbound Logistics is limited by the performance of Assembly (variable LxFP). Outbound Logistics can use only the amount of Finished products provided by Assembly. The warehouse remains empty until the Assembly performance becomes higher than Outbound Logistics.

- **Full** – this is an extreme state, when the warehouse becomes full. This situation is not a limiting factor for Outbound Logistics (Finished products are available and ready for shipping), but it is for Assembly, since there is no more available space to store Finished Products. In this case, the inoperability propagates backward, meaning that while the warehouse is full the performance of Assembly is limited by the performance of Outbound Logistics (variable AxFP). In other words, Assembly can add only the amount of Finished Products taken away by Outbound Logistics. The warehouse remains in this state (full) until the Outbound Logistics performance becomes higher than Assembly.

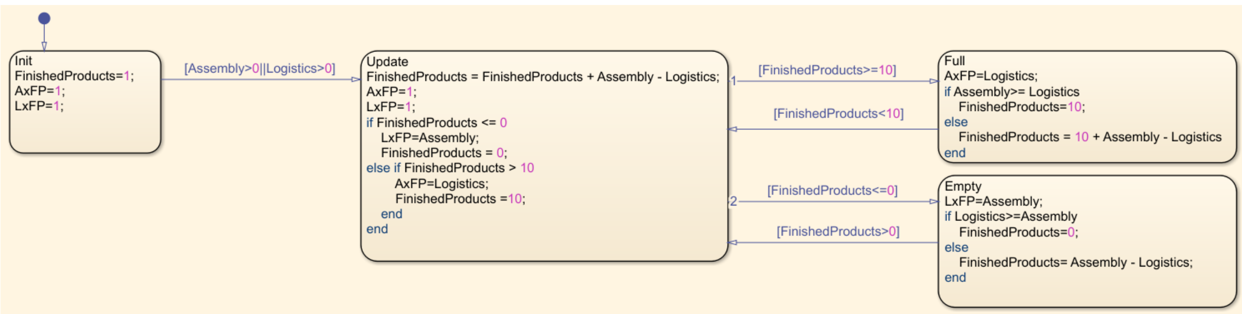


Figure 18 Finished Products Stock model

Variables:

- Finished Products (Internal variable) – amount of Finished Products in the warehouse (in days of Assembly)
- Assembly (Input) – performance of Assembly
- Logistics (Input) – performance of Outbound Logistics function (external provider)
- LxFP (Output) – Limit to Logistics performance coming from Finished Products storage
- AxFP (Output) – Limit to Assembly performance coming from Finished Products storage

Orders

The existing orders are treated as a stock of available orders, ready to be assembled.

- There is no upper limit on the number of existing orders
- The initial (default) level of existing orders is 32.
- The stock is topped up by *Marketing&Sales* (proportional to its performance)
- The stock is consumed by *Assembly* (proportional to its performance)

As shown in Figure 19, the existing orders stock is modelled using State Chart where three different states are defined:

- **Initiation** – where the initial values are defined, such as the initial level of existing orders (32) and the default values of parameters representing limitations due to inoperability (1, as there is no inoperability in normal operation).
- **Update** – used for the period of normal operation where at each step the amount of orders is updated by adding new orders coming from the Marketing & Sales performance and subtracting orders completed by the performance of Assembly.
- **Empty** – when all the Orders are Assembled the stock becomes empty. This situation is not a limiting factor for Marketing & Sales (since new orders can be taken), but it is for Assembly, since there are no more orders to Assemble. In this case, the inoperability propagates forward, meaning that while the stock of orders is empty the performance of Assembly is limited by the performance of Marketing & Sales (variable AxO). Assembly can use only the amount of orders generated by Marketing & Sales. The stock of orders remains empty until the performance of Marketing & Sales becomes higher than Assembly.

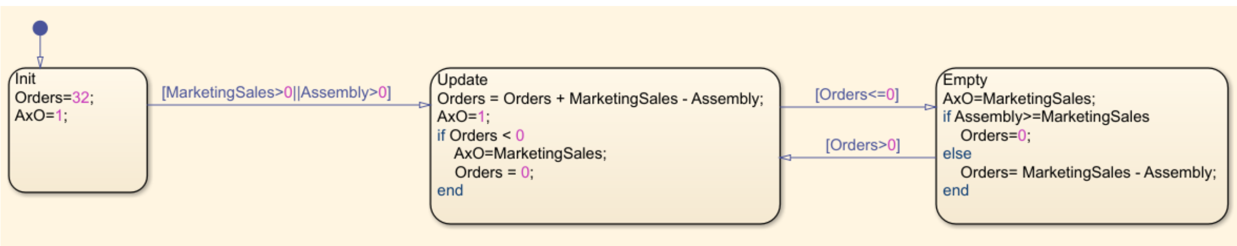


Figure 19 Orders Stock model

Variables:

- Orders (Internal variable) – amount of Orders (in Assembly days)
- Assembly (Input) – performance of Assembly
- Marketing & Sales (Input) – performance of Marketing & Sales
- AxO (Output) – Limit to Assembly performance coming from Orders

5.3 Recovery Strategies Modeling

Carware has different recovery strategies as options to consider. Those are:

- Increasing the warehouse capacity for storing finished products
- Increasing stocking capacities of Raw Material stock, Internal and External Parts stocks
- Factory's partial transfer
- Backup equipment
- Alternative shipping
- Alternative maintenance provider

Each one of these strategies can be modeled by changing the corresponding input parameters in the simulation model.

1) Increasing the warehouse capacity for storing finished products.

Carware could increase the warehouse capacity for storing finished products to make sure it can keep the production running when the shipping is disrupted. This strategy can be modeled by increasing the number in the code of State Chart of Finished Products Stock, which represents the maximum capacity of the Stock, as shown in Figure 18.

2) Increasing stocking capacities of Raw Material stock, Internal and External Parts stocks

Carware could increase the levels of stocking of raw material to make sure it can maintain manufacturing for longer periods, when the inbound logistics are disrupted. This strategy can be modeled by increasing the number in the code of State Chart of Raw Material Stock, which represents the maximum capacity of the Stock, as shown in Figure 15.

Similarly, Carware could increase the levels of stocking of internal parts to make sure it can maintain assembly for longer periods, when manufacturing is disrupted. This strategy can be modeled by increasing the number in the code of State Chart of Internal Parts Stock, which represents the maximum capacity of the Stock, as shown in Figure 16. Similarly, Carware could increase the levels of stocking of external parts to make sure it can maintain assembly for longer periods, when the inbound logistics are disrupted. This strategy can be modeled by increasing the number in the code of State Chart of External Parts Stock, which represents the maximum capacity of the Stock, as shown in Figure 17.

3) Factory's partial transfer

Another recovery strategy is the factory's partial transfer in which Carware could split into two locations (far enough not to be impacted by the same earthquake). By doing so, Carware could run production activities in parallel, so that in the event of disruption at one location, the activities can continue at the alternate location. This strategy can be modeled by considering the performance of the modelled manufacturing company as a half of the total performance, while considering the other half undisturbed (maximum performance). It basically means that the losses coming from the simulated business disruption are halved. The losses from the physical damage are not reduced.

4) Backup equipment

Getting a backup equipment is another recovery strategy of Carware. Carware could duplicate the Manufacturing equipment and Assembly equipment vulnerable to earthquakes and keep it ready in a remote location. When the equipment, either Manufacturing equipment or assembly equipment or both, gets damaged because of an earthquake, it can be delivered to Carware to restore Manufacturing process or Assembly process or both. This recovery strategy can be modeled by reducing the downtime of Manufacturing infrastructure and Assembly infrastructure that is assumed after an earthquake. Since infrastructure includes equipment and buildings, there will be still some downtime in the infrastructures of both Manufacturing and Assembly even after applying this strategy due to the damaged buildings. However, the overall downtimes of Manufacturing infrastructure and Assembly infrastructure will be reduced due to the application of backup equipment recovery strategy.

5) Alternative shipping

To deal with the disruption in external logistics, a recovery strategy offered in the game propose alternative shipping. Carware could use an alternative mode of inbound and outbound transport for the delivery of raw materials, external parts and finished products. This alternative mode could be road transport or rail freight. This strategy can be modeled by increasing the values of the performances of both Inbound and Outbound logistics coming from the performance of the external logistics provider. In other words, the strategy can be modeled by reducing the downtime of the logistics provider in the model since an alternative logistics provider exists.

6) Alternative maintenance provider

The last recovery strategy suggested by this study is an alternative Maintenance provider. Carware could find another maintenance provider for emergency cases that is located far enough not to be impacted by the same earthquake, but able to provide maintenance services in an aftermath of an earthquake. By doing so, Carware will be able to reduce the downtime of the regular maintenance provider after an earthquake which will help the company to recover its performance faster. This recovery strategy can be modeled by faster recovery of the maintenance performance in the model.

5.4 BCP performance evaluation

The players will be the business continuity team of the manufacturing company and they will face a series of choices to define the key BCP strategies and parameters. These choices impact the performance in an earthquake scenario, and players are scored based on these outcomes. In order to evaluate the performance of the BCP, total financial losses and costs have to be calculated to see whether chosen BCP is economically feasible or not. The financial performance is calculated as the sum of:

- Losses from business disruption or its lower-level performance.
- BCP setup costs.
- BCP deployment costs.

Losses from business disruption of lower-level performance includes all financial losses due to disruptions of business functions. It includes loss of sales, either contracts, orders or online orders. Loss of sales comes from the opportunities missed, orders not taken or contracts that cannot be signed. In addition, losses from business disruption of lower-level performance includes contractual penalties. Contractual penalties happen in the case if the production or delivery is delayed. Knowing that half of the sales are contractual partners. According to service level agreement between the company and customers, contractual penalties are calculated as follows:

- If the production or delivery is delayed over 15 days, contractual penalties will equal 10% of the order value.
- If the production or delivery is delayed over 60 days, contractual penalties will equal 50% of the order value.
- If the production or delivery is delayed over 90 days, contractual penalties will equal 80% of the order value.

Furthermore, losses from business disruption of lower-level performance includes the loss of the competitiveness and market share of Carware. This could happen in case Marketing and Sales are disrupted for more than 45 days, it would cause a reduction in offline orders by 30% for every 45 days.

Also, losses from business disruption of lower-level performance includes loss in the reputation of Carware. This could happen if the production or delivery is delayed for over 60 days, and as a result it would reduce overall sales by one third. In addition, if business (manufacturing, assembly or marketing) is disrupted for over 30 days, Carware will lose 15% of annual growth due to new ventures held up, delayed new products, and delayed entry into new markets.

BCP setup costs are the money invested in advance in order to have business continuity options and to be ready for any disruptive event. For example, the cost of increasing the warehouse capacity, the cost of factory's partial transfer strategy, and the cost of backup equipment strategy are all considered as BCP setup costs. Whereas BCP deployment costs the money invested to have reactive practices in order to have business continuity options and to mitigate the consequences of any disruptive event. For example, the cost of alternative shipping strategy and the cost of alternative maintenance provider are considered as BCP deployment costs.

Financial losses we be calculated on a daily basis from the simulation model. After calculating the total financial losses and total BCP setup and deployment costs, the performance of the BCP in an earthquake scenario can be evaluated.

6. Model testing

6.1 Introduction

In this chapter, a scenario was assumed for an earthquake to hit the area and disrupt business functions of three organizations: Carware, the electricity provider and the logistics provider. The impacts are simulated and inserted in the simulation model to investigate the performances of all business functions and stocks of the focal company; Carware. The aim of doing so is to test and validate the model to investigate whether the model outcomes make sense or not. Then, a combination of recovery strategies was chosen from suggested ones based on the outcomes of the scenario. These selected recovery strategies were applied on the chosen earthquake scenario to investigate the performances of all business functions and stocks of Carware after applying some of the recovery strategies.

