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# Designing a data-driven model for business continuity planning evaluation using robustness indicators

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Université Fédérale



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# THÈSE



IMT Mines Albi-Carmaux  
École Mines-Télécom

En vue de l'obtention du

## DOCTORAT DE L'UNIVERSITÉ DE TOULOUSE

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présentée et soutenue par

**Oussema BEN AMARA**

le 27 novembre 2023

Titre :

### **Designing a Data-Driven Model for Business Continuity Planning Evaluation using Robustness Indicators**

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## ABSTRACT

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The importance of business continuity planning (BCP) has been underscored by the increase in risky events such as natural disasters and pandemics. Despite the critical nature of these plans, evaluating their effectiveness has remained a challenge. This thesis project proposes a data-driven approach to evaluate BCPs through the use of robustness indicators.

To address the research question of how to design a data collection process for BCP evaluation, this project follows a three-step approach. Firstly, a comprehensive literature review establishes a state-of-the-art understanding of business continuity management. Secondly, a proposed data collection model considers different types of data, including physical and societal factors, and outlines approaches for their collection. The proposed model incorporates a data-driven approach to ensure accuracy and reliability in the evaluation process. This model is designed to address specific use cases within the scope of BCP, including a pediatric ward and an urban transportation company. Thirdly, a Proof of Concept (POC) analysis is conducted for these use cases to demonstrate the relevance and impact of the collected data on their respective business continuity strategies. The POC involves the design of robustness indicators for the evaluation of BCPs, and the analysis will provide valuable insights about the entire proposed model.

The proposed approach aims to measure the ability of BCPs to maintain critical business functions and minimize disruptions. Introducing robustness indicators as part of the evaluation process represents a contribution to the field of business continuity management. The proposed data collection model considers various data types to provide a comprehensive evaluation of BCPs. The POC analysis demonstrates the practical application of the proposed model and the value of robustness indicators in assessing BCP effectiveness.

The results of this study were examined through the following cases: (i) a data collection model and its approaches, (ii) a BC assessment grid, (iii) a BC ontology and a knowledge graph, and (iv) dynamic dashboards for presenting patients' and personnel's data along with their sociological profiles.

This thesis project aims at improving the BCP by providing a robustness evaluation model. The proposed model has the potential to improve the assessment of business continuity planning and improve organizations' ability to withstand disruptive events. The research findings can be reproduced within organizations seeking to enhance their business continuity planning and risk management strategies.

**Keywords:** Business continuity planning, Robustness indicators, Data-driven approach, Risk management, Disaster preparedness, Business continuity assessment, Resilience.



## RESUME

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L'importance de la planification de la continuité d'activité a été, consécutivement à l'augmentation d'événements à risque tels que les catastrophes naturelles et les pandémies, reconnue comme essentielle. Bien que cette planification soit discutable, l'évaluation de son efficacité demeure un défi. Cette thèse est consacrée aux données qui servent à évaluer différents Plans de Continuité d'Activité (PCAs) à partir de l'utilisation d'indicateurs de robustesse.

La question à laquelle tente de répondre cette thèse porte plus spécifiquement sur la conception d'un processus de collecte de données pour l'évaluation de PCAs. Afin de répondre à notre questionnement nous emprunterons un cheminement constitué de trois étapes. La première se présente sous la forme d'une revue systématique de la littérature qui permet de proposer un état de l'art de la gestion de la continuité d'activité. La seconde aborde un modèle de recueil de données qui associe différents types de données, aussi bien des facteurs physiques que sociétaux, et décrit les approches qui permettent de les collecter. Le modèle proposé intègre une approche prioritairement centrée sur les données dans l'objectif de renforcer l'exactitude et la fiabilité du processus d'évaluation. La troisième étape est consacrée à une preuve de concept (POC) effectuée pour démontrer la pertinence et l'impact des données collectées à propos de la continuité d'activité. Le POC implique de concevoir des indicateurs de robustesse pour l'évaluation des PCAs, alors que l'analyse fournit des informations précieuses à propos de l'intégralité du modèle proposé.

L'approche retenue vise à mesurer la capacité des PCAs à maintenir les fonctions critiques d'une organisation et à minimiser les perturbations dont elle souffre. L'introduction d'indicateurs de robustesse dans le cadre du processus d'évaluation représente une contribution au domaine de la gestion de la continuité d'activité. Le modèle de collecte de données proposé prend en compte différents types d'indicateurs afin de fournir une évaluation complète des PCAs. L'analyse du POC permet de simuler la faisabilité du modèle proposé et la pertinence des indicateurs de robustesse dans l'évaluation de l'efficacité des PCAs.

Les résultats de cette étude ont été traités à travers : (i) un modèle de collecte de données et ses approches, (ii) une grille d'évaluation de la continuité d'activité, (iii) une ontologie de la continuité d'activité et un graphe de connaissances, et (iv) des tableaux de bord dynamiques pour présenter les données des patients et du personnel ainsi que leurs profils sociologiques.

Ce travail ambitionne de contribuer à l'amélioration des PCAs en fournissant un modèle d'évaluation de la robustesse. Les résultats de la recherche souhaitent être utiles pour les organisations cherchant à améliorer leur planification de la continuité d'activité et leurs stratégies de gestion des risques.

**Mots clés :** Planification de la continuité d'activité, Indicateurs de robustesse, Approche axée sur les données, Gestion des risques, Préparation aux catastrophes, Évaluation de la continuité d'activité, Résilience.



## RESUME LONG EN FRANÇAIS

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### PREFACE

Ce projet de thèse de doctorat intitulé "Évaluation des Plans de Continuité d'Activité à travers les Indicateurs de Robustesse" aborde l'importance croissante de la planification de la continuité d'activité dans le monde d'aujourd'hui, compte tenu des risques croissants posés par les catastrophes naturelles, les cyberattaques et les pandémies. Il met l'accent sur la nécessité pour les organisations de maintenir leurs fonctions critiques et de minimiser les perturbations pour assurer leur survie.

Cette approche vise à mesurer la capacité des PCA à maintenir les fonctions critiques de l'organisation et à minimiser les perturbations. L'introduction d'indicateurs de robustesse dans le processus d'évaluation représente une contribution au domaine de la gestion de la continuité d'activité. Le modèle de collecte de données considère divers types d'indicateurs pour offrir une évaluation couvrante des PCA. L'analyse du POC permettra d'évaluer le modèle et sur la base de cas applicatifs, de situations et données réelles.

L'objectif principal de la thèse est ainsi de :

**Proposer une approche basée sur les données pour évaluer les plans de continuité d'activité à l'aide d'indicateurs de robustesse.** L'approche se compose de trois étapes essentielles :

- 1. Revue de la littérature :** La première étape implique une revue approfondie de la littérature pour établir l'état actuel des connaissances dans le domaine de la gestion de la continuité d'activité. Cette revue englobe la recherche académique, les meilleures pratiques de l'industrie et des études de cas du monde réel pour identifier les lacunes et les limites des méthodologies d'évaluation existantes.
- 2. Modèle de collecte de données :** La deuxième étape se concentre sur le développement d'un modèle de collecte de données complet qui prend en compte divers types de données, y compris des facteurs physiques, sociétaux et économiques influençant la continuité d'activité. Le modèle adopte une perspective holistique, combinant des sources de données quantitatives et qualitatives pour garantir l'exactitude et la couverture de tous les aspects pertinents, tout en tenant compte des tendances émergentes et des risques futurs.
- 3. Analyse de la preuve de concept (POC) :** La troisième étape implique une analyse de la preuve de concept où des indicateurs de robustesse spécifiques à l'efficacité des plans de continuité d'activité sont conçus et appliqués. Ces indicateurs évaluent les aspects de la préparation, de la réponse et de la récupération des plans. Des scénarios du monde réel sont utilisés pour valider le modèle de collecte de données et les indicateurs de robustesse en pratique.

L'incorporation d'indicateurs de robustesse représente l'idée principale de cette thèse dans le domaine de la continuité d'activité. Ceci permet une évaluation des plans de continuité d'activité, en tenant compte à la fois des facteurs internes et externes qui affectent la capacité d'une organisation à résister aux perturbations.



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Deux études de cas sont présentées pour démontrer l'application pratique de la recherche :

1. **Étude de cas dans le domaine de la santé :** Cette étude se concentre sur les perturbations dans un service de pédiatrie pendant le confinement lié à la COVID-19. Une analyse des données sociétales et une POC ont été utilisées pour identifier des paramètres spécifiques affectant les soins aux patients et l'efficacité des prestataires de soins de santé. Les résultats ont montré une amélioration des résultats des soins aux patients et une plus grande efficacité.
2. **Étude de cas dans le domaine des transports urbains :** Dans l'industrie des transports, la recherche visait à optimiser la circulation dans une zone urbaine très fréquentée. Des techniques avancées d'analyse des données et d'ingénierie ont été utilisées pour identifier les menaces à la continuité d'activité et développer des mesures d'évaluation. Ces informations ont conduit à des interventions ciblées et à une meilleure gestion et efficacité de la circulation.

Ces études de cas mettent en évidence l'applicabilité réelle de la recherche et son potentiel pour améliorer la planification et la préparation à la continuité d'activité dans divers secteurs.

## **CHAPITRE I. LA PLANIFICATION DE LA CONTINUITÉ D'ACTIVITÉ : UNE NÉCESSITÉ CRUCIALE**

Le chapitre I de cette thèse sert d'introduction à l'importance de la Planification de la Continuité d'Activité (PCA) dans l'environnement commercial en constante évolution d'aujourd'hui.

**Introduction à la PCA :** Le chapitre commence par mettre en évidence le rôle essentiel de la PCA dans les organisations contemporaines. Il souligne que la PCA est essentielle pour identifier et atténuer divers risques et perturbations, tels que les catastrophes naturelles, les cyberattaques, les pandémies et les problèmes de chaîne d'approvisionnement.

**Diversité des risques :** L'étude reconnaît la nécessité de différencier entre différents types de risques, y compris les risques naturels, industriels et sociaux. Elle met en évidence la complexité croissante de la prise en charge de ces défis multifacettes.

**Contexte de la recherche :** Cette section décrit l'évolution des risques et des perturbations dans l'environnement commercial contemporain, en soulignant la nécessité croissante de stratégies adaptables et robustes pour assurer la continuité d'activité. Elle identifie également les lacunes dans la recherche existante et les opportunités de recherche future.

**Problème de recherche :** Le chapitre aborde les problèmes et les défis fondamentaux qui rendent nécessaire le développement et la mise en œuvre de la PCA. Il met en avant les conséquences potentielles de l'absence d'une PCA efficace, notamment les pertes financières, les dommages à la réputation et les perturbations opérationnelles.

**Proposition de recherche :** Cette section décrit les objectifs de recherche, qui visent à améliorer la compréhension et la pratique de la PCA. Ces objectifs peuvent impliquer l'exploration des meilleures pratiques, l'évaluation des cadres de PCA existants, l'identification

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des tendances émergentes et la formulation de recommandations pour améliorer les capacités de PCA.

**Méthodologie :** Le chapitre discute de l'approche de recherche et des techniques à utiliser, y compris les méthodes de recherche qualitatives et quantitatives telles que la revue de la littérature, les études de cas, les enquêtes et les entretiens (voir Figure 4).

**Plan de thèse :** Le chapitre fournit une feuille de route pour les chapitres suivants, résumant brièvement la structure et le contenu de la thèse, et mettant en évidence les thèmes et les sujets clés qui seront abordés (voir Figure 2).

En conclusion, le chapitre I établit l'importance de la PCA dans un monde caractérisé par des risques et des perturbations croissants. Il prépare le terrain pour les chapitres suivants en introduisant le contexte de la recherche, le problème, les objectifs, la méthodologie et le plan de thèse, en soulignant l'importance de la PCA pour la résilience des entreprises. Le chapitre II devrait approfondir la recherche existante sur la PCA pour fournir une base à l'exploration ultérieure dans les chapitres suivants.

## CHAPITRE II. EXAMEN DU CONTEXTE DE LA RECHERCHE SUR LA PCA : ÉTAT DE L'ART

Le chapitre II de cette thèse offre une exploration approfondie du contexte de la recherche dans le domaine de la Planification de la Continuité d'Activité (PCA), englobant divers concepts, théories, motivations et approches basées sur les données. Voici une synthèse des points clés de ce chapitre :

**Introduction au contexte de la recherche :** Ce chapitre sert d'exploration fondamentale des connaissances et de la recherche existantes liées à la PCA. Il vise à fournir une synthèse complète des travaux antérieurs dans le domaine, à identifier les concepts principaux, les théories et les motivations, et à découvrir d'éventuelles controverses ou débats.

**Concepts principaux et motivations :** Le chapitre commence par aborder les concepts principaux et les motivations de la PCA. Il définit la Continuité d'Activité (CA) comme une stratégie/processus de gestion holistique qui identifie les menaces potentielles, leurs impacts, et fournit un cadre pour renforcer la résilience et une réponse efficace pour protéger les intérêts des parties prenantes, la réputation, la marque et les activités génératrices de valeur. De plus, il reconnaît la CA comme la capacité d'une organisation à maintenir des niveaux prédéfinis de livraison de produits ou de services après un incident perturbateur.

**Robustesse des (Plans de Continuité d'Activité) PCAs :** Le chapitre explore la robustesse des PCAs et fait la distinction entre robustesse et résilience. Il examine différentes définitions et types de résilience, tels que la résilience  $\alpha$ ,  $\beta$  et  $\gamma$ , en mettant l'accent sur la capacité du système à s'adapter aux perturbations. Il reconnaît la complexité de la réalisation de la robustesse dans la société moderne, où le retour à un état stable est souvent irréaliste.

**Crises et perturbations :** Le chapitre définit les crises comme des événements soudains et inattendus qui posent des menaces importantes à une organisation, mettant en évidence leurs enjeux élevés, leur urgence et leur imprévisibilité. Il différencie les crises des perturbations, qui

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font référence à des changements importants perturbant les dynamiques traditionnelles de l'industrie ou du marché (voir Figure 3)..

**Utilisation des PCAs :** Cette section se penche sur la manière dont les PCAs sont utilisés dans divers contextes, y compris l'environnement naturel, les personnes, les organisations et la technologie. Elle souligne l'importance de prendre en compte les besoins et les rôles des individus et des collectifs pour garantir la PCA et une gestion efficace des infrastructures critiques. Elle explique notamment le lien que la Continuité d'Activité a avec ces concepts, à savoir la technologie, l'environnement naturel, les organisations et les personnes.

**Approches basées sur les données :** Le chapitre explore l'évolution des approches de collecte de données, englobant les méthodes basées sur l'ordinateur, sur le web et basées sur les données. Il discute du rôle de la technologie, en particulier de l'Internet des objets (IoT), dans l'amélioration de la collecte et de l'analyse de données pour la PCA.

**Conclusion :** Le chapitre II se conclut en résumant ses contributions. Il a fourni un aperçu complet du contexte de la recherche en PCA, identifié les lacunes et les limites des connaissances existantes, présenté un cadre conceptuel et formulé des hypothèses de recherche. Le chapitre jette les bases de l'enquête empirique à suivre, dans le but d'avancer dans le domaine de la PCA et d'offrir des perspectives pratiques pour les organisations cherchant à renforcer leur résilience.

En résumé, le chapitre II sert de base cruciale pour votre thèse, offrant un examen approfondi du paysage de recherche existant en PCA et fournissant une direction claire pour une exploration ultérieure et une analyse dans les chapitres suivants.

## CHAPITRE III. LA MÉTHODOLOGIE DE RECHERCHE

Le chapitre III de cette thèse de doctorat, intitulé "La Méthodologie de Recherche," décrit l'approche adoptée pour analyser la Planification de la Continuité d'Activité (PCA). Le chapitre englobe les éléments clés de la méthodologie de recherche, comme suit :

**Introduction à la méthodologie de recherche :** Ce chapitre pose les bases de l'investigation systématique de la Planification de la Continuité d'Activité (PCA). Il met en avant l'importance d'adopter une approche structurée et systématique pour comprendre pleinement les subtilités de la PCA. Les méthodes de recherche employées sont introduites pour fournir un plan de travail pour l'étude.

**Échantillon et population :** Le chapitre discute de la sélection d'un échantillon représentant deux cas d'utilisation spécifiques : les hôpitaux publics et les entreprises de transport urbain. Ces cas se trouvent dans une ville de taille moyenne du sud-ouest de la France et dans une plus grande ville en Italie, illustrant des scénarios de PCA du monde réel dans un contexte spécifique.

**Modèle de collecte de données :** Un modèle de collecte de données est introduit pour faciliter la collecte de données organisée. Ce modèle est essentiel pour garantir que les données collectées restent cohérentes et alignées sur les objectifs de recherche. Il constitue la base d'une analyse systématique des données liées à la PCA (voir Figure 5).

**Sources de données et leur importance :** Le chapitre met en avant l'importance de l'utilisation de sources de données diverses, notamment des données sociétales, financières et physiques

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provenant de différents capteurs et dispositifs IoT. Ces sources contribuent à une analyse complète de l'environnement de l'organisation et de son PCA (voir Figure 6 et Figure 7).

**Approches de collecte de données :** Reconnaisant la nature multidimensionnelle de la PCA, le chapitre fait la distinction entre les données physiques (techniques) et les données sociétales. Ces types de données sont cruciaux pour formuler des stratégies de continuité d'activité et comprendre les facteurs socioculturels qui influencent l'efficacité du PCA.

**Modèle de double hybridité :** La recherche adopte un modèle de double hybridité, signifiant son adaptabilité à la gestion de deux types distincts de données et l'utilisation d'approches hybrides pour la collecte de données. Cette approche permet à la recherche de capturer les aspects techniques et socioculturels de la PCA (voir Figure 8).

**Évaluation de la PCA :** L'évaluation des PCAs est un aspect essentiel de la méthodologie de recherche. Le chapitre introduit la Grille d'Évaluation de la Continuité d'Activité (BC Assessment Grid), fournissant un cadre structuré pour évaluer l'efficacité de la PCA. Elle examine les piliers de la PCA et explore les facteurs influençant la robustesse du PCA (voir Figure 15).

**Développement de l'ontologie de la Continuité d'Activité :** Le chapitre détaille le développement d'une Ontologie de la Continuité d'Activité (ontologie de la CA) pour structurer et organiser les connaissances en matière de PCA. Cette ontologie vise à faciliter le partage des connaissances dans le domaine en fournissant une représentation structurée des pratiques du PCA (voir Figure 19).

**Interopérabilité de l'ontologie :** Les aspects techniques de l'interopérabilité de l'ontologie entre WebProtégé et Obsidian sont explorés. Cette intégration favorise la collaboration et maximise l'utilité de l'ontologie de la CA, améliorant l'accessibilité et l'utilisabilité dans l'analyse de la PCA.

**Création d'une base de connaissances :** Une base de connaissances émerge de l'ontologie de la CA, offrant une représentation structurée des connaissances en matière de PCA. Cette base de connaissances permet la visualisation et l'exploration des informations liées au PCA, servant de ressource précieuse pour les parties prenantes à la recherche de perspectives sur les pratiques de PCA (voir Figure 22).

**Reconnaissance des limites de la recherche :** Le chapitre se termine en reconnaissant les limites de la recherche. Ces limites englobent divers aspects, notamment les contraintes méthodologiques, les considérations éthiques, les complexités conceptuelles et les défis pratiques. La reconnaissance de ces limites offre une perspective sur la portée et l'applicabilité des résultats.

En résumé, le chapitre III offre un aperçu complet de la méthodologie de recherche employée dans cette thèse de doctorat. Il aborde la sélection de l'échantillon, la collecte de données, l'évaluation de la PCA, le développement de l'ontologie de la Continuité d'Activité, l'interopérabilité de l'ontologie, la création de la base de connaissances et les limites de la recherche. Ces éléments contribuent collectivement à une exploration de la Planification de la Continuité d'Activité dans le contexte de cas d'utilisation du monde réel. Cette exploration est détaillée dans le 4<sup>ème</sup> et dernier chapitre de cette thèse. Elle consiste principalement à analyser

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les résultats à partir de deux cas d'études différents en appliquant la méthodologie de cette recherche.

## **CHAPITRE IV. TEST DE LA MÉTHODOLOGIE : RÉSULTATS DE LA RECHERCHE**

Le chapitre IV de la thèse de doctorat, intitulé "Test de la Méthodologie : Résultats de la Recherche," présente les résultats de la recherche après l'application de la méthodologie proposée. Le chapitre commence par des introductions aux deux études de cas distinctes, fournissant un contexte essentiel pour encadrer efficacement les résultats de la recherche qui suivent.

### **Étude de cas 1 : Service de Pédiatrie d'un Hôpital Public**

Dans la première étude de cas, la recherche s'est concentrée sur les perturbations au sein d'un service de pédiatrie pendant le confinement lié à la COVID-19. L'objectif était d'analyser les données sociétales d'une grande cohorte de patients et de développer une preuve de concept (POC) visant à identifier des paramètres spécifiques associés aux catégories de patients les plus touchées. L'objectif était d'améliorer les résultats des soins et d'augmenter l'efficacité au sein du service de pédiatrie.

### **Étude de cas 2 : Centre des Opérations de Sécurité (SOC) d'une Entreprise de Transport Urbain**

La deuxième étude de cas était centrée sur l'industrie des transports, en particulier sur l'optimisation de la circulation routière et la réduction de la congestion dans une zone urbaine très fréquentée. Des techniques avancées d'analyse des données et d'ingénierie ont été utilisées pour développer un modèle d'évaluation capable d'identifier les menaces à la continuité d'activité (CA) dans différentes catégories et de déterminer les indicateurs d'évaluation pertinents pour la CA. L'objectif était d'améliorer la gestion du trafic et l'efficacité globale du système de transport, en se concentrant notamment sur le centre de données du centre des opérations de sécurité.

**Grille de Test Multidimensionnelle :** Pour tester et évaluer la méthodologie dans chaque étude de cas, une grille de test multidimensionnelle a été mise en place. Cette grille impliquait la collecte systématique et l'analyse des données à partir de diverses sources, telles que les données sociétales dans l'étude de cas de la santé et les données liées à la circulation dans l'étude de cas des transports. La grille de test multidimensionnelle permettait une évaluation complète de l'efficacité de la méthodologie pour relever les défis spécifiques à chaque secteur (voir Figure 31).

**Résultats Attendus :** Dans les deux études de cas, certains résultats attendus étaient anticipés. Dans l'étude de cas du service de pédiatrie, l'application de la méthodologie de recherche devait conduire à une amélioration des résultats des soins en identifiant des paramètres spécifiques associés aux catégories de patients les plus touchées. Ces informations étaient destinées à fournir des insights précieux pour optimiser les options de traitement et assurer un service ininterrompu.

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Dans l'étude de cas des transports, la méthodologie de recherche était censée aboutir à une meilleure gestion de la circulation et à une réduction de la congestion. En identifiant avec précision les menaces à la continuité d'activité et en déterminant les indicateurs d'évaluation pertinents, les résultats attendus comprenaient une meilleure fluidité de la circulation, une meilleure efficacité et une amélioration globale du système de transport.

**Présentation des Données :** Le chapitre présente les résultats bruts obtenus à partir des études empiriques menées dans les deux études de cas. La présentation des données sert de base fondamentale pour l'analyse ultérieure, offrant une vision non filtrée des résultats de l'étude. Elle permet une compréhension claire des données collectées et prépare le terrain pour une analyse et une interprétation approfondie. Ces données sont présentées dans leur forme brute afin d'expliquer les divers traitements et analyses effectués ensuite ainsi que le processus de transformation de ces données et de la formation des indicateurs de robustesse des PCAs.

**Analyse des Résultats :** L'analyse des résultats est effectuée séparément pour chaque étude de cas. Dans l'étude de cas du service de pédiatrie, la recherche s'est concentrée sur les indicateurs sociologiques de la robustesse de la PCA, notamment les taux de présence du personnel, la satisfaction des patients, les niveaux de peur, l'occupation des services, et bien d'autres. Ces indicateurs ont été méticuleusement analysés dans le contexte de la grille d'évaluation, offrant une évaluation structurée de la robustesse de la PCA dans diverses dimensions (voir Figure 28, Figure 29, Figure 33 et Figure 34).

Dans l'étude de cas des transports, les principales conclusions ont porté sur les métriques de la CA globale, l'évaluation de la CA du SOC et les recommandations pour l'amélioration de la réglementation et des normes de la CA. L'étude a examiné l'impact de la densité routière sur la congestion du trafic et a exploré l'adaptation dynamique des ressources énergétiques au sein du SOC lors d'événements difficiles (voir Figure 36 et Figure 35).

**Test des Hypothèses :** Des hypothèses ont été formulées et testées pour évaluer les relations et les corrélations au sein de chaque étude de cas. Dans l'étude de cas du service de pédiatrie, des hypothèses liées à des facteurs tels que la situation économique et l'absentéisme, la situation sociale et la satisfaction des patients, et la situation professionnelle et la présence des parents ont été testées.

Dans l'étude de cas des transports, des hypothèses concernant la densité routière et la congestion du trafic, la diligence due des fournisseurs et l'inventaire de l'entreprise, et les interruptions de service électrique et l'absentéisme des employés ont été examinées.

**Discussion des Résultats :** Le chapitre se conclut par une discussion approfondie des résultats, les replaçant dans le contexte de la littérature existante et mettant en évidence leur alignement et leurs disparités avec les efforts de recherche antérieurs. Il explore les implications pratiques des résultats dans les secteurs respectifs et envisage des pistes potentielles pour de futures recherches et applications pratiques.

**Conclusion et Principales Conclusions :** Le chapitre IV se conclut par un résumé concis des principales conclusions. Il souligne l'importance des résultats empiriques dans la confirmation de l'efficacité de l'approche méthodologique, sa transférabilité entre les domaines et son potentiel en tant que base pour de futures recherches dans le domaine de la Planification de la Continuité d'Activité.

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Dans l'ensemble, le chapitre IV contribue au débat sur la PCA en offrant des perspectives du monde réel et des preuves empiriques de l'applicabilité et de l'efficacité de la méthodologie. Tout au long de ce chapitre, une approche scientifique et objective est maintenue, mettant en avant l'efficacité de la méthodologie pour atteindre les objectifs de recherche et fournir des informations précieuses sur la Planification de la Continuité d'Activité dans les contextes des soins de santé et des transports urbains.

## **RESUME DE LA DISCUSSION ET DE LA CONCLUSION :**

La dernière section de la thèse fait à la fois office de discussion et de conclusion. Elle résume les résultats, aborde le problème de recherche et les questions connexes, présente les contributions, souligne les limitations et discute des perspectives futures. Voici un résumé concis des points clés de cette section :

**Objectif Principal de la Recherche :** L'objectif principal de cette étude était d'avancer dans le domaine de la gestion de la continuité d'activité en créant un cadre complet et flexible pour l'évaluation des Plans de Continuité d'Activité (PCAs). Le résultat est une technique qui utilise des indicateurs de robustesse et un modèle basé sur les données.

**Importance de la Revue de la Littérature :** Une revue de la littérature critique a été réalisée pour établir les fondements de la recherche. Cette phase a permis d'identifier les lacunes et les défis liés à l'évaluation de l'efficacité des PCAs, en soulignant la nécessité d'une perspective holistique qui tienne compte à la fois des processus internes et des facteurs externes.

**Modèle de Collecte de Données :** La recherche visait à établir une procédure efficace de collecte de données pour évaluer la robustesse des PCAs, en mettant l'accent sur les infrastructures critiques et les organisations. Des questions de recherche ont été formulées pour explorer la mise en œuvre des PCA dans divers domaines, y compris les aspects environnementaux, techniques et organisationnels.

**Questions de Recherche (QR) :** Les principales QR de l'étude se sont concentrées sur la manière dont les principes de la continuité d'activité étaient appliqués dans ces domaines et sur leurs relations avec la technologie, les rôles organisationnels/humains et les caractéristiques environnementales.

**Contributions au domaine** (voir Figure 37) :

1. **Ct1 : Modèle et Approches de Collecte de Données :** Une approche générique de collecte de données a été développée, permettant d'accueillir différents types de données pour garantir une évaluation complète des PCAs, en tenant compte à la fois des facteurs internes et externes.
2. **Ct2 : Grille d'Évaluation de la CA :** La création d'une grille d'évaluation de la CA a fourni un cadre systématique pour l'évaluation des PCAs, en incorporant des indicateurs de robustesse comme outils pour évaluer la résilience des plans.
3. **Ct3 : Ontologie de la CA et Graphe de Connaissances :** Une ontologie de la CA et un graphe de connaissances ont été établis, améliorant la compréhension des relations entre les éléments de la CA et améliorant l'évaluation des PCAs en tenant compte de multiples menaces et caractéristiques organisationnelles.

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**4. Ct4 : Tableaux de Bord de Données Dynamiques et Profils Sociologiques :** Le développement de tableaux de bord de données dynamiques et de profils sociologiques, illustré dans un scénario d'utilisation, a amélioré l'évaluation des PCAs en fournissant des informations en temps réel sur les conditions et les vulnérabilités des patients et du personnel, améliorant la prise de décision en cas de perturbations.

**Liens avec les Questions de Recherche et les Hypothèses :** Les contributions ont été liées aux questions de recherche (QR) et aux hypothèses (H1, H2, H3) pour démontrer leur pertinence dans la résolution du problème de recherche.

**Limitations :** L'étude a reconnu plusieurs limitations, notamment celles liées à la méthodologie, à l'éthique, aux défis conceptuels et aux contraintes pratiques. Ces limitations influencent l'interprétation et l'applicabilité des résultats de la recherche.

Bien que ce travail de recherche fournisse les contributions énoncées et vise à répondre aux QR exprimées précédemment, il est encore limité par de nombreuses contraintes telles que :

- **Contraintes liées à la méthodologie de pilotage :** Ces limites émergent des limitations imposées par la méthodologie choisie pour la recherche. L'échantillon et la population choisis peuvent ne pas refléter entièrement le vaste paysage du PCA, ce qui pourrait influencer la pertinence des résultats pour la QR2 concernant l'interaction entre la CA et les caractéristiques des rôles organisationnels/humains. En outre, les méthodologies de collecte de données peuvent présenter des contraintes inhérentes à la disponibilité et à l'exhaustivité des données, ce qui peut avoir un impact sur l'évaluation de l'Ct1, le modèle et les approches de la collecte de données.
- **Limites éthiques :** Les considérations éthiques impliquent des contraintes liées à la confidentialité et au respect de la vie privée. Bien que le respect des directives éthiques soit essentiel, des limitations telles que l'accès restreint à des informations sensibles peuvent affecter l'exhaustivité des résultats concernant la QR3, qui explore l'association de la CA avec des éléments environnementaux. Les préoccupations éthiques ont également des ramifications sur l'application de l'Ct4, qui porte sur les tableaux de bord dynamiques pour les patients et le personnel et sur l'identification des profils sociologiques.
- **Contraintes conceptuelles :** Ces contraintes découlent de la complexité de l'étude de la PCA. Les diverses interprétations des pratiques de PCA parmi les individus et les organisations peuvent introduire des vides dans la conceptualisation de la recherche, ce qui pourrait avoir un impact sur l'évaluation de la Ct2, la grille d'évaluation de la CB. En outre, le cadre ontologique pourrait ne pas englober toutes les facettes ou tous les points de vue, ce qui est conforme à l'Ct3, qui porte sur l'ontologie de la CA et le graphique des connaissances.
- **Restrictions pratiques :** Les limitations pratiques comprennent des facteurs tels que le temps, les ressources et les complexités techniques. Ces limitations doivent être prises en compte lors de la traduction des résultats de la recherche en applications pratiques dans des scénarios du monde réel, en particulier en ce qui concerne les implications pragmatiques des contributions comme Ct1, Ct2 et Ct3, qui englobent respectivement le modèle et les approches de collecte de données, la grille d'évaluation de la CA et l'ontologie et le graphe de connaissances de la CA.