6.2 Model testing

Based on Carware vulnerability estimates presented previously, a severe earthquake, with strength equal to 8 on modified Mercalli scale, was assumed to hit the area of the three organizations. The assumed consequences of that earthquake are as follows:

Very heavy structural and non-structural damages were assumed. Serious failure of walls, partial structural failure of roofs and floors, possible collapse of building and warehouses were assumed. The manufacturing and assembly processes would be disrupted. The equipment would be heavily damaged. Up to 80% of the parts stocks and finished products would be lost. Electricity provider and logistics provider will suffer from severe damages in the buildings and equipment.

The assumed values and performances after the assumed earthquake are as follows:

The performance of electricity provider will be disrupted for 30 days and then it will be fully recovered. In addition, the performance of the seaport logistics provider will be disrupted for 45 days and then it will be fully recovered. In addition, the Manufacturing infrastructure, which includes manufacturing equipment and building, will be fully disrupted for 45 days, and then its performance will be fully recovered. Similarly, the Assembly infrastructure, which includes assembly equipment and building, will be fully disrupted for 45 days, and then its performance will be fully recovered. Since the 80% of the parts stocks and finished products would be lost due to the earthquake, the initial level of Internal Parts will be one day of manufacturing at fully capacity. Similarly, the initial level of External Parts will be two days of assembly at fully capacity. And the initial level of Finished Products will be one days of assembly at fully capacity. Furthermore, the initial level of Raw Material will be two days of manufacturing at fully capacity.

In addition, loss of maintenance period is 90 days. However, IT system, administration, and Marketing and Sales could work remotely, so their performances will not be dropped.

By inserting these values of this scenario as inputs to the simulation model, the outputs will be as follows:

Figure 20 shows the performances of electricity provider and the Manufacturing infrastructure after the chosen earthquake scenario. Electricity will be disrupted for 30 days and then it will be fully recovered. And Manufacturing infrastructure will be disrupted for 45 days and then it will be fully recovered.

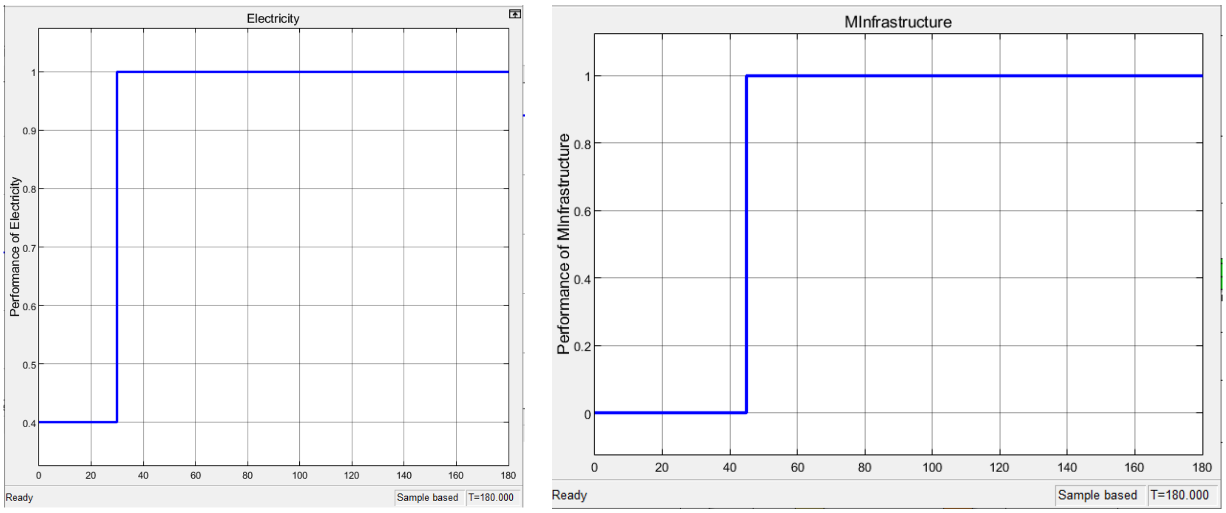
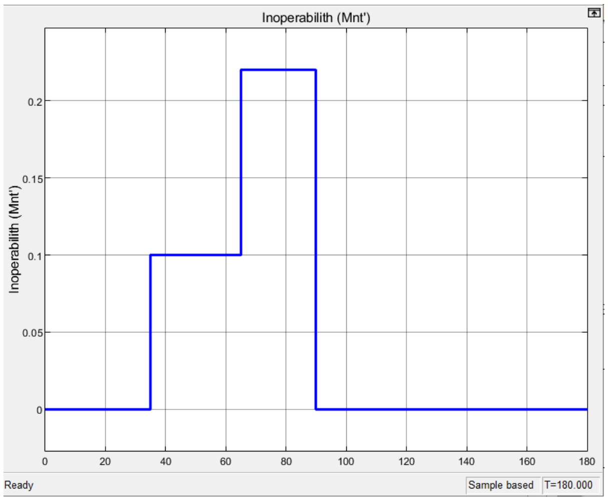


Figure 20 Performances of Electricity (left) and Manufacturing Infrastructure (right) after an earthquake

Although Manufacturing depends on Maintenance as an input, the effect of losing Maintenance on Manufacturing will take some time for the impact to take place and this impact will not be constant with time, it will get worse if no action was taken with time. In the investigated case, no actions were taken to recover the Maintenance for 90 days, the inoperability will keep increasing with a behavior more than linear in which each increase is 20% larger than the previous. For simplicity, the non-linear behavior of the inoperability will be modeled as steps with increase of 20% larger than the previous.

Figure 21 shows the inoperability due to losing Maintenance for 90 days, and it shows the graph of the drop in Manufacturing performance due to only the inoperability coming from maintenance.



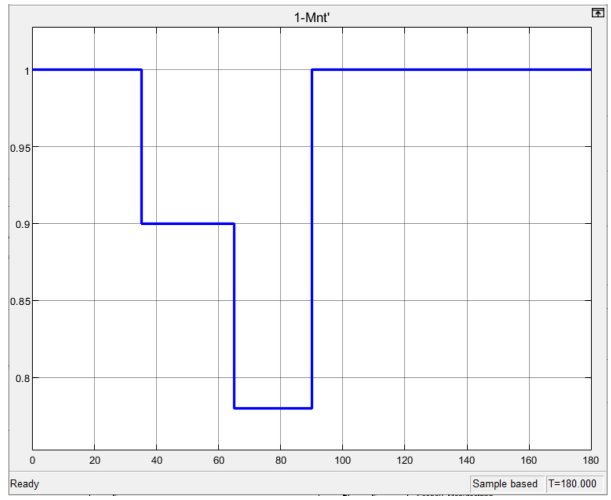


Figure 21 Inoperability in Manufacturing due to losing maintenance (left) and drop in Manufacturing performance due to only the inoperability coming from maintenance (right).

As mentioned in the model description, the performance of Manufacturing will be calculated as follows:

Manufacturing MIN = MIN (Electricity, MInfrastructure, IT)

Manufacturing 1 = Manufacturing MIN * (1-Mnt')

Manufacturing = MIN (Manufacturing 1, MxMR, MxIP)

As shown in Figure 22, for 45 days Manufacturing 1 is Zero because the MInfrastructure is Zero during this period. After day 45, both Electricity and MInfrastructure were fully performing. However, Manufacturing 1 was recovered partially due the inoperability coming from the absence of maintenance for 90 days. Since the maintenance will not be available for 90 days, Manufacturing 1 will keep decreasing till day 90. After that, the maintenance will be fully recovered, and Manufacturing 1 will be performing perfectly.

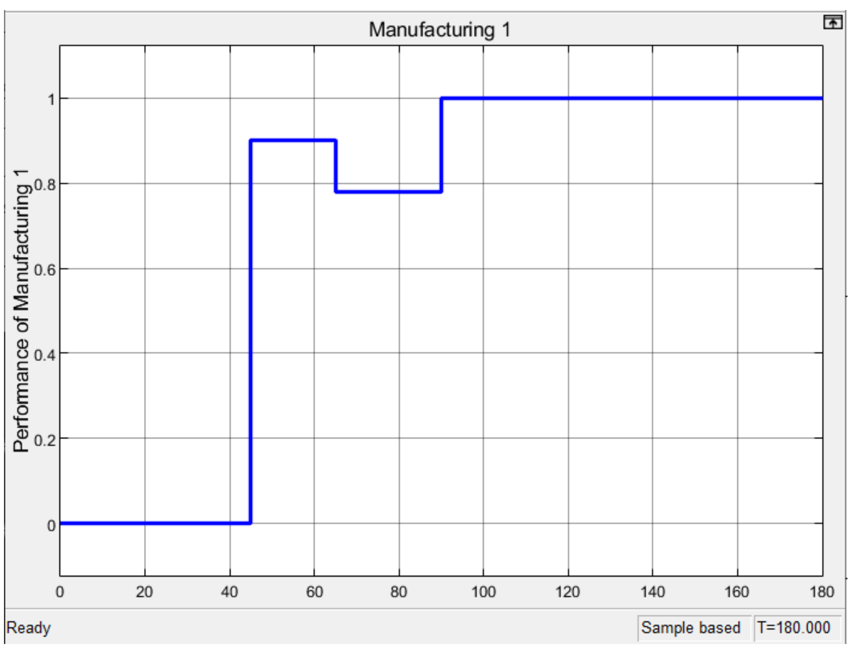


Figure 22 The performance of Manufacturing 1 for the chosen scenario

As shown in Figure 23 on left, the diagram shows the level of Raw Material stock (in days of manufacturing at full capacity). During the first 45 days, the stock was full of the initial level which is two days of manufacturing at full capacity because both Manufacturing and Inbound logistics was disrupted. Then, from day 45 till day 90, Inbound logistics was fully recovered, but Manufacturing was recovered partially due to inoperability due to absence of Maintenance during this period. Which means that, from day 45 till day 90 the performance of Inbound logistics is higher than the one of Manufacturing. In other words, the addition of Raw Material is higher than its consumption. And as mentioned before, the equation used in the Raw Material stock is as follows:

Raw Material = Raw Material + Logistics - Manufacturing

As a result, the level of Raw Material Stock will keep increasing from day 45 till day 90, as shown in Figure 23 on left. After day 90, Manufacturing will be fully recovered. Since both Manufacturing and Inbound logistics have performance equal to 100%, that means the level of stock of Raw Material will remain constant. The maximum capacity of Raw Material stock (in days of manufacturing at full capacity) is 20 days, and since this limit was not reached during the down time of Manufacturing, Raw Material stock will not limit the performance of Manufacturing, as shown in Figure 23 on the right.

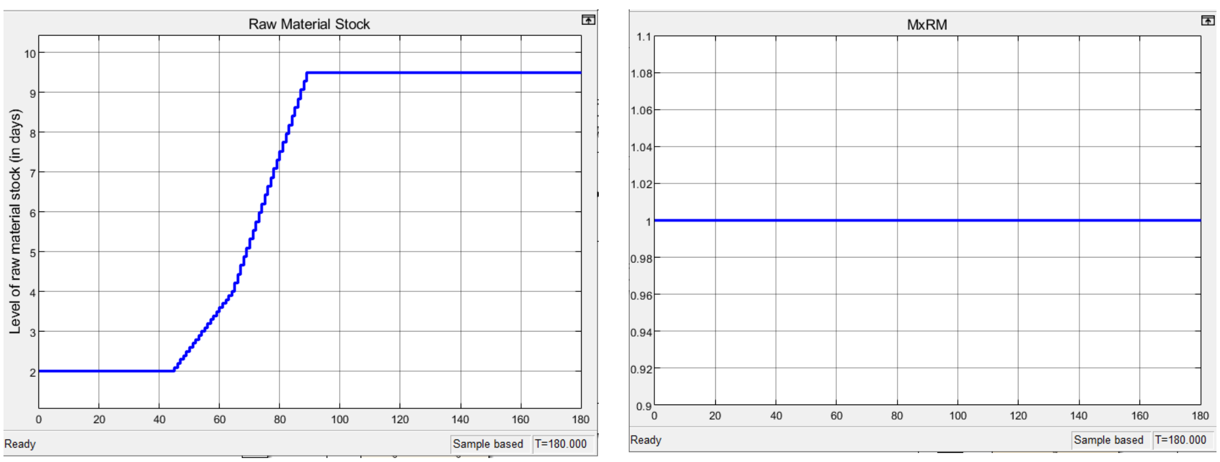


Figure 23 Stock of Raw Material Stock with time (left), Limit to Manufacturing performance coming from Material stock (Right)

As shown in Figure 24 on left, the diagram shows the level of Internal Parts stock (in days of manufacturing at full capacity). During the first 45 days, the stock was full of the initial level which is one day of manufacturing of Internal parts at full capacity. The level was constant because both Assembly and Manufacturing were disrupted. Then, after day 45 both Assembly and Manufacturing were recovered. However, the Assembly performance was higher than manufacturing performance just after the day 45 day because the inoperability coming from loss in maintenance. As a result, the stock starts to drop because the consumption from Assembly is higher than the supplying from Manufacturing, according to the following equation:

IParts = IParts + Manufacturing - Assembly.

The stock will be finished after day 55. From day 55 till day 90, the level of Internal Parts Stock is zero. This will not limit the performance of Manufacturing, as shown in the figure 24 on the right, since manufacturing is adding parts to the Internal Parts Stock. After day 90, both Manufacturing and Assembly will be fully recovered. As a result, the level of Internal parts Stock will be constant.

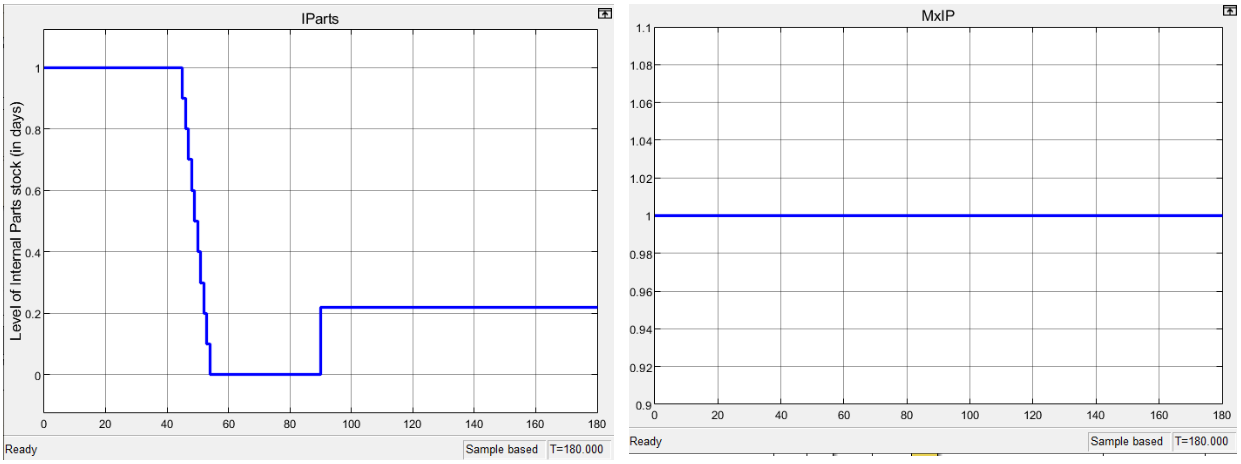


Figure 24 Stock of Internal Parts with time (left), Limit to Manufacturing performance coming from Internal Parts stock (Right)

Figure 25 shows the final performance of Manufacturing after the earthquake. In this scenario, Manufacturing will be same as Manufacturing 1 because it was the minimum among all the three, and neither Internal Parts stock nor Raw Material stock limited the performance of Manufacturing.

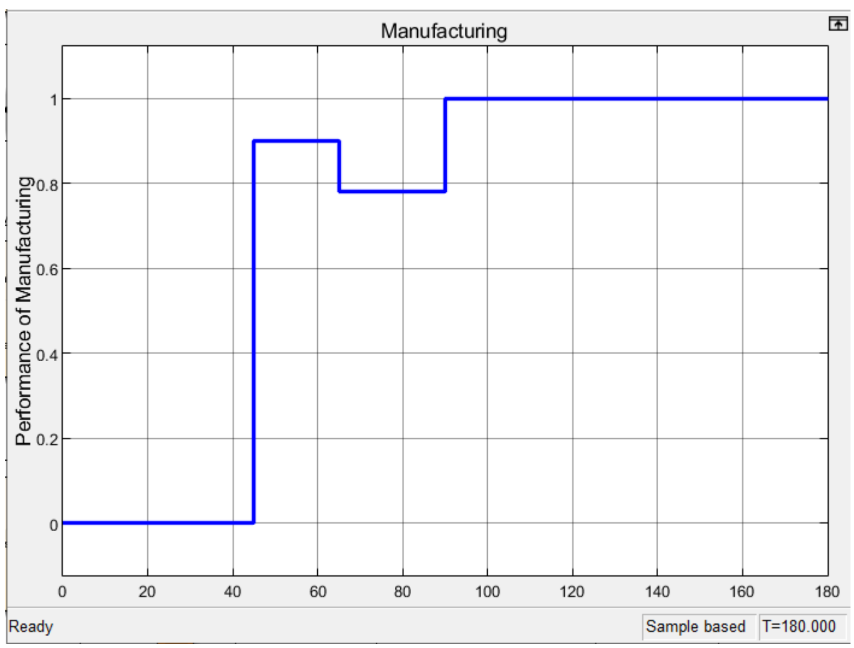


Figure 25 Performance of Manufacturing after the chosen earthquake scenario

In order to calculate the performance of Assembly business function, the following equations are used

Assembly 1 = MIN (Electricity, AInfrastructure, IT)

Assembly = MIN (Assembly 1, AxEP, AxO, AxIP, AxFP,)

Figure 26 shows the performances of electricity provider and the Assembly infrastructure after the chosen earthquake scenario. Electricity will be disrupted for 30 days and then it will be fully recovered. However, Assembly infrastructure will be disrupted for 45 days and then it will be fully recovered.

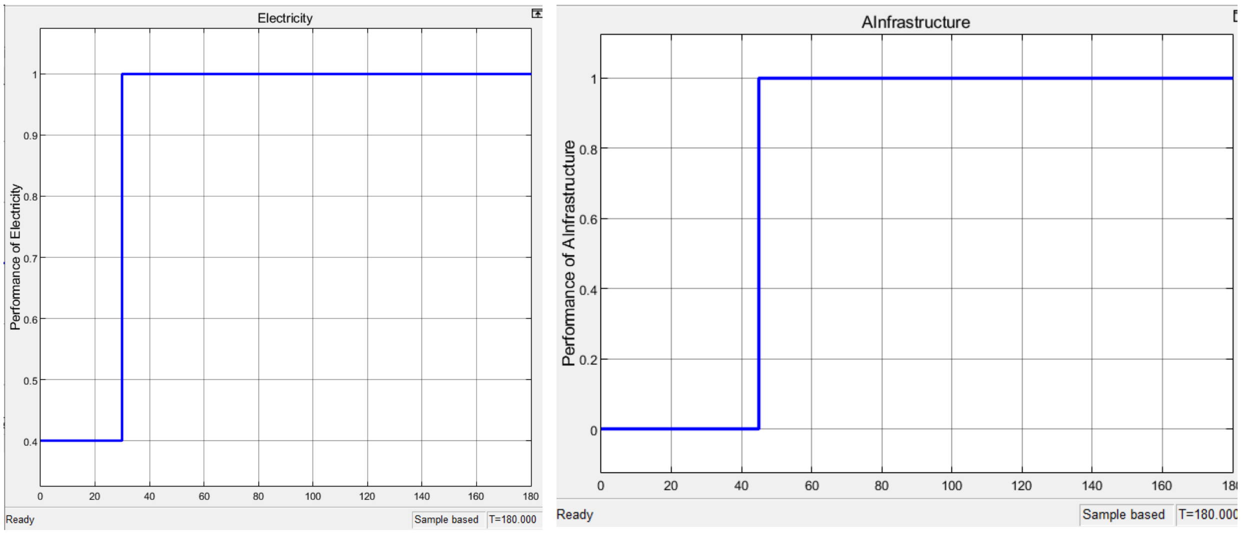


Figure 26 Performances of Electricity (left) and Assembly Infrastructure (right) after an earthquake

As shown in Figure 27, for 45 days Assembly 1 is Zero because the AInfrastructure is Zero during this period. After day 45, both Electricity and AInfrastructure were fully performing. As a result, Assembly 1 will be performing perfectly after day 45.

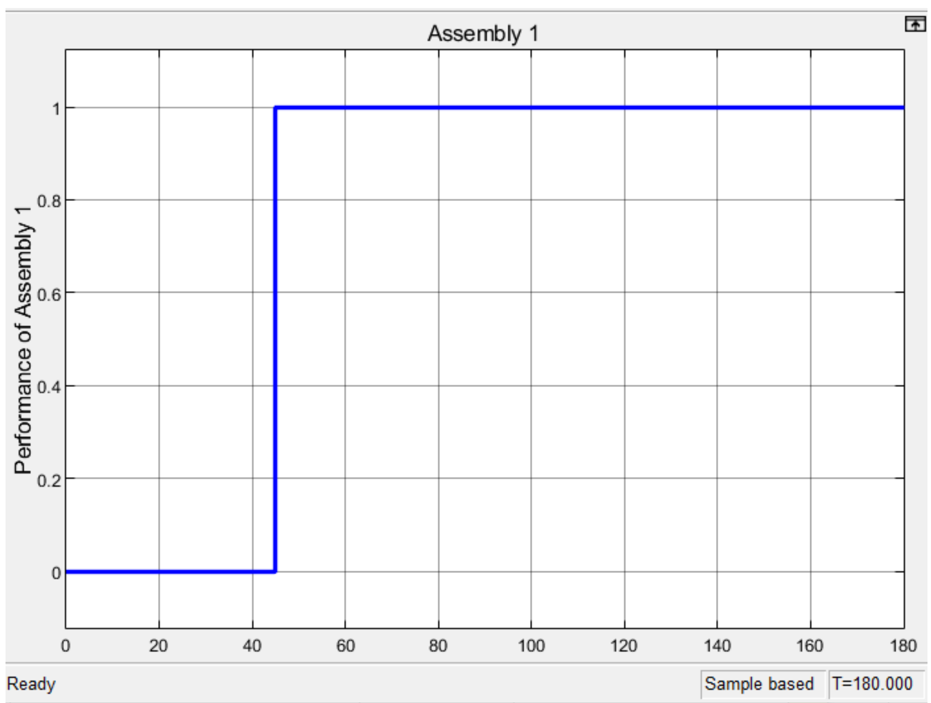


Figure 27 The performance of Assembly 1

As shown in Figure 28 on left, the diagram shows the level of Internal Parts stock (in days of manufacturing at full capacity). During the first 45 days, the stock was full of the initial level which is one day of manufacturing of Internal parts at full capacity. The level was constant because both Assembly and Manufacturing was disrupted. Then, from day 45 till day 55, Assembly was fully recovered, but Manufacturing was partially recovered due to the inoperability coming from the absence of maintenance. In other words, the performance of Assembly is higher than the Manufacturing performance between day

45 and day 55. As a result, the stock starts to drop because the consumption from Assembly is higher than the supplying from Manufacturing, and according to the following equation:

IParts = IParts + Manufacturing – Assembly.