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Ces contraintes soulignent les complexités contextuelles qui influencent le parcours de la recherche, en les reliant aux requêtes et aux contributions de la recherche. Elles soulignent l'importance d'une compréhension nuancée des résultats de la recherche et de leur applicabilité dans le monde réel dans le domaine de la PCA et de ses associations avec la technologie, les caractéristiques des rôles organisationnels/humains et les caractéristiques de l'environnement.

Pour l'avenir, il existe des possibilités passionnantes à explorer. L'une d'entre elles consiste à approfondir l'utilisation des données et de la technologie pour s'assurer que les plans de continuité d'activité sont bien conçus. Il s'agit d'utiliser des ordinateurs pour nous aider à mieux comprendre ces plans et à rendre le processus de vérification plus rapide et plus précis.

Des programmes informatiques intelligents peuvent être développés pour prendre en charge une grande partie du travail d'évaluation de ces plans, ce qui permet de gagner du temps et de mieux comprendre leur efficacité. L'impact des nouvelles technologies telles que l'internet des objets, la blockchain et les machines intelligentes sur la planification de la continuité d'activité doit être surveillé en raison de l'évolution constante de la technologie. Cela permettra de s'assurer que les plans peuvent être ajustés pour tenir compte des technologies émergentes. En outre, ces idées devraient être testées dans divers secteurs et scénarios réels afin de vérifier leur efficacité pour un large éventail d'utilisateurs.

**Perspectives Futures :** La conclusion met en avant les orientations futures de la recherche, en mettant l'accent sur la nécessité d'explorer l'utilisation des données et de la technologie pour améliorer l'évaluation des PCAs. Cela comprend le développement de programmes informatiques intelligents pour l'évaluation des plans, la surveillance de l'impact des technologies émergentes et la mise à l'épreuve de ces idées dans diverses industries et situations.

En conclusion, cette recherche contribue au domaine de la gestion de la continuité d'activité en introduisant un cadre holistique pour l'évaluation des PCA, en tenant compte à la fois des facteurs internes et externes. Tout en reconnaissant les limitations, l'étude envisage d'exploiter les données et la technologie pour améliorer davantage l'évaluation des PCA et la préparation aux perturbations et aux crises inattendues.

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## LIST OF ABBREVIATIONS

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AI	Artificial Intelligence
ANOVA	Analysis of Variance
APIC	Analysis and Protection of Critical Infrastructures
AZF	AZote Fertilisants (Company's name)
BCI	Business Continuity Institute
BCIN	Business Continuity Information Network
BCM	Business Continuity Management
BCMS	Business Continuity Management System
BCP	Business Continuity Plan
BEP	Professional Studies Certificate
BTS	Advanced Technician's Certificate
CAP	Certificate of Professional Aptitude
CCTV	Closed-Circuit Television
CNIL	Commission Nationale de l'Informatique et des Libertés
CPI	Corruption Perceptions Index
CSV	Comma-Separated Values
DIKW	Data, Information, Knowledge and Wisdom
DRII	Disaster Recovery Institute International
DUT	Technical University Diploma
GDPR	European Union General Data Protection Regulation
HIPAA	Health Insurance Portability and Accountability Act
ICT	Information and Communication Technologies
IDS	Intrusion Detection System
INSIIST	Robustness Indicators of business continuity plans for the resilience of organizations
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MRR	Methodology-Relationships-Rules

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MTBF	Mean Time Between Failures
NIST	National Institute of Standards and Technology
NPSSA	Number of Telecommuting Parents who missed their child's Appointment
NPTTA	Number of On-site Parents who missed their child's Appointment
OECD	Organization for Economic Cooperation and Development
OS	Operation System
OWL	Web Ontology Language
PDCA	Plan-Do-Check-Act
POC	Proof Of Concept
PUE	Power Usage Effectiveness
RDBMS	Relational Database Management System
RDF	Resource Description Framework
SDGN	General Secretariat for Defense and National Security
SIRES	System for Insertion of Risky Events
SOC	Security Operations Center
SOX	Sarbanes-Oxley Act
SPI	Societal Performance Indicator
TVOC	Total Volatile Organic Compounds
VHRD	Virtual Human Resource Development
XML	Extensible Markup Language

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## FOREWORD

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Business continuity planning has become increasingly critical in recent years, as organizations have faced a growing number of risks and disruptions, including natural disasters, cyber-attacks, and pandemics. The ability to maintain critical business functions and minimize disruptions has become essential to ensuring the survival of organizations and protecting their stakeholders. Despite the importance of business continuity planning, evaluating the effectiveness of these plans remains a challenge, with many organizations struggling to determine whether their plans are sufficient to withstand potential disruptions.

It is in this context that this PhD thesis project, "Evaluating Business Continuity Plans Through Robustness Indicators," aims to make a valuable contribution to the field of business continuity management. By proposing a data-driven approach to evaluate business continuity plans through the use of robustness indicators, this project seeks to enhance the assessment of business continuity planning and improve organizations' ability to withstand disruptive events.

The global approach developed by this work follows a meticulous three-step process that ensures a comprehensive evaluation of business continuity plans. The first step involves an in-depth literature review, which serves to establish a state-of-the-art understanding of business continuity management. This review encompasses a wide range of scholar works, industry best practices, and real-world case studies, enabling to gain a deep appreciation of the subject matter and identify the existing gaps and limitations in current evaluation methodologies.

Building upon the insights gained from the literature review, the second step entails the development of a robust data collection model. This model considers various types of data, including physical, societal, and economic factors that influence business continuity. The significance of adopting a holistic perspective when evaluating business continuity plans is recognized through the analysis of the collected data and the identified threats. Thus, the model encompasses both quantitative and qualitative data sources, leveraging data-driven methodologies to ensure accuracy, reliability, and comprehensive coverage of all relevant aspects. The importance of considering emerging trends and future risks to develop a forward-looking evaluation framework that can adapt to evolving business environments is also highlighted.

The third and final step of the proposed approach involves a Proof of Concept (POC) analysis. This analysis serves as a tangible demonstration of the relevance and impact of the collected data on the evaluation of business continuity plans. To achieve this, robustness indicators specifically tailored to the assessment of BCP effectiveness are designed and implemented. These indicators are carefully selected to capture key dimensions of preparedness, response, and recovery, providing valuable insights into the strengths and weaknesses of the evaluated plans. The application of the proposed model to real-world scenarios in the POC analysis enables the effectiveness of the data collection model and robustness indicators to be validated in practice.

The incorporation of robustness indicators in the evaluation process represents a contribution to the field of business continuity management. By considering a broad range of data types,

including physical, societal, and economic factors, the proposed data collection model allows for a comprehensive evaluation of business continuity plans. It recognizes that a successful evaluation should not be limited to assessing internal processes and systems but should also consider external factors that can significantly impact an organization's ability to withstand disruptions. By adopting this holistic approach, the proposed model ensures a comprehensive evaluation that captures the complexity of modern business environments.

The POC analysis, conducted as part of this research, serves as a pivotal aspect of the proposed approach. By applying the data collection model and robustness indicators to real-world scenarios, the practical application and effectiveness of the proposed model can be demonstrated. This analysis provides valuable insights into the strengths and weaknesses of existing business continuity plans, enabling organizations to identify areas for improvement and enhance their preparedness strategies accordingly.

To this instance, this research work has been applied in two compelling case studies. The two case studies are explored in order to test the research's results within a wide range of scenarios.

In the first case study, the research was implemented in the field of healthcare, specifically in the case of a paediatric ward disruptions and their consequences due to the COVID-19 lockdown. The study involved analysing societal data from a large cohort of patients and developing a POC to identify specific parameters associated with the most impacted patients' categories. The POC was then applied to identify the same categories of workers used to predict the most effective treatment options to keep the service running interruptedly and avoid absences from the patients but also from the healthcare providers side. The results of this case study demonstrated that the research work improved care outcomes, leading to better patient responses and increased efficiency rates.

The second case study focused on the application of the research in the transportation industry. Here, the research team aimed to optimize traffic flow and reduce congestion in a busy urban area. By leveraging advanced data analytics and ontological engineering techniques, they developed an assessment model that could accurately identify the threats to the Business Continuity (BC) within different categories and identify potential BC assessment metrics. This information allowed transportation authorities to implement targeted interventions, such as adjusting signal timings and optimizing road infrastructure, resulting in smoother traffic flow and reduced travel times for commuters. The outcomes of this case study indicated a substantial improvement in traffic management and overall efficiency in the transportation system.

The case studies showcase the application and outcomes of the research work in real-world scenarios, confirming its possible utilization.



# CHAPTER I. THE BUSINESS CONTINUITY PLANNING: A CRUCIAL NECESSITY

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“Finally, strategy must have continuity. It can't be constantly reinvented.”

Michael Porter

In today's rapidly evolving business landscape, organizations face an array of risks and disruptions that can significantly impact their operations, reputation, and bottom line. From natural disasters and cyber-attacks to pandemics and supply chain disruptions, the need for effective business continuity planning has never been more critical. Business Continuity Planning (BCP) is a proactive approach that enables organizations to identify potential threats and develop strategies to mitigate their impact, ensuring the resilience, defined as “system's ability to adapt to disturbances in order to return to its initial state” (detailed later on in this chapter's section Chapter I.1.1.2), and survival of the business.

The assessment of risk in this study requires distinguishing between various types, such as natural, industrial, and social risks. Given the multifaceted nature of crises faced by organizations, the resolution of problems and the necessary trade-offs become increasingly complex. A broader factor contributing to the growing emphasis on risk management is the diminishing tolerance for unpredictability within modern societies. Doubts have arisen regarding the capacity of both scientific advancements and public authorities to address and manage crises. Compelling examples, such as the disasters at Fukushima, Chernobyl, and AZF, serve as stark reminders of the authorities' inability to anticipate and adequately handle these risks. These events underscore the urgent need to reevaluate risk management strategies in contemporary society.

Prominent sociologist (Beck, 2001) addresses this pivotal shift in his acclaimed work, "Risk Society: Towards a New Modernity". Beck contends that industrial societies are currently grappling with what he calls a "break within modernity," marked by a profound questioning of the traditional "religion of progress". Across industrialized nations, the promises of modernity have not been entirely fulfilled, as evident in the persistence of threats and unpredictable hazards. Issues such as pollution, industrial or nuclear disasters, environmental risks, and threats to health, safety, and overall well-being continue to manifest. As a result, Beck asserts that "the fear of the unpredictable has become the primary driver of action." His book has gained widespread recognition and remains a prominent reference in discussions concerning risk and modernity.

Moreover, (Peretti-Watel, 2010) reinforces the notion that contemporary societies are characterized by a paradoxical state. While they have become less overtly dangerous, they are inherently more susceptible to risks of varying magnitudes. This contemporary preoccupation with risk encompasses a wide range of areas, from major global threats like ozone layer depletion

and the greenhouse effect to individual behaviors that punctuate our daily lives, such as smoking and driving.

Therefore, this study recognizes the significance of different risk types in shaping an organization's resilience and decision-making process and contextualizes the present-day complexities in risk management within the broader societal shifts towards a risk-conscious landscape.

Additionally, this chapter investigates the up-to-date understanding of Business Continuity Planning as an unavoidable need, examining its research context, the problem it addresses, the objectives to be achieved, the methodology employed, and providing an outline of the thesis. It is structured according to five sections:

**The research context** section sets the stage for understanding the significance of Business Continuity Planning in the contemporary business environment. It explores the evolving landscape of risks and disruptions faced by organizations, highlighting the increasing need for robust and adaptable strategies to ensure business continuity. This section also discusses the current state of research, identifying key gaps and opportunities for further investigation.

**The research problem** section identifies the core challenges and issues that necessitate the development and implementation of Business Continuity Planning. It explores the potential consequences of not having an effective BCP in place, such as financial losses, reputational damage, and operational disruptions. This section also emphasizes the importance of understanding the specific needs and requirements of organizations when designing and implementing a BCP.

**The proposal section** outlines the goals and aims of the research, which will contribute to enhancing the understanding and practice of Business Continuity Planning. These objectives may include exploring best practices in BCP, assessing the effectiveness of existing BCP frameworks, identifying emerging trends and technologies in the field, and developing recommendations for organizations to improve their BCP capabilities.

**The methodology** section describes the approach and techniques used to conduct the research. It discusses the research design, data collection methods, and analysis techniques employed to achieve the research objectives. This section may include a combination of qualitative and quantitative research methods, such as literature review, case studies, surveys, interviews, or simulations.

**The thesis outline** provides a roadmap for the subsequent chapters, presenting the “big picture” of this research work, and a brief overview of the structure and content of the thesis (see Figure 2). It highlights the key themes and topics that will be covered, enabling readers to anticipate the flow of information and insights throughout the document.

By thoroughly discussing the research context, problem, objectives, methodology, and thesis outline, this chapter explores the significance and utilization of Business Continuity Planning in today's dynamic and uncertain business environment. It aims at setting the foundation for the subsequent chapters, which will further explore specific aspects of BCP, ultimately the understanding and implementation of effective business resilience.

## 1. Research context

In recent years, there has been a significant increase in the occurrence of risky events such as natural disasters and deadly pandemics, which have caused major disruptions to businesses worldwide (Elmqvist et al., 2019). These disruptive events have highlighted the critical importance of Business Continuity Planning (BCP) in ensuring the resilience and survival of organizations. This enables businesses to identify potential risks, develop strategies to mitigate them, and establish processes and procedures to ensure the continuity of essential functions during and after a crisis. As a result, the need for measuring the robustness of an activity has become increasingly important. **Robustness refers to the ability of an organization or activity to withstand and recover from a disruptive event with minimal negative impact on its operations** (Anderies et al., 2013).

The main objective of BCP is to minimize the impact of disruptive events on business operations, protect the organization's assets, and enable a swift recovery to normalcy. The BCP involves establishing temporary substitute modes of operation (often referred to as "degraded mode") to ensure essential functions during crises, such as the educational sector's response to COVID-19. Also, the BCP can have a preventive role in "pushing back" or "delaying" the onset of crisis situations. By implementing BCP, organizations can safeguard their employees, maintain customer service, preserve their reputation, and avoid significant financial losses (Aleksandrova et al., 2018).

To achieve these objectives, BCP involves a systematic and comprehensive assessment of potential risks and vulnerabilities. This assessment includes identifying critical business processes, dependencies, and resources that are crucial for the organization's functioning (Collins et al., 2011; Muflihah & Subriadi, 2019; R.K. & R., 2022; Zsidisin & Ragatz, 2003). Additionally, BCP involves creating contingency plans and establishing clear roles and responsibilities for employees during a crisis. These plans outline step-by-step procedures for emergency response, communication strategies, data backup and recovery, alternate work arrangements, and coordination with relevant stakeholders such as suppliers and customers (Alexander, 2015; Bongiovanni et al., 2017; Perry & Lindell, 2003).

Furthermore, BCP is often guided by industry-specific norms, regulations, and standards such as the ISO22301:2019 and the ISO22313:2012. Various organizations, such as regulatory bodies, industry associations, and government agencies, provide guidelines and frameworks for implementing effective BCP. Compliance with these norms ensures that organizations meet specific requirements, enhance their resilience, and demonstrate their commitment to risk management and business continuity (Fani & Subriadi, 2019; Muflihah & Subriadi, 2019).

Business continuity norms refer to established standards, guidelines, and best practices that organizations can adhere to when developing and implementing their business continuity plans. These norms are often developed by industry associations, professional organizations, regulatory bodies, and international standards organizations. They provide a framework for organizations to follow in order to ensure that their business continuity efforts align with recognized industry standards and best practices.

Some of the well-known business continuity norms, good practice guidelines and standards include:

- ISO 22301: The International Organization for Standardization (ISO) developed ISO 22301, which is the international standard for business continuity management systems. It provides a systematic approach to establishing, implementing, operating, monitoring, reviewing, maintaining, and continually improving a documented management system for business continuity. While the ISO 22313:2012: complements ISO 22301 by providing detailed guidance for implementing the requirements outlined in ISO 22301. It offers practical advice on developing business continuity plans, conducting business impact analysis, and managing the overall business continuity process.
- National and Industry-specific Regulations: Many countries have regulations in place that require certain industries, such as banking, healthcare, or critical infrastructure (such as airports, railway stations, computer systems, servers, national and local networks, Internet access, etc.), to have business continuity plans in order to protect public safety and ensure the continuity of essential services. In France for example, public services have an obligation of continuity. Services such as water supply, electricity, telecommunications, etc., which fall under industrial and commercial public services, are legally required to maintain uninterrupted service even outside the crises you mentioned. For instance, they cannot conduct work that would result in cutting off water or electricity without providing an alternative solution. The law mandates ensuring operations, even in a degraded mode. This principle applies universally to all public services, including schools, government agencies, hospitals, etc. Continuity also extends to the functioning of the State and essential services for sovereignty, such as the police, judiciary, and military. Without these services, the optimal functioning of society is threatened. These principles have been systematized in the administrative doctrine known as the "Rolland laws" in France. The principle of continuity is often invoked during strikes in public services. In such instances, the public administration imposes a "minimum service" to be maintained by the striking employees. This minimum service exists in reference to the principle of continuity. It is essential to note that in France, there is a longstanding "administrative" tradition of BCP in public services to uphold a fundamental principle of French society: "the common interest" (Fijalkow, 2020). These regulations often outline specific requirements and expectations for business continuity planning and response. Some examples are:
  - Sarbanes-Oxley Act (SOX): In the United States, SOX mandates that publicly traded companies have internal controls and procedures in place, including business continuity plans, to ensure the accuracy and reliability of financial reporting.
  - Health Insurance Portability and Accountability Act (HIPAA): In the healthcare industry, HIPAA requires organizations to have contingency plans, including business continuity and disaster recovery plans, to protect the availability, integrity, and confidentiality of patient health information.
  - European Union General Data Protection Regulation (GDPR): GDPR requires organizations to implement appropriate technical and organizational measures, which may include business continuity plans, to ensure the security of personal data.

- Disaster Recovery Institute International (DRII): DRII is a professional organization that offers certifications and promotes best practices in business continuity and disaster recovery planning. They provide guidelines and frameworks for organizations to follow, including the Professional Practices for Business Continuity Management, which outline key areas and activities for effective business continuity planning. For example: The Professional Practices for Business Continuity Management (DRII) which presents a comprehensive framework for business continuity management. They cover various areas, including program initiation and management, risk assessment, business impact analysis, plan development and implementation, awareness and training, testing and exercising, and program improvement.
- Business Continuity Institute (BCI): BCI is a global professional organization for business continuity professionals. They provide resources, training, and certification programs to support the development and implementation of business continuity plans. BCI also publishes the Good Practice Guidelines, which offer a comprehensive framework for business continuity management. For example: The Professional Practices for Business Continuity Management (DRII that provides a comprehensive framework for business continuity management. They cover various areas, including program initiation and management, risk assessment, business impact analysis, plan development and implementation, awareness and training, testing and exercising, and program improvement.
- National Institute of Standards and Technology (NIST): In the United States, NIST has developed the NIST Special Publication 800-34, Contingency Planning Guide for Federal Information Systems, which provides guidance on developing and maintaining effective contingency plans, including business continuity planning, for federal information systems. For example: The NIST Special Publication 800-34 provides guidance for federal agencies in the United States on developing contingency plans, including business continuity planning, for information systems. It covers key elements such as plan development, plan testing and maintenance, and plan implementation. For instance, in France, it is the military (the national defense) that takes charge of this aspect. The national defense is responsible for safeguarding the security of the territory and ensuring the functioning of institutions and socio-economic activities. This role is specifically reflected in the development of a guide to assist in creating a BCP (SDGN, 2022). In France, the BCP is now approached from the perspective of potential risks and dangers.

It is worth noting that BCP is an ongoing process rather than a one-time activity. As businesses evolve, their operating environments change, and new risks emerge. Therefore, regular reviews, updates, and exercises of the BCP are essential to ensure its effectiveness and relevance over time. This iterative approach allows organizations to adapt to evolving threats and challenges and continuously improve their preparedness for disruptive events (Henry, 2007; Rezaei Soufi et al., 2019).

In summary, BCP is a crucial necessity in today's unpredictable and increasingly complex business landscape. It provides organizations with the tools and strategies to proactively mitigate risks, ensure business continuity, and minimize the negative impacts of disruptive events. By



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adopting BCP, businesses can enhance their resilience, protect their stakeholders, and maintain their operations even in the face of challenging circumstances.

In this context, this thesis manuscript proposes the design of a model for massive data collection to evaluate Business Continuity Plans (BCPs) through robustness indicators. BCPs are plans that organizations put in place to ensure that they can continue their essential functions during and after a disaster or other disruptive event. The proposed model aims to collect data on the effectiveness of BCPs in terms of their ability to maintain operations during and after a disruptive event. The research work is based on a scientific evaluation process that aligns with the requirements of the business environment. Key indicators of robustness, including operational continuity, recovery speed, and adaptability, were identified as important factors. A model for extensive data collection was developed to assess the effectiveness of Business Continuity Plans (BCPs) within this context.

The proposed model comes within the context of collecting data from various sources such as surveys, interviews, and existing systems. Statistical methods are utilized to analyze the data, identify patterns, and evaluate the effectiveness of BCPs in maintaining operations during and after disruptive events. The insights gained from this analysis contribute to recommendations for improving BCPs. Overall, the proposed model, incorporating robustness indicators and extensive data collection, has implications for the business environment. It aims mainly at enhancing organizations' ability to withstand and recover from disruptive events. Further research is necessary to refine and enhance the model and encourage its adoption by organizations worldwide.

Finally, this research work is part of the INSIIST project "Robustness Indicators of business continuity plans for the resilience of organizations" and has been carried out between many partners and organizations. Namely, two institutions: IMT Mines Albi and the National Institute of Champollion, three research labs: Industrial Engineering Center at IMT Mines Albi, CERTOP Laboratory (UMR5044) at University of Toulouse – Jean Jaurès and the Laboratory for the Analysis and Protection of Critical Infrastructures (APIC Lab.) at the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) of Rome, Casaccia, and two external organizations serving as two use cases for this work such as a French Hospital and an Urban Transportation Company.

## 2. Research problem

Organizations and infrastructures that provide essential services, such as hospitals, power plants, and communication networks, are particularly vulnerable to disruptive events such as natural disasters and pandemics. As a result, they must have effective BCPs in place to ensure that their critical functions continue to operate during and after such events.

The research problem addressed in this study is to design an effective data collection process for identifying and utilizing critical robustness indicators essential to evaluating the effectiveness of Business Continuity Plans (BCPs). These indicators encompass measures assessing an organization's or infrastructure's capacity to endure and recuperate from disruptive incidents, while minimizing adverse operational impacts. These indicators, exemplified by factors like backup system availability, emergency protocol establishment, and employee training levels, form the keystone of this research.

Subsequently, the research aims to establish a comprehensive data collection methodology. This methodology encompasses the acquisition of data from various sources such as surveys, interviews, and pre-existing systems. The gathered data will then undergo statistical analysis aimed at recognizing underlying patterns and trends that might offer insights into the degree of BCP effectiveness in sustaining operations during and after disruptive events.

This data collection process is suggested for critical organizations and infrastructures that are subject to strict regulatory requirements. These requirements may include the need to demonstrate the effectiveness of BCPs regularly. In such cases, the proposed data collection process can provide a standardized and objective method for evaluating BCPs.

Overall, the proposed data collection process aims at enhancing the ability of critical organizations and infrastructures to withstand and recover from disruptive events. The use of robustness indicators can provide a more comprehensive and accurate assessment of BCP effectiveness than traditional methods. The proposed process is also flexible enough to adapt to different contexts and can be applied to a wide range of organizations and infrastructures.

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The primary objective of this thesis project is to provide a comprehensive answer to the crucial question of **how to design a data collection process to evaluate a business continuity plan (BCP) using robustness indicators**, particularly in the context of critical organizations and infrastructures.

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### 3. Research proposal

The research objectives of this thesis project are aimed at providing a comprehensive solution to the question of designing a data collection process to evaluate business continuity plans (BCPs) using robustness indicators, particularly in the context of critical organizations and infrastructures. In other terms, this work aims consequently at developing tools and a method to identify the factors and mechanisms that constitute signals of potential disruptions.

To achieve these objectives, the proposal is structured into five main components. Firstly, the establishment of a **state of the art**, related works and literature reviews in the field of business continuity management, which will provide the necessary background knowledge and understanding of the field. This component will also help in identifying the existing gaps in the literature and will serve as a foundation for subsequent research work.

Secondly, the proposal of a **data collection model** and the different classes of data types considered in the evaluation of a BCP. This component will outline the different approaches that will be followed to collect different types of data, such as physical and societal data. The proposed hybrid approach for gathering multidimensional information and knowledge through the use of various technologies and tools such as sociological surveys, sensor networks, and databases will also be explained in this component.

Thirdly, the demonstration of the relevance and impact of the collected data on business continuity through the **analysis of the impact** of the collected data on business continuity through the exposition of a Proof of Concept (**POC**); the design of some robustness indicators for the evaluation of BCPs. This component will demonstrate the practical application of the proposed data collection model by designing, calculating, and testing robustness indicators.

Fourthly, the integration of the designed indicators and their values and thresholds into **interactive dashboards** that are easily interpretable by the user. This component will focus on the development of user-friendly dashboards that will allow easy interpretation of the data collected and the robustness indicators designed.

Finally, the modelling of the entire system and the creation of a **generic metamodel and a knowledge base** in the form of a graph network. This last step will be carried out on the basis of an ontological framework for the evaluation of business continuity which has been developed thanks to an extensive bibliographical search of more than 2500 articles and books in the field. This component will provide a comprehensive understanding of the entire system and the relationships between its various components.

In summary, the research objectives of this thesis project aim to design a comprehensive data collection process that can be used to evaluate BCPs using robustness indicators. The project will use a hybrid approach for gathering multidimensional information and knowledge through the use of various technologies and tools and will take into consideration the societal and technical dimensions of the data collected. The ultimate goal is to provide critical organizations and infrastructures with a standardized and objective method for evaluating the effectiveness of their BCPs.

#### 4. Overview of the research methodology

To meet these objectives and answer the research question, this research work is structured in the following manner:

1. Design a hybrid approach for collecting multidimensional information and knowledge by leveraging various technologies and tools (e.g., sociological surveys, sensor networks, databases, etc.).
2. Identify the organisational threats then design, calculate, and test robustness indicators. Later on, integrate the designed indicators and their values and thresholds into interactive dashboards that are easily interpretable by the user.
3. Model the entire system and create a generic metamodel as well as a knowledge base in the form of a graph network. This final step is to be carried out based on an ontological framework for the evaluation of business continuity that was developed through an extensive literature review of over 2500 articles and books on the subject.

The project also involves the design, calculation, and testing of robustness indicators. These indicators will provide valuable insights into the effectiveness of BCPs and their ability to maintain critical business functions and minimize disruptions. Hence, these BC indicators are mainly based on identified threats to the organization. In a simplistic way, this Q-S-A (Questions-Survey-Answers) approach can be represented as in Figure 1 below. Please refer to chapter 3 of this thesis for a detailed explication of this approach as well as its application procedure.

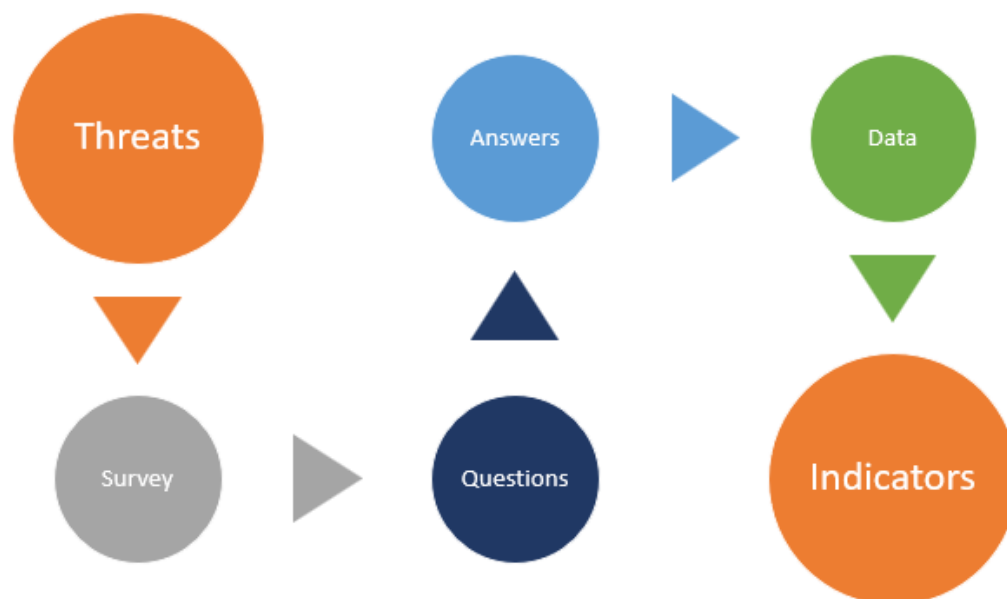


Figure 1. A simplistic overview of the Q-S-A approach

In conclusion, this methodology aims to provide a data-driven approach to evaluating BCPs and enhance the assessment of business continuity planning to improve organizations' ability to withstand disruptive events.

## 5. Thesis outline

The thesis proposes an evaluation of Business Continuity Plans (BCP) through the design of robustness indicators, which are used by collecting and interpreting massive data. The primary objective is to assess the effectiveness of BCPs in the face of potential disruptions, by measuring their ability to maintain critical business functions and minimize the impact of disruptions.

To achieve this objective, this manuscript is organized as the following (see Figure 2):

1. Starting by the Foreword proving the general background of this work, some insights and reflections about its unfolding.
2. Moving to Chapter I. The Business Continuity Planning: A crucial necessity which mainly underlines the research context, problem and proposal of this work.
3. Chapter II. Investigating the BCP research background for its part clarifies the concepts and motivations that led to this work, enumerates previous works and theories, and identifies the gaps and contradictions between them.
4. Chapter III. designing the research methodology leads the way to designing this work's methodology, based on a data model, analysis and visualization of the data, its gathering approaches, and finishes by depicting an upper model which is an ontological framework and later on a knowledge base.
5. Chapter IV. Testing the methodology: research findings introduces the two case studies considered by this work (one in Albi, Tarn, France, and another in Roma, Lazio, Italy), explores their results, analysis and testing, and furthermore provides interpretations to these results.
6. Finally, the Discussion and Conclusion section sums up and closes this work by synthesizing the results, enumerating the contributions (theoretical, methodological and practical/technological/applicative) resulting from this work, and explaining the limitations, implications and possible future works. The thesis will conclude with opening towards future research avenues.