After day 55, the stock will be finished. during these 55 days, Internal Parts Stock will not limit the performance of Assembly, as shown in the Figure 28 on the right. However, from day 55 till day 90 the level of Internal Parts is zero and that means Internal Parts will limit the performance of Assembly, as shown in the Figure 28 on the right. During this period, performance of Assembly will be equal to the performance of Manufacturing, according to the Internal Parts Stock equation used in the model. Then after day 90, Manufacturing will be fully recovered and that means the IP will not limit the performance of Assembly anymore and the Assembly will be fully recovered.

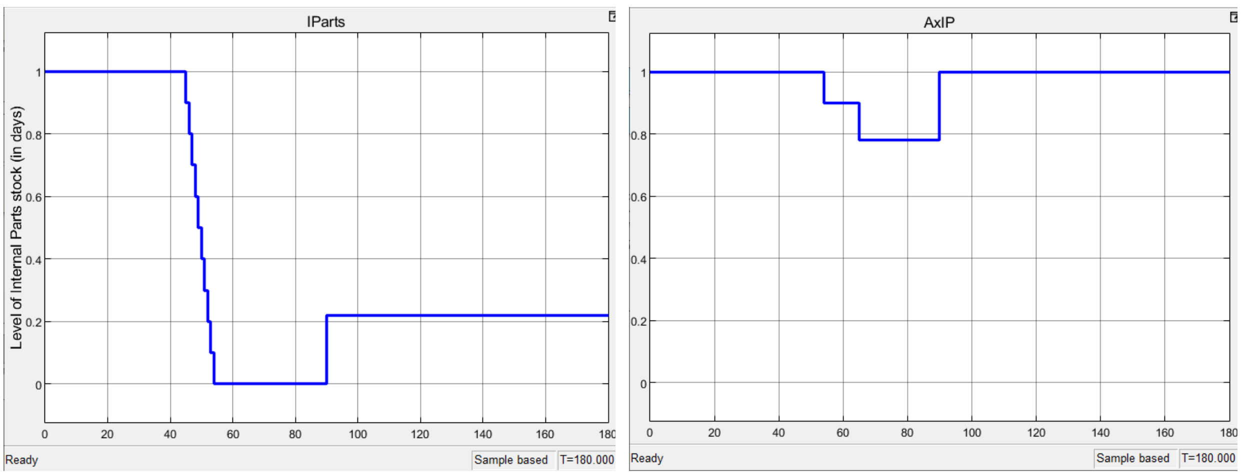


Figure 28 Stock of Internal Parts with time (left), Limit to Assembly performance coming from Internal Parts stock (Right)

As shown in Figure 29 on left, the diagram shows the level of External Parts stock (in days of assembly at full capacity). During the first 45 days, the stock was full of the initial level which is two days of assembly of External parts at full capacity. It was constant during this period because both Assembly and Inbound logistics was disrupted during this period. However, from day 45 till day 55, both Assembly and Inbound logistics were fully recovered. Since their performances equal to 100%, the level of stock of External parts will remain constant, according to the following equation used in the model:

EParts = EParts + Logistics – Assembly.

From day 55 till day 90, Assembly performance will drop because of the limitation of Assembly performance due to Internal Parts stocks. That means the addition from Inbound logistics will be higher than the consumption from Assembly. As a result, the External Parts stock will start to increase, as shown in the Figure 29 on the left. After day 90, Assembly will be fully recovered and the level of the stock will remain constant again, since both Assembly and Inbound logistics are performing at 100%.

Since the level of External Parts stock (in days of purchasing at full capacity) did not reach zero, External Parts stock will not limit the performance of Assembly, as shown in the Figure 29 on the right.

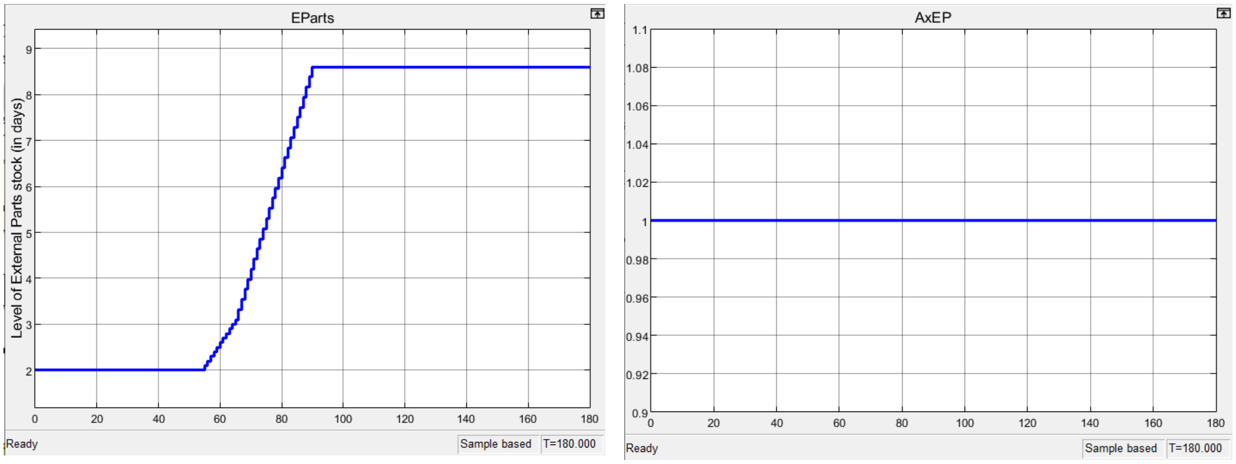


Figure 29 Stock of External Parts with time (left), Limit to Assembly performance coming from External Parts stock (Right)

As shown in Figure 30 on left, the diagram shows the level of Finished products stock (in days of assembly at full capacity). During the first 45 days, the stock was full of the initial level which is one day of assembly of Finished products at full capacity. The level of stock is constant during this period because both Assembly and Outbound logistics was disrupted. Then, from day 45 till day 55, both Assembly and Outbound logistics were fully recovered. Since both Assembly and Outbound logistics have performance equal to 100%, the level of Finished products stock will remain constant. From day 55 till day 90, Assembly performance will drop due to the limitation of Assembly performance due to Internal Parts stock. That means the consumption from Outbound logistics will be higher than the addition from Assembly. As a result, the Finished products stock will start to decrease, as shown in the Figure 30 on the left. After day 90, Assembly will be fully recovered and the level of the stock will remain constant again, since both Assembly and Inbound logistics are performing at 100%. Since the maximum capacity of Finished products stock (in days of purchasing at full capacity) is 10 days, and since this limit was not reached during the down time of Assembly, Finished products stock will not limit the performance of Assembly, as shown in the Figure 30 on the right.

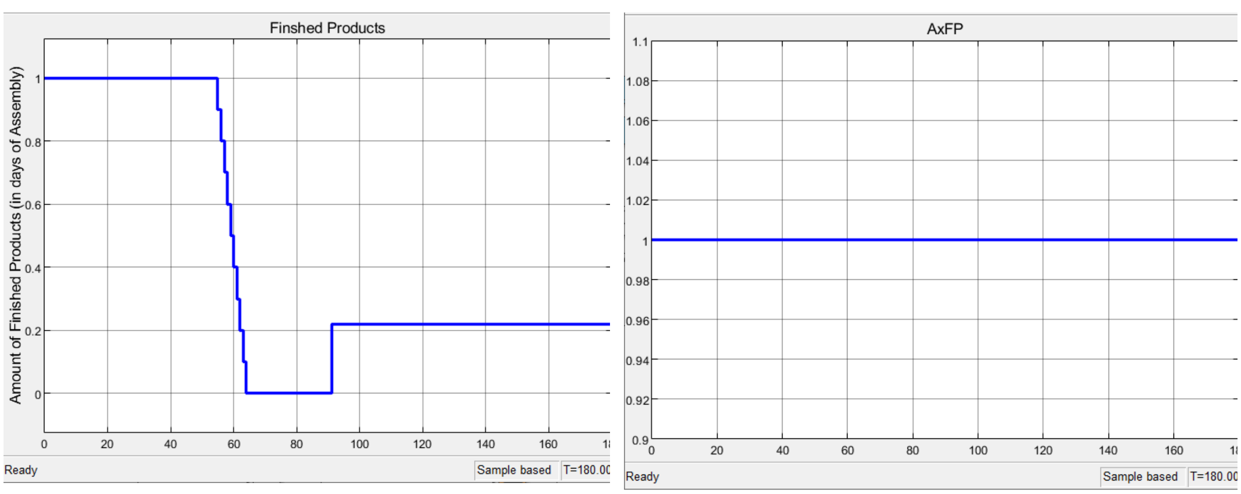


Figure 30 Stock of Finished Products with time (left), Limit to Assembly performance coming from Finished Products stock (Right)

As shown in Figure 31 on left, the diagram shows the amount of Orders (in days of assembly at full capacity). The initial level of the stock is 32 days of assembly of Orders. During the first 45 days, the stock was increasing because Assembly was disrupted, and no orders were processed. In addition, Marketing and Sales department is always performing at 100% since this department can be functioning remotely. Then, from day 45 till day 55, Assembly was fully recovered. Since both Assembly and Marketing and Sales have performance equal to 100%, that means the level of stock of Orders will remain constant. From day 55 till day 90, Assembly performance will drop due to the limitation of Assembly performance due to Internal Parts stock. That means the Orders addition from Marketing and Sales will be higher than the consumption from Assembly. As a result, the Finished products stock will start to increase again, as shown in the Figure 31 on the left. After day 90, Assembly will be fully recovered and the level of the stock will remain constant again, since both Assembly and Marketing and Sales are performing at 100%. Since there are always Orders in the stock, Orders stock will not limit the performance of Assembly, as shown in the Figure 31 on the right.

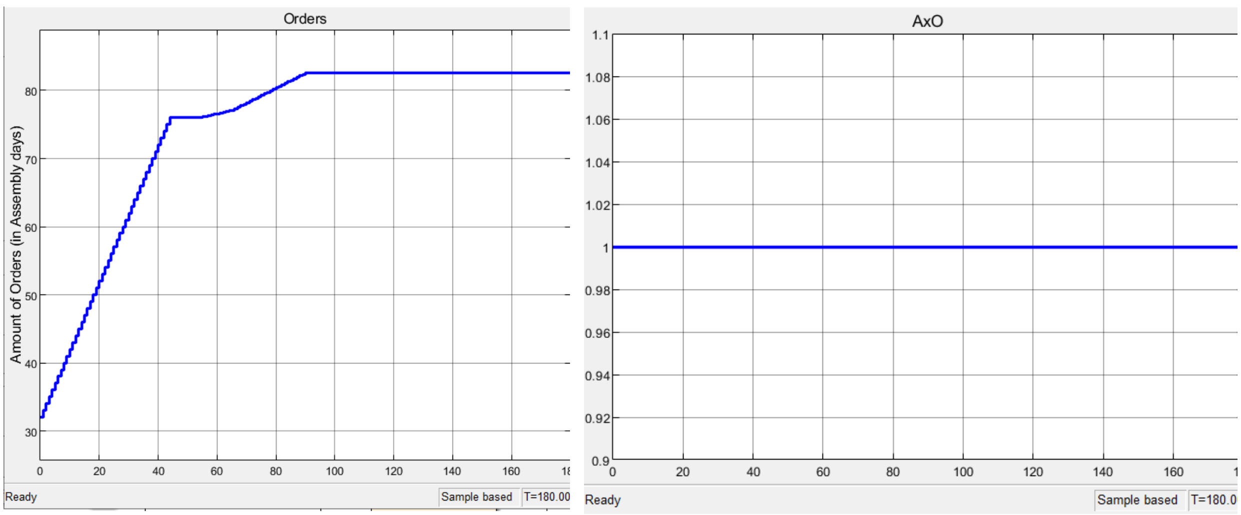


Figure 31 Stock of Orders with time (left), Limit to Assembly performance coming from Orders stock (Right)

Figure 32 shows the final performance of Assembly after the earthquake after taking in the consideration the electricity performance, Assembly infrastructure performance, limit to Assembly performance coming from Finished Products Stock, limit to Assembly performance coming from Internal Parts Stock, limit to Assembly performance coming from External Parts Stock, and limit to Assembly performance coming from Orders Stock. In this scenario, Assembly was disrupted for 45 days because the AInfrastructure was disrupted during this period. Then from day 45 till day 55, AInfrastructure and electricity were preforming fully. As a result, Assembly was fully recovered. Then from day 55 till days 90, the performance of Assembly was limited because of the Internal Parts stock which limit the performance of Assembly. The IP stock limited the Assembly due to the drop in the performance of manufacturing which happed because of the inoperability coming from the absence of maintenance. Then after day 90, Assembly has been fully recovered.

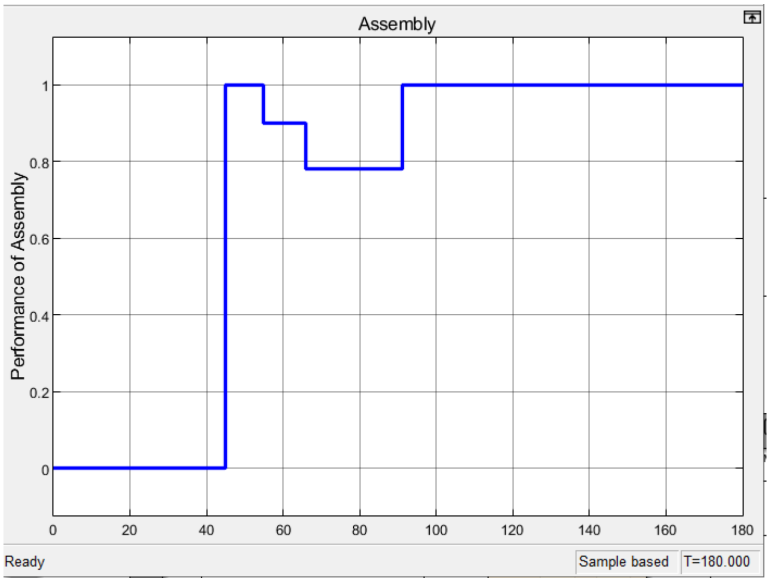


Figure 32 Performance of Assembly after the chosen earthquake scenario

In order to calculate the performance of Outbound logistics business function, the following equation will be used

Outbound logistics = MIN (Outbound x Logistics Provider, LxFP)

Figure 33 shows the performances of seaport logistics provider after the chosen earthquake scenario. Disruption in Seaport lasts for 45 days and then it fully recovered. And that limit the performance of the Outbound logistics.

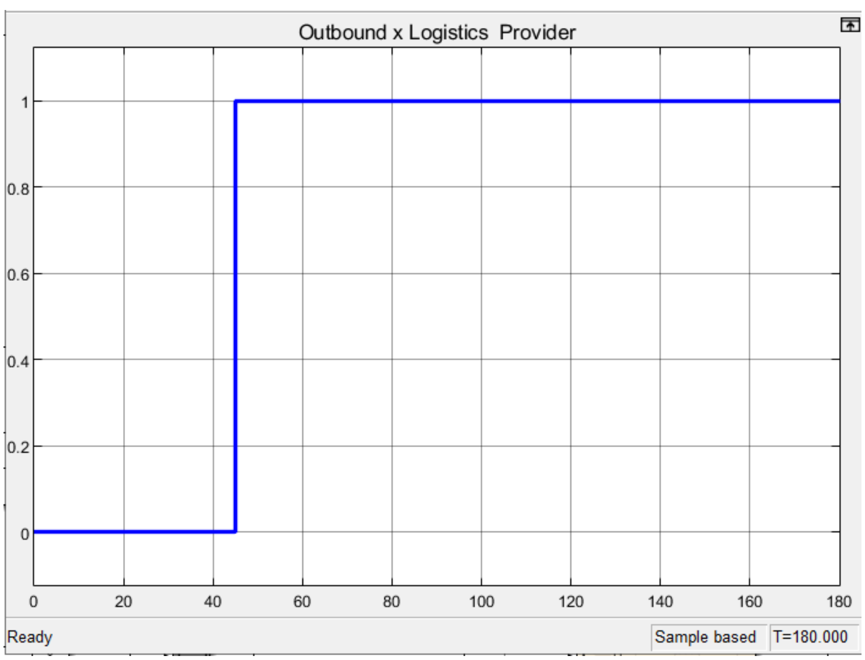


Figure 33 Performances of seaport after the chosen earthquake scenario

As shown in Figure 34 on left, the diagram shows the level of Finished products stock (in days of assembly at full capacity). During the first 45 days, the stock was full of the initial level which is one day of assembly of Finished products at full capacity. The level of the stock was constant because both Assembly and Outbound logistics was disrupted. However, from day 45 till day 55, both Assembly and Outbound logistics were fully recovered. Since both Assembly and Outbound logistics have performances equal to 100%, that means the level of stock of Finished products will remain constant. From day 55, Assembly performance will drop due to the limitation of Assembly performance due to Internal Parts stock. That means the consumption from Outbound logistics will be higher than the addition from Assembly. As a result, the Finished products stock will start to decrease starting from day 55, as shown in the figure 34 on the left. From day 65 till day 90, the level of Finished products stock will reach zero. As a result, the performance of Outbound logistics will be limited, as shown in the Figure 34 on the right. From day 65 till day 90, the performance of Outbound Logistics will equal to the performance of Assembly during this period since Finished products stock is zero, and according to the following equation:

Finished Products = Finished Products + Assembly - Logistics

After day 90, Assembly will be fully recovered, and the level of the stock will increase. As a result, the limitation on the performance of Outbound logistics because of Finished products stock will be removed. That means after day 90, the outbound logistics will be performing at 100% without any limitation in the performance in the Outbound logistics because of Finished products stock, as shown in the Figure 34 on the right.

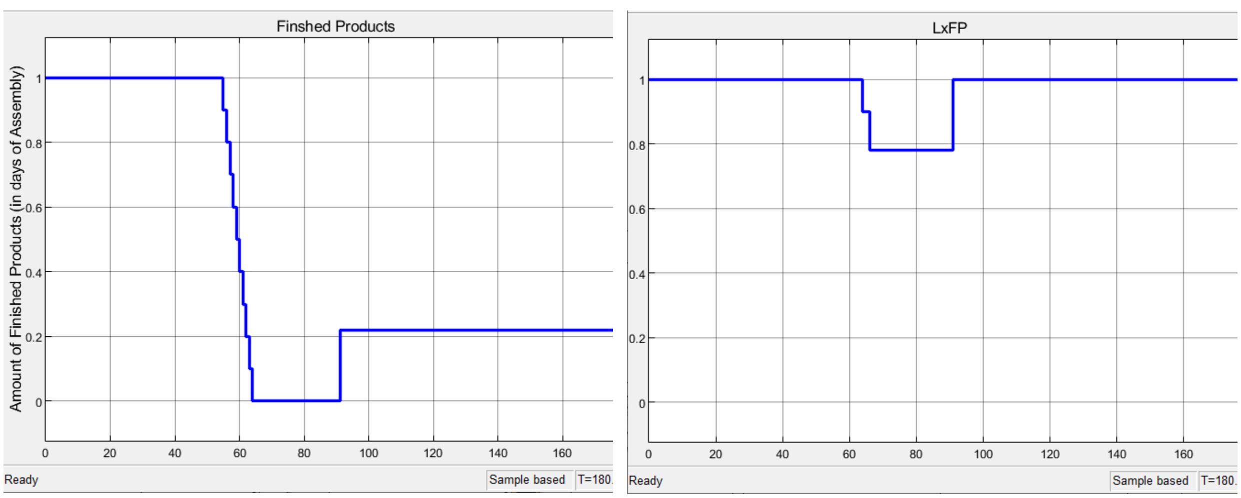


Figure 34 Stock of Finished Products with time (left), Limit to Outbound Logistics performance coming from Finished Products stock (Right)

Figure 35 shows the final performance of Outbound logistics after the earthquake after taking in the consideration the logistics provider performance, and limit to Outbound logistics performance coming from Finished Products Stock. The outbound logistics was not working for 45 days due to the disruption in the port. Then the port will fully recover and so do the outbound logistics. However, A drop in performance of Outbound logistics will take place due to a limitation in performance of Outbound logistics from Finished product stock which happened due to the drop in Assembly performance. However, after day 90, outbound logistics will be fully recovered.

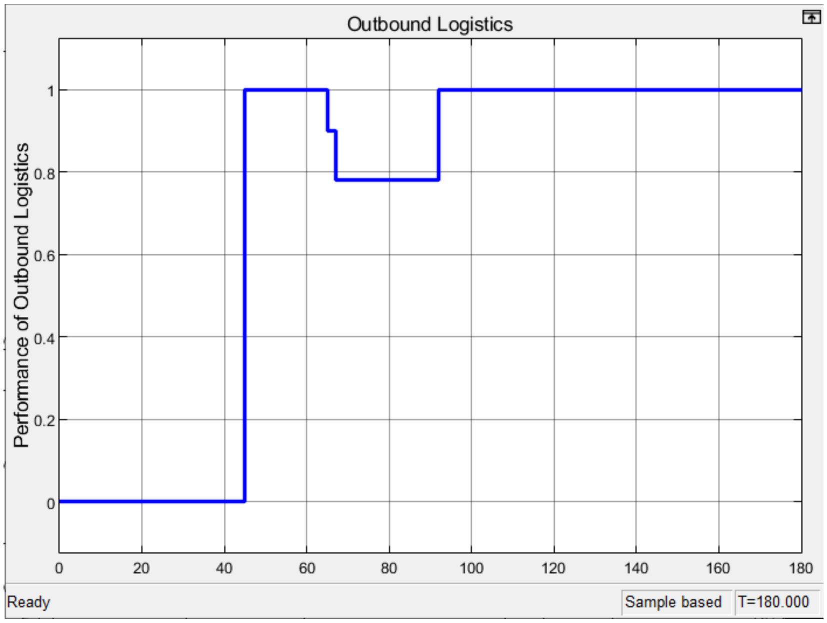


Figure 35 Final performance of Outbound logistics after the chosen earthquake scenario

In order to calculate the performance of Inbound logistics business function, the following equation will be used

Inbound logistics MIN = MIN (Inbound x Logistics Provider, LxEP, LxRM)

Figure 36 shows the performances of seaport logistics provider after the chosen earthquake scenario. Disruption in Seaport lasts for 45 days and then it fully recovered. And that limit the performance of the Outbound logistics.