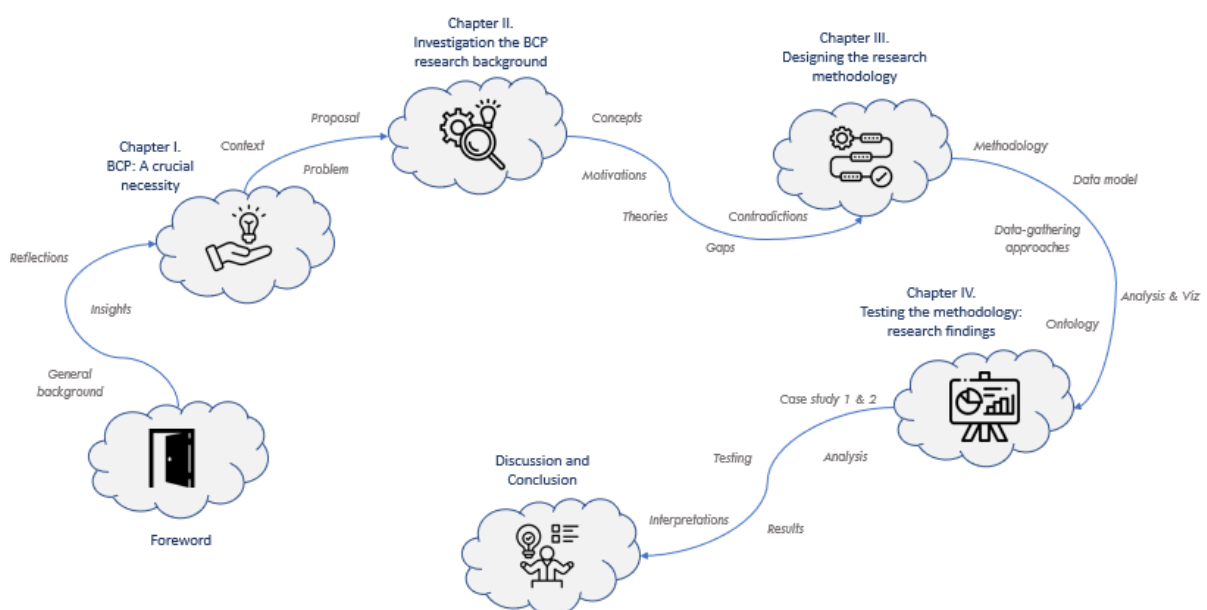


Figure 2. Designing a Data-Driven Model for Business Continuity Planning Evaluation using Robustness Indicators

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## 6. Conclusion

In conclusion, this chapter has introduced the topic of Business Continuity Planning (BCP) and has laid the groundwork for the subsequent chapters of this thesis. The discussion has highlighted the evolving nature of risks and disruptions faced by organizations in today's business environment, emphasizing the crucial role of BCP in mitigating these threats and ensuring the continuity of operations.

The research context section has underscored the need for an up-to-date understanding of BCP, considering the dynamic and ever-changing landscape of risks and the current state of research in the field. By identifying key gaps and opportunities, it has set the stage for further investigation into this critical area. In fact, there has been a rise in risky events like natural disasters and pandemics, disrupting businesses worldwide and emphasizing the need for Business Continuity Planning (BCP). BCP aims to minimize the impact of such events, protect assets, and enable a swift recovery. It involves assessing risks, identifying critical processes and resources, creating contingency plans, and assigning responsibilities. Industry-specific norms and standards, such as ISO22301:2019 and ISO22313:2012, guide BCP implementation. Adhering to these norms helps organizations meet requirements, enhance resilience, and demonstrate commitment to risk management and business continuity.

The problem section has shed light on the potential consequences of inadequate BCP, emphasizing the financial, reputational, and operational risks organizations face when unprepared. It has emphasized the importance of tailoring BCP approaches to the specific needs and requirements of each organization, recognizing the need for customization in developing effective strategies.

The proposal outlined in this chapter has provided the goals for this research. By exploring best practices, assessing existing BCP frameworks, identifying emerging trends and technologies, and developing recommendations, this research aims to enhance the understanding and practice of BCP, equipping organizations with the knowledge and tools to improve their resilience.

The methodology section has discussed the approach and techniques that will be employed to achieve the research objectives. By utilizing a combination of qualitative and quantitative research methods, this study will leverage literature review, case studies, surveys, and interviews to gather comprehensive insights into BCP practices and their effectiveness.

Looking ahead, the next chapter, "Investigating the BCP Research Background," will explore further the existing research on Business Continuity Planning. It will provide an extensive review of relevant literature, examining various theoretical frameworks, models, and studies related to BCP. This chapter will serve as a foundation for subsequent chapters, allowing for a comprehensive exploration of the topic.

In summary, this chapter has laid the groundwork for the thesis, introducing BCP and establishing the research context, problem, objectives, methodology, and thesis outline. Next, chapter II explains the research background, clarifying concepts, motivations, and identifying gaps and contradictions in previous works. Chapter III outlines the methodology employed in this work, including data modelling, analysis, and visualization, along with the creation of an ontological framework and knowledge base. Chapter IV presents the research findings through

two case studies conducted in Albi, France, and Roma, Italy, providing an analysis of the results and interpretations. The Discussion and Conclusion section summarizes the work, highlighting its theoretical, methodological, and practical contributions, while also addressing limitations, implications, and future research directions.

## CHAPTER II. INVESTIGATING THE BCP RESEARCH BACKGROUND: STATE OF THE ART

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“No research without action, no action without  
research”

Kurt Lewin

This chapter provides the state-of-the-art foundation for the empirical investigation conducted in this study. It mainly sets a comprehensive synthesis of existing works on the topic, the identification of main concepts, theories, and motivations driving the research, and the exploration of any controversies or debates within the field.

Within the realm of Business Continuity Planning (BCP), numerous concepts, theories, and motivations have been examined by researchers. This chapter consolidates these **existing works**, offering a comprehensive synthesis that brings together various perspectives. By exploring the main schools of thought within the field, we aim to provide a holistic understanding of BCP and shed light on the diverse approaches and viewpoints adopted by scholars. Furthermore, this exploration will aid in identifying any controversies or conflicting theories that exist, laying the groundwork for a more nuanced analysis.

While existing research works have contributed significantly to our understanding of BCP, it is crucial to acknowledge the **limitations, gaps, and contradictions** present in the existing body of knowledge. This chapter critically evaluates these shortcomings, examining the inconsistencies that hinder a comprehensive understanding of BCP. By pinpointing these gaps, we can justify the need for the present thesis, which seeks to address and bridge these knowledge deficiencies. The identification of these gaps also establishes the basis for formulating research questions and hypotheses, which will be explored in subsequent chapters.

In this chapter, we present the **theoretical concepts and frameworks considered by this thesis** to investigate the intricacies of BCP. The chosen concepts are carefully selected to provide a foundation for examining the research problem, ensuring coherence and relevance throughout the study. Based on this, the research problem is addressed and described within a **conceptual framework**.

This chapter finishes with a description of the **research hypotheses** that will be investigated in the empirical research, based on the synthesis of prior works, identification of gaps, and conceptual framework. These hypotheses capture the expected results and relationships to be investigated, giving a framework for the empirical research carried out in later chapters; namely chapters III and IV.

In summary, Chapter 2 aims at establishing the research background for this thesis. It synthesizes existing works, identifies gaps and contradictions, presents the conceptual framework, and outlines the research hypotheses. By undertaking this comprehensive analysis, we aim to lay a foundation for the empirical investigation, ensuring an informed approach to



exploring the research problem at hand while testing this work's results in real-life scenarios of two different use cases.

## **1. Main concepts, theories and motivations**

In an era characterized by rapid technological advancements, globalization, and an increasingly interconnected business landscape, organizations face a myriad of challenges that can disrupt their operations and jeopardize their long-term viability (Kleindorfer & Saad, 2005). Disruptions such as natural disasters, cyber-attacks, pandemics, supply chain disruptions, and financial crises can have severe consequences for businesses, leading to financial losses, reputational damage, and even organizational failure.

To navigate these turbulent waters and maintain their resilience in the face of unforeseen events, organizations have turned to the field of business continuity (BCI, 2018). Business continuity encompasses a set of strategies, processes, and practices aimed at ensuring the continuous operation of critical business functions in the event of a disruption. It involves the identification of potential risks, the development of comprehensive response plans, and the implementation of preventive and recovery measures.

This thesis section analyses the main concepts, theories, and motivations concerning business continuity. By exploring the fundamental principles and theories underlying business continuity, we aim to provide a solid foundation for understanding the significance and practical applications of this field. Furthermore, we will examine the key motivations that drive organizations to invest in business continuity, including regulatory requirements, risk mitigation, competitive advantage, and stakeholder expectations (Cerullo & Cerullo, 2004).

Through a comprehensive analysis of these main concepts, theories, and motivations, this section aims to establish a theoretical framework that will serve as a basis for the subsequent sections of this thesis (*The Definitive Handbook of Business Continuity Management* - Andrew Hiles - Google Livres, 2017). By gaining a deeper understanding of business continuity, organizations can enhance their preparedness and responsiveness, ultimately safeguarding their operations, protecting their assets, and ensuring the continuity of their services to customers. In broader terms, it concerns the functioning of a society, of a human collective as a whole. The objective is to understand how these societies and collectives can enhance their resilience in the face of disruptions and challenges. This involves identifying early signals, key factors, and mechanisms that enable them to adapt and thrive in changing conditions. The ultimate goal is to foster the well-being and sustainability of these social entities resulting in reducing the vulnerability of the human factor in a industrial process (Rubini et al., 2023, p. 0; Semeraro et al., 2023).

The subsequent subsections will explore various key elements within the realm of business continuity, including risk assessment, business impact analysis, incident response, disaster recovery planning, and the role of leadership in driving a culture of resilience (*ISO 22301:2019(En), Security and Resilience — Business Continuity Management Systems — Requirements*, 2019; Osterwalde & Pigneur, 2010). By exploring these interconnected facets, we will gain insights into the practical implementation of business continuity practices and their implications for organizational sustainability.

In conclusion, this section sets the stage for a comprehensive exploration of business continuity within the broader context of organizational resilience. By examining the main concepts, theories, and motivations underlying business continuity, we lay the groundwork for

understanding the strategic importance of this discipline and its potential to mitigate risks and ensure the long-term survival of organizations in an increasingly unpredictable business environment (BCI, 2018).

## 1.1. Principal concepts and motivations

### 1.1.1. Business Continuity

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This subsection answers the following research question: What is Business Continuity?

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Business Continuity along with its organizational concepts (BC planning, management, etc.) has several definitions in the literature that are mostly complementary with slight nuances depending on the context (e.g. crisis management, decision making, disaster recovery, PDCA cycle, etc) and the application field such as IT, SC and so forth. These definitions should be demarcated before any discussion of the business continuity processes and aspects. In this section, some of these definitions are presented.

1. “Business continuity is the planning and management of contingency measures aimed at keeping critical operational business processes running in the event of a disruption. Business continuity planning is a subset of organizational contingency planning, which is usually classified as risk management. In terms of data security, contingency planning and management include incident response, disaster recovery, and continuity planning. In general, when the term Business Continuity Management (BCM) is used in an organizational context, it refers to both management and planning” (Peterson, 2009).
2. “Business continuity management is a holistic management process that identifies potential impacts that threaten an organization and provides a framework for building resilience and the capability for an effective response that protects the interests of its key stakeholders, reputation, brand, and value creating activities” (Reuvid, 2006).
3. “Business continuity planning is defined as "the ability to sustain an income stream during a crisis” (Castillo, 2005; Stucke et al., 2016).
4. “Business continuity is defined as an organization's ability to continue delivering products or services at acceptable predefined levels in the aftermath of a disruptive incident” (*ISO 22301:2019(En), Security and Resilience — Business Continuity Management Systems — Requirements*, 2019; Koen et al., 2016).
5. “Business continuity is a systematic management approach to achieving best practice controls, quantifying the level of acceptable risk, and implementing appropriate measures for business continuity and recovery, thereby protecting the organization's and its stakeholders' interests” (Dey, 2011).
6. “Business continuity planning is the general strategy and preparation which are required to identify the impact of potential losses, formulate and implement feasible continuity strategies, and develop continuity plan(s) to guarantee the reliability of organizational services in the case of an incident” (Mano et al., 2012).

*The BC definition adopted by this thesis:*

In fact, by excluding definitions 1 and 3, and incorporating definitions 2, 4, 5, and 6, the adopted definition of business continuity provides a more comprehensive perspective. It highlights BC as a holistic management process that identifies potential impacts, builds resilience, and ensures an effective response to protect the interests of key stakeholders, reputation, brand, and value creating activities. Additionally, it recognizes BC as an organization's ability to continue delivering products or services at acceptable predefined levels following a disruptive incident. This combined definition encompasses the essential elements of BC and aligns with the research objectives and focus of this study.

Therefore, this research work considers the following definition which is essentially a combination of 2, 4, 5 and 6:

**“BC is a holistic management strategy (process in the case of a BCP) that identifies potential threats to an organization, as well as the threats’ impacts and that provides a framework to build the organization's resilience, with an effective response capability that preserves the interests of its key stakeholders, its reputation, its brand, and its value-producing ‘vital’ activities.”**

Moreover, business continuity refers to the ability of an organization to maintain its critical operations and services during and after a disruptive event. Business continuity planning (BCP) is the process of creating a strategy that outlines how an organization will continue its operations in the event of a disruption (*ISO 22301:2019(En), Security and Resilience — Business Continuity Management Systems — Requirements*, 2019). Disaster recovery is a crucial aspect of BCP, focused on restoring the organization's ability to conduct business after a disaster. Business continuity management (BCM) encompasses the entire lifecycle of BCP, including risk assessment, planning, testing, and maintenance (Adamou, 2014; Ajimoko, 2016; Aleksandrova et al., 2018). A business continuity management system (BCMS) is a structured approach to managing business continuity, based on internationally recognized standards (*ISO 22313:2020(En), Security and Resilience — Business Continuity Management Systems — Guidance on the Use of ISO 22301, 2020*, p. 22). Integrating strategic management, business risk analysis, awareness, and information life cycle management forms a strong foundation for managing and addressing potential risks. It also involves identifying relevant benchmarks and metrics to develop an efficient business continuity strategy. However, traditionally, BCPs merely serving as internal documentation within an organization might prove insufficient. In fact, the BCPs need continuous evaluation and improvement to effectively manage hazardous events and minimize their impact on business continuity.

Indeed, there is a confusion in the literature. Often, risk is associated with external factors that threaten the organization, such as pandemics, natural disasters, technological accidents, and so on (Aven & Renn, 2020; Brito & Jacinto, 2020). However, risk is not only external; it also exists internally, involving human and technical factors. This justifies the interest of this work in internal organizational data, as understanding and addressing internal risks are equally crucial for enhancing resilience and ensuring the overall stability and success of the organization.

### 1.1.2. Robustness of BCPs

To begin specifying the BCP robustness dependencies, a robustness definition should be considered in this notion. To avoid any potential misunderstandings, resilience and robustness

should be differentiated. Overall, the definitions of robustness and resilience varies across areas, yet they have significant commonalities.

To achieve robustness, various research studies emphasize the importance of maintaining an "initial state" that remains unaffected by disturbances capable of altering the system or its primary functions. Conversely, resilience research highlights the significance of a system's ability to adapt to disturbances in order to return to its initial state. This adaptation process is commonly divided into two phases: responding to the disturbance and restoring the system to its initial state while learning from the last fluctuation in order to master it, as described in the studies conducted by (Ben Amara et al., 2023; Clément et al., 2018; Ibanez et al., 2016; Pavard et al., 2009; Urruty et al., 2016). Moreover, the instability of modern society renders the idea of returning to a stable state a utopian aspiration. Rather, the situation calls for a perpetual adjustment to this instability (Benaben et al., 2022).

Clement et al., (2021) conducted a comprehensive literature review spanning from 1975 to 2018, identifying three distinct types of resilience, denoted as  $\alpha$ ,  $\beta$ , and  $\gamma$ . These resilience types primarily differ in their concepts of absorption and response zones, as well as their approach to returning to a stable state. Type  $\alpha$  resilience defines a system as resilient if it can absorb disruptions, allowing it to return to its initial performance level after a disturbance, reflecting a focus on the ability to respond quickly to critical situations. Type  $\beta$  resilience shares similarities with Type  $\alpha$  but introduces the concept of a performance zone, emphasizing the system's capacity to return to an acceptable performance level rather than its initial state. Lastly, Type  $\gamma$  resilience centers on adaptation, where a system achieves stability by adapting and transitioning to a new stable state after a disruption. This adaptation often involves reconfiguring and realigning resources to respond effectively to changes in the external environment. These distinct resilience types provide valuable insights into understanding and characterizing supply chain resilience (Ambulkar et al., 2015; Brandon-Jones et al., 2014; Cerabona et al., 2023; Christopher & Peck, 2004; Han et al., 2020; Hohenstein et al., 2015; Ivanov & Sokolov, 2013; Rajesh, 2016).

To understand the impact of vulnerability on an organization's robustness and resilience, it is important to have a clear definition of vulnerability. Vulnerability is commonly described as an underlying condition that is separate from the risky events that may lead to negative outcomes (Webb, 1993). However, the literature can be unclear regarding what constitutes a loss or damage, and to whom these losses or damages matter. In the context of disaster management, vulnerability is often divided into two categories: prevention and response (Siegel & Jorgensen, 2001).

The vulnerability approach has led to the recognition that human organizations, and not just what threatens them, are now at the heart of sociologists' interrogations. Analysing risks by focusing on vulnerability means considering what can, both in terms of the organization's professionals and the organizational context, amplify the impact of an external risk (pandemic, technological accident, act of terrorism, etc.) (Gilbert, 2013).

For our purposes, the following definition of robustness is appropriate: "**Robustness refers to an organization's ability to survive and maintain control by adapting to new organizational patterns while keeping its most important or 'vital' activities in**

**continuity in the face of disruptions of any kind"** (Wybo, 2008). Based on this definition, three types of robustness can be distinguished:

- a. "Absolute" robustness, which refers to complete invariance to disturbances.
- b. "Tolerated" robustness, which allows for some variance within a robustness zone.
- c. "Mastered" or "controlled" robustness, which derives secondary functions from the main invariant function. Thus, if the system's primary function continues to operate normally in the face of disruption, it is said to be robust. Thus, it's a "degraded" robustness focused on core functions (Clément, 2019).

This research focuses on the second type of robustness, which measures an organization's ability to tolerate disturbances while maintaining its critical activities. The indicators developed in this work are designed to measure this capacity.

### 1.1.3. Crises and disruptions

A crisis can be defined as a sudden and unexpected event that poses a significant threat to an organization's operations, reputation, or financial stability (Bonyngé et al., 2005; Callahan, 1994).

In broad terms, a crisis is "a disruption occurring within the state of a system, unveiling instability and interruption, necessitating a distinct approach to address undesired outcomes and achieve a renewed satisfactory condition for the given system" (Bénaben et al., 2016). The repercussions and effects of crisis scenarios typically encompass multiple dimensions and pertain to various aspects such as public health, politics, economics, and more (Bénaben et al., 2016).

Crises can take many forms, including natural disasters, cyber-attacks, product recalls, or scandals (Starbuck et al., 1978). According to Barton, (1994), crises are characterized by their high stakes, urgency, and unpredictability, and they require swift action to mitigate their impact.

On the other hand, disruption refers to a significant change that upsets the traditional way of doing things in a particular industry or market. Disruption can be caused by technological innovations, shifts in consumer or personnel's behaviour, or changes in government regulations. Christensen et al., (2013) define disruption as a process whereby a smaller company with limited resources successfully challenges an established industry leader by introducing a new business model, technology, or product that meets the needs of underserved customers.

While crises and disruptions share some similarities, they differ in their nature, causes, outcomes, and magnitude. Crises are typically unforeseen events that require immediate action to manage the risk, while disruptions are often driven by long-term trends that can be anticipated to some extent. Furthermore, crises can have severe negative consequences for an organization, whereas disruptions can create new opportunities for growth and innovation (Becker, 2014; Sayed et al., 2021; Vollmer, 2013). Taleb, (2014)'s concept of antifragility, however, challenges this notion. Antifragile entities thrive amid uncertainty, evolving from impacts. Unlike fragility, where absence of stressors weakens, antifragility emphasizes learning from mistakes and deriving innovation from necessity. This view contrasts how impacts affect fragility and antifragility. Fragile components suffer as impact intensity increases, while antifragile elements improve within certain thresholds. For instance, experienced weightlifters benefit from lifting heavier

weights, displaying antifragility (Taleb, 2014). Organizations that are able to navigate both crises and disruptions effectively, which is very unlikely, can position themselves for long-term success in today's rapidly changing business environment (Williams et al., 2017).

Different types of crises can be classified based on their origin and impact. Hyper-crises can be external in case of pandemics or significant natural disasters like the eruption of the Icelandic volcano "Eyjafjallajökull" in 2010. These types of crises can have a global impact, resulting in widespread damage and loss, as seen in the airline industry's US\$1.7 billion loss and 95,000 flight cancellations (Lund & Benediktsson, 2011). On the other hand, major crises can also be external and internal crises, however, typically occur within the firm and only affect its operations and stakeholders. Crises can also be classified based on their frequency, occurring either on a daily basis such as staff's absence, incompetence or unfulfillment (depending on the considered situation and organization) or triggered by specific events such as storms or floods (Pearson & Mitroff, 1993). In the case of the COVID-19 crisis faced by the pediatric ward, it can be categorized as an event-driven hyper-crisis as shown in Figure 3 (Ben Amara et al., 2022).

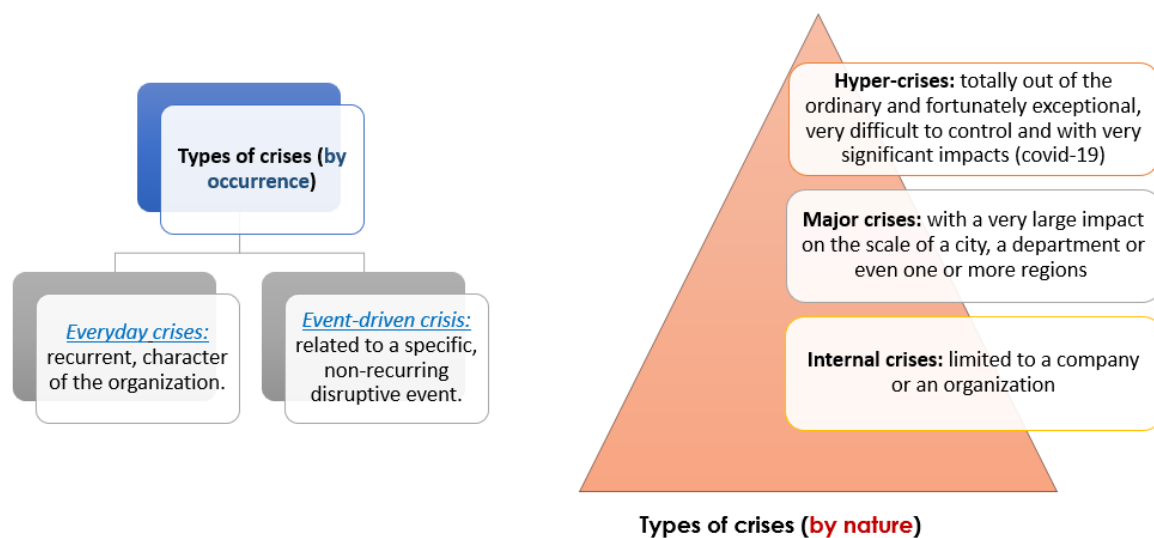


Figure 3. Types of crises by (Ben Amara et al., 2022)

Crises can be classified by impacted categories as well, and here is more exhaustive classification of crises by category according to several previous research works:

- **Natural Crises** encompass events triggered by environmental and natural disruptions, such as hurricanes, earthquakes, floods, and droughts, leading to potential harm (Middleton et al., 2013; Sakurai & Chughtai, 2020).
- **Technological Crises** emerge from technology-related failures, including system breakdowns, software corruption, and cybersecurity threats, which can compromise operations (Harrington, 2007; Shrivastava, 1994; Vielhaber & Waltman, 2008).
- **Personnel Crises** involve employee-related issues like strikes, layoffs, or scandals, impacting the organization's workforce and reputation (Anderson et al., 2020; J. P. Bailey & Schurz, 2020; McMahon et al., 2022; Saiget, 2012).
- **Organizational Crises** affect the entire organization and can involve bankruptcy, product recalls, or negative publicity, significantly affecting its stability (Bénaben et al., 2008; Nystrom & Starbuck, 2015; Simola, 2005, 2005).

- **Confrontation Crises** arise from conflicts with stakeholders, including customers, suppliers, and regulators, potentially leading to disruptions (Arfina Osman, 2010; Kuklan, 1988; Leng & Walker, 1982, 1982).
- **Crisis of Malevolence** results from deliberate harm to the organization, such as sabotage, hacking, and the spread of false information with malicious intent (DeVries & Fitzpatrick, 2006; Gribas et al., 2018; Kippenberger, 1999).
- **Crisis of Organizational Misdemeanors** stems from unethical or illegal actions within the organization, such as fraud, embezzlement, or environmental violations, posing legal and ethical challenges (An et al., 2011; An & Gower, 2009; Coombs & Holladay, 2005).
- **Crisis of Skewed Management Values** emerges when there's a misalignment between the organization's stated values and its actual actions, encompassing issues like discrimination, harassment, and safety violations, leading to reputational damage (Khodarahmi, 2009; Tse et al., 2006).

Moreover, research in sociology has shown since the accidents of Three Mile Island in 1979, Bhopal in 1984, Chernobyl and Challenger in 1986, and Piper Alpha in 1988 that human errors alone do not explain the poor management of these accidents. According to several authors (Cummings, 1984; Llory, 1996; Reason, 2007; Vaughan, 2016), these accidents occurred because the organizational context was favorable to their occurrence. In each of the cited accidents, operators were somehow constrained to make errors and had no other choice but to fail due to their organizational work environment. (Bieder, 2006) uses the term "Error Forcing Context," previously used in the United States, to express the idea that some professionals were compelled to make errors by the organizational context of their work. The author compares professionals to puppets whose movements are influenced by the organization pulling the strings. These works gave rise to sociological research on organizational reliability and seek to shed light on what is now commonly referred to as "organizational factors" in sociology.

Regarding the Challenger space shuttle accident studied by sociologist (Vaughan, 2016), economic and political pressures contribute to the "poor" decisions made by managers and those responsible for management, even when the technical problem is identified.

The work done by (Cummings, 1984), on the other hand, offers a somewhat more alarming view of organizations. His analysis of the hearings following the nuclear accident at Three Mile Island led him to believe that the accident was bound to happen. He argues that the installation had excessively complex technical and organizational arrangements, leaving little room for operators to react. Such complex systems are inevitably prone to accidents due to the risks associated with the system's design and the very nature of the activities performed.

#### 1.1.4. Utilization of BCPs

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This subsection treats mainly the following research question: To which environmental, technological, organizational and human work areas BC is applied?

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Business continuity measures are implemented in environmental, technological, organizational, and human work areas due to the high potential of disruptions of these four domains: Environmental factors include natural disasters, extreme weather events, and geographical risks that can impact business operations. Technological aspects encompass system failures, cyber-attacks, and data breaches, while organizational and human work areas involve risks like leadership changes, supply chain interruptions, and operational failures. Addressing these susceptible areas enables organizations to identify and mitigate risks, ensuring the smooth functioning of critical business functions during disruptive events (Baba et al., 2015; Hájek & Urbancová, 2013; Kosieradzka et al., 2022; Miller & Engemann, 2012; Svata, 2013).

A methodical structure for understanding and responding to various risks and disruptions is provided by categorizing BC measures into environmental, technological, organizational, and human work domains. These categories, defined and detailed in the following subsections, enable a BCP strategy that is more focused and accurate. Each category encapsulates a distinct set of risks and vulnerabilities, including environmental features like natural catastrophes, technology aspects like system outages, and organizational and human work environments with hazards like leadership changes and supply chain disruptions (Bajgoric, 2006; Cervone, 2017; Zsidisin et al., 2005).

#### **1.1.4.1. Regarding the “natural environment”:**

The natural environment is described as a set of natural occurrences, characteristics, and events (Hallegatte, 2014). At a BC level and when considering the possible strategic consequences of climate change or various natural catastrophes, it may also be designated as a key stakeholder (Haigh, 2007).

On one hand, in this section the topic representing natural diseases, such as Influenzas and, recently, covid-19, are crucial to the natural environment and BC. The research work done in (Tay et al., 2020) demonstrates the significance of a set of workflow metrics, disciplined yet prudent personal protection equipment protocols, and clear strategic goals in order to continue managing a significant proportion of patients in the otolaryngology-head and neck surgery service in a safe environment for patients and caregivers. Another work done by (Hennessey et al., 2010) explains how cleaning and disinfection protocols have been developed for products that require relocation to ensure business continuity. The cleaning procedure model provides a template for individual companies or locations to adapt these protocols according to their specific needs.

Moreover, earthquakes can appear as a serious matter to BC as well. In fact, since the Great East Japan Earthquake, medical institutions have recognized the importance of formulating alerts of maximum severity, and public demand for this type of alerts has increased in disaster base hospitals (Matsumura et al., 2015). The basic disaster hospital requirements issued by the Department of Health, Labor and Welfare are defined by a single indicator that qualifies the power shortages. However, based on the experience of large earthquakes, these specific requirements have been modified, in relation to water supply facilities, these requirements are: "Having a water tank of sufficient capacity, the supply can cover the needs of use during power cuts and guarantee the availability of water and medical treatment in the event of a disaster, by

signing preferential water supply agreements” (Nakagawa et al., 2013). The findings of this study realized in (Matsumura et al., 2015) support these claims.

From another perspective and as indicated in (Horvath et al., 2006), Australia has taken a "whole-of-government" approach. This recognizes that decisions related to health protection during a pandemic, such as border control, quarantine, and school closures, have broader societal implications beyond health alone. Factors such as food supply, energy supply, and overall business continuity need to be considered in pandemic response. In summary, pandemic planning is an ongoing and extensive process that requires continuous updates and refinement based on new evidence. Primary care plays a crucial role in pandemic response, and each practice must have a well-defined plan that outlines staff roles, incorporates infection control and staff protection measures, and addresses BC. The implementation of such a plan is of utmost importance.

On the other hand, the environmental protection and the decarbonization methods and techniques play an essential role in the relation between the natural environment and BC. In fact, the work done in (Gasbarro et al., 2017) gives an overview of how reduced/disrupted production capacity and inability to do business, or business continuity, correspond to climate-induced physical risk; reduced demand for goods/services corresponds to changing consumer behavior; and reduced stock price (market valuation) corresponds to reputation risk. Finally, increased operational costs are associated with regulatory risk such as emission reporting obligations, fuel/energy taxes and regulations. In summary, the natural environment comprises natural occurrences, traits, and events, also considered a vital stakeholder in BC. This section emphasizes the significance of natural diseases like influenza and COVID-19 in BC, illustrated by research on workflow metrics and cleaning protocols. Earthquakes are also a BC concern, post the Great East Japan Earthquake, with increased alert importance and modified requirements such as water supply.

#### **1.1.4.2. Regarding the “people”:**

The people in this research work could be either the staff (managers, workers, engineers, medical personnel, etc.) or the people receiving the services or the products of one organization such as customers or patients in the case of healthcare organizations (Kantabutra & Avery, 2007).