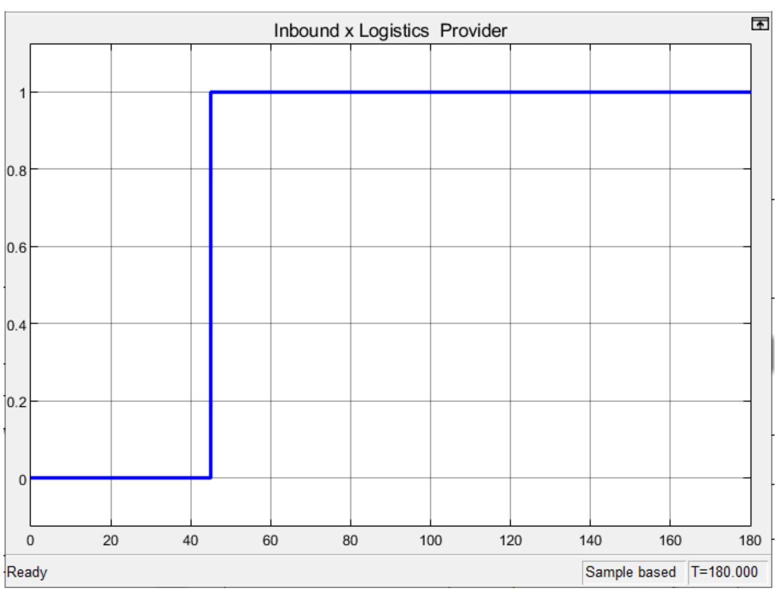


Figure 36 Performances of seaport after the chosen earthquake scenario

As shown in Figure 37 on left, the diagram shows the level of External Parts stock (in days of assembly at full capacity). During the first 45 days, the stock was full of the initial level which is two days of assembly of External parts at full capacity. The level of stock was constant during this period because both Assembly and Inbound logistics was disrupted. However, from day 45 till day 55, both Assembly and Inbound logistics were fully recovered. Since both Assembly and Inbound logistics have performances equal to 100%, that means the level of stock of External parts will remain constant. From day 55 till day 90, Assembly performance will drop due to the limitation of Assembly performance due to Internal Parts stock. That means the addition from Inbound logistics will be higher than the consumption from Assembly. As a result, the External Parts stock will start to increase, as shown in the Figure 37 on the left. After day 90, Assembly will be fully recovered and the level of the stock will remain constant again, since both Assembly and Inbound logistics are performing at 100%. Since the maximum capacity of External Parts stock (in days of purchasing at full capacity) is 10 days, and since this limit was not reached during the down time of Assembly, External Parts stock will not limit the performance of Inbound logistics, as shown in the figure 37 on the right.

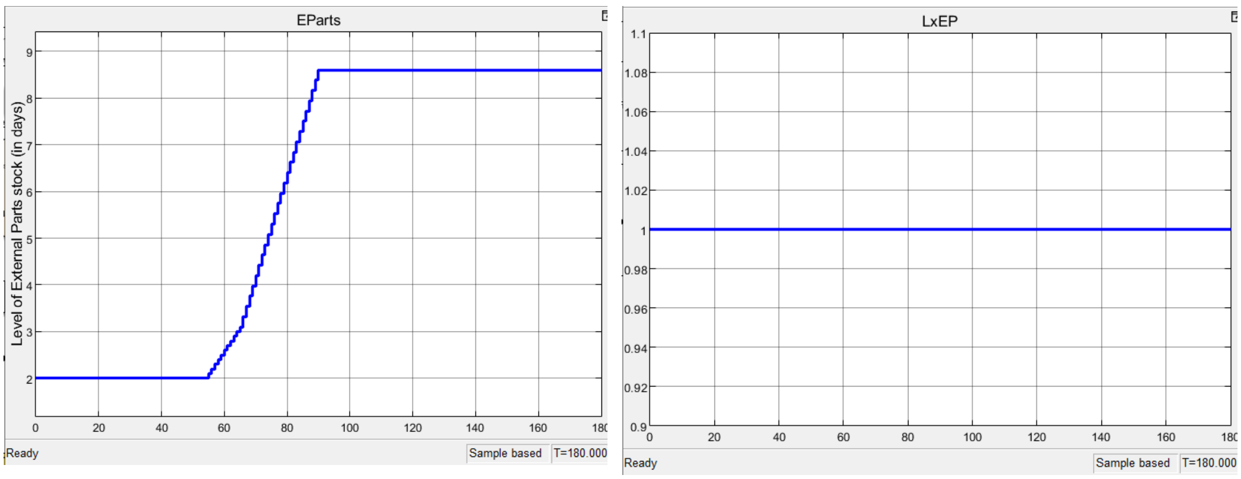


Figure 37 Stock of External Parts with time (left), Limit to Inbound Logistics performance coming from External Parts stock (Right)

As shown in Figure 38 on left, the diagram shows the level of Raw Material stock (in days of manufacturing at full capacity). During the first 45 days, the stock was full of the initial level which is two days of manufacturing at full capacity. The level of stock was constant because both Manufacturing and Inbound logistics was disrupted. Then, from day 45 till day 90, Inbound logistics was fully recovered, however Manufacturing was recovered partially due to inoperability due to absence of Maintenance. which means that the performance of Inbound logistics is higher than the one of Manufacturing from day 45 till day 90. That means that the addition of Raw Material is higher than the consumption of Raw Material. As a result, the level of stock of Raw Material will keep increasing from day 45 till day 90, As shown in the Figure 38 on left. After day 90, Manufacturing will be fully recovered. Since both Manufacturing and Inbound logistics have performances equal to 100%, that means the level of stock of Raw Material will remain constant. Since the maximum capacity of Raw Material stock (in days of manufacturing at full capacity) is 20 days, and since this limit was not reached during the down time of Manufacturing, Raw Material stock will not limit the performance of Inbound logistics, as shown in the Figure 38 on the right.

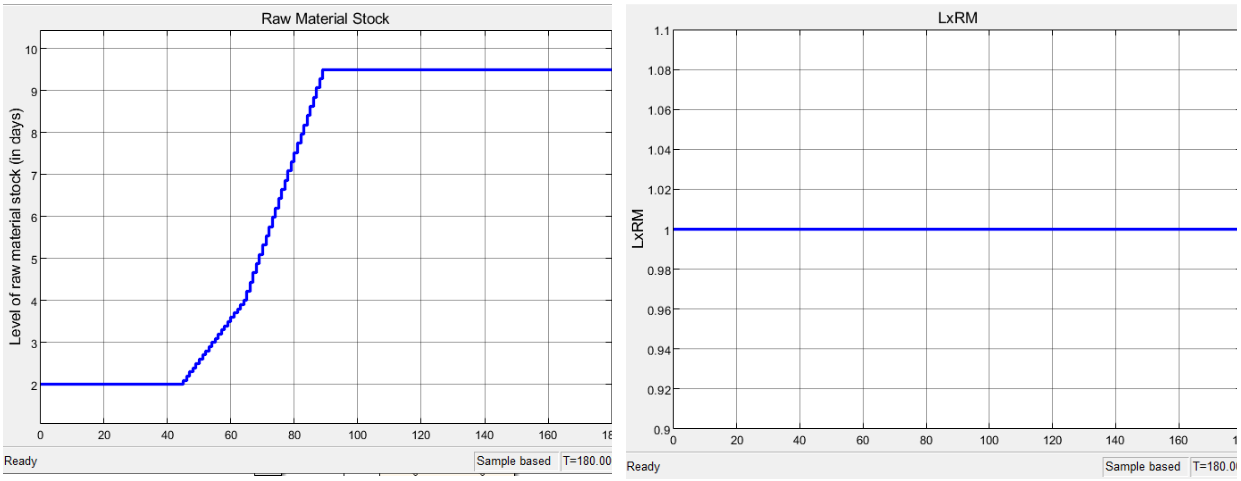


Figure 38 Stock of Raw Material Stock with time (left), Limit to Inbound Logistics performance coming from Material stock (Right

Figure 39 shows the final performance of Inbound logistics after the earthquake after taking in the consideration the logistics provider performance, limit to Inbound logistics performance coming from External Parts Stock, and limit to Inbound logistics performance coming from Raw Material Stock. The inbound logistics was not working for 45 days due to the disruption in the port. Then the port will fully recover and so do the outbound logistics. Furthermore, the performance of Inbound logistics will not be limited by neither Raw Material stock nor External Parts stock.

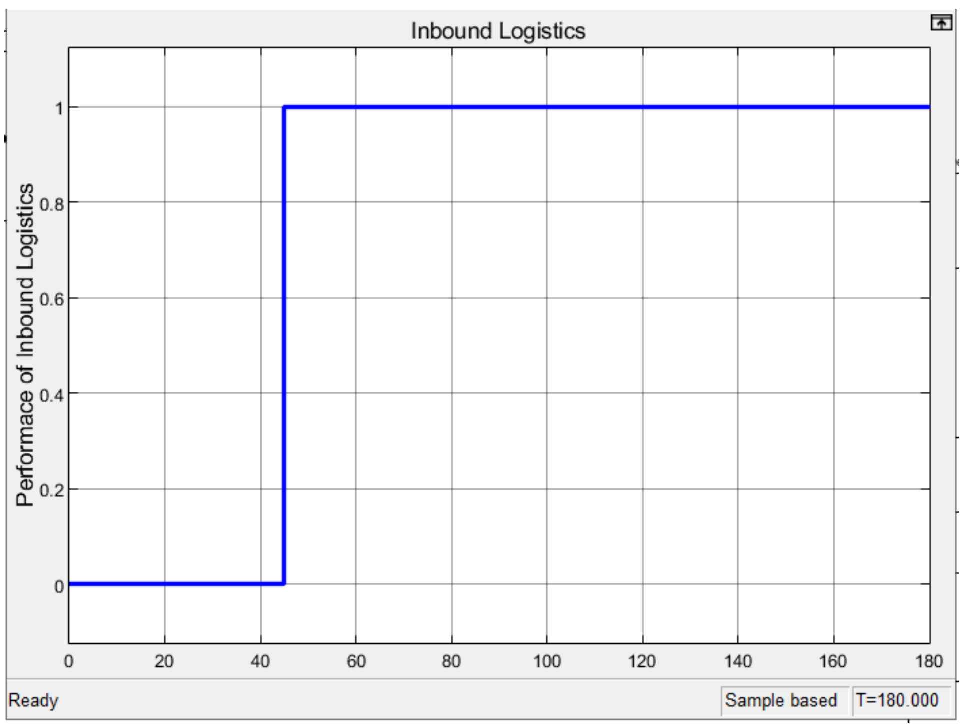


Figure 39 Final performance of Inbound logistics after the chosen earthquake scenario

Now, a combination of recovery strategies was chosen from suggested ones based on the outcomes of the scenario. These selected recovery strategies are going to be applied on the chosen earthquake scenario to investigate the performances of all business functions and stocks of Carware after applying these strategies. For the chosen earthquake scenario, applying some recovery strategies will not help in recovering the performances. For example, the strategies of increasing the capacity of finished products stock, raw material stock, external and internal parts stocks will not help in the chosen earthquake scenario since the levels of these stocks did not reach the limit. However, these strategies could be useful in low scale earthquakes.

The selected recovery strategies that have been applied in the chosen earthquake scenario are Alternative shipping, Backup equipment, and Alternative Emergency Maintenance Provider. These strategies have been selected based on the outcomes of the scenario, but they do not have to be the best combination for this scenario. To know the best combination for any scenario, tail and error approach should be followed. However, the objective of this section is to choose suitable strategies and apply them on the scenario to see if the performances will improve or not, and to prove the concept of applying recovery strategies in the presented model.

By applying Backup equipment, Carware could duplicate both the Manufacturing equipment vulnerable to earthquakes (used in machining process) and the Assembly equipment, keep it ready in a remote location. If any of this equipment has been destroyed due to an earthquake, backup equipment will be brought to the Carware in few days. Simulating this recovery strategy in the model will be by reducing the downtime of both Assembly infrastructure and Manufacturing infrastructure. The downtimes will not be eliminated since infrastructure includes buildings and equipment, and buildings need to be maintained. The new values are 30 days for Assembly infrastructure and 30 days for Manufacturing infrastructure instead of 45 days and 45 days respectively. A resilience option is finding an Alternative (or emergency) Maintenance Provider, which is located far enough not to be impacted by the same earthquake. By doing so, Carware will be able to reduce the downtime of the regular maintenance provider after an earthquake which will help the company to recover its performance faster. This recovery strategy can be modeled by reducing the value of loss of maintenance period in the model. The new value of Loss of maintenance period is 60 days instead of 90 days.

By applying Alternative shipping, an alternative mode of both inbound and outbound transport can be used in case the seaport was disrupted due to an earthquake. In the assumed case, the seaport limited the performance of both inbound and outbound logistics since the port was disrupted for 45 days due to the earthquake. This value can be reduced by using an alternative mode of both inbound and inbound transport. The new value of the performance of both inbound and outbound logistics due to the performance of the port is 30 days for inbound logistics and 30 days for outbound logistics, instead of 45 days and 45 days respectively.

As shown in Figure 40 on the left, the performance of Manufacturing without applying the recovery strategies was zero until day 45. Then it was recovered partially from day 45 until day 90. After day 90 it was fully recovered. However, and as shown in Figure 40 on the right, the performance of Manufacturing after applying the recovery strategy is zero until day 30. Then it was recovered partially from day 30 until day 60. After day 60 it was fully recovered. Furthermore, the partial recovery of Manufacturing performance after applying the recovery strategies is higher than the performance without applying the recovery strategies. This behavior is due to the reductions that happened to both the downtime period of Manufacturing infrastructure, and the Loss of maintenance period. These reductions happened because of applying the recovery strategies.

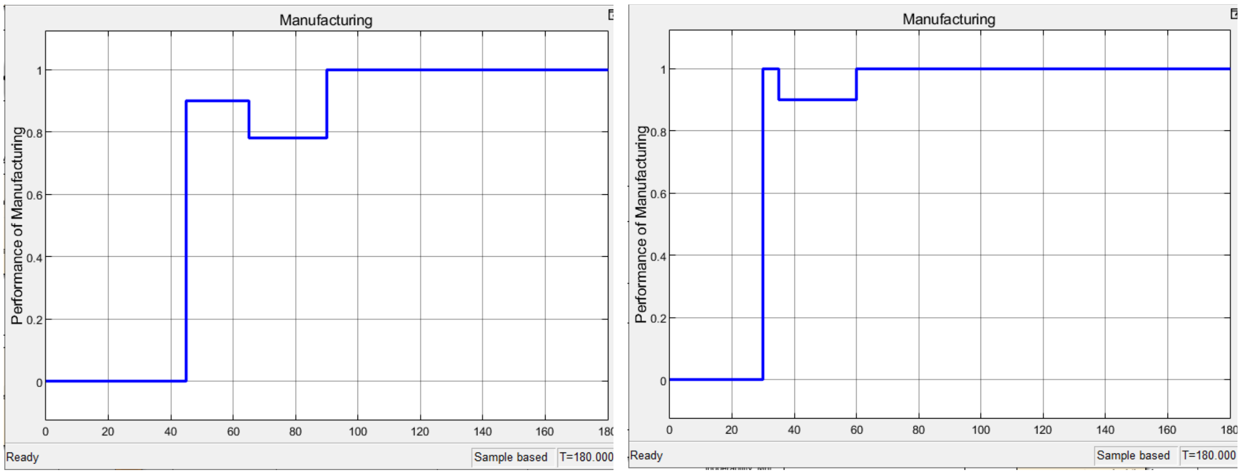


Figure 40 Performance of Manufacturing without recovery strategies (Left) and after applying the recovery strategies (right)

As shown in Figure 41 on the left, the performance of Assembly without applying the recovery strategies was zero till day 45. Then it was recovered partially from day 45 till day 90. After day 90 it was fully recovered.

However, and as shown in Figure 41 on the right, the performance of Assembly after applying the recovery strategy is zero till day 30. Then it was recovered partially from day 30 till day 60. After day 60 it was fully recovered. Furthermore, the partial recovery of Assembly performance after applying the recovery strategies is higher than the performance without applying the recovery strategies.

This behavior is due to the reductions that happened to both the downtime period of Manufacturing infrastructure, and the Loss of maintenance period. These reductions happened because of applying the recovery strategies.

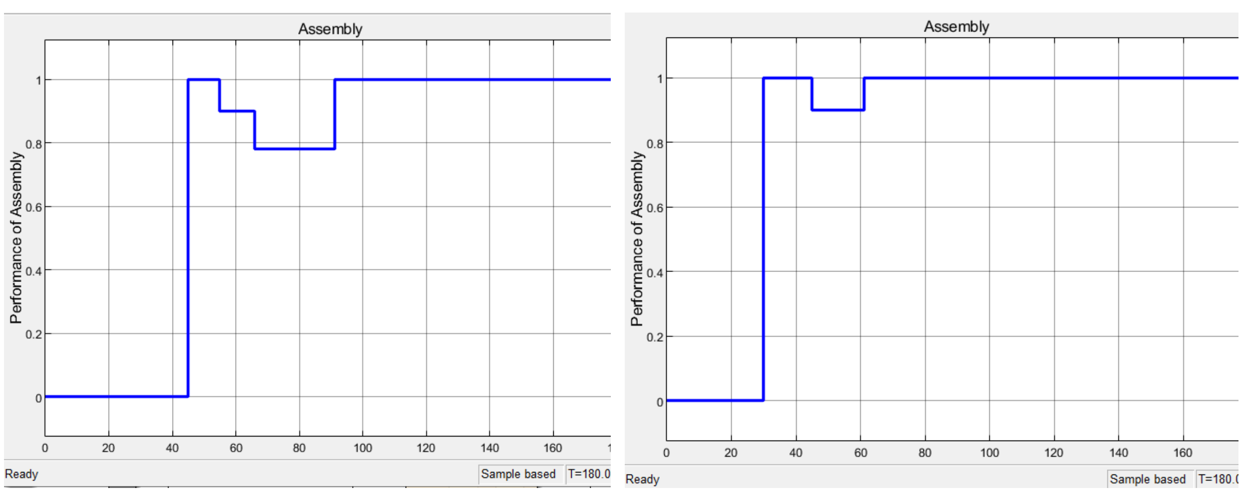


Figure 41 Performance of Assembly without recovery strategies (Left) and after applying the recovery strategies (right)

As shown in Figure 42 on the left, the performance of Outbound logistics without applying the recovery strategies was zero till day 45. Then it was recovered partially from day 45 till day 90. After day 90 it was fully recovered.

However, and as shown in Figure 42 on the right, the performance of Outbound logistics after applying the recovery strategy is zero till day 30. Then it was almost fully recovered from day 30 till day 60. After day 60 it was fully recovered. Furthermore, the partial recovery of Outbound logistics performance after applying the recovery strategies is higher than the performance without applying the recovery strategies.

This behavior is due to the reduction that happened to the down time of logistics provider due to applying Alternative shipping recovery strategy.

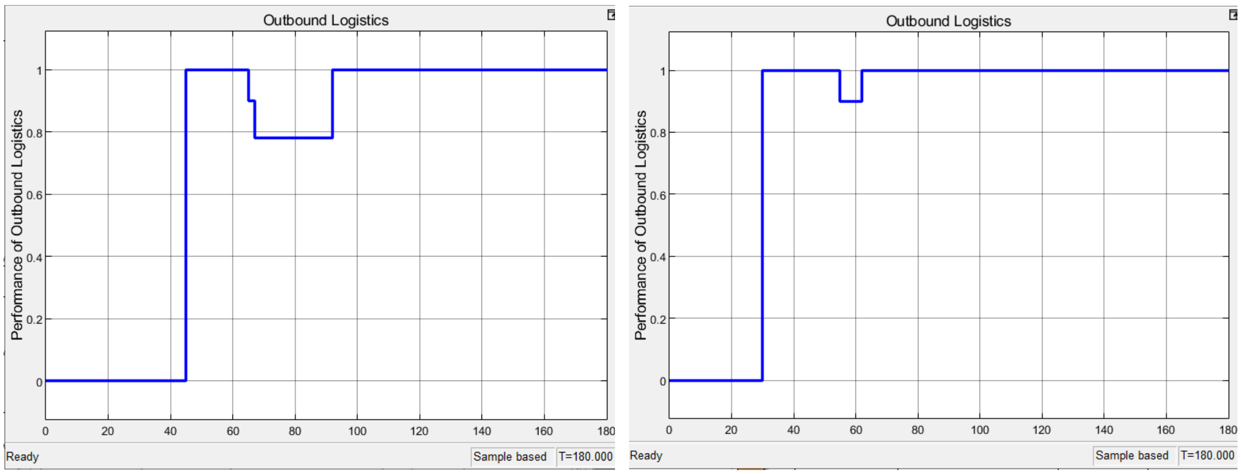


Figure 42 Performance of Outbound logistics without recovery strategies (Left) and after applying the recovery strategies (right)

As shown in Figure 43 on the left, the performance of Inbound logistics without applying the recovery strategies was zero till day 45. Then it was fully recovered.

However, and as shown in Figure 43 on the right, the performance of Inbound logistics after applying the recovery strategy is zero till day 30. Then it was fully recovered.

This behavior is due to the reduction that happened to the down time of logistics provider due to applying Alternative shipping recovery strategy.

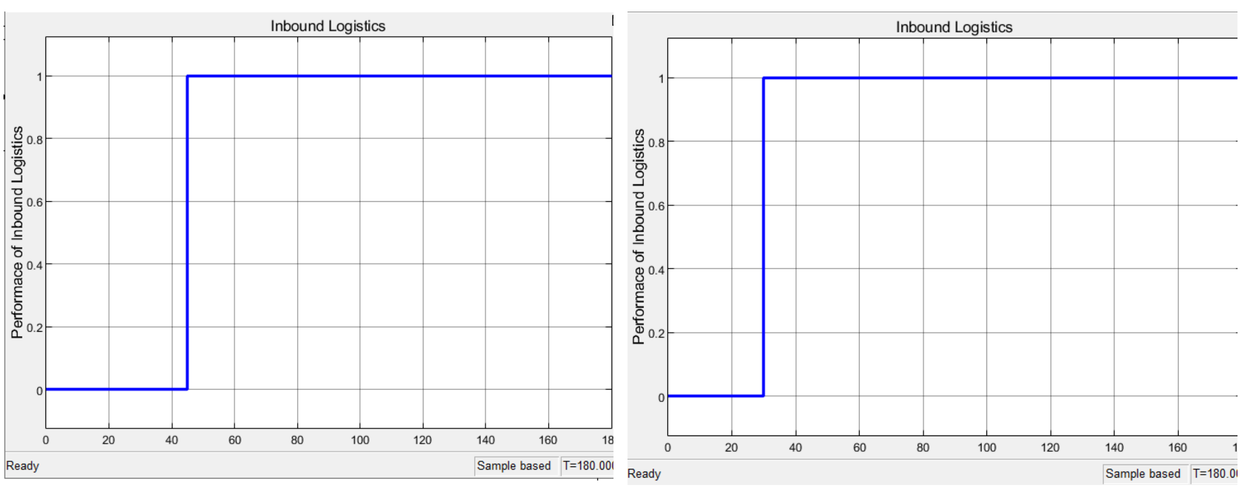


Figure 43 Performance of Inbound logistics without recovery strategies (Left) and after applying the recovery strategies (right)

As shown in Figure 44 on the left, the level of stock of Finished Products without applying the recovery strategies was zero from day 65 till day 90. As a result, the performance of Outbound logistics will be limited during this period. After day 90 the level of stock of Finished Products was partially recovered. However, and as shown in Figure 44 on the right, the level of stock of Finished Products after applying the recovery strategies is zero from day 54 till day 61. As a result, the performance of Outbound logistics will be limited during this period. After day 61 the level of stock of Finished Products was partially recovered. That means, after applying the recovery strategies, the duration in which the performance of Outbound logistics was limited will be reduced. Furthermore, the Carware's out-of-stock period will be reduced, which help to maintain the repetition of the company.