The model developed by Vojtko et al., (2019) was built on an analysis of empirical data from 554 crises from 183 Czech companies, with the main goal of identifying the co-occurrence of different types of crises and how managers dealt with them. The application of such a model focused on manufacturing firms, including its calibration, is demonstrated further through a case study of a real company and related scenario analysis. This analysis could be very useful for the manager, for example, to predict the potential consequences of various managerial decisions when a certain type of crisis occurs, allowing them to avoid causing further problems in the future. A model like this can be used as a decision support tool for managers dealing with various crises, as well as a means of explaining crisis dynamics.

Another survey developed by Galbusera et al., (2021) revealed the importance of BCP during the covid-19 pandemic in CI (Critical Infrastructures) management. In fact, as stated in (OECD, 2003), "business continuity throughout society is heavily reliant on the ability to avoid disruptions to vital systems such as the health system, water and energy supplies, administration and public security, transportation, communication, and so on." As a result, the effectiveness of

measures implemented within CI businesses has the potential to impact BC in general. On the whole, the survey results for "COVID-19: Emergency & Business Continuity" are encouraging since many organizations reported taking appropriate COVID-19 crisis response measures.

Moreover, aside from natural disasters mentioned previously in the "natural environment subsection", there are man-made disasters. Human-caused disasters occur when human actions cause various types of infrastructure threats. These types of disasters, whether intentional or unintentional, can cause massive harm to the public. Hence, since it is no longer a question of managing the crisis from the point of view of continuity, but rather of the causes/origin of the crisis. One could also classify these crisis occurrences according to the timing of the events: cause of the crisis, identification of the crisis and launch of the alert, management of the crisis, learning from the crisis, and so on (Magutshwa & Radianti, 2021). Furthermore, they are sometimes directed by people or organizations to gain hidden benefits, and they may be influenced by religion or belief. The 9/11 attack was a disaster in which 19 Al-Qaida terrorists hijacked four planes and intentionally crashed them into the World Trade Center Twin Towers and Pentagon, killing all passengers and approximately 2,976 people in the buildings. The Sasser worm is yet another man-made disaster that affects computers running Microsoft operating systems (Sithirasenan & Almahdouri, 2010).

As explained in (Hom & Chous, 2007), it's very likely that there will be an outbreak of influenza in the future, but we don't know when or how severe it will be. Epidemiologists and business consultants are warning about the possibility of an outbreak. That makes it important to pay attention to these warnings since our livelihoods may be affected (Chateauraynaud, 2020).

It is also worth mentioning the difficulty of predicting human behavior during a crisis. For example, the competition between the United States and other countries to obtain masks during the Covid-19 pandemic. A shipment of masks from China to another country was diverted to the United States after Americans outbid others on the airport tarmac. A behavior of such demonstrates that human behaviors are always challenging to predict.

At an individual level, it is equally complex. For example, for a soldier engaged in armed conflict for months, a direct engagement with the enemy may not be perceived as an exceptional or extreme situation in the same way it would be for a civilian.

What characterizes a risky situation is uncertainty, and thus the difficulty in predicting how a person will behave. Generally, the outcomes of studied situations can be understood in a probabilistic manner. For instance, we know that in a particular situation, the probability of a soldier engaging in combat against an enemy is higher than the probability of fleeing. Sociology, therefore, needs to qualify an individual based on social and demographic characteristics (age, education level, qualifications, etc.) to proceed with a probabilistic study. Decision-making, or more generally, the choice between different options, is one of the themes that has attracted a large number of studies in the sociology of organizations. The sociology of organizations is a specialized field that examines how members of an organization (the actors) construct and coordinate collective activities. In other words, a professional in an organization faces power relations, possesses resources and negotiation margins, and operates within an organizational context that must be understood. Being a doctor in a public hospital in France is different from being a doctor in a private clinic, for example, as organizational constraints are not entirely the same, as demonstrated by Bergeron & Castel, (2023).

In summary, the research work focuses on the involvement of people's roles within organizations in crisis management, including staff, customers, and patients. Models are developed to analyze crises and assist managers, representing organizational roles, in decision-making, highlighting the importance of considering the needs and roles of individuals and collectives in ensuring BC and effective critical infrastructure management.

#### **1.1.4.3. Regarding the “Organizations”:**

An organization is a structured collection of human and physical resources who coordinate their activities and cooperate to achieve goals, such as a corporation or government department, healthcare institutions, universities, research centers, banks, and so on (Grunig et al., 2008). In this perspective, an organization is defined here as the employees who cooperate within a technical environment with which they have to deal, and the relations between them such as the hierarchy, the tasks performed, the division of work and grouping in units or departments.

When it comes to the business management strategies, some firms tend to enhance their partnership creations as explained in (Mongioi et al., 2009). In fact, bringing together private and public partners can be crucial to strengthening the link between emergency preparedness and business continuity. Safeway, a national grocery chain, is one example of a private partner identifying measures for ensuring business continuity in the transportation sector. The retail store's strategy is to remain actively involved in county-level choices about how to access local transit resources for crises. Including private enterprises in the conversation through conferences and seminars can be crucial in establishing a region's level of preparedness and ensuring commercial continuity.

Similarly, innovation is an important matter to BC. In fact, as stated in (Mihajlović & Raguz, 2018), customers, new technologies, and an experiential competition incorporating in company idea value system based on socio-environmental sustainability are the primary drivers of market developments. The change relies heavily on innovation (Dumičić et al., 2016) but also on the ability of providing high quality, low pricing, and efficient services (Laesser & Jäger, 2001; Mihajlović & Raguz, 2018; Stojcic & Vojvodic, 2012).

Another relationship between the BCM and the organization's facilities could be the impact of electrical architecture on the BC, as addressed by Parise et al., (2015). In reality, efficient design, supervision control systems, and BCM improve service quality and safety while allowing management of operation, maintenance, and energy expenses (Parise et al., 2015). Some strategies can also be applied to the system updates deployment solution to ensure no business disruption. For example, scaling and fine-tuning an OS Update would ensure that needed updates are delivered on time. By having the offered updates, patches, and service packs, it will ensure a more secure environment as well as compatibility and business continuity (Dimov & Tsonev, 2018). Consequently, and as one of the statements delivered by one of interviewees in (Galbusera et al., 2021): recently, the majority of public organizations, along with universities and research centers, have recognized the necessity of Business Continuity Planning (BCP) and have incorporated it into their Management Systems and Strategic Planning. This will be as successful as the daily incorporation of core activities following the by the PDCA cycle, especially risk management, emergency management, disaster prevention and recovery, at all

levels of their services (curriculum/education, administrative, technical support, and IT infrastructures).

However, critical infrastructures are an interesting case in regards to BC. In fact, in such infrastructures, beyond significant financial losses, the potential implications of cyber threats for example include disruptions to BC, data loss, reputational injury, loss of future competitive advantage, and hostility from partners and consumers (Jensen et al., 2019). These disruptions are particularly important since findings of the vulnerability assessment can be used as input for BC and maturity assessments (Heikkilä et al., 2011). As a result, the efficiency of the architecture, supervision control systems, and business continuity management (BCM) improve the quality and safety of the services while allowing management of the operation, maintenance, and energy costs (Parise et al., 2015).

According to (Guidry & Mehmood, 2013; *NFPA 1600®: Standard on Continuity, Emergency, and Crisis Management*, 2019), a BCP should identify stakeholders who must be notified, critical and time-sensitive applications, alternative work sites, vital records, contact lists, processes and functions that must be maintained, as well as personnel, procedures, and resources that are required while the entity is recovering. For this reason, an alternative BC facility could be for example designing a web-based prototype implementation of a BCIN (Business Continuity Information Network) capable of connecting participating businesses to form a community network, providing businesses with effective and timely disaster recovery information, and facilitating collaboration and information exchange with other businesses and government agencies as within the project proposed in (Zheng et al., 2010). Consequently, disaster and emergency management education offerings in Canada for example are expanding, with schools offering diploma and certificate programs and universities offering bachelor's and graduate degrees in the discipline (de Jong, 2003; Oostlander et al., 2020).

Like many other industries, healthcare organizations adopt various strategies and methods to manage specific risks, including maintaining confidentiality and ensuring system availability. These approaches are crucial for organizations to continue operating, maintain business continuity and protect sensitive information (Ziemniak, 2011). However, cloud-based services offer organizations a cost-effective alternative to purchasing and maintaining hardware and software in-house. Organizations can use cloud-based services and pay only for what they use. This approach allows organizations not only to access tools and resources across multiple devices, which can significantly improve productivity and efficiency, but also to reduce unnecessary costs (Li et al., 2010).

In a nutshell, the concept of business continuity (BC) is vital for organizations across various sectors. Partnerships between private and public entities can strengthen emergency preparedness and ensure commercial continuity. Innovation, driven by customers, new technologies, and socio-environmental sustainability, plays a significant role in market developments and BC. Effective electrical architecture, supervision control systems, and BCM enhance service quality, safety, and management of operations and energy expenses. Critical infrastructures face cyber threats that can lead to financial losses, data loss, reputational damage, and other disruptions, emphasizing the importance of vulnerability assessments for BC. Stakeholder identification, alternative work sites, vital records, and collaboration with government agencies are crucial elements of a comprehensive business continuity plan.

Healthcare organizations rely on strategies like confidentiality and system availability to ensure business continuity and protect sensitive information. Cloud-based services provide cost-effective solutions, improving productivity, efficiency, and reducing unnecessary expenses for organizations.

#### **1.1.4.4. Regarding the “Technology”:**

The technology in this research study is outlined as the developed and under-development technologies, which are largely ICT, and their integration into users' personal and professional lives (Marangunić & Granić, 2015).

As mentioned in (Manning, 1999), proof testing against all possible outcomes becomes increasingly difficult as complexity grows inexorably. Risk management methods used in systems engineering and process continuity assurance must be extended beyond their current macro domains all the way down to the micro level. As a result, risk and impact analysis techniques, as well as potential failure mode assessment and avoidance and prevention planning, has to become an integral part of all engineers' basic knowledge.

On this same basis, the work proposed in 2021 by Bennett & McWhorter, (2021) aims at explaining VHRD (Virtual Human Resource Development ) role in the maintaining of the BC within many organizations while and after the Covid-19 crisis. In fact, with technology so critical to business survival and education throughout the epidemic, the world needed VHRD. VHRD has progressed from the margins to the heart of organizational practice. Many new companies and professions were thrown into the realm of VHRD in the year 2020 to accommodate work-from-home mandates and alternative work tactics (Bennett, 2009). The epidemic resulted in a new split between necessary and non-essential personnel, sanitation practices, layoffs and decreased hours, supply chain disruption, quick innovation, and other changes. In retrospect, the world ended with a schism between the pre and post Covid-19 historical periods. Virtual recruiting and onboarding, for example, become essential components of pandemic VHRD to keep the economy and corporate operations running (Bennett & McWhorter, 2021).

Other similar findings were discussed by Ano, (2018) with regards to the advanced technologies role in maintaining the BC. In fact, it has been seriously considered how packing technologies have contributed to the market. In other words, how trustworthy sophisticated technology have been integrated into such items. However, some severe quality faults have been observed after the product was released to the market. Unfortunately, when this occurs, it harms the company's reputation and puts business continuity at risk (Shimizu et al., 2010). As a result, it serves as a reminder to development engineers of the need of assessing potential quality risks during the new product development process since the choice of technology is not independent of the socio-historical context. In other words, risk cannot be limited to quality issues (Ano, 2018).

In the same perspective, a research work established by Chen et al., (2012) demonstrates that computer resources are a key performer to business continuity but they are sensitive to power networks and cyber-attacks. Cloud computing offers affordable and efficient solutions for ensuring the continuity and agility of business operations. Traditional methods for high availability, fault tolerance, and disaster recovery can be costly and complex, even with doubling hardware for protection. However, with cloud computing, it's possible to achieve reliable recovery without the need for similar hardware, making it a more cost-effective and accessible

solution. Additionally, server consolidation can be used to reduce the cost of the server infrastructure needed for both production and disaster recovery purposes. This means that a business can potentially save money on hardware costs by utilizing existing resources in a more efficient way (Bailey, 2009). Furthermore, resource pooling involves combining and sharing resources like hardware, software, or personnel to increase efficiency and reduce waste. This practice can help avoid the need for additional physical servers when implementing new services over a long period of time, which is a significant investment (Chen et al., 2012). And as exploited by a use case concerning e-learning in Kenya by Kihara & Gichoya, (2014), many options exist with cloud computing technologies, including disaster recovery, business continuity, data consolidation, availability, confidentiality, and data integrity. Consequently, users are not required to set up a data backup and disaster recovery solution to ensure data security and business continuity. In fact, utilizing cloud storage, there is no need to be worried about the type of storage devices included, the interface and protocol used, the connecting medium between storage and server, and so on, as if each storage device were utilized individually according to the feedback in (Tang, 2013).

Regarding emergencies and informational assets, according to the research done in (Pingel et al., 2012), a BCP should consider at least: (a) the critical functions of an organization, (b) the critical staff, (c) the alternative staff to serve as a backup in the case of a crisis, (d) the critical resources and their backup, (e) the communication guidelines and templates, and (f) the special equipment for emergencies. As (d) and (f) are relative to technology deployment within the company, it's thus clear that technological assets play an important role for the BC.

Another research published by Bianchin et al., (2010) suggests a new measure to quantify the similarity of CP activities in the context of IT change management, with the goal of improving risk assessments and thus the BC based on previous data. It was demonstrated that, among the primary factors considered in this similarity metric, the relevance of considering previous activities and comparing participant resources of activities, linking them to their categories (Bianchin et al., 2010). Similarly, planned digital infrastructure construction might be halted until it directly contributes to disaster response. Organizations had plans to operate from internet-connected remote sites due to the increasing adoption of cloud-based services, legal requirements to maintain excess capacity, and ongoing digital transformation initiatives. These plans were in place before the COVID-19 pandemic and were meant to increase flexibility, scalability, and operational continuity (Papagiannidis et al., 2020).

Paradoxically, Samejima & Yajima, (2012) proposed an IT risk management framework for business continuity based on an examination of what types of changes in information systems cause IT risks to alter and diversify. Hence, IT continuity management is an important aspect of business continuity management. In fact, IT outages are recognized as a significant threat to business continuity, and IT continuity management involves taking a systematic approach to ensuring that IT systems and infrastructure remain operational during disruptive events. By prioritizing IT continuity management, businesses can minimize the impact of IT outages and maintain their operations during disruptive events (Draheim & Pirinen, 2011).

As a result, technology has an essential role in BCP. These various studies clarify that technology, particularly ICT, plays a pivotal role in addressing disruption challenges. This includes risk management, IT change management, remote work, efficient data storage, cloud

computing and IT continuity management, all essential aspects of maintaining operational resilience. Overall, technology is crucial for modern organizational strategies aimed at ensuring BC. Utilizing technology effectively in BC requires doing risk assessments, taking past actions into account, and putting risk management frameworks into place.

### **1.1.5. Data-based approaches**

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This subsection answers the following research question: What are the data-based approaches used to treat BC-like subjects?

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#### **1.1.5.1. The evolution of computer-based data-collection approaches**

During the early 1970s, significant trials like the Hypertension Detection and Follow-up Program gathered vast quantities of data using paper questionnaires filled out at doctors' offices. These forms were then sent to a central location where the data was manually entered into mainframe computers (Cooper et al., 2006; Curb et al., 1983). By the early 1980s, studies such as the Systolic Hypertension in the Elderly Program (Aronow, 2012; Cooper et al., 2006) enhanced data quality and availability by utilizing personal computers at local sites for data entry. This data was then transferred electronically to mainframes via modems. In the late 1990s, new methods emerged that employed the internet for data collection, including sending questionnaires directly through the internet and utilizing web-based systems for data entry and management (Hunt et al., 2001; Schleyer & Forrest, 2000; Swoboda et al., 1997). More recently, researchers have been exploring modern techniques for remote data entry, such as utilizing handheld devices like mobile phones (Cooper et al., 2006; Eikemeier et al., 2000) with Wireless Mark-up Language, as well as computer-assisted personal and telephone interviews (Cooper et al., 2006; Garson, 2003).

Moreover, the Internet of Things (IoT) has brought about significant changes in computer-based data collection methods. IoT incorporates sensors within devices for real-time data gathering, like monitoring temperature and energy consumption in smart homes. This data is transmitted instantly over networks, enabling quick analysis and decision-making, with applications like predictive maintenance in industries. IoT manages vast data streams, often referred to as big data, necessitating optimized strategies for collection, storage, and interpretation. Moreover, it enhances data accuracy through tailored collection processes and techniques like filtering and aggregation. Automation is a key feature, allowing connected devices to streamline processes in contexts such as smart homes and industries. Integrating IoT data with traditional sources provides a comprehensive perspective. In essence, IoT has revolutionized data collection, enabling real-time, sensor-driven accuracy and automation, unlocking new possibilities across diverse industries and domains (Kumar et al., 2019; Mohindru et al., 2020; Sofia et al., 2019; Yuan & Elhoseny, 2019).

#### **1.1.5.2. Web-based data collection approaches**

The process of entering data through web-based forms has emerged as a significant breakthrough in remote data entry. This approach has gained popularity due to the widespread availability of internet access, enabling direct input of data into a centralized database. Moreover,



it reduces reliance on specific equipment for data entry. Web-based methods offer the advantage of immediate editing checks as responses are being entered. Additionally, they allow for various traditional techniques of inputting responses, such as textboxes, dropdown menus, checkboxes, and other styles available through web programming. This eliminates the need for additional software on the client's end, as a web browser is sufficient (Cooper et al., 2006).

Web-based data collection methods, although efficient, may encounter issues such as sampling bias—like when surveys are restricted to website users—integrity problems, such as false information in open online forums, and data security challenges, including potential violations due to insufficient protection measures (Das et al., 2018; Marcell & Falls, 2001).

### **1.1.5.3. Data-driven approaches**

The study done by Wen et al., (2019) introduces a data model that possesses multi-dimensional and unrestricted characteristics, aiming to enhance the support for data mining algorithms. The model efficiently organizes diverse data in both relational databases and memories, facilitating analysis-oriented data extractions. Building upon this data model, an Operation & Management data mining approach is proposed, encompassing procedures such as data preparation, data clustering, and data mining.

Similarly, Harvey et al., (2017) presents the concept and implementation of a data repository for research data management that is driven by metadata. The collection of metadata is automated during the information submission process whenever feasible and adheres to the metadata schema specified by DataCite which is an international consortium of libraries and services dedicated to the data sciences. In return, a persistent digital object identifier is obtained. This work showcases two instances of data preview, one of which demonstrates the integration of commercial software for domain-specific data analytics without the need for customizing the repository itself.

Balakrishnan et al., (2020) demonstrated significant implications for utilizing various data management solutions, including RDBMS (Relational Database Management System), NoSQL, NewSQL, Big Data, and real-time reporting tools. These solutions can support transactional data within internal systems as well as other types of data sourced from external systems like Social Media. The study's outcome is the development of a technology-independent framework for data management, which organizations can adopt when formulating data strategies. This study offers valuable guidelines for establishing a comprehensive data management solution across the enterprise, benefiting both academic researchers and industry practitioners.

Liu, (2019) made a significant contribution by utilizing data analysis to transform unstructured data into structured data. This approach integrates diverse data formats and facilitates data analysis, particularly in the realm of customer relationship management. By aligning consumer values with technology, businesses can enhance promotional activities and technological transfers, thereby improving and maintaining business continuity (Liu, 2019).

Furthermore, there is a growing demand for advanced backup and recovery solutions that can meet the increasingly complex business continuity requirements. It is estimated that by 2016, one-third of enterprises will switch backup suppliers (offering recovery solutions for enterprises' data and systems) due to factors such as cost, administrative complexity, and limited capabilities (Kowall & Cappelli, 2012; Song et al., 2014). The corporate distributed system backup/recovery

software market has increased by almost 70% from 2011 to 2014 and is constantly growing. Consequently, IT management teams need to prioritize the development of reliable, user-friendly, and intelligent backup solutions to enhance their company's competitiveness and market leadership (Song et al., 2014).

To address these challenges, platforms for scalable data mining have been developed, enabling the implementation of data mining algorithms on large datasets. Multiple use case studies demonstrate the application of data mining techniques for effective corporate backup management using big data analytics approaches (Song et al., 2014).

Likewise, it is advisable for the Business Continuity Planning (BCP) department to directly report to an Executive Director. In order to bring about organizational-wide change, the individual leading the change should operate from a broad or neutral position rather than from a specialized field (King, 2003). Hence, there are establishments known as telecom hotels which are specialized data center facilities that provide a secure and reliable environment for telecommunication companies and other businesses to house their networking and telecommunications equipment. These facilities are utilized by local exchange carriers, Internet service providers (ISPs), web hosting companies, competitive access providers, and various non-telecommunications organizations (Armbruster et al., 2012). As a result, both large and small enterprises are increasingly reliant on telecom hotels, which are specialized facilities designed to house telecommunication equipment and infrastructure, to carry out their business operations (Armbruster et al., 2012).

In a nutshell, the utilization of web-based data collection approaches has facilitated remote data entry and reduced reliance on specific equipment, while data-driven approaches have enhanced support for data mining algorithms and analysis-oriented data extractions. Transforming unstructured data into structured data through data analysis holds potential for optimizing customer relationship management and improving business continuity. The increasing demand for advanced backup and recovery solutions underscores the importance of reliable and intelligent backup systems such as platforms for scalable data mining and telecom hotels that offer a secure environment for housing networking equipment catering to the needs of diverse organizations.

## 2. Identification of gaps and contradictions

In this section, we analyze the crucial task of identifying the gaps and contradictions within existing research that lay the foundation for the need and significance of the present thesis. As research progresses, it is imperative to critically assess the body of knowledge that already exists and pinpoint its limitations, inconsistencies, and areas where further exploration is warranted. By doing so, we set the stage for our own contribution, highlighting the value and relevance of this work.

### 2.1. Improving the business continuity: The competitors' research works

Different approaches can be utilized to evaluate and enhance business continuity, which is essentially overseen by the Business Continuity Plan (BCP). Business experts generally recommend starting with business continuity planning and then prioritizing disaster recovery for the most critical aspects of the organization, which falls under the third step in the four phases of crisis management (Prevention, Preparation, Response, Recovery) (Mitroff et al., 1987). Regardless of the type of disaster, a BCP focused on restoring the organization's ability to conduct business may face various types of distractions. Therefore, disaster management planning should integrate disaster preparedness using (i) strategic management, (ii) business risk management analysis, (iii) awareness, and (iv) information life cycle management to construct a business continuity plan, in addition to the traditional (v) disaster response planning. The integration of these five critical criteria should provide a solid foundation for managing and responding to potential risks (fires, storms, pandemics, etc.) (Karim, 2011).

However, despite most companies acknowledging that certain calamities are inevitable, too many firms are unprepared to handle them (Herbane, 2010; Pitt & Goyal, 2004). Only 20% of firms feel that they have an effective Business Continuity strategy in place in case of an emergency (Swartz, 2003). To prevent such circumstances and better prepare for crisis situations, some firms create a BCP and also implement an auditing process. However, a fully designed and executed BCP audit is insufficient as a means of raising management awareness. A series of Best-in-Class case studies must also be included in the audit to identify the firms, the creation and implementation of their BCP procedures, and the subsequent advantages realized as a consequence of these processes. Firms must be willing to participate in the management education process. Identifying appropriate BCP benchmarks and metrics can also be crucial steps in effectively building the business continuity strategy (Zsidisin & Ragatz, 2003).

BCP documentation within the organization is created for a "general" disaster ignoring the reality that the chaos generated by terrorist attacks, pandemics, or floods is not the same. Given the variability of the nature of organizations and crises, this should constantly be examined, since the company is as specific as the problems it may face. BCP encompasses a wide range of measures and actions aimed at ensuring an organization's ability to continue its critical functions during and after disruptions, which can include evacuation and intrusion exercises as part of its strategy. Furthermore, while BCPs are predictive, they are rarely based on actual past crises. Given that expectations are never clear, the COVID19 crisis demonstrates both our lack of preparedness and how much we have learned. In conclusion, constructing a "traditional" BCP to be rigidly enforced does not appear to be always beneficial, since BCPs should be evaluated and revised on a regular basis and crises should be occasionally simulated. Therefore, hazardous

occurrences may be well-managed with the least impact on the structure's business continuity through a continual and purpose-oriented review process of the BCP (Margherita & Heikkilä, 2021).

## **2.2. About data modelling and performance measuring: The contributors' related works**

Data analysis may be beneficial for a variety of objectives. As circumstances multiply, the data grows larger and the goals become more complex. As a result, developing a model to identify and cluster the data (sources, kinds, domains, etc.) remains essential. Structured, unstructured, machine and sensor-generated data, batch and real-time processing data, biometric data, human-generated data, and business-generated data, for example, are all descriptors for a healthy data domain. The following are examples of data domains: (a) Data created by machines; (b) Data generated by humans. Data types might be descriptive, predictive, or prescriptive from the same perspective (Saggi & Jain, 2018).

As previously stated, evaluating data inside a single firm helps to develop more effective business continuity measures. The majority of businesses really start with a business impact analysis to assess the financial effects of being out of service. This first phase does not provide any recovery implementations; rather, it just expresses a business requirement that will be considered in succeeding stages that will assess IT-related conditions. To qualify the business implications, these tasks should be conducted to: (a) Determine the crucial business operations, (b) determine the impact of a loss or deterioration, (c) determine the IT processes that support mission-critical applications, and (d) evaluate risk and vulnerability, and (d) have the capacity to explain probable outage causes and risk mitigation alternatives (Lumpp et al., 2008).

Another important consideration when assessing success in terms of business continuity is to consider all of the data that is accessible, particularly societal statistics. In reality, corporations should perform risk assessments in relation to economic, social, and environmental aspects while creating a BCP. When formulating their strategy, the surveyed companies in (Wysokińska-Senkus & Górna, 2021) consider economic, environmental, and social factors. Economic/market elements were discovered to be the most essential variables (92.1% of businesses regarded this feature as important). Environmental issues came in second with 67.8% of the vote, followed by social concerns with 65.8%.

This approach gains significance during events like the initial COVID-19 wave when non-COVID-19 patients faced limited medical access (Negrini et al., 2020), similar to the situation in our first use case in France. This underscores the need for a "crisis within a crisis" strategy for handling pandemic-related disruptions, such as staff and patient absences from hospitals (renunciation of care). Comprehensive data collection becomes imperative for effective BCP and crisis response in multifaceted scenarios.

The BCP must account for both individual and group human elements, such as absenteeism and collective mental representations of risk (such as fear of contracting a virus, panic, and panic brought on by rumours). Hence, age, education level, distance to the hospital, kind of occupation, and other characteristics of individuals who are most concerned can be collected through sociological studies (surveys for patients and workers).

The contribution of these studies tries to quantify the impact of various elements on an organization's functioning. In the event of a dangerous circumstance, such as a pandemic, it is feasible to forecast behaviour of the individual and the collective by differentiating data kinds and sources and processing its results.

### 3. Conceptual framework

In today's fast-paced and ever-changing business environment, the ability to respond effectively to unexpected events is essential for organizations to maintain their operations and protect their assets. Business Continuity Planning (BCP) is a critical component of this process, providing a roadmap for organizations to mitigate risks and respond to unexpected events. However, evaluating the effectiveness of BCP can be a challenging task, requiring a comprehensive and data-driven approach that considers a wide range of factors.

The field of business continuity planning has witnessed significant advancements in recent years, driven by the increasing recognition of the importance of organizational resilience. As organizations face a growing array of risks and uncertainties, the need for robust and effective strategies to ensure business continuity has become paramount. Extensive research has been conducted to explore various aspects of business continuity planning, including risk assessment, crisis management, and response strategies. While these studies have provided valuable insights, there remains a gap in the literature regarding **the evaluation of the effectiveness of business continuity plans**. Assessing the robustness and impact of such plans requires a systematic and comprehensive approach that incorporates data-driven methodologies and indicators.

To address this challenge, this research work aims to present a conceptual framework entitled "Designing a Data-Driven Model for Business Continuity Planning Evaluation using Robustness Indicators." Building upon the existing body of research in the field of business continuity planning, this framework combines theoretical foundations, data analysis techniques, and practical assessment tools to provide a comprehensive evaluation of business continuity planning strategies. By integrating robustness indicators and data-driven methodologies, this framework aims to enable organizations to assess the effectiveness of their business continuity plans, identify areas for improvement, and enhance their resilience in the face of unexpected events. Through this research, the objective is to provide organizations with measures for their preparedness and response capabilities. The proposed framework (Figure 4) aims at providing a comprehensive and practical approach to evaluating BCP, ultimately helping organizations to prepare for and respond to unexpected events.

This framework consists of three key components: **the data-gathering model, the BC ontological framework, and the assessment grid** (see Figure 4). The data-gathering model ensures that all relevant data is collected and analyzed, while the BC ontological framework provides a theoretical foundation for understanding the different aspects of BCP. The assessment grid provides a practical tool for evaluating the effectiveness of BCP against pre-defined indicators of robustness. By combining these three components, this conceptual framework promises to provide valuable insights into the effectiveness of BCP and help organizations improve their resilience in the face of unexpected events. The proposed framework (Figure 4) is expected to contribute to the existing literature by providing a comprehensive and practical approach to evaluating BCP, ultimately helping organizations to better prepare for and respond to unexpected events.

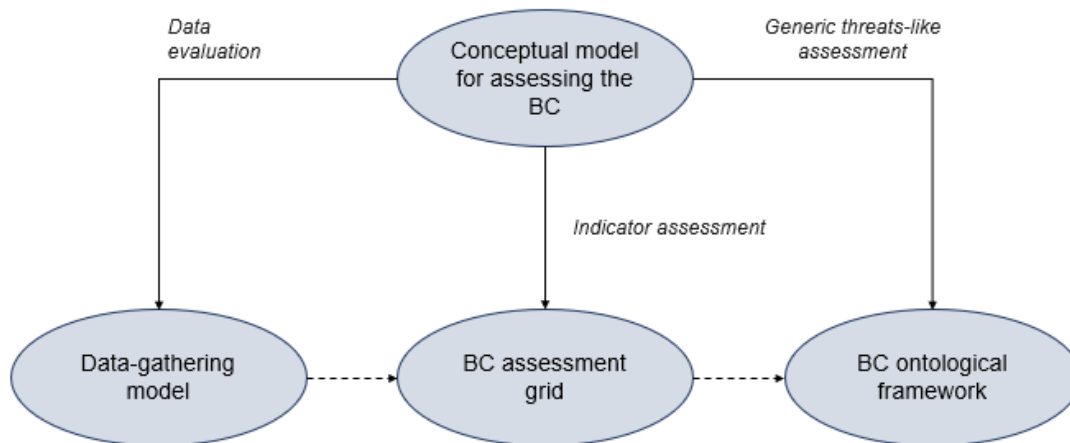


Figure 4. BC conceptual framework

This BC conceptual framework, along with its three subsystems mentioned above, is explicitly detailed in Chapter 3 of this thesis. The mention of this framework serves to foreshadow its comprehensive methodology, which will be thoroughly explained and explored later in the thesis. By introducing the framework at this point, the foundation is established for the subsequent chapters and anticipation is created for the in-depth analysis to follow.

Chapter 3 is dedicated to explain in details the methodology of this work along with this BC conceptual framework and its three subsystems. A comprehensive overview of each component is provided, highlighting their significance and interdependencies. A deeper understanding of the data-gathering model, which ensures the comprehensive collection and analysis of relevant data, is gained. The BC ontological framework, which forms the theoretical basis for comprehending different aspects of BCP, is explored. Additionally, the assessment grid, a practical tool for evaluating the effectiveness of BCP, is thoroughly discussed.

## 4. Research hypotheses

In this section, the hypotheses that this research work considered are provided, along with relevant examples in the context of the evaluation of an organization's Business Continuity.

The research hypotheses presented in this chapter are dictated to make the link between the existing knowledge in the field and the specific questions addressed by this work. This approach showcases the understanding of the current state of Business Continuity Planning (BCP) research but also highlights the gaps and areas where this study intends to make contributions. By explicitly stating these hypotheses in this chapter, a roadmap of the research objectives is provided, and the stage is set for the subsequent chapters that will provide a hands-on understanding and practice of evaluating BC.

Research Hypothesis:

- **"H1:** Some robustness indicators might not be significantly related to the implementation of a data-driven model for business continuity planning evaluation of an organization/company." Thus, these robustness indicators won't be considered in this work.
- **"H2:** There is a significant relationship between the implementation of a data-driven model for business continuity planning evaluation and the robustness indicators of an organization/company." Thus, it is legit to compile some robustness indicators and link them to assessing the BCP.
- **"H3:** The creation of a generic metamodel, an ontology for business continuity assessment, and a knowledge graph significantly enhances the effectiveness of a data-driven model for business continuity planning evaluation in an organization/company."

To clarify the "falsely visible" contradiction between hypotheses (H1) and (H2): there can be several reasons why, although BCP evaluation can be based on a robustness indicator (H2), some robustness indicators might not show a significant relationship with the implementation of a data-driven model for business continuity planning evaluation in a considered organization/company (H1). Here are a few possible explanations:

1. **Irrelevant or unmeasured factors:** There could be other variables or factors influencing the robustness indicators that are not considered in the study or not captured in the data. These undetected variables may overshadow or mask the relationship with the data-driven model.
2. **Insufficient sample size:** The sample size of the study might be too small, leading to limited statistical power. With a small sample, it becomes harder to detect significant relationships even if they exist.
3. **Methodological limitations:** The research methodology or design may have limitations that impact the ability to detect significant relationships. Issues such as measurement errors, sampling bias, or inadequate statistical techniques could contribute to non-significant findings.
4. **Implementation challenges:** The implementation of the data-driven model might face obstacles or limitations within the considered organization or company. Factors such as organizational resistance, resource constraints, or technical difficulties may hinder the effective



utilization of the model, resulting in a weaker or non-significant relationship with robustness indicators.

5. **Time lag or delayed effects:** It is possible that the impact of the data-driven model takes time to manifest or becomes evident in the robustness indicators. Short-term assessments may not capture the full extent of the relationship, and a longer follow-up period might be necessary.

These are just a few potential reasons why some robustness indicators may not exhibit a significant relationship with the implementation of a data-driven model for business continuity planning evaluation. The specific context, variables, and circumstances of the study can influence the outcomes and significance of the relationships observed.

Additionally, all the above hypotheses (H1, H2, and H3) propose a specific claim or assumption about the relationship between some factors or variables. The following examples will explain further these hypotheses.

### **Example 1: Public Hospital**

Let's consider conducting research on designing a data-driven model for business continuity planning evaluation in a public hospital. The robustness indicators could include the hospital's ability to maintain critical medical services during emergencies or disruptions, such as natural disasters or outbreaks.

Data on different components of the hospital's BCP, such as the presence of backup power systems, emergency response procedures, staff training programs, and the installation of telemedicine services, might be gathered to test the hypothesis. The performance of the hospital in previous emergency circumstances or by simulating possible scenarios might then be used to assess the robustness indicators.

The development of a general metamodel, an ontology, and a knowledge graph in the context of a public hospital may require creating a standardized framework that encapsulates the key elements of BCP particular to healthcare settings. This framework might incorporate connections between various BCP components, preset data models, and consistent nomenclature. The knowledge graph may show how these components are connected and dependent on one another, enabling a thorough evaluation of the hospital's BC capabilities.

### **Example 2: Urban Transportation Company**

Now, let's consider an urban transportation company, such as a city's public transportation authority. In this case, the robustness indicators could be related to the company's ability to maintain regular transportation services during unforeseen events, such as strikes, extreme weather conditions, or infrastructure failures.

To investigate the research hypothesis, one could collect data on the transportation company's BCP efforts, including the implementation of real-time monitoring systems, backup fleet management strategies, contingency plans for rerouting or adjusting schedules, and communication protocols with passengers during disruptions. By analyzing historical data on disruptions and evaluating the company's response, one can assess the relationship between the data-driven model for business continuity planning evaluation and the robustness indicators.

For an urban transportation company, creating a generic metamodel, an ontology, and a knowledge graph could involve designing a structured representation of key aspects of BCP, such as infrastructure assets, operational processes, stakeholder roles, and communication channels. The ontology would define the concepts and relationships, while the knowledge graph would enable the visualization and analysis of these interconnected elements. This comprehensive model would enhance the evaluation of BCP effectiveness in urban transportation operations.

In both examples, the research hypothesis aims to determine whether the implementation of a data-driven model for BCP evaluation has a significant impact on the robustness indicators of the organization. The hypothesis assumes that some robustness indicators might not be directly related to the data-driven model (H1) or there might be a significant relationship (H2) between these variables, and the research study would involve collecting relevant data and conducting statistical analysis to support or reject the hypothesis. Whereas the research hypothesis (H3) proposes that the integration of a generic metamodel, an ontology for business continuity assessment, and a knowledge graph enhances the data-driven model's effectiveness in evaluating BCP in public hospitals or urban transportation companies. The hypothesis can be tested by implementing the proposed model, comparing the results obtained from using the enhanced model with those from a traditional data-driven model, and assessing any significant improvements in the evaluation process.

To examine these hypotheses, this research focuses on two distinct organizational contexts: a public hospital and an urban transportation company. These contexts represent critical sectors where BCP is of utmost importance. By applying the proposed framework to these sectors, the research aims to investigate the relationship between the implementation of a data-driven model for BCP evaluation and the robustness indicators specific to public hospitals and urban transportation companies.

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## 5. Conclusion

In conclusion, Chapter II has provided an exploration of the research background in the field of Business Continuity Planning (BCP). Through a synthesis of existing works, this chapter has shed light on the main concepts, theories, and motivations that have guided previous research efforts. By identifying the main schools of thought and examining any controversies or debates within the field, a nuanced understanding of BCP has been achieved.

Furthermore, this chapter has critically evaluated the limitations, gaps, and contradictions present in the existing body of knowledge, thereby justifying the need for the present thesis. These identified gaps not only highlight the areas where further research is necessary but also serve as the basis for formulating research questions and hypotheses to be explored in subsequent chapters.

The conceptual framework presented in this chapter has established a foundation for investigating the research problem. This framework will guide the empirical research and facilitate a comprehensive analysis of BCP.

Finally, the research hypotheses synthesized in this chapter provide the direction for the empirical investigation. These hypotheses encapsulate the anticipated outcomes and relationships that will be examined, contributing to the advancement of knowledge in the field of BCP and providing practical insights for organizations seeking to enhance their resilience.

In summary, Chapter II has laid the groundwork for the empirical investigation conducted in subsequent chapters. Through the synthesis of existing works, identification of gaps, presentation of the conceptual framework, and formulation of research hypotheses, this chapter has provided a comprehensive understanding of the research background in BCP. By addressing the limitations of previous research and exploring new avenues of inquiry, this thesis aims to contribute to the existing knowledge and offer insights for both academia and practice in the field of Business Continuity Planning.

## CHAPTER III. DESIGNING THE RESEARCH METHODOLOGY

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“The tonal leads the way. You have to have a methodology.”

Frederick Lenz

This chapter serves as a comprehensive guide to the research methodology employed in this Ph.D. thesis, which aims to analyze the intricacies of Business Continuity Planning (BCP). The methodology adopted for this study provides a structured and systematic approach to investigate and understand the various aspects of BCP. By employing research methods, this chapter sets the foundation for depicting the methodology designed by this work.

The research methodology encompasses various elements that contribute to a comprehensive analysis of BCP practices. The first aspect addressed is the **sample and population** used in this study, ensuring that it represents the target population.

In order to gather data effectively, a **data-gathering model** is implemented, which provides a systematic roadmap for collecting and organizing relevant information. This model ensures that the data collected is coherent, consistent, and aligns with the research objectives.

The **sources of data and their significance** are thoroughly discussed to emphasize the importance of utilizing diverse and authoritative sources. This approach enables a comprehensive exploration of BCP by incorporating multiple perspectives and reliable information from various sources.

The chapter further examines **the data collection approaches** employed in this research. It distinguishes between physical (technical) data and societal data, acknowledging the multidimensional nature of BCP. By considering both the technical and societal aspects, a holistic understanding of BCP dynamics is achieved. Additionally, the model's double-hybridity is explored, which emphasizes the interconnectedness between technical and societal factors in the context of BCP.

An integral part of the research methodology is the **analysis and visualization of data**. This enables the extraction of meaningful insights and facilitates a clear representation of the research findings. Technical data analysis techniques are employed to interpret and comprehend the complexities of BCP from a technical standpoint. Similarly, societal data analysis techniques are utilized to understand the social and behavioral aspects that influence BCP effectiveness.

The evaluation of BCPs is a crucial component of the research methodology. The chapter introduces the BC Assessment Grid, which provides a structured framework for assessing the efficacy of BCPs. It examines the pillars of BCP, encompassing the key elements that contribute to a robust and resilient BCP strategy. Additionally, the factors influencing the robustness of BCPs are explored, leading to the development of a proposed evaluation grid.

To enhance the understanding and application of BCP, this research endeavors to develop a **Business Continuity Ontology** (BC ontology). The customized framework used for building the BC ontology is presented, emphasizing its role in structuring and organizing BCP

knowledge. The design and implementation of the BC ontological framework are discussed. It aims potentially at providing a structured representation of BCP practices to facilitate knowledge sharing in this specific field of study.

Furthermore, the chapter addresses the **ontology interoperability** achieved between WebProtégé and Obsidian. This interoperability allows for seamless integration between these tools, promoting collaboration and maximizing the utilization of the BC ontology.

The **creation of a knowledge base using the BC ontology** is also explored. The overview of the BC ontology emphasizes its role in organizing and structuring BCP knowledge.

Finally, this chapter acknowledges the **limitations of the research**, recognizing the boundaries and constraints within which the study operates. By highlighting these limitations, the research provides a perspective on the scope of possible generalizability of the findings.

In summary, this chapter outlines the comprehensive research methodology employed in this Ph.D. thesis, *encompassing sample selection, data gathering, analysis and visualization, evaluation of BCPs, development of a BC ontology, ontology interoperability, knowledge base creation, and acknowledging the research limitations*. These elements collectively contribute to an exploration of possible ways to assess Business Continuity within the scope of this work.

## 1. Sample and population

When conducting research, it is essential to carefully consider the sample and population involved. The sample refers to the specific group of individuals or objects that are selected for study, while the population represents the larger group from which the sample is drawn. In this context, let's discuss two use cases—one in Albi, Tarn, France, and one in Rome, Lazio, Italy (see Figure 5)—and explore the selection criteria and characteristics of the research participants, along with the justification for the choices made.

In this context, this research work's attention is directed towards examining and analyzing two geographical areas that possess significant sites relevant to Business Continuity Planning (BCP). These sites include a hospital and a public transportation network, both of which contribute in maintaining critical functions during times of disruption. These regions have been selected because they stand as exemplars of two different European countries, each contributing unique perspectives and experiences to the study of BCP. These two different case studies aim to gain insights into how BCP strategies are shaped by national characteristics and operational dynamics, providing a better understanding of effective resilience in various settings.

In general, the utilization of these two instances provides somehow a comprehension of the efficacy of BCP and BCM protocols in managing diverse disruptions. Irrespective of the nature of potential emergencies, the research conducted on these samples reveals the importance of BCP and BCM in risk management and reducing the consequences of disruptive incidents on an organization's operational continuity.



Figure 5. Location of the case studies

This study considers two distinct regions for Business Continuity Planning (BCP) – a hospital and a public transportation network. These regions represent Italy and France, with the Tarn department in France (population: approximately 400 000) as the first case and the Lazio region

in Italy (population: approximately 6 million) as the second. This approach provides insight into BCP strategies influenced by the specific characteristics of each sampled population.

This study uses two cases—the more populous Italian area of Lazio and the less populated French department of Tarn—to highlight BCP techniques that combine qualitative and quantitative factors. When there are disturbances, Tarn's small community encourages quick communication, whereas Lazio's greater population increases logistical complexity and necessitates strong responsiveness. In terms of quality, Tarn benefits from strong community ties and increased resilience, whereas diverse Lazio requires flexible BCP to meet a range of requirements. Resource variations are quantitatively influenced by population size: Tarn's controllable scale facilitates distribution, but Lazio's size requires supplier collaboration and thorough inventory management.

The following sections, specifically sections 2, 3, and 4, will go into detail about the model that has been gathering the data resulting from these samples of populations, as well as how precisely these data were collected, throughout different approaches, and used to conduct the indicators that assess the BCP of the two use-cases.

## 2. The data-gathering model

Our first milestone, based on the preceding subsections, involves evaluating the Business Continuity strategy. This evaluation is accomplished by creating a data model that categorizes the data and considers its types, domains, and sources within the organization. The model also integrates with the logical progression of data interpretation. It provides comprehensive outcomes for every data cluster, meticulously navigating through distinct phases, including the initial raw data stage, followed by the aggregation of data, subsequent information extraction, knowledge synthesis, and ultimately culminating in informed decision-making as within the DIKW pyramid (Frické, 2009). This systematic alignment complements the process, enabling an analysis of data at each stage while facilitating the extraction of important insights and actionable knowledge.

The proposed model in this research integrates key points for assessing Business Continuity with the relevant datastore available in an organization. Additionally, it follows a standardized flow for interpreting the three-dimensional data (refer to Figure 6). Within this model, data possess three attributes: type, source, and significance within the Business Continuity Plan (BCP). These attributes are essential for the interpretation process that leads to decision-making. Anticipating individual and group behavior in hazardous situations is indeed crucial.

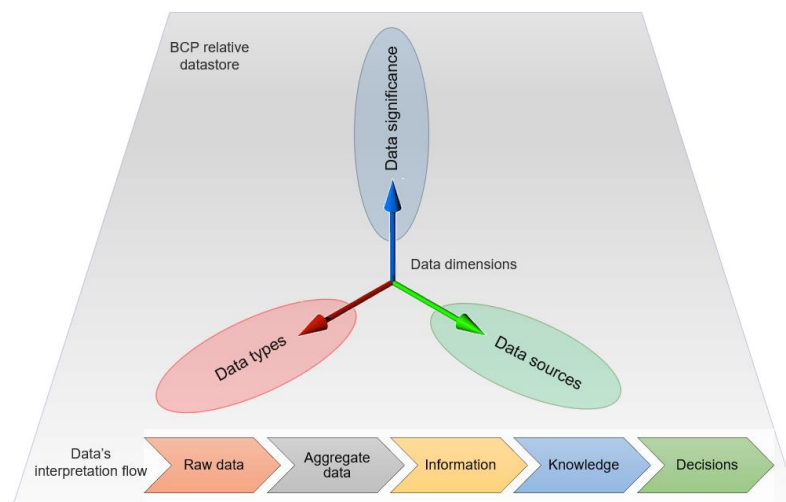


Figure 6. Our model's dimensions and perspectives

By processing data categories and sources in a segregated manner, it becomes possible to anticipate behaviours and make informed decisions, thereby mitigating potential harm. Furthermore, a BCP must guarantee the preservation and protection of essential activities within the organization. With this in mind, the model described in this study gathers and interprets relevant data to specifically evaluate the comprehensiveness of the BCP.

In this section, the data model was introduced. This model, which progresses logically from raw data to informed decisions, categorizes data based on types, domains, and sources. Its significance lies in evaluating BCP strategies. The following Section 3 will explore further this model's dimensions, providing explanation of its fundamental attributes and architecture. This exploration will be integral to assessing the comprehensiveness of the BCP.



### 3. The data sources and significance

The key highlight of this proposal lies in its capability to consider and integrate diverse types of data, including societal data, financial data, and physical data from sensors and IoT devices. By harnessing these data sources, a comprehensive analysis of the organization's environment can be constructed. This methodology aims at providing a holistic and multidimensional evaluation of the BCP.

The 3-dimensional model (Figure 6) incorporates various data sources as illustrated in Figure 7. The data is organized into distinct categories, and within each category, different origins can exist under a common type. For instance, physical data may originate from diverse sources such as analog or digital sensors, Hall-effect sensors, wireless devices, or geolocation modules.

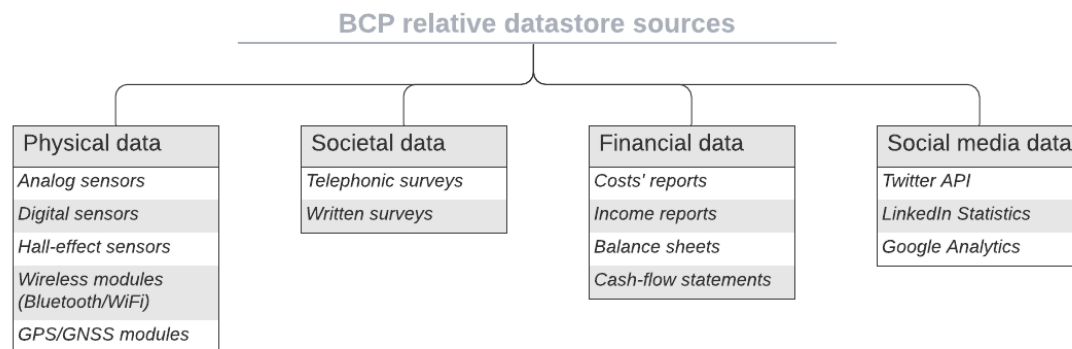


Figure 7. The model's data sources

Building on the framework established in the previous section, where a **comprehensive data model** was introduced to facilitate the evaluation of Business BCP strategies, we now expose the data sources and their significance (Figure 7). Each source representing distinct categories of data, such as technical, societal, and organizational, with their unique types and implications that collectively contribute to assessing the robustness of BCP. For example, in the physical data category, data can be categorized as either analog or digital, reflecting the technical characteristics of the environment. Meanwhile, societal data captures diverse elements like fear, influenced by alarmist information evaluated through social networks, rumors, and the tendency to replicate others' behavior (Ferrara & Yang, 2015).

Namely, organizations differ in their existing distress levels, which can be indicated by factors such as absenteeism, burnout, and increased turnover. This variation is especially evident in certain settings like hospitals, where healthcare workers experience higher levels of workplace stress and are more familiar with employing workarounds (Nobre, 2020). In fact, social studies speak of "managerial domination" in place of medical dominance. For them, managers are imposing transformations on hospitals, turning them into "hospital-companies" (Mas et al., 2011; Velut, 2020) or "care factories" (Velut, 2020) and adapting them to the imperatives of neoliberal bureaucracy. Hospitals are presented as being on the brink of bankruptcy, with pressurized hospital staff subjected to an exhausting organization whose aim is efficiency (Morel, 2019).

Furthermore, assessing the collective intensity of fear involves the collection of phrases that encourage individuals to take time off work, limit their movements, seek refuge in rural areas, and procure essential supplies. By connecting these data sources and their implications, we continue to pave the way for a comprehensive understanding of the multifaceted dimensions of BCP.

## 4. Data collection approaches

Various approaches and methods are employed to collect data, including interviews, questionnaires, observations, and more (Combessie, 2007). In this introduction, we will present an overview of the different data collection approaches, providing a description of the tools and procedures commonly used in each method.

To implement a beta (first) version of our model (Figure 7), we focused on incorporating physical and societal data. These data types are often crucial in formulating business continuity strategies, as the guidelines provided by regulations (*ISO 22301:2019(En), Security and Resilience — Business Continuity Management Systems — Requirements*, 2019; *ISO 22313:2020(En), Security and Resilience — Business Continuity Management Systems — Guidance on the Use of ISO 22301*, 2020, p. 2020) primarily revolve around them. Furthermore, the inclusion of other data clusters, such as financial and social media data, will be addressed in subsequent steps of the research project, once the initial phases are completed. These data collection approaches are explained in the next subsections.

This implementation took place within the pediatric ward of a public healthcare organization in a mid-sized city in southwestern France, with an approximate population of 80,000 inhabitants (including the metropolitan area). During the initial wave of the COVID-19 pandemic, non-Covid-19 patients faced limited access to healthcare services (Negrini et al., 2020). This was specifically observed in our use case in France, prompting the need for conducting this survey. In a pandemic crisis, hospitals are confronted with a "crisis within a crisis" situation. It becomes essential to understand the reasons behind the absence of hospital personnel and patients' renunciation of care. The business continuity plan must consider individual and group human factors, including the causes of absence and collective perceptions of threat and risk (such as fear of viral exposure and the impact of rumors). Sociological investigations, such as surveys among patients and employees, enable the identification of the profiles most affected by these factors, considering variables such as age, education level, proximity to the hospital, and occupation type. This forms a "causal approach" which is the approach that seeks to identify the influence of variables characterizing the members of a population, developed by (Durkheim, 2023).

### 4.1. The physical (technical) data

The approach for collecting physical data followed a *top-down approach*, involving the following steps: **(a) Formalizing the data collection requirements**—defining what data needs to be gathered. **(b) Categorizing the data into specific groups**—organizing data based on shared characteristics. **(c) Implementing a sensor-based solution**—employing sensors to capture relevant data. **(d) Proposing data utilization methods**—suggesting ways to use collected data, such as backups and real-time display through "Dashboard" gauges. **(e) Finalizing the generic model**—creating a comprehensive framework for data collection. **(f) Studying the organization's technical data needs**—understanding the specific data requirements of the organization. **(g) Extracting a sub-model and sub-features**—deriving a more focused subset of the comprehensive model. **(h) Completing the development of the customized model**—crafting a tailored data collection model aligned with the organization's distinct requirements.

## 4.2. The societal data

For the gathering of societal data, a *bottom-up approach* was adopted, encompassing the following steps: **(a) Initiation of the investigation**—commencing the inquiry into societal aspects. **(b) Obtaining final approval from the organization**—securing the organization's official endorsement for data collection. **(c) Declaration to the CNIL** (Commission Nationale de l'Informatique et des Libertés)—formally notifying the data protection authority. **(d) Updating the survey**—making necessary refinements to the survey instrument. **(e) Discussing and making modifications**—reviewing and implementing alterations based on discussions. **(f) Developing the survey**—creating a comprehensive questionnaire. **(g) Confirming its relevance with the concerned organization**—validating the survey's pertinence with the relevant organization. **(h) Defining the sociological survey methodology**—establishing the approach for conducting the sociological survey within the research context.

## 4.3. The model's double-hybridity

The model proposed in this research work, as depicted in Figure 8, exhibits a dual hybridity. This hybridity is reflected in two aspects: the nature of the data and the approaches used for data collection. It enables data collection and processing while accommodating two distinct types of data. Notably, this model is designed to operate without considering financial and social media data sources due to specific considerations detailed earlier in section 4.

Firstly, the model embraces the hybrid nature of the data it operates with. It recognizes and accommodates two distinct types of data, each offering nuanced insights crucial for the comprehensive evaluation of BC. This approach accounts for the diverse array of data sources relevant to BCP evaluation, thus ensuring the model's capacity to capture and leverage information from both data types (Mikalef et al., 2019).

Secondly, the model adopts hybrid approaches for data collection. It leverages a combination of methods to gather the necessary data. By integrating established techniques with emerging data collection methods, the model maximizes the data resulting issued from the collection process. This hybrid approach allows for flexibility and adaptability in data collection, ensuring that the model can keep pace with evolving practices and technologies. For instance, this model leverages traditional surveys and questionnaires (through confirmed techniques) in conjunction with real-time data streams from sensors (emerging data collection methods). This hybridized approach allows for the collection of subjective human responses alongside objective environmental data, providing a richer and more holistic perspective on the subject under study (P. Zhao et al., 2019).

Finally, the double-hybridity of the proposed model (see Figure 8) positions it as a versatile framework for BCP evaluation. In fact, it can incorporate new techniques as they emerge, ensuring that the data it gathers remains relevant and reflective of the purpose of study. This hybridized approach also enhances the model's capacity to tackle complex and multifaceted challenges by complementing information through multi-sourcing and multidimensional data.

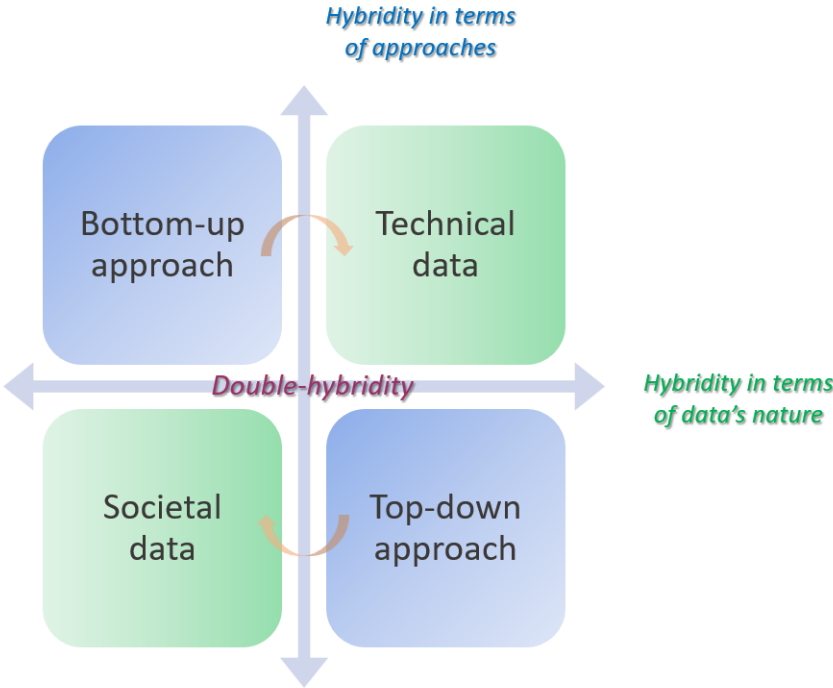


Figure 8. The model's double-hybridity

## 5. Data analysis & visualization

In order to evaluate the suggested method and make it a Proof of Concept (POC), a hardware architecture and implementation have been discussed for processing the technical data using the steps outlined in the preceding section, as per the healthcare organization's specifications. Additionally, a telephonic survey was conducted with parents of patients in the pediatric ward of the same organization to collect societal data. The subsequent subsections provide an explanation of the preliminary results derived from this case study and the progress made in processing each type of data.

### 5.1. Technical Data:

To address the technical data, the generic sensor-based solution was discussed following the steps outlined previously in section 4.1. The data model for this generic architecture is depicted in Figure 9. However, the customization process is being held and guided by the findings of the need's assessment conducted within the specific use-case organization.

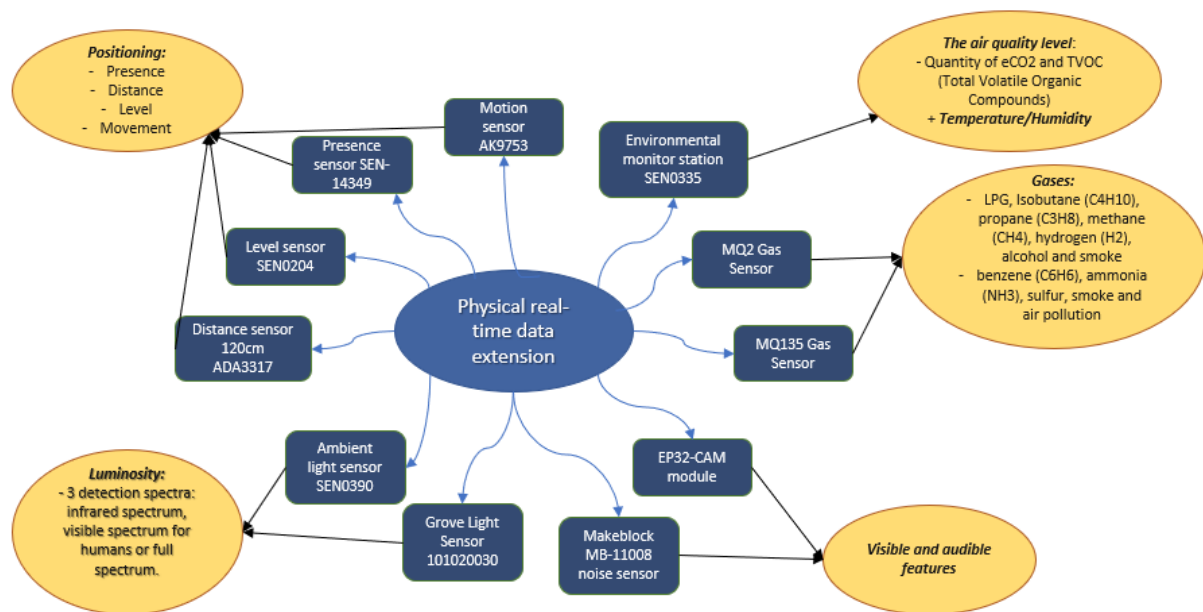


Figure 9. The physical data model

Within this hardware architecture, comprehensive collection of the crucial types of technical-environmental data is carried out. These data are categorized into four main groups, as elaborated below:

- **Positioning:** The technical data related to positioning includes information about presence, distance, level, and movement within the environment.
- **Air quality level:** The technical data pertaining to air quality consists of measurements for eCO<sub>2</sub> (equivalent carbon dioxide) and TVOC (total volatile organic compounds) quantities.
- **Gases:** The technical data regarding liquefied petroleum gas encompasses measurements for various gases such as isobutane (C<sub>4</sub>H<sub>10</sub>), propane (C<sub>3</sub>H<sub>8</sub>), methane (CH<sub>4</sub>), hydrogen, and others.

- **Visible & audible features:** The technical data related to visible and audible features comprises images and noise measurements.
- **Luminosity:** The technical data concerning luminosity includes measurements for infrared, human-visible, and full spectrums of light.

In fact, the hardware architecture was customized later on through an exchange-review process with the use case organization. This  $\beta$ -version implementation encompasses a comprehensive model that encompasses all possible and significant flows of technical-environmental data.

These indicators serve multiple purposes: (a) describing the technical environment of the organization, (b) assessing potential risks that may lead to disruptions in vital activities, and consequently, (c) evaluating the business continuity plan (BCP).

## 5.2. Societal Data:

Relying solely on technical data is insufficient for gaining a comprehensive understanding of the complex organizational environment. Consequently, additional data known as societal data is incorporated. The primary focus of investigation in this survey was to identify the reasons why parents are not adhering to scheduled hospital visits for their children. Specifically, a telephonic survey was conducted within the pediatric department of the specified use case. The survey consisted of approximately 44 questions and received responses from roughly 673 parents whose children were undergoing treatment in this department.

Hence, the responses provided by parents were recorded using LimeSurvey, a software for statistical survey and polling, and subsequently processed following the methodology illustrated in Figure 10.