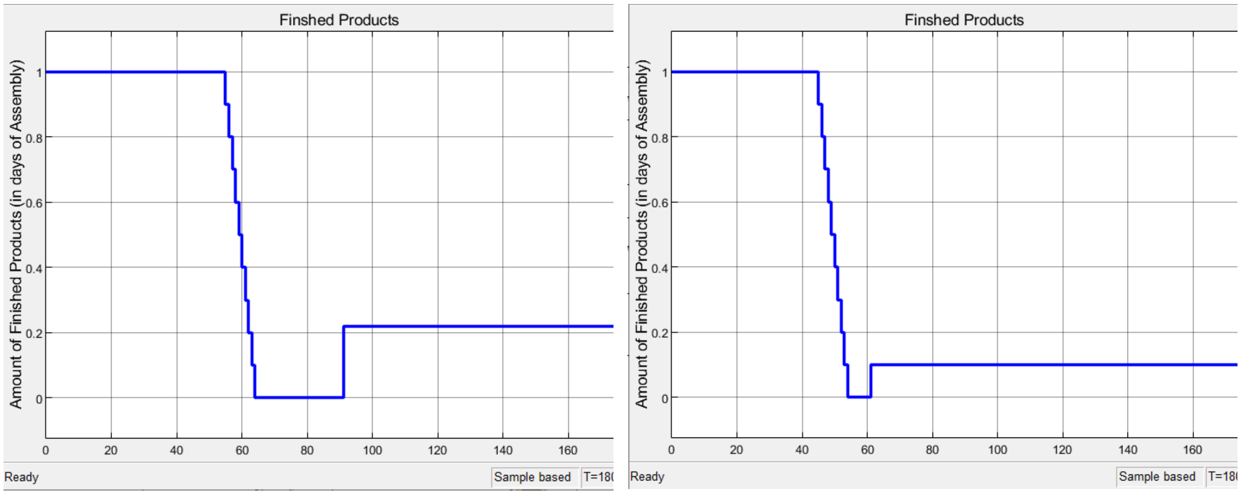


Figure 44 Finished Products Stock without recovery strategies (left) and after applying the recovery strategies (right)

As shown in Figure 45 on the left, the level of stock of Internal Parts without applying the recovery strategies was zero from day 55 till day 90. As a result, the performance of Assembly will be limited during this period. After day 90 the level of stock of Internal Parts was partially recovered.

However, and as shown in Figure 45 on the right, the level of stock of Internal Parts after applying the recovery strategies is zero from day 45 till day 60. As a result, the performance of Assembly will be limited during this period. After day 60 the level of stock of Internal Parts was partially recovered.

That means, after applying the recovery strategies, the duration in which the performance of Assembly was limited will be reduced. Furthermore, the Carware's out-of-stock period will be reduced, which help to maintain the repetition of the company.

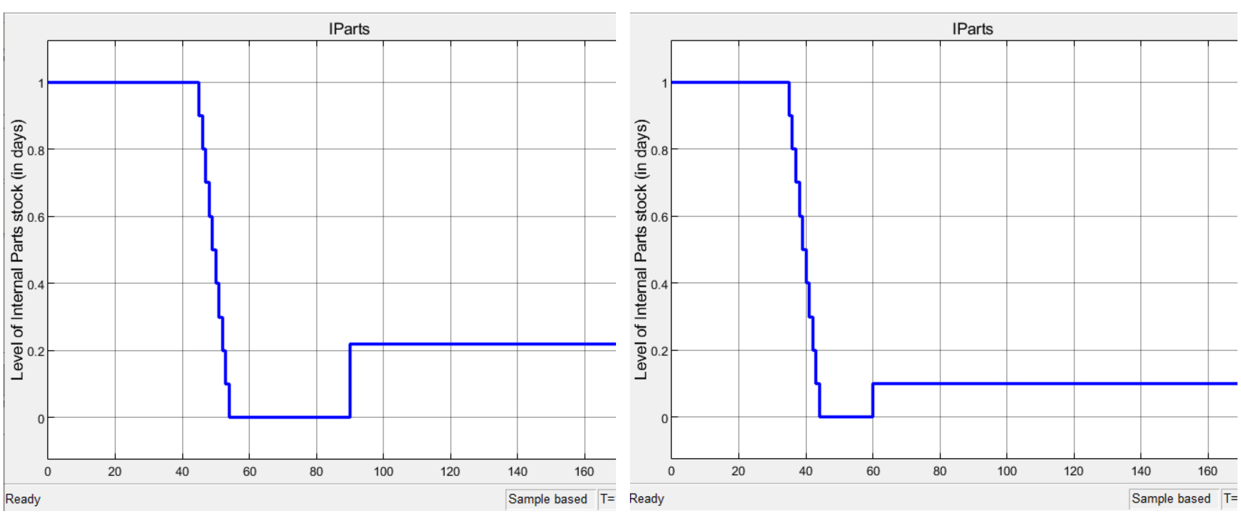


Figure 45 Internal Parts Stock without recovery strategies (left) and after applying the recovery strategies (right)

In conclusion, it is clear that applying this combination of the three recovery strategies improved the performances of the business functions and stocks of Carware for chosen earthquake scenario.

The presented simulation model is ready to be used for different earthquake scenarios and different recovery strategies. Carware company can use this simulation model to choose appropriate combinations of recovery strategies for different earthquake scenarios to be prepared for any earthquake scenario. Using this simulation model to prepare for earthquakes will save time and money compared to traditional methods, and it will provide more accurate results. Furthermore, this model is flexible in science that any other recovery strategy, other than the suggested ones, can be simulated and applied in the model.

7. Conclusion and Recommendations

This chapter includes the conclusion of the study, study limitations, and recommendations for future studies.

7.1 Conclusion

The objective of this study is to develop a pre-production of an educational serious game on coordinated Business Continuity Management in an earthquake-prone area. Firstly, a review of the state of the art in Business Continuity Management was done, to highlight the need for moving towards coordinated approaches between interdependent companies. An overview of the Serious Gaming approach was also done. Secondly, a general game flow was developed as well as a fictional case study of manufacturing company (Carware) and its external providers. Then, a simulations model has been developed to model internal interdependencies between business functions within Carware as well as the external interdependencies between Carware and both electricity and logistics providers. The model is also used to simulate recovery strategies to investigate their impacts on business functions' performances in Carware. After that, the model was tested by assuming an earthquake scenario and simulating this scenario in the model to investigate the performances of business functions and stocks in Carware. Finally, a combination of suitable recovery strategies was simulated on the assumed earthquake scenario in order to investigate the improvement in the performances of business functions and stocks in Carware.

The simulation model presented by this study is ready to be used for different earthquake scenarios and different recovery strategies. The simulation model enables players to choose appropriate combinations of recovery strategies for different earthquake scenarios to be prepared for any earthquake scenario. Using this simulation model to prepare for earthquakes will save time and money compared to traditional methods, and it will provide more accurate results. Furthermore, this model is flexible in sense that any other recovery strategy, other than the suggested ones, can be simulated and applied in the model. As a result, this simulation model is ready to be used as a back engine for the Area BCM educational serious game.

7.2 Limitations of the study

This study faces limitations due to the simplified concepts that were assumed during developing the Simulink model. One of these simplified assumptions is the impact of the lack of Maintenance on the performance of Manufacturing. The effect of losing Maintenance on Manufacturing is not instant since it will take some time for the impact to show up and this impact will not be constant with time, it will get worse if no action was taken with time. The loss of Manufacturing performance is a bit faster than linear. In the simulation model, it is approximated as a step function on every 30 days, with a 20% larger decrease compared to the previous step. Another limitation in the study is the instant recovery that is assumed in the model. In real cases, the recovery process could take days and it happens gradually. As a result, it is a curved line which increases with time. However, in the simulation model, it is assumed that the recovery process is instant, or it takes less than a day to go from one state of performance to another. Another limitation in the simulation model is that the simulation step is daily, so what happened within the day is not considered and the performances and stock levels are measured on daily level. Another limitation is that the consumption rate of each stock is assumed to be equal to storage rate entering the stock. This applies for all four physical stocks as well as the logical stock in the model. The last limitation in the model is that we did not distinguish between different types of parts used in Assembly process, we distinguished between two categories (Internal parts and external parts). Finally, for the simplicity, we assumed a constant use of both types of parts (internal and external) in Assembly. However, all of these approximations will not disturb the comparison of the company's performance under different BC plans, and the quality of players' decisions.

7.3 Recommendations for Further Study

In future studies, the Cosmetecor technology capabilities can be integrated to improve the coordinated BCM between the three organizations for the earthquake scenario since it is used for early detection of earthquakes. In most cases, the Cosmetecor issues an accurate warning up to 30 days ahead of time in the proximity of the company location. The alert indicates that there is an approaching ground motion close to the user's position. It uses time series forecasting to enhance the ability of possible stakeholders to take the appropriate response in the event of a certain ground-shaking intensity near the business location.

The Cosmetecor technology will provide companies with an early warning few days before the occurrence of an earthquake. The technology may provide information about upcoming earthquakes like the timing, location and severity of the earthquake. As a result, players will have an opportunity to adjust their coordinated business continuity plans accordingly and be prepared for the earthquake. Then, players could evaluate how this technology can improve the entire risk management and business continuity management.

Furthermore, in the future development, electricity provider and logistics provider cases might be further developed into a full game choice. Simulation models for these two organizations might be developed using Simulink to model internal interdependencies within each organization and external interdependencies between the three organizations. After that, the serious game has to be developed as an online software following a new general flow of the game. In this new general game, there will be a step called company selection in which the players will be divided into three groups and each group will be the business continuity team of one of the three organizations. Each team has to follow the same game flow of manufacturing company, which is presented in this study, and to perform risk evaluation for each business function. In this stage, each team will share the recovery objectives of its corresponding company with the other two companies. The recovery objectives include MTPD, RTO and RLO. By doing so, each company can evaluate the risk of all business functions and modify its business continuity plans accordingly. Then the serious game will be ready, and the next step is to perform an earthquake simulation scenario in the area and let the players to investigate the performances of the three organizations after an earthquake.

Once the serious game is completely developed, it will be available online for the students of Politecnico di Milano to develop and test their Business Continuity Management knowledge. Their feedback will be collected in order to revise and improve the game.

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