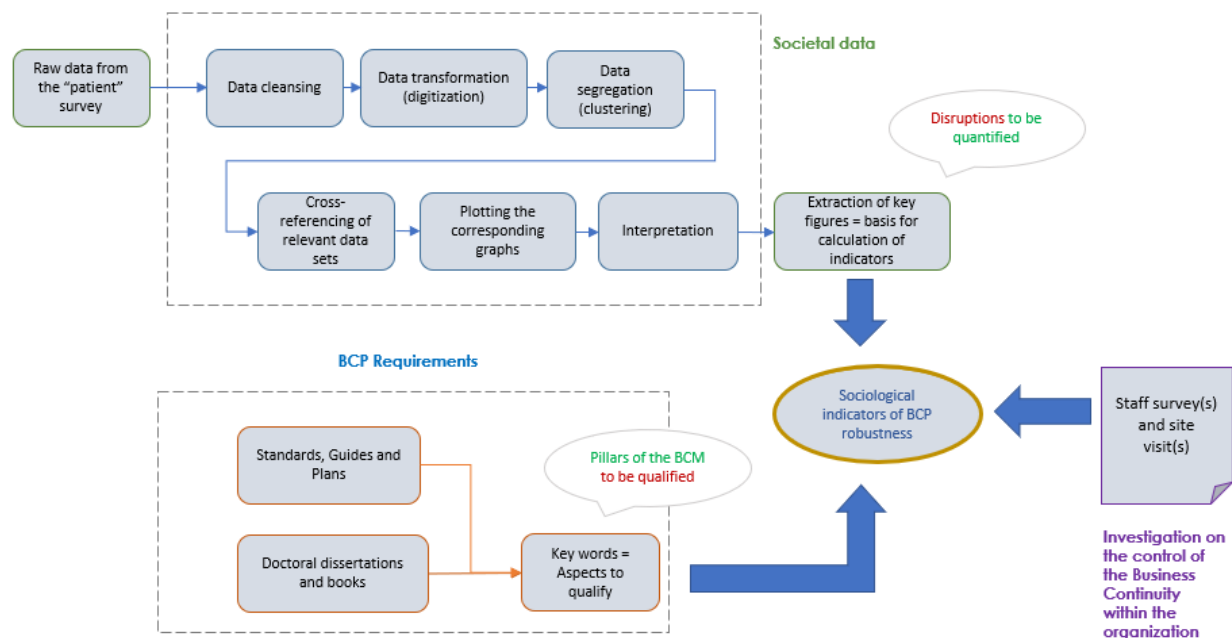


Figure 10. A full overview of the survey's data handling methodology

The objective of this conducted survey was to extract essential information from the parents' responses, which would be utilized in calculating sociological indicators for assessing the resilience of the business continuity plan (BCP). This in-house methodology, as in (Ben Amara et al., 2022), employed for processing the societal data primarily involves:

- **Data clustering:** Considering that patients displayed hesitancy in seeking healthcare during the semi-lockdown period due to concerns over contracting COVID-19, preservation of healthcare resources, and unawareness of the availability of health services (Lazzerini et al., 2020; Magutshwa & Radianti, 2022), the collected data is categorized into various groups. These categories include comparisons between the first French lockdown in 2020 and the corresponding period in 2019, reasons and causes for absence related to fear of the pandemic, socio-professional status (educational level and occupation, such as manager, employee, etc.), economic situation (monthly income, employment status such as suspended or unemployed, etc.), professional situation during the first lockdown, and the parents' place of residence.
- **Illustrative graphical representations:** After segregating the societal data, the pertinent digitized responses were employed to generate informative graphs, including the example depicted in Figure 11. One instance of such data visualization involves presenting the distribution of appointments during the initial lockdown period, along with the parents' refusal based on their employment status. The **Appendices** section provides some of these graphical representations that were performed using the surveys questions and relative answers (44 in total).

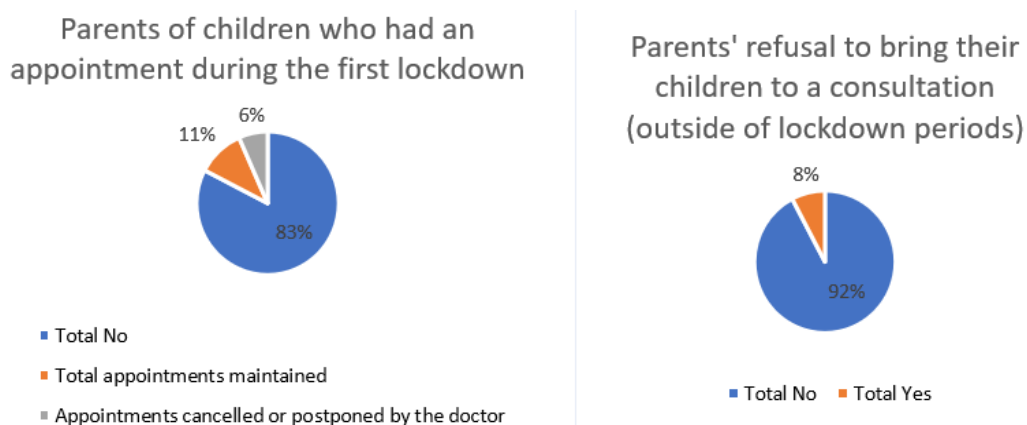


Figure 11. The distribution of appointments during the first lockdown, the parents' refusal and their employability status

- **Key figures extractions:** By analyzing multiple graphs and conducting data processing, important metrics were identified and incorporated into a dashboard called "Societal Performance Indicators (SPI)." The beta version SPI dashboard is illustrated in Figure 12, which highlights the significance of the graphs in obtaining key indicators such as Np<sub>ttA</sub> and Np<sub>ssA</sub>.



Outside the periods of lockdown				During the periods of lockdown							
Np = 673	Nmch1 = 790	Nmch2 = 857	NpjrC = 473	Np = 673	NRdvpC = 116	NRdvA = 44	NRdvR = 51	NRdvM = 72	Npssp = 613	Npipp = 41	NRdvRpC = 7
			NpjrCmax = 128				Nppta = 11	Npssa = 13			
			NpjrCmin = 1								
			Home address: 81000								
			81000								
			PtpjrCmax = 94,32%								
			PtpjrCmin = 91,59%								
			Age range: 18-29								
			Age range: 30-39								

**Appendix:**

Np= Number of parents surveyed.

NRdvpC= Number of parents who had an appointment during the first lockdown

NRdvA= Number of cancelled/rescheduled appointments by hospital physician

NRdvR = Number of appointments that parents declined to bring their child to

NRdvM= Number of appointments kept by the hospital

Npssp= Number of parents satisfied with the hospital's pediatric service during the first lockdown

Npipp= Number of parents whose child's health was impacted due to difficulties accessing care during the lockdown

Nmch1= Minimum number of visits to the hospital's pediatric service in 2019-2020

Nmch2= Minimum number of visits to the hospital's pediatric service between 04/2021 and 04/2020

NRdvRpC= Number of appointments that parents declined to bring their child to due to fear of becoming infected with COVID-19

Nppta= Number of telecommuting parents who missed their child's appointment

Npssa= Number of on-site parents who missed their child's appointment

NpjrC= Number of parents who never gave up taking their child to a consultation, test or hospitalization outside of lockdown periods

PtpjrC= Percentage by age group of parents who never gave up taking their child to a consultation, examination or hospitalization outside of lockdown periods

Figure 12. An extract of the SPI dashboard and its appendix

- β-version indicators calculus:*** Using the aforementioned key figures, several ratios were computed. These ratios primarily assess the following: the rate of appointment cancellations during the initial lockdown, the dropout rates of parents for their children's appointments, parental satisfaction with the paediatric ward, and the rate of appointment non-attendance due to COVID-19 fears. All ratios fall within the range of 0 to 1 and can be calculated using the key figures presented in Figure 9. These indicators serve as global representations of (a) patient satisfaction, (b) the frequency of disruptions (dropout rates, health implications, missed appointments, etc.), and (c) their impact. As these factors are crucial parameters for evaluating Business Continuity Planning (BCP) (*ISO 22301:2019(En), Security and Resilience — Business Continuity Management Systems — Requirements*, 2019; *ISO 22313:2020(En), Security and Resilience — Business Continuity Management Systems — Guidance on the Use of ISO 22301*, 2020, p. 301), the provided indicators enable BCP assessment. The results of this use case study will be explicated in chapter 4 of this thesis, as this subsection concerns only the methodology conceived and applied.
- Complementary investigations:*** Moreover, the research work for evaluating the BCP should take into consideration the pre-existent basis of the BC strategy established within the organization. In fact, before developing a BCP, these needs should be met: (a) assigning a "Business Continuity" manager who is responsible for developing, maintaining and testing the organization's BCM program, (b) identifying business continuity needs, (c) assessing the potential number of employees present at their place of work during a crisis, according to three alternative scenarios, (d) evaluating the nature and volume of the necessary protective means to be made available for the staff, (e) knowing the conditions of supply in a degraded mode and (f) maintaining particularly sensitive services known as vital activities (Breton-Kueny & Segovia-Kueny, 2008). In addition to these measures, there is the constraint of the provision of specialized and dedicated staff within the establishment to take care of children as regulated in (*Enjeux et spécificités de la prise en charge des enfants et des adolescents en établissement de santé*, 2011).

## 6. The BC assessment grid

The following BC assessment grid methodology and details mentioned in this subsection are included in (Ben Amara et al., 2023).

Although multi-criteria performance evaluation is a field of research in its own right, in this section we take a simple, even simplistic view of it which, even if a fuller consideration of the contributions of this field would be an added value, does not compromise the proposals and results of this work.

Typically, business continuity is specific to each organization, but its implementation can have broader implications affecting the wider community and third parties. An organization may rely on external entities, just as other external organizations may rely on it in return. Hence, the efficacy of business continuity measures enhances the overall resilience of society (*ISO 22301:2019(En), Security and Resilience — Business Continuity Management Systems — Requirements*, 2019). A BCP should be practical and applicable in real-world scenarios, not just theoretical. The objective for an organization should be to handle all challenges in a controlled and systematic way without needing to refer to the business continuity guidelines, which ought to be comprehended and internalized (Lindström et al., 2010).

Organizations can develop an excessive reliance on predefined checklists provided in existing standards (Bozkus Kahyaoglu & Caliyurt, 2018; Hainmueller et al., 2019; Lindström et al., 2010). To enhance its usefulness, a business continuity plan (BCP) should be seen as a versatile support tool capable of addressing various types of crises and disruptions, rather than merely serving as a guide for predetermined scenarios (although checklists for specific situations can still be prepared). It is crucial to create and regularly update these checklists for predefined circumstances during the business continuity planning phase (the nominal phase) and subsequent maintenance processes. In addition to risk mitigation and uncertainty reduction, managers should also cultivate strategic thinking skills in high-risk contexts, as it is arguably equally important (Bazerman & Moore, 2009).

To effectively maintain the checklists within the BCP, it is important to identify the fundamental pillars of the plan. This enables the determination of specific aspects to measure, allowing for the use of designed indicators to assess these aspects. For instance, (Øien, 2001) demonstrates an alternative approach to safety assessment, moving away from time-consuming safety audit techniques and instead focusing on safety indicators, especially those that evaluate remote organizational factors. The utilization of indicators simplifies the need for a swift evaluation while providing quantitative statements about the status of the organizational factors. The indicator values are derived from registrations of observable variables conducted over a predefined period. These values are then transformed into a "state" for each organizational factor. Therefore, there is no reliance on time-consuming techniques like interviews or surveys, only on observations and registrations. The validity of the selected indicators, both individually and in terms of complete coverage, is, nevertheless, given important weight in this.

Applying a similar rationale to this research, the concept of "**rating**" or "**qualifying**" the business continuity factors involves **assessing the quality or effectiveness of these factors**. It serves as a measure of the current "state" of a specific factor. **The process of allocating**

**weights to various organizational components necessitates a thorough assessment of their direct and indirect effects on the BCP's effectiveness.**

According to (*ISO 22301:2019(En), Security and Resilience — Business Continuity Management Systems — Requirements, 2019*), a standard on Business Continuity Management Systems, a resilient society is closely linked to a strong business continuity approach. Subsequently, this section will present and elucidate the "factors" or "pillars" that this study considers essential for the BCP and its robustness. In the subsequent sections, the focus will shift to the indicators and the utilization of an evaluation tool. These aspects will be demonstrated based on the proposed evaluation grid and the factors incorporated in its design, definition, and calculation of the indicators that determine the robustness.

In this section, we will provide an explanation of our proposed assessment grid for evaluating robustness. The design of this grid considered two key factors: (a) the pillars of a BCP, encompassing its crucial components and structures, and (b) the dependencies of BCP robustness, determining the factors on which the resilience of these plans is contingent.

### 6.1. The pillars of BCP

Figure 13 below shows the main four pillars of a BCP that we are considering in this research work and that are inspired from the ISO 22301:2019 (*ISO 22301:2019(En), Security and Resilience — Business Continuity Management Systems — Requirements, 2019*). The four mentioned pillars are explained in details in the next paragraphs.



Figure 13. BCP main pillars (*by interpretation of the ISO 22301:2019*)

#### 1. Commitment

The level of commitment within an organization, regardless of its nature and role, can be demonstrated through the following actions:

- Staff training: Providing guidance and support to individuals, enabling them to contribute effectively to the Business Continuity Management System (BCMS). This includes promoting continuous improvement and assisting other managers in demonstrating leadership and commitment within their respective areas of responsibility.

- Informative meetings: Ensuring that BCMS requirements are seamlessly integrated into the organization's business processes. This involves making sure that the necessary resources for the BCMS are available and communicating the importance of business continuity and compliance with BCMS requirements.
- Staff awareness: Guiding and raising awareness among staff members about the significance of business continuity and its implications.

These actions collectively demonstrate the organization's commitment by actively involving resources, promoting continuous improvement, integrating BCMS requirements, and ensuring staff awareness of business continuity matters.

## **2. Policy**

A policy serves as the guiding framework for an organization's conduct and actions. It can be established through the following means:

- Certifications: Inclusion and certification of a commitment and expertise to meet relevant requirements. This demonstrates the organization's dedication to adhering to recognized standards.
- Control of standards: Ensuring the maintenance of certification levels and frequencies, while providing a framework for establishing business continuity objectives. This helps in consistently meeting the required standards and continuously improving business continuity practices.
- Hierarchy and assigned responsibilities (department/team and manager): Clearly defining the responsibilities and authorities within the organization, including identifying individuals or teams responsible for ensuring compliance with the BCMS requirements specified in the policy. It also designates individuals responsible for reporting BCMS performance to the executive desk.
- Control of recurring or non-recurring disruptions: Demonstrating a commitment to continuously improving the Business Continuity Management System (BCMS) to manage future disruptions. This involves estimating the frequency and potential impact of various risks, such as workforce absenteeism, and taking proactive measures to mitigate those risks.

By incorporating certifications, maintaining standards, defining responsibilities, and addressing recurring or non-recurring disruptions, an organization establishes a comprehensive policy that promotes continuous improvement and effective management of business continuity.

## **3. Support**

BC support is a proactive business process that aims to identify potential threats, vulnerabilities, and weaknesses within an organization. This support can be verified and strengthened through the following measures:

- Documentation of a Business Continuity Plan (BCP): The organization's Business Continuity Management System (BCMS) should include the necessary documented information as specified by the BCP. Additionally, the organization should identify

and document any additional information deemed essential for the effective functioning of the BCMS.

- Integration of the BCP into the organization's Information System (IS): The documented information required by the BCMS must be controlled to ensure the following: (i) seamless integration into the IS, making it readily available and suitable for use when and where needed, (ii) adequate protection against breaches of confidentiality, inappropriate use, or loss of integrity, and (iii) proper data storage and preservation, including measures such as maintaining readability, controlling version changes, and managing information retention and disposal.

By documenting the BCP and integrating it into the organization's Information System, the business continuity support process can be verified and strengthened, allowing for proactive identification of threats and vulnerabilities while ensuring the availability, protection, and preservation of critical information.

#### 4. Operation

The operational functioning of an organization refers to its routine activities aimed at creating value. This operational efficiency can be improved through the following measures:

- Fallback site: Establishing a designated alternative site that can be utilized in the event of a significant risk that poses a potential disruption to the organization's primary activities.
- Utilizing telecommuting, subcontracting, or mutual aid agreements: Employing alternative work arrangements, such as remote work options, subcontracting services, or mutual aid agreements with other organizations. These measures provide additional avenues for continuing operations in case of workplace difficulties or challenging conditions.
- Procurement of specialized equipment for disaster scenarios: Acquiring specific equipment designed to address various major risks, such as equipment for handling fires, attacks, floods, and other significant hazards.

By implementing a fallback site, exploring alternative work arrangements, and acquiring appropriate disaster-specific equipment, organizations can enhance their operational resilience, ensuring the continuity of value creation even in the face of potential disruptions.

## 6.2. Factors of the robustness of BCPs

To establish the dependencies and indicators for a Business Continuity Plan (BCP), it is necessary to first define the concept of robustness within this context. Additionally, it is important to differentiate between robustness and resilience to avoid any potential confusion. While the definitions of robustness and resilience vary across different domains, it is notable that they share significant similarities. In the case of robustness, many research works refer to an "initial state" and emphasize that **robustness is characterized by the ability to withstand disturbances without significant modifications or disruptions to its core functionalities.** On the other hand, **resilience is commonly defined as the system's capacity to adapt to a disturbance and eventually return to its initial state.** This process of adaptation is often described in two phases: the undergone reaction to the disturbance and the subsequent response

that leads to a restoration of the initial state. By clarifying the distinction between robustness and resilience, we can establish a solid foundation for defining the dependencies and indicators necessary for a comprehensive BCP robustness assessment. This ensures an understanding of the system's ability to withstand disruptions (**robustness**) while also highlighting its capacity to adapt and recover (**resilience**) (Clément et al., 2018; Gilbert, 2013; Ibanez et al., 2016; Wybo, 2008).

In the same context, it's important to define also the vulnerability in order to differentiate from the robustness. In fact, the definition of vulnerability should be specific and aligned with its context, as it has the potential to affect the strength and adaptability of an organization. **Vulnerability is commonly characterized as an inherent state separate from the hazardous events that may lead to certain consequences** (Webb, 1993).

Last but not least, it's necessary to clarify what is meant by damage or loss since all these three definitions (robustness, resilience and vulnerability refer directly or indirectly to these terms. The literature lacks clarity regarding the definition of loss or damage and the significance of who experiences these losses or damages. However, the field of disaster management classifies vulnerability into two distinct categories: (a) prevention of disasters and (b) response to disasters (Siegel & Jorgensen, 2001).

Lastly, the definition that we would adopt in our situation is as follows: **“Robustness refers to the organization's capacity to withstand and effectively manage the emergence of new organizational disruptions or crises, ensuring the continuity of its crucial or 'vital' operations in the face of disruptions of various types”** (Wybo, 2008).

Therefore, three types of robustness are distinguished as mentioned by Chapter I.1.1.2 :

1. “Absolute” robustness: total invariance to disturbances.
2. “Tolerated” robustness: variance within a robustness zone.
3. “Mastered” or “controlled” robustness: "Mastered" secondary functions are derived from the main invariant function (Clément, 2019).

This research work is positioned within the realm of the second form of robustness, as the indicators formulated in this work assess the organization's ability to handle a "tolerated" disturbance and sustain its critical activities accordingly.

Through the interpretation of the ISO 22313:2020 (ISO 22313:2020(En), Security and Resilience — Business Continuity Management Systems — Guidance on the Use of ISO 22301, 2020), and as shown by Figure 14 below, the robustness of a BCP is impacted by:

1. **The physical arrangement of the organization** that includes its premises, such as different offices, production units, administrative offices, and storage facilities.
2. **Satisfaction of customers and staff** which refers to the effect of the organization's services on meeting the needs and expectations of both customers and staff members.
3. **Internal management of staff and skilled workers** that encompasses the deployed management strategies, communication methods with the staff, evaluation processes, assignment of tasks, conflict resolution, and more.

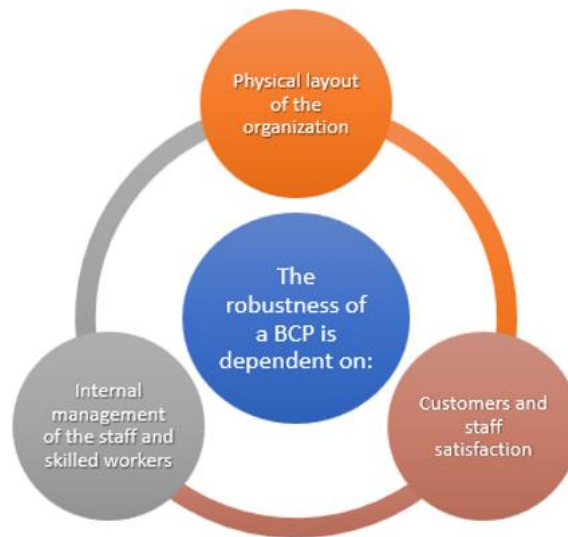


Figure 14. BCP's robustness dependencies

### 6.3. The proposed evaluation grid

Based on 6 and 6.2, a grid for assessing the robustness of BCP has been created, providing flexibility in incorporating robustness indicators. This grid comprises three distribution layers that illustrate the interdependencies of a BCP's robustness and four axes for enhancing BCP's key pillars: operations, policies, support, and commitment. In total, there are twelve placing patches available within the grid to accommodate BC robustness indicators. Figure 15. below illustrates the evaluation grid and its components.

This assessment grid for BCP robustness is proposed, and it is tested using sociological indicators in Chapter IV. of this thesis. While one case study accompanying sociological data were used to evaluate the idea, other types of data may also be employed, leading to the development of additional robustness indicators. The placement of indicators on this grid results from identifying both the considered layers and the improvement axes.

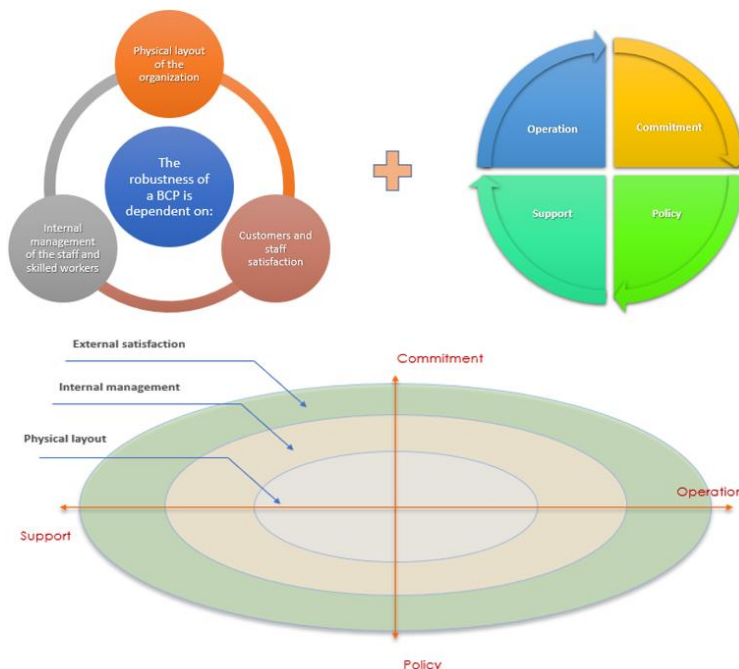


Figure 15. The BCP robustness evaluation grid

## 7. Development of a Business Continuity Ontology

In order to evaluate the effectiveness of BCP, organizations often rely on data-driven models that assess various aspects of preparedness and response. However, as the complexity of modern organizations is growing, there is a need for more advanced approaches that go beyond conventional data analysis techniques. This section focuses on exploring the potential benefits of integrating an ontology for business continuity assessment, and a knowledge graph within the context of evaluating BCP in public hospitals and urban transportation companies.

The integration of a generic metamodel, an ontology, and a knowledge graph aims to enhance the evaluation process by providing a structured framework and interconnected representation of the essential elements of business continuity planning. A metamodel serves as a standardized template capturing the core components and relationships within a specific domain, while an ontology defines the concepts and relationships in a more formal and semantically rich manner. Complementing these elements, a knowledge graph enables the visualization and analysis of the interconnected elements, facilitating a holistic assessment of an organization's business continuity preparedness. Thus, this section includes the following: **(i) the framework from which this BC ontology was inspired, (ii) the design process of this BC ontology, (iii) how this design was implemented, and (iv) an ontology-supported methodology: an applied methodology that was based on and supported by this ontology.**

In the case of public hospitals, where the uninterrupted delivery of critical medical services is of utmost importance, evaluating business continuity planning becomes crucial. By creating a generic metamodel, an ontology, and a knowledge graph tailored to the healthcare setting, the assessment process can be standardized, enabling a comprehensive evaluation of the hospital's resilience during emergencies or disruptions.

Similarly, in the context of urban transportation companies, evaluating the effectiveness of business continuity planning is essential for maintaining regular transportation services, especially in the face of unexpected events. The creation of a generic metamodel, an ontology, and a knowledge graph specific to urban transportation operations allows for a structured representation of critical infrastructure assets, operational processes, stakeholder roles, and communication channels, facilitating an in-depth assessment of the company's preparedness and response capabilities.

Thus, this subsection explores the proposal that integrating a generic metamodel, an ontology for business continuity assessment, and a knowledge graph enhances the effectiveness of data-driven models for evaluating BCP in public hospitals and urban transportation companies. By providing a structured framework and interconnected representation, this approach has the potential to improve the assessment process, ultimately contributing to the resilience and continuity of critical services provided by these organizations.

In this context, the next subsections aim to explain the framework that was utilized in order to build the BC ontology, its design, its implementation, and finally its use in this research work methodology. However, the section 9 of this chapter rather investigates the BC knowledge base creation and exploration.



### 7.1. The customized framework for building the BC ontology

To build the BC ontology the research work defined by (Hevner et al., 2004) is mainly used to model the business continuity playground. This framework considers organizational strategies, structure, culture, and established business processes to evaluate business requirements. Additionally, it factors in the current technological infrastructure, applications, communication systems, and development capacities. The aim is to provide a comprehensive understanding of the business need or "issue." By framing research activities to address these business needs, the research is made more relevant and impactful (Hevner et al., 2004).

Given such a clear and consistent business needs, the IS research by (Hevner et al., 2004) is conducted in two stages. As shown in Figure 16 below, this research starts by developing and justifying theories (**foundations** and **methodologies**) that explain or predict phenomena associated with specific applicable knowledge. Later on, the research tackles assessing artifacts aimed at meeting a specific **business need**. These business needs usually result from an appropriate **environment** that serves the **application case** and comprises **human roles, organizations** and involved **technologies**. Overall, the goal of behavioral science research is to discover the reality of the situation since theory is briefed by truth, and design is informed by utility (Hevner et al., 2004).

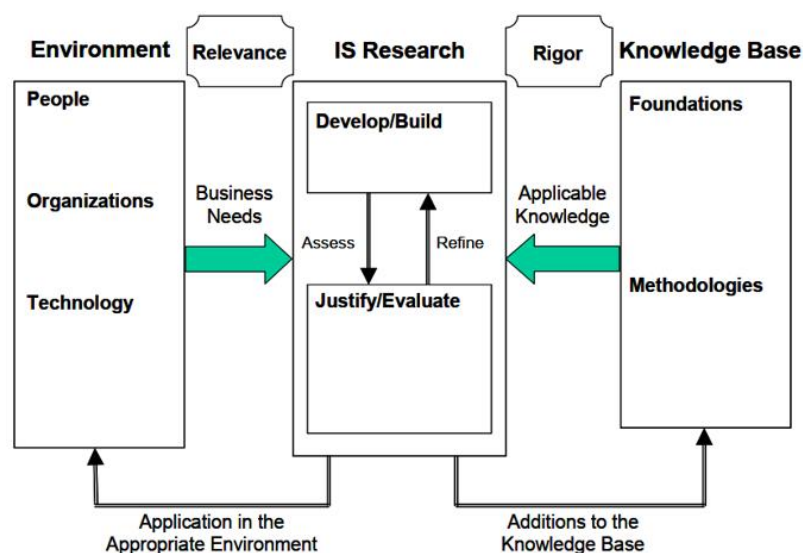


Figure 16. A sketchy view of the IS research framework defined in (Hevner et al., 2004)

### 7.2. The design of the BC ontological framework

The application of information technologies (IT) has recently been recognized as a facilitator of business continuity. Since the early days of the e-business era, researchers and IT professionals have explored the utilization of various IT solutions to enhance business continuity levels. From an economic perspective, IT can play a role in reducing downtime and increasing uptime, thereby contributing to improved financial outcomes. Each minute of downtime incurs a cost, making continuous computing solutions crucial for ensuring business continuity (Bajgoric, 2006). Given these factors, the fields of Information Systems (IS) and Business Continuity (BC) complement each other and offer several ways of mutual support. These include: (a) documenting and regularly updating BCP requirements and validations, (b) implementing the

BCP and integrating its functionalities into the organization's IT systems, and (c) testing the BCP's effectiveness and resilience by troubleshooting the implemented BC features within the IS environment.

Hence, this work developed a Business Continuity (BC) ontology based primarily on the IS research framework (Figure 16) discussed earlier. Despite an extensive search, no existing ontology specifically addressing the characterization of the BC environment and its foundations was discovered. Consequently, to construct the BC ontology, a comprehensive collection of scientific papers related to "Business Continuity" was obtained through a research query conducted on SCOPUS. Additionally, other research engines like Web of Science (WoS) were utilized to gather supplementary information, including the country, year (Figure 17), and WoS category of the publications (Figure 18), for a more comprehensive overview. A total of almost 2600 articles was analyzed to gain deeper insights into the domain. Initially, all papers were included for coverage purposes, but their relevance would be assessed and determined later based on the ontology's application. The research papers were then meticulously examined, and all the keywords associated with them were extracted to serve as concepts for the designed ontology. As a result, an initial BC knowledge graph was established, encompassing concepts (or "topics"), authors, article types (journals, conferences, books, etc.), and publication locations relevant to each article. The topics were linked to one another based on their occurrence frequency. Additionally, the knowledge graph provided details such as article titles, summaries, DOIs (Digital Object Identifiers), and contributors.

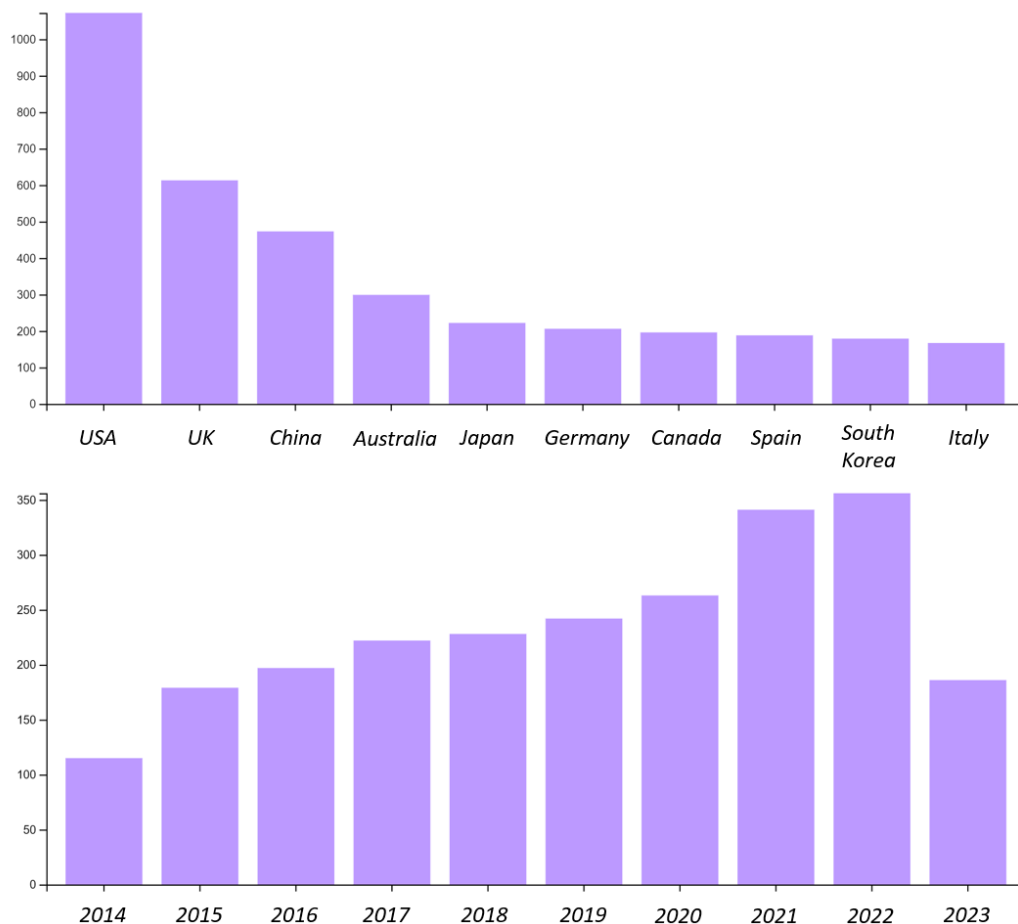


Figure 17. Year and country of the retrieved publications

Select All <input type="checkbox"/>	Field: Web of Science Categories	Record Count
<input type="checkbox"/>	Management	875
<input type="checkbox"/>	Business	772
<input type="checkbox"/>	Computer Science Theory Methods	480
<input type="checkbox"/>	Computer Science Information Systems	475

Figure 18. The four most important WoS publication categories

Lastly, despite the existence of ontology development methodologies such as NeOn (Gómez-Pérez & Suárez-Figueroa, 2019) and Ontology 101 development (Noy & McGuinness, 2001), which expedite the process and facilitate the reuse of knowledge resources, this research work does not incorporate any of them. This decision is primarily driven by the following reasons: (a) the ontology developed in this work is constructed from scratch, exclusively based on the research query results, forming a knowledge base, (b) the ontology is in a single format and does not involve the merging of two or more ontologies, (c) the construction of the ontology is a manual process, aligned with the IS research framework, but the exploitation of the ontology is automated, and (d) The concepts within the ontology are derived from the keywords of the papers, which are retrieved and classified manually to address the notion of BC and its diverse requirements.

### 7.3. The implementation of the BC ontological framework

The implemented ontology's class hierarchy primarily consists of IS research framework classes and subclasses, with the retrieved paper topic serving as concepts. Some hierarchal properties were implemented as well such as: papers “*has\_Author/has\_Type*” or “concerns” some topics, topic “*is\_Related\_To; provides\_business\_needs\_to or provides\_rigor\_to*” other topics, and other relationships.

After that, the concepts were categorized within the ontology to have a deeper understanding of the BC environment and procedures. Because the concepts or "themes" are immediately linked to the papers, gaining access to the remainder of the information on a certain topic is rather simple. The ontology has four layers (paper elements, classification elements, subclassification elements and retrieved concepts) and is accessible for evaluation here: <https://tinyurl.com/4pc2ejkf>.

Figure 19 depicts the OWL visualization of the first two layers of the implemented ontological framework for the BC. It portrays the classes and their relationships within the first two layers. In fact, OWLViz is built to work with the protégé owl-editor; it allows class hierarchies in the OWL (The W3C Web Ontology Language) ontology to be viewed and incrementally navigated, allowing comparison of asserted and inferred class hierarchies. A comprehensive examination for source of componential analysis was conducted in order to develop the proposed ontology (Alshehab et al., 2019).

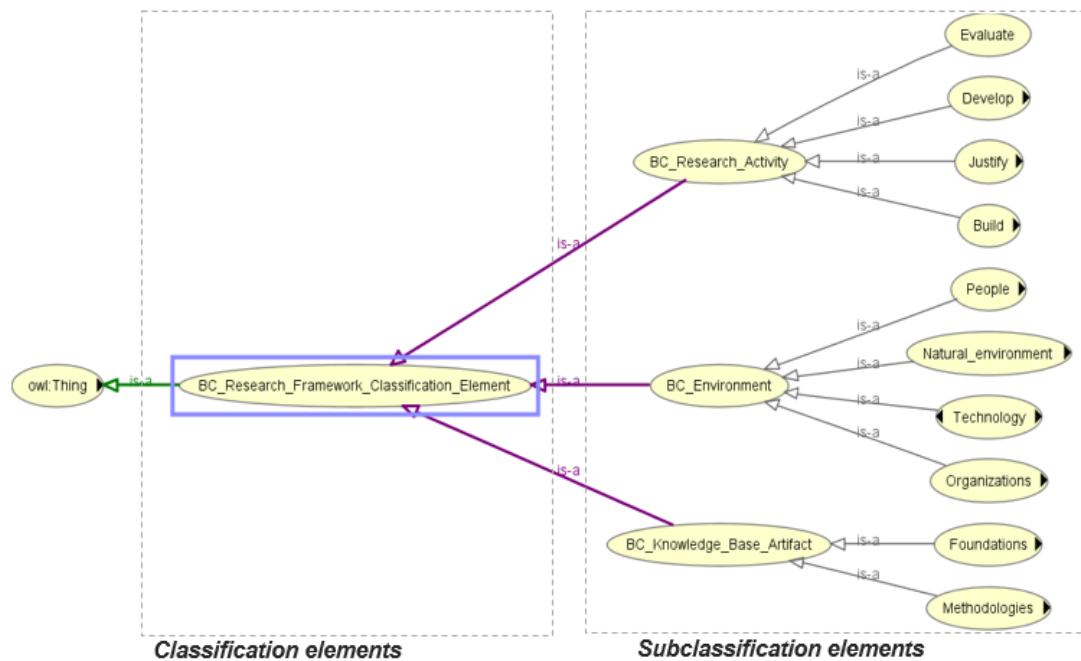


Figure 19. The BC ontology class graph visualization presented with OWLViz

#### 7.4. The ontology-supported research work methodology

The ontology-supported research work methodology described here is a systematic approach to collecting and analyzing data, which is discussed in sections 2 and 3 of this chapter, in order to evaluate the organizations' BC. The methodology involves several steps, which are explained in detail below:

1. **Identify threats:** The first step is to identify the potential threats that organizations may face. This is done by referring to the ontology developed in the current section, which provides a structured representation of different types of threats.
2. **Build indicators:** Once the threats are identified, the next step is to develop indicators that can be used to assess each category of these threats. These indicators serve as quantifiable measures for evaluating the organization's resilience against each threat category.
3. **Generate survey questions:** Based on the indicators established in the previous step, specific survey questions are manually formulated for each category of these indicators. These questions are designed to gather relevant information from the organization and its stakeholders. The survey is a structured data collection instrument that helps in obtaining systematic and standardized responses from participants.
4. **Collect information:** In this step, the survey is administered to the targeted participants, which may include organizational members, stakeholders, or external experts. The survey responses provide the necessary information to answer the questions related to the identified threats and indicators. Additionally, other (physical or societal) data collection methods such as interviews, observations, or document analysis may also be employed to gather additional information.
5. **Extract useful data:** Once the information is collected, it is analyzed through its relevance to the questions and threats addressed in the first place, and processed to extract the useful data relevant to assessing the business continuity of the organization.

The data extracted from the survey responses, interviews, and other sources are examined in relation to the established indicators. In fact, these data may serve: (a) **directly as an indicator** or (b) **indirectly as a calculation data for an indicator**. The rest of the data obtained are later on eliminated. Thus, this analysis helps in identifying strengths, weaknesses, and potential areas of improvement in the organization's business continuity efforts.

6. **Assess business continuity:** Lastly, the organization's BC is evaluated using the indications and the retrieved data. The organization's level of readiness, reaction capacity, and resilience to various threats may be assessed by comparing the data with the indicators. This evaluation allows recommendations for boosting the organization's resilience and offers insights into the efficiency of its BC procedures.

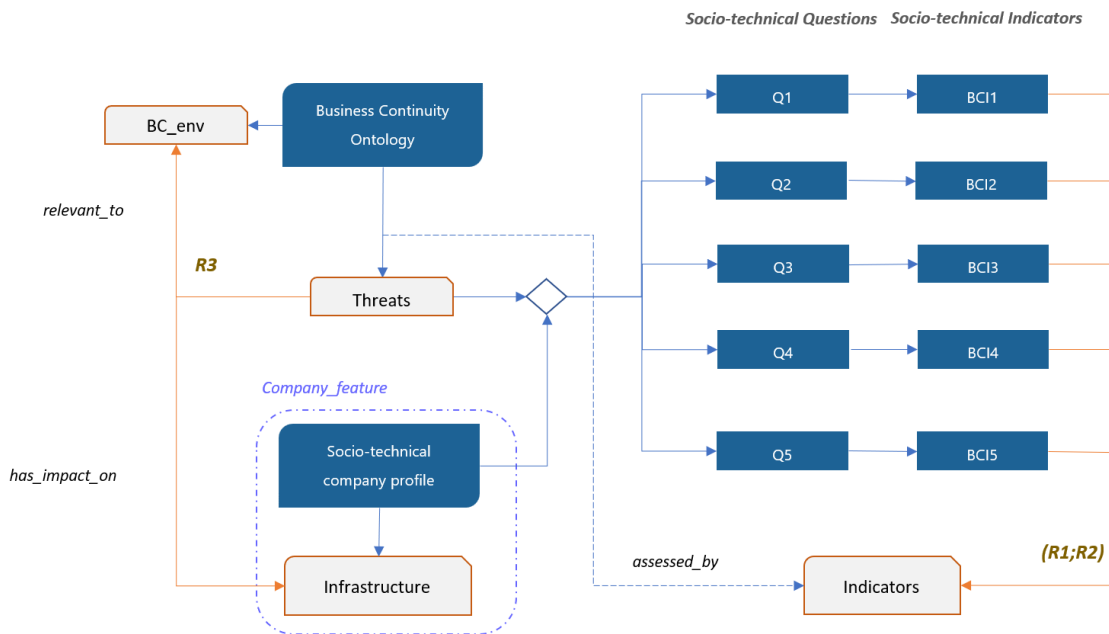


Figure 20. The MRR (Methodology-Relationships-Rules) Model

Overall, the ontology-supported research work methodology, outlined here and depicted by the MRR (Methodology-Relationships-Rules) Model, **which is a conceptual model developed by this research work to highlight the methodology concepts, their relationships and rules**, and presented in Figure 20 above, provides a structured and systematic approach to gathering data, analyzing threats, and evaluating the business continuity of organizations. It leverages the ontology to identify threats, establish indicators, and guide the data collection process, ultimately leading to a comprehensive assessment of an organization's resilience and ability to withstand potential disruptions. However, some rules are needed for this MRR model. The provided rules help clarify the relationships between indicators, threats, and BC environment ontological elements in the ontology-supported research work methodology.

What are these rules and how they encompass the relationships:

- **Rule 1 (R1): An indicator can evaluate 0 or more threats.**

This rule states that an indicator, which is a measurable variable or parameter, can be associated with and assess zero or more threats. In other words, an indicator provides a

means to evaluate the presence or severity of specific threats. However, it is not mandatory for an indicator to assess any threats; it may evaluate none at all.

- **Rule 2 (R2): A threat can be assessed by one or more indicators.**

This rule indicates that a threat, representing a potential harm or disruption to the organization, can be evaluated by one or more indicators. The indicators provide a way to measure or assess the existence and impact of a particular threat. Multiple indicators may be used to comprehensively evaluate a threat and capture different aspects of its potential impact.

- **Rule 3 (R3): A threat can be relevant for one or more BC\_env elements.**

This rule highlights that a threat can be associated with one or more BC environment ontological elements. The BC environment elements represent different aspects of the organization's environment that can influence its business continuity. The relevance of a threat to specific BC environment elements signifies the potential impact it may have on those elements and their interdependencies.

Taken together, these rules encompass the following aspects:

- i. **Surjection between indicators and threats:**

The rules state that indicators can evaluate threats, indicating a relationship between these two entities. This surjection means that indicators are linked to threats, providing a means to assess and measure them.

- ii. **Surjection between threats and BC environment ontological elements:**

The rules establish that threats can be relevant to BC environment elements, implying a connection between these entities. This surjection signifies that threats can impact different aspects of the organization's environment, and they need to be evaluated in relation to the relevant BC environment elements.

- iii. **Mandatory assessment of threats by BC indicators but not vice versa:**

The rules specify that threats must be assessed by BC indicators, meaning that indicators are designed to evaluate threats. However, it is not mandatory for indicators to assess any threats; they can exist independently without evaluating any specific threat.

In summary, these rules provide a framework that ensures the integration of indicators, threats, and BC environment elements in the ontology-supported research work methodology. They establish the relationships between these entities, guiding the assessment process and facilitating a comprehensive understanding of the organization's business continuity capabilities and vulnerabilities.

Finally, to apply this ontology-supported methodology, an application version of the latter was created (see Figure 21). This basically consists in generating a knowledge graph from the ontology (that will be explained in sections 8 and 9 of this chapter), using it to extract the BC metrics and follow on.

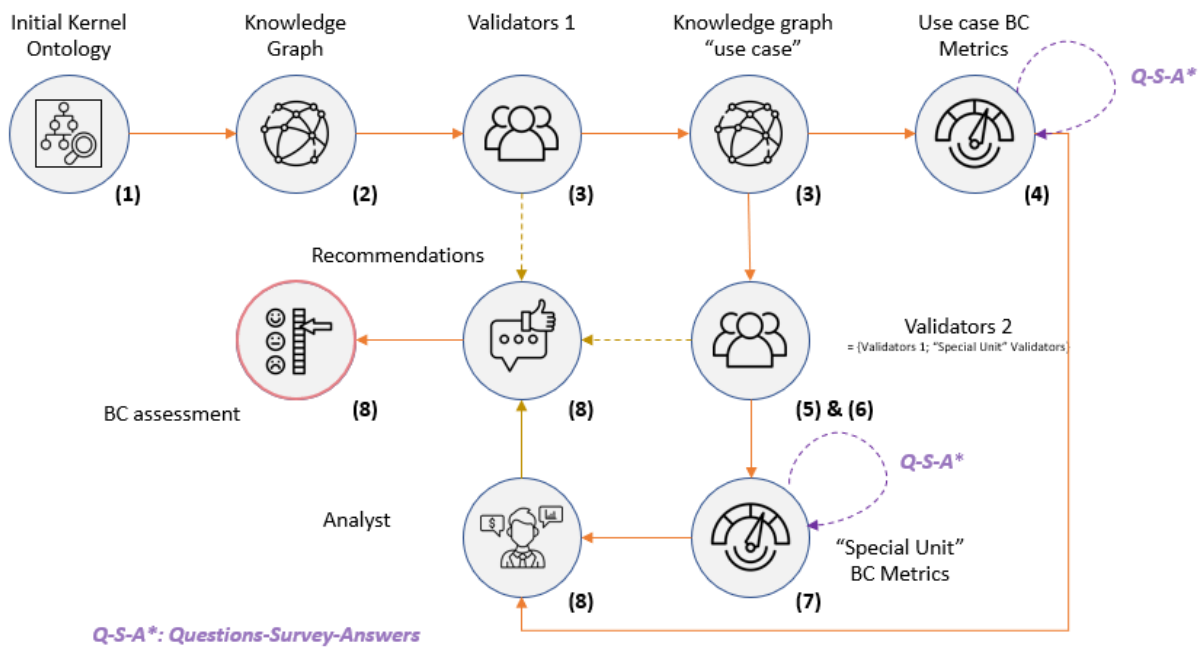


Figure 21. The methodology application

This application version (Figure 21) involves the following steps:

- Utilizing the existing ontology (*Initial Kernel Ontology*):** The methodology utilizes the ontology developed through this research work, serving as the foundation for creating a knowledge graph. This knowledge graph is derived from the ontology and captures the interconnected relationships between various concepts and entities.
- Deriving BC metrics for the case study (*knowledge graph*):** Based on the knowledge graph generated from the ontology, specific metrics for assessing the BC of the case study organization are proposed. These metrics are derived from the information and relationships represented in the knowledge graph.
- Validating the BC metrics (*validators 1*):** The proposed metrics undergo a validation process to ensure their relevance and accuracy. This validation involves verifying the metrics with experts or stakeholders in the field of business continuity to assess their appropriateness and effectiveness in measuring the organization's resilience.
- Questions-Survey-Answers approach for obtaining metrics (*use-Case BC metrics*):** To gather the necessary data for the metrics suggested in the case study, a Questions-Survey-Answers approach is followed. This approach involves formulating targeted questions based on the identified metrics, conducting surveys to collect responses from relevant participants, and analyzing the answers obtained to calculate and determine the metrics.
- Proposing BC metrics for the special unit (*validators 2*):** Additionally, specific business continuity metrics are proposed for the special unit within the case study organization. These metrics are tailored to assess the unique characteristics, risks, and requirements of the special unit.
- Validating the special unit metrics (*validators 2*):** Similar to step 3, the proposed metrics for the special unit undergo a validation process to ensure their suitability and

relevance. This validation involves consulting experts or stakeholders who possess domain knowledge related to the special unit to assess the appropriateness of the metrics.

7. **Questions-Survey-Answers approach for obtaining special unit metrics (*special unit BC metrics*):** A Questions-Survey-Answers approach is followed to obtain the metrics suggested for the special unit. This approach involves formulating targeted questions specific to the special unit, conducting surveys or interviews with relevant individuals, and analyzing the responses to derive the metrics.
8. **Providing recommendations and assessing BC (*analyst, recommendations & BC assessment*):** Finally, based on the obtained metrics and the assessment of business continuity in both the general case of the use case and the particular special unit, recommendations are generated. These recommendations aim to improve the organization's resilience and address any identified vulnerabilities. An overall assessment of the organization's business continuity capabilities is also conducted, considering the metrics and findings derived from the methodology.

These steps aim at utilizing the ontology-supported methodology in order to extract relevant BC metrics and help assessing the BC for both the general case of the use case and the specific special unit. The findings resulting of the application of this ontology-supported methodology are discussed in Chapter IV. of this thesis.



## 8. Ontology interoperability between WebProtégé and Obsidian

WebProtégé is a collaborative ontology editor and knowledge acquisition tool for the web (Horridge et al., 2019; Tudorache et al., 2013). It is an open-source, lightweight, web-based ontology editor that allows communities to create and discuss ontologies using a complex web interface (Tudorache et al., 2013). WebProtégé is a cloud-based application that allows users to collaboratively edit OWL ontologies (Horridge et al., 2019). It is available for use at <https://webprotege.stanford.edu> (Horridge et al., 2019).

According to (Ouksel & Sheth, 1999) and other researches outlined below, different types of interoperability exist such as:

1. **Syntactic Interoperability:** It focuses on the compatibility of formats and protocols used for communication between systems. It ensures that systems can exchange data successfully by using compatible syntax, structure, and communication protocols. In the context of ontologies, syntactic interoperability involves utilizing standard ontology languages like OWL or RDF to represent and communicate ontological information. By adhering to a common syntax and format, ontologies can be easily parsed and understood by different systems, enabling effective data exchange (Zacharewicz et al., 2020).
2. **Semantic Interoperability:** This type goes beyond the syntax and explores the meaning or semantics of the information being exchanged. It aims to enable systems to understand and interpret the shared data accurately. In the context of ontologies, achieving semantic interoperability requires resolving differences in the interpretation of concepts, relationships, and attributes. This involves establishing mappings or alignments between ontologies to ensure that equivalent or related concepts are represented consistently across different systems. By addressing semantic inconsistencies, systems can exchange and integrate ontological knowledge, enabling shared understanding and interoperability (Ouksel & Sheth, 1999).
3. **Inter-domain or Inter-organizational Interoperability:** It mainly deals with the exchange of information between different domains or organizations. It focuses on enabling collaboration and communication between systems that may have different ontologies or represent data from distinct domains. This type of interoperability often requires a higher level of mediation and coordination to bridge the gap between diverse ontologies. It may involve establishing common vocabularies, creating mappings or translation mechanisms, and ensuring mutual understanding of the shared information. Inter-domain or inter-organizational interoperability is crucial in scenarios where multiple organizations or domains need to exchange information while maintaining their respective ontologies (Benaben et al., 2015, 2020; Chen & Daclin, 2006).

In summary, syntactic interoperability ensures that systems can communicate using compatible formats and protocols, while semantic interoperability addresses the shared meaning and interpretation of the exchanged data. Inter-domain or inter-organizational interoperability, on the other hand, focuses on enabling communication and collaboration between systems with

different ontologies or representing different domains. All three types of interoperability are relevant to ontology interoperability as they contribute to the effective exchange, integration, and understanding of ontological knowledge across systems, domains, or organizations. However, the Ontology interoperability with a knowledge base or graph (such as with Obsidian) is mostly a combination of the first and second types (syntactic and semantic interoperability).

Ontology interoperability is a crucial aspect of data integration, automatic inference, and knowledge discovery based on formal representations of knowledge (Hoehndorf et al., 2011). Interoperability between biomedical ontologies can be achieved through aligning terms in biomedical ontologies with foundational classes in a top-level ontology and formalizing composite relations as class expressions (Hoehndorf et al., 2011).

Key aspects of ontology interoperability, according to (Heflin & Hendler, 2000) include:

- **Consistency:** Ontologies need to be consistent in terms of their concepts, attributes, and relationships to avoid conflicts or misunderstandings when exchanging information.
- **Mapping:** Ontologies may need to be mapped or aligned to establish connections between corresponding concepts, properties, or relationships in different ontologies. Mapping enables data integration and retrieval across diverse ontologies. In order to achieve this one must define transformation rules by relying on established mappings between the various elements found in both meta-models (Touzi et al., 2009).
- **Standardization:** The use of standard formats, languages, and protocols facilitates interoperability. Popular ontology languages include OWL (Web Ontology Language) and RDF (Resource Description Framework), which provide a common syntax for representing ontologies.
- **Mediation:** Mediation involves creating an intermediary layer or a mapping infrastructure to facilitate communication between ontologies with differing structures, semantics, or representations. It is used to establish collaborative processes and carry them out between partner interfaces and online services (Bénaben et al., 2016).
- **Semantic Integration:** Ontology interoperability often involves ensuring semantic compatibility between ontologies. This includes understanding and resolving semantic differences or inconsistencies, such as different interpretations of concepts or relationships.

Conversely, Obsidian is a note-taking app that supports the creation of a knowledge graph (*Semantic Web - The Mind's Eye - Obsidian Publish*). It allows users to create, edit and link notes, which can be used to represent concepts, relationships between entities, and categories of things (*Semantic Web - The Mind's Eye - Obsidian Publish*). However, the up-to-date discovered results make no explicit mention of WebProtégé and Obsidian's ontology interoperability.

Finally, another important use of ontology interoperability could consist of sharing and exchanging knowledge across different systems, domains, or communities between different organizations, enabling better collaboration, data integration, and interoperable applications (Hoehndorf et al., 2011; Olan et al., 2016).

## 9. Knowledge base creation

Resulting from what was previously explained in the last section, this work considered transforming a part of the developed BC ontology into a knowledge graph. This permits: (a) better manipulation and exploitation since knowledge graphs are more user-friendly, a visualization that helps filtering certain aspects of the ontology, (c) clear links between the components of knowledge base such as indicators, threats and so on, and (d) an easy integration of this work later on within other applications such as a dashboard or an applicative software. Figure 22 represents the research framework focusing on four areas: two and four refer to the user experience in visualizing an Ontology in Web Protégé and Obsidian environments. While the areas one, three and four refer to the technical methodologies to exchange the Ontology between Web Protégé and Obsidian. To recap Figure 22:

1. At the bottom there is development of the Ontology in Web Protégé defining the business continuity model in terms of classes, hierarchies, attributes, and relationships.
2. On the right-hand side on the blue section “Web Protégé” the key users can visualize and navigate the Ontology based on Web Protégé functionalities
3. On the left-hand side 3a and 3b represent the architecture developed to transfer the Ontology from Web Protégé to Obsidian
4. In the centre Obsidian section (#4) identifies the new environment for a key user to visualize and enrich an Ontology following a new approach

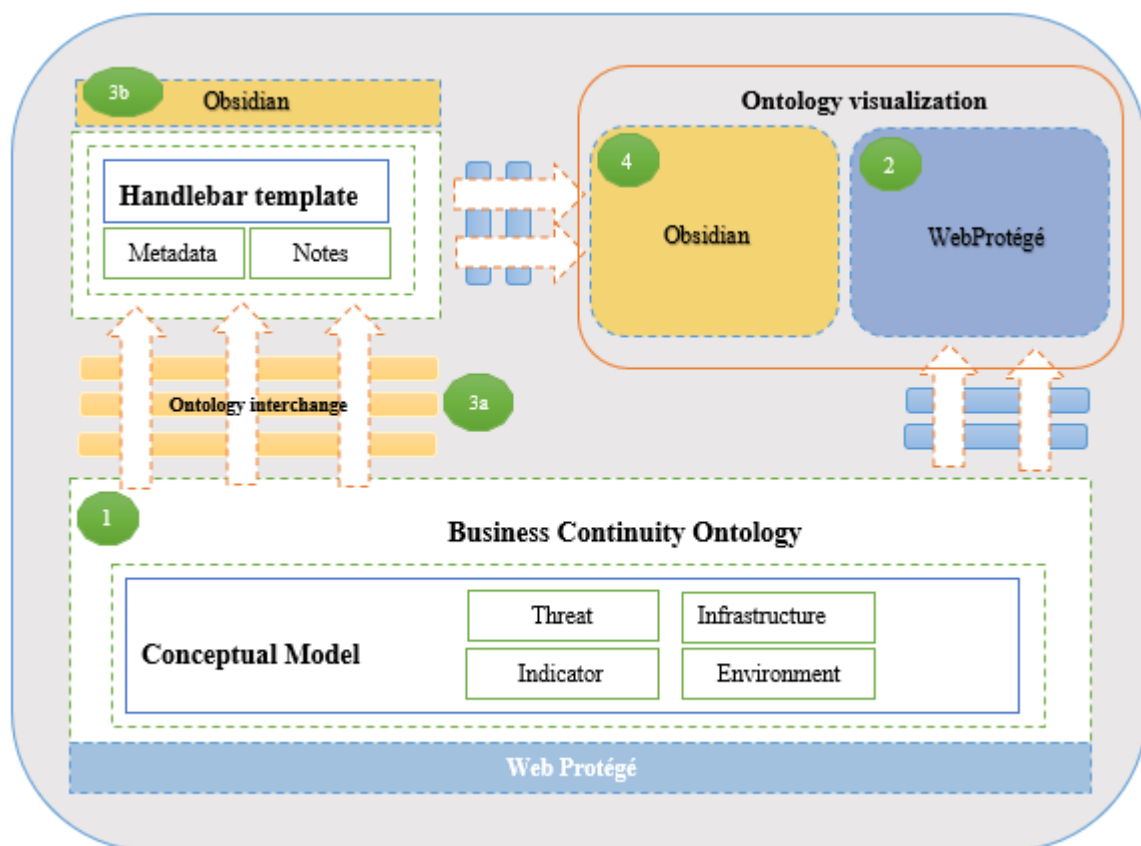


Figure 22. BC ontology-to-knowledge-graph transformation framework by Deidda, S. (2023)

### 9.1. BC ontology's overview

Figure 23 illustrates a three-dimensional approach to “seeing from above” or overviewing our BC Ontology. **The first layer**, known as "Business Context," represents **the environment that needs to be evaluated**. At this stage, the information is unstructured and lacks logical connections.

**The second layer**, referred to as "Ontology Constructions" pertains to the working environment where the Ontology is built. This involves defining classes, hierarchies, and relationships. The outcome of this stage is a structured Ontology that provides a clear understanding of the business context. **This layer represents the already-implemented BC ontology that we know, developed by this research work, and discovered its components in section 7.3 of this chapter.**

**The third and final layer**, called "Ontology Visualization," focuses on presenting the Ontology in a visual format for user analysis. Various visualization methods can be employed at this stage based on the specific requirements and preferences of the user. **This layer represents the BC knowledge base/graph creation.**

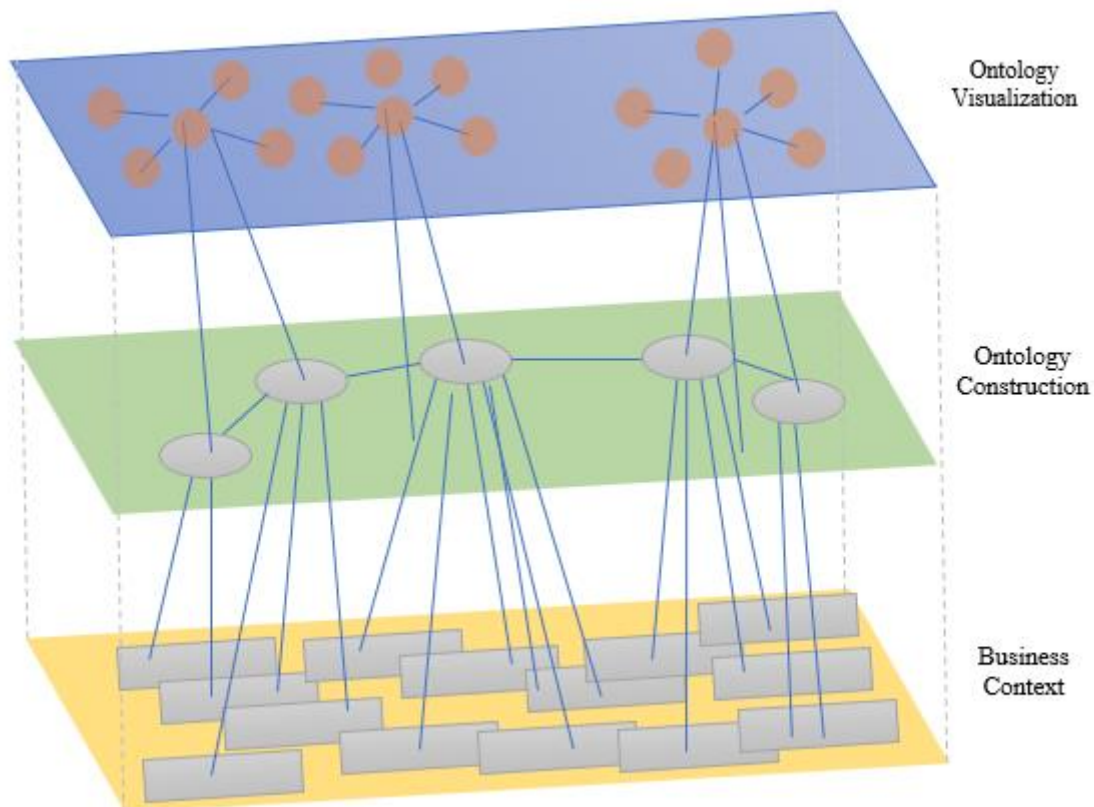


Figure 23. Modelling the BC Ontology by Deidda, S. (2023)

The constructed ontology serves in fact as a metamodel that can instantiate some nodes relating the addressed threats with their according indicators and the information regarding those. This permits an applicable instantiation of the ontology, according the considered use-case and its characteristics (type, size, sector, etc.).

## 9.2. The BC applicable Ontology components

The BC Ontology is a structured representation of concepts and relationships relevant to the domain of BC in the transport industry. It provides an applicable framework for organizing and understanding the different elements involved in ensuring the continuity of operations in the face of potential threats. In fact, this BC applicable ontology is an instantiation of the ontology developed through this work and explained previously in 7.3. This instantiation focuses on the following elements: (a) the BC robustness indicators, (b) the identified threats by categories, and (c) the organization infrastructure resulting from its characteristics (sector, size, etc.).

The applicable ontology is represented visually in Figure 24, where Level 2 represents the domain of threats. This level encompasses various potential risks and hazards that can disrupt normal business operations in the transport industry. These threats could include natural disasters, accidents, infrastructure failures, security breaches, or any other event that may have a negative impact on the industry, Deidda, S. (2023).

Level 3 of the ontology represents the relations within the domain. It focuses on the connections and dependencies between different elements of the transport industry and the threats identified in Level 2. These relations could include cause-and-effect relationships, dependencies, mitigation strategies, response actions, or any other relevant connections.

Figure 24 provides an overview of the complete ontology framework, illustrating the three levels mentioned above. This framework serves as a guide for understanding the hierarchical structure and relationships within the ontology. It helps stakeholders in the considered industry to navigate and make sense of the various concepts and connections involved in business continuity planning and response.

By using this ontology, stakeholders can enhance their understanding of the potential threats faced by the considered industry and develop effective strategies to mitigate risks and ensure business continuity. The structured representation allows for a systematic approach to analyzing, planning, and implementing measures to safeguard operations and minimize disruptions.

It's worth noting that the specific details of Figure 1 and Figure 15, such as the exact concepts and relationships depicted, may vary depending on the specific ontology implementation and the scope of the transport industry being considered.

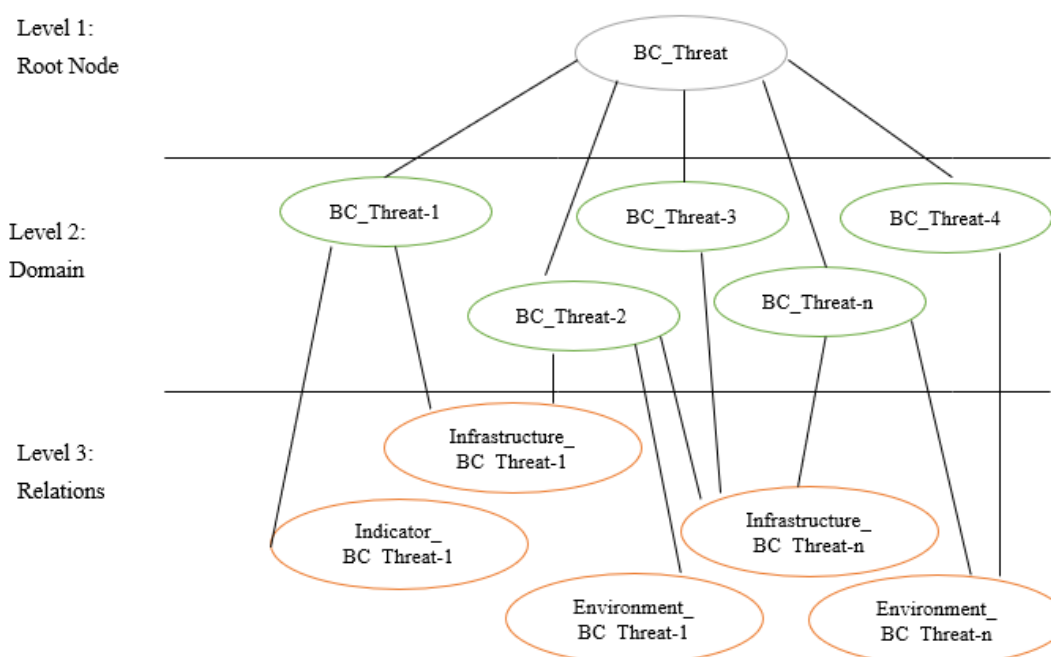


Figure 24. The BC applicable ontology components

### 9.2.1. Example:

To provide an explicative or in other terms “naïve” example, let's examine Figure 25, which represents the Corruption threat within the context of the financial class that is relevant to both People and Organizations. As per Deidda, S. (2023), the following indicators are used to measure this threat:

- **bank\_robbery\_arrest\_rate**: This refers to the rate at which individuals suspected of robbing a bank are arrested. This indicator can be used to understand the effectiveness of law enforcement in preventing bank robberies and to identify potential trends in bank crime.
- **Control\_of\_corruption**: This refers to the effectiveness of a country's or region's institutions in preventing and combating corruption. This indicator can be used to understand the level of corruption in a particular country or region and to identify potential areas of concern.
- **Corruption\_Perceptions\_Index\_(CPI)**: It is a measure of the perceived level of public sector corruption in a country or region, as determined by a variety of expert and business surveys. This indicator can be used to understand the level of corruption in a particular country or region and to identify potential areas of concern.
- **Total\_%\_of\_revenue\_lost\_to\_fraud**: This refers to the percentage of a company's revenue that is lost as a result of fraudulent activities. This indicator can be used to understand the impact of fraud on a company's financial health and to identify potential areas of concern.

The data to obtain these indicators was mainly divided into three categories: (a) open source data through regional, state and company's open policy and transparency pages data, (b) data obtained through surveys and online data requests, and (c) data obtained through onsite visits and offline interviews.

These indicators help assess the presence and extent of corruption within the system. These impacts refer to how corruption can affect the functioning and stability of business operations,

particularly within the realms of operating environments, transportation routes, and the overall transportation system.

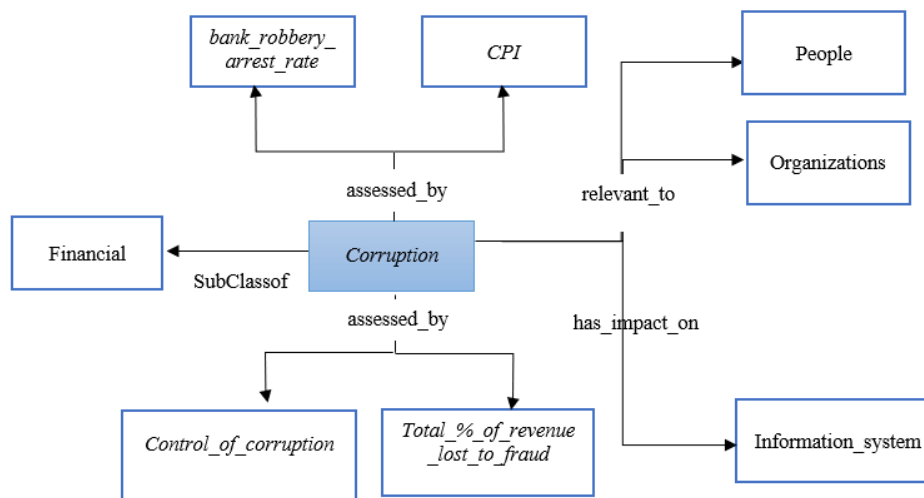


Figure 25. Corruption Threat flow

### 9.3. The BC ontology transformation into a knowledge graph

The E2E process, as represented in Figure 26, consists of four main steps that lead from the export phase in Web Protégé to the final import in Obsidian. Let's summarize each step:

1. **Export File Creation:** To begin, access the Web Protégé Home Page and locate the desired project. Then, open the Menu on the right-hand side and select the download option. Choose the RDF/XML format and confirm the download. Finally, save the ontology as a .owl file in a designated local folder.
2. **Export File Format Conversion:** Next, employ the DataFileConverter tool to convert the exported file from .RDF format to .CSV format. Start the conversion process and specify both the source and destination formats. Import the file to be converted and indicate the destination folder. Run the format conversion and save the resulting .CSV file.
3. **Transformation Process:** Moving on, develop the final file required for the import phase by following a dedicated procedure. Gain a comprehensive understanding of the structure and content of the export file. Utilize the Obsidian tool to create the import file concept and layout. Revise the export file to facilitate data transfer to the import file. Finally, build the import file content based on the information derived from the export file and the ontology.
4. **Import Phase:** In the last step, leverage the JSON/CSV importer plug-in within Obsidian to import the BC ontology. Configure the Handlebars templates, which govern metadata and layout. Launch the plug-in, provide the necessary information, and confirm the import process. As a result, the ontology will be imported, generating a note for each threat present in the import file.

Overall, the E2E process involves exporting the ontology from Web Protégé, converting the format, transforming the export file into an import file with the desired structure, and finally importing it into Obsidian using the JSON/CSV importer plug-in. By following these four

steps, you can successfully navigate the E2E process and achieve the desired import of the ontology from Web Protégé to Obsidian.

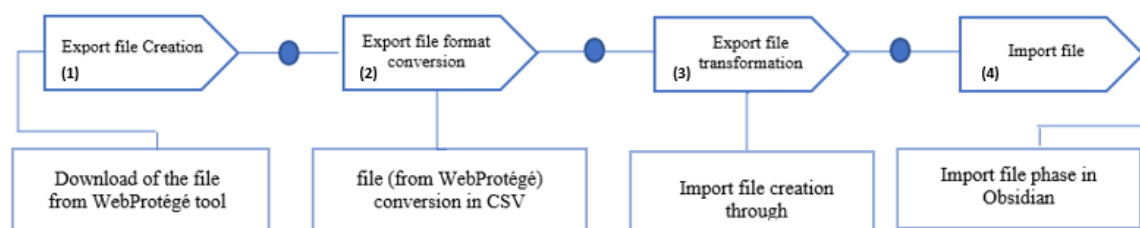


Figure 26. E2E Transformation process by Deidda, S. (2023)

#### 9.4. The knowledge graph within Obsidian

Once the transformation steps mentioned in 9.3 are successfully compelled, the knowledge graph given by Figure 27 is obtained.

A key component of this research is the use of a knowledge network within Obsidian, particularly in the context of ontology exploration and user experience. Knowledge graphs are effective representational tools for complicated links between different items or concepts, making them especially suitable for capturing the deep linkages seen in the BC ontology created in this work (F.-L. Peng et al., 2023; Pujara et al., 2013; Wang et al., 2019).

Obsidian was selected as the platform for a number of convincing reasons. It primarily provides a simple and straightforward interface for visualizing and traversing knowledge graphs. The selection of Obsidian is in line with the requirement to make sure that users can readily understand and explore the BC ontology. This is crucial because a user's capacity to engage with and gain knowledge from the ontology directly influences

The effectiveness of the knowledge graph within Obsidian can be assessed through various metrics. One crucial metric is the ease with which users can visualize and explore the ontology. The graph visualization, as demonstrated in Figure 27,, allows users to intuitively grasp the connections between different threats and elements within the BC ontology. This includes functionalities like grouping threats or highlighting relationships with distinct colors, enabling users to swiftly identify and understand the relationships and dependencies present in the ontology. The key factor to measure is how easily the content can be visualized, navigated, and enriched. The example provided in the previous section 9.2.1 serves as a case that support this assessment. In summary, the metrics for evaluating user experience include visualizing and exploring the ontology, as shown in Figure 27, where the graph visualization allows for various functionalities such as grouping threats or relationships with different colors to quickly identify connections within the ontology. This is one possibility among others to visualize and to explore the BC ontology categorizing the threats with a specific colour. On this sample *bombing* threat is highlighted with red, *drought* with orange, etc. This view helps searching and grouping threats in a vast ontology.



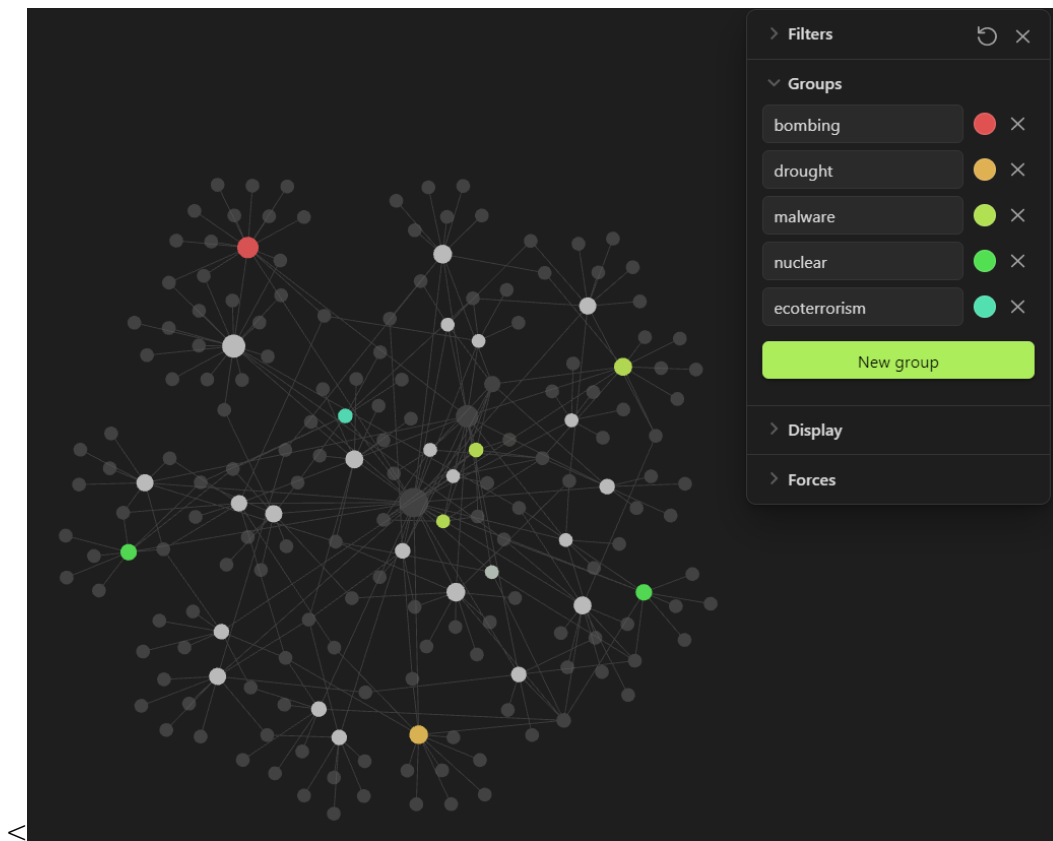


Figure 27. Business Continuity Ontology in Obsidian

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## 10. Limitations of the research

While this research endeavors to provide a comprehensive analysis of Business Continuity Planning (BCP), it is essential to acknowledge certain limitations that may affect the scope and generalizability of the findings. These limitations span various aspects of the research, including methodological, ethical, conceptual, and practical considerations.

**Methodological limitations** encompass the constraints imposed by the chosen research methodology. The selected sample and population may not fully represent the entire BCP landscape, leading to potential biases or limitations in the applicability of the findings. Additionally, the data collection approaches employed in this study may have inherent limitations in terms of data availability, reliability, or comprehensiveness. It's also impossible to totally predict individual behavior on the basis of a few variables (age, gender, place of residence...).

**Ethical considerations** also play a role in defining the limitations of the research. Adhering to ethical guidelines and ensuring the privacy and confidentiality of participants and data sources is of utmost importance. However, certain ethical constraints, such as limited access to sensitive information or restrictions in data sharing, may limit the depth or breadth of the research findings.

**Conceptual limitations** arise from the complexities and nuances inherent in studying BCP. While efforts have been made to develop a robust and comprehensive BC ontology, it is essential to acknowledge that the ontology may not capture every aspect or perspective of BCP. The interpretation and understanding of BCP practices may vary among individuals and organizations, leading to potential gaps or limitations in the conceptualization of the research.

**Practical limitations** refer to the constraints encountered while putting the research into action. These constraints can include factors like time constraints, resource limitations, or technical challenges, such as the integration of tools like WebProtégé and Obsidian. These practical limitations need to be considered when interpreting the research findings and applying them in real-world scenarios.

Here are three examples that support the statements regarding the limitations of the research:

1. **Methodological Limitation: Sample Selection Bias:** The research methodology involves selecting a sample that represents the target population. However, due to limited resources and time constraints, it may not be feasible to include a diverse range of organizations or industries in the study. For instance, the research may primarily focus on specific sectors such as finance and healthcare, potentially leading to a bias towards those industries. This limitation could affect the generalizability of the findings to other sectors and organizations.
2. **Ethical Limitation: Data Sharing Restrictions:** Respecting ethical guidelines and ensuring the privacy and confidentiality of participants and data sources is crucial. However, some organizations or individuals may impose restrictions on data sharing, especially when it involves sensitive information related to their business continuity plans. As a result, accessing comprehensive and detailed data from certain organizations

may be challenging, limiting the depth and richness of the analysis and potentially introducing a bias in the findings.

3. **Conceptual Limitation: Incomplete Representation in the BC Ontology:** Despite efforts to develop a comprehensive Business Continuity Ontology (BC ontology), it is important to acknowledge that it may not capture every aspect or perspective of BCP. For example, the ontology may predominantly focus on technical aspects, such as infrastructure and IT systems, while giving less emphasis to social or behavioral factors that influence BCP effectiveness. This conceptual limitation could restrict the holistic understanding of BCP and may require further refinement or expansion of the ontology in future research.
4. **Practical Limitation: Time and Resource Constraints:** Conducting a thorough and comprehensive study on Business Continuity Planning (BCP) requires significant time, resources, and collaboration with organizations and stakeholders. However, practical constraints, such as limited funding, time restrictions, and access to participants, may impose limitations on the research. For instance, the research may have a predetermined timeline or budget, which restricts the depth and breadth of data collection and analysis. As a result, certain aspects of BCP may not be explored in as much detail as desired, and the research findings may be influenced by these practical constraints.

These examples highlight specific limitations related to sample selection bias, data sharing restrictions, and incomplete representation in the BC ontology. By recognizing these limitations, the research maintains transparency and acknowledges the factors that may influence the scope and applicability of the findings.

Acknowledging certain limitations is important in understanding the scope of this research. These limitations include factors like how we chose our sample, ethical considerations regarding data sharing, potential gaps in our understanding of BCP, and practical constraints. Despite these limitations, some insights are offered by our study. In the upcoming Chapter IV, how these insights are put into action will be explained.

To conclude, this chapter primarily provided the following insights: **(i) where the data for this research work was collected, how, and why, (ii) the design of the BC ontology, how, why, and its intended uses, namely two; (iii) the creation of a knowledge base and graph, and (iv) a research methodology supported by this ontology and applied to a real use-case.** The following chapter will present the findings related to two use-cases resulting from the elements explained earlier, namely the data-gathering model, the BC ontology, and the knowledge base.

## CHAPTER IV. TESTING THE METHODOLOGY: RESEARCH FINDINGS

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“However beautiful the strategy, you should occasionally look at the results”

Winston Churchill

This chapter presents the research findings obtained through the testing of the proposed methodology. The primary objective of this chapter is to provide an objective and detailed analysis of the data collected during the case studies and to test the formulated hypotheses. The chapter begins with **an introduction to each case study**, providing the necessary context and background information to frame the research findings.

Following the introduction, **the data collected in each case study** is presented. The data is organized and structured to facilitate a comprehensive understanding of the research outcomes. This presentation ensures transparency and allows for a detailed analysis of the collected information.

Subsequently, an **analysis of the results** is conducted. The analysis explores the relationships and patterns observed in the data, examining the implications and significance of the findings. This examination involves the assessment of the outcomes, identifying both the strengths and limitations of the research methodology employed. The analysis aims to provide a holistic view of the research findings, considering various factors that may have influenced the results.

Moreover, **the formulated hypotheses are tested** using the collected data. Statistical methods, data modeling techniques, or other relevant methodologies are applied to validate or refute the formulated hypotheses. The findings are then presented within this chapter, allowing for an understanding of the outcomes and their alignment with the research objectives.

Finally, this chapter provides a **discussion of the results**. The discussion aims at assessing the implications and significance of the research findings. It explores the practical implications of the results within the respective industries and considers potential avenues for future research and practical applications. The discussion also highlights any unexpected findings or areas that require further investigation.

The goal of this chapter is to offer a thorough examination of the methodology and its role in reaching the study objectives.

## **1. Introduction to case study (1) and (2)**

### **1.1. Case study definition**

In the first case study, the research was conducted in the field of healthcare, specifically focusing on the disruptions experienced in a pediatric ward due to the COVID-19 lockdown. The objective was to analyze societal data from a large cohort of patients and develop a proof-of-concept (POC) to identify specific parameters associated with the most impacted categories of patients. The research aimed to improve care outcomes and increase efficiency rates within the pediatric ward setting.

The second case study is centered around the transportation industry, with a focus on optimizing traffic flow and reducing congestion in a busy urban area. Advanced data analytics and ontological engineering techniques were employed to develop an assessment model capable of identifying threats to business continuity (BC) across different categories and determining relevant BC assessment metrics. The goal was to improve traffic management and overall efficiency within the transportation system.

### **1.2. Case study testing design: the multidimensional testing grid**

To test the proposed methodology in each case study, a multidimensional testing grid was implemented. This testing design involved the systematic collection and analysis of data from various sources, such as societal data in the healthcare case study and traffic-related data in the transportation case study. The multidimensional testing grid allowed for a comprehensive evaluation of the methodology's effectiveness and impact. The second use case, however, is tested using an ontological framework that results into forming BC metrics, and presents also some algorithms to test certain crisis scenarios.

### **1.3. Case study expected results**

In the first case study, it was anticipated that the application of the research methodology would lead to improved care outcomes within the pediatric ward. By identifying specific parameters associated with the most impacted patient categories, the research work was expected to provide valuable insights for optimizing treatment options and ensuring uninterrupted service, benefiting both patients and healthcare providers.

In the second case study, the implementation of the research methodology was expected to result in enhanced traffic management and reduced congestion. By accurately identifying threats to business continuity and determining relevant assessment metrics, targeted interventions could be implemented to improve traffic flow and reduce travel times for commuters. The expected results included smoother traffic flow, improved efficiency, and an overall enhancement in the transportation system.

Through the systematic testing of these case studies, the research aimed to validate the effectiveness of the methodology in addressing complex challenges within the healthcare and transportation industries. The expected results served as a guide to assess the impact and applicability of the research findings in each respective case study.

## 2. Data presentation

In this section, the raw results obtained from the empirical study conducted for case studies (1) and (2) are presented. Data presentation forms the fundamental groundwork for the analysis, where a comprehensive description of the gathered information is provided. Presenting these unprocessed findings aims at providing an unfiltered glimpse into the outcomes of the study, enabling a clear understanding of the data's essence and facilitating subsequent in-depth analysis and interpretation.

### 2.1. Case study (1): Pediatric ward of a public hospital

Utilizing the approach outlined in section 4 of Chapter III, a final version ( $\gamma$ -version) of the sociological indicators for BCP (Business Continuity Plan) robustness was formulated. This version comprehensively assesses societal aspects crucial for plan resilience, deriving from both patient and staff behaviors and impressions. Within this context, various underlying assumptions were considered, acknowledging the crisis's disproportionate impact on disadvantaged and less educated populations. Epidemiological surveys consistently reveal structural social inequalities in health, with working-class individuals being particularly vulnerable to epidemics, demonstrated by the COVID-19 pandemic in severe and fatal forms. These disparities are further compounded by reduced hospital resources, emphasizing the significance of patients' social capital, especially for those from working-class backgrounds, as their ability to cope outside of hospital care is constrained (Bastos et al., 2021; Her, 2020; Miskowiak et al., 2021; Rees et al., 2020). The hospital itself plays a vital role in safeguarding these vulnerable environments (Buchet-Molfessis, 2008). Additionally, the hospital staff's insufficient numbers and challenging working conditions have been highlighted during normal times, and during the COVID-19 crisis, they face increased illness, exhaustion, and fear due to heightened exposure to disease. Consequently, while essential, the staff may potentially be absent from the organization.

Thus, the designed indicators ultimately quantify the following factors: (a) the relative attendance of the staff during the first lockdown period in France (17/03/2020 to 11/05/2020) compared with the same period in 2019, revealing a 6.25-fold increase in collective absence of pediatric ward personnel, (b) the capacity of the pediatric ward, (c) the overall satisfaction rate of patients' parents, (d) the patient's fear concerning the sanitary situation, (e) the service occupancy, and (f) the attendance of the staff during the aforementioned lockdown period in France (Ben Amara et al., 2022).

The Figure 28 presents the  $\gamma$ -version indicators, along with their respective definitions and formulas. It is important to mention that  $T_{sppC}$ ,  $T_{ipC}$ ,  $T_{rppC}$ , and  $T_{trpcC}$  are sociological robustness indicators derived from the beta-version of this dashboard. These indicators respectively measure the following during the first lockdown period: **the satisfaction rate of parents with the pediatric service, the health impact rate on children in the pediatric ward, the rate of missed appointments due to fear of COVID-19 infection, and the rate of parents skipping their children's appointments.**

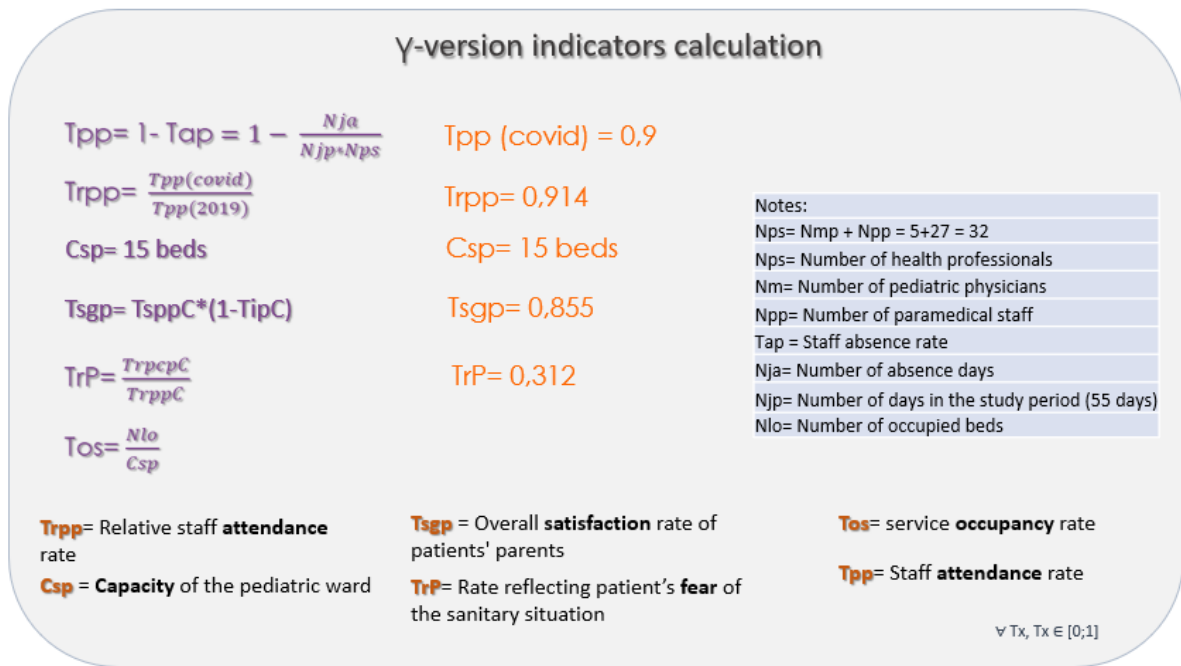


Figure 28. The γ-version indicators calculation

After computing these indicators, we proceeded to calculate their values and present them visually in a dashboard, as depicted in Figure 29 below. To assess the impact of these values on the BCP's robustness, we positioned these indicators within the robustness evaluation grid detailed in section 6. The subsequent section analyses the classification of these indicators and their significance.

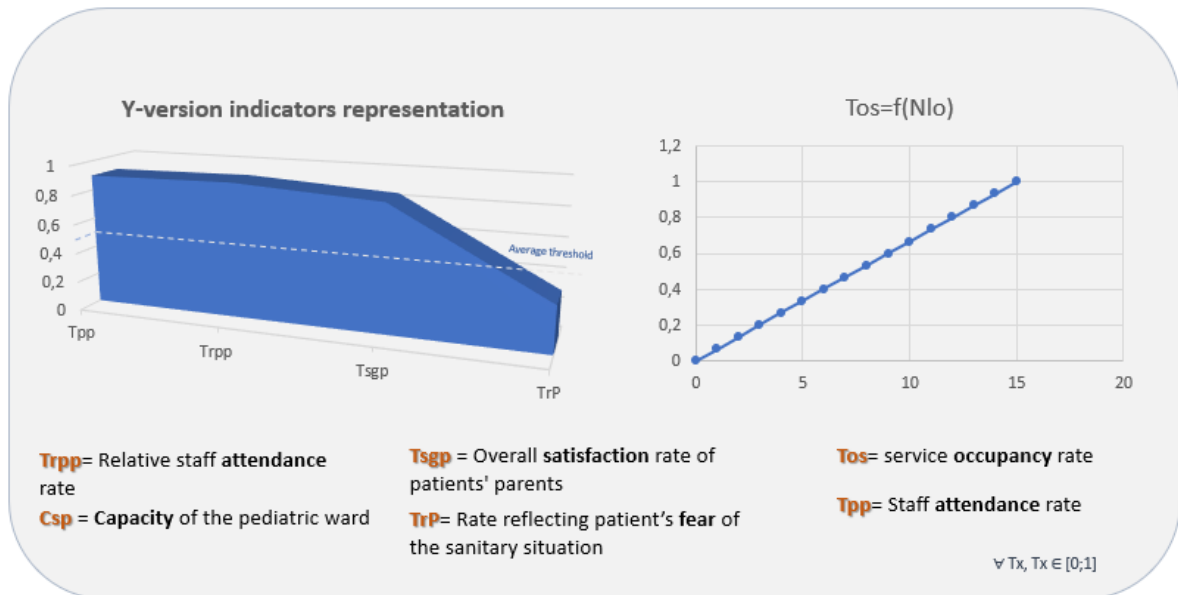


Figure 29. The γ-version indicators representation

**The task slippage coefficient:** Another remarkable ratio was formulated based on a crucial phenomenon in the sociology of organizations referred to as "Task Slippage."

In fact, task "slippage" or "shifting" refers to performing actions that are not directly related to the performer's designated duties or position (Michaud, 2004; Sainsaulieu, 2004). This issue of task shifting raises concerns about accountability, which does not seem to be adequately addressed in day-to-day work. There are several reasons contributing to this situation:

- Cyclical reasons, such as a lack of personnel or an overwhelming workload, leading to predominantly "occasional" task slippage.
- Structural reasons, as the nursing profession often grapples with staff shortages (de Barros, 2016; Michaud, 2004).
- Reasons linked to the strategies of the individuals involved; caregivers may harbor negative feelings about the tasks they perform and may not receive recognition from their colleagues for engaging in what is sometimes referred to as "the dirty work" (de Barros, 2016).

In this study, certain activities that fall within the responsibilities of a nurse are being carried out by a nursing assistant. However, due to nursing being a regulated profession, having a caregiver perform nursing actions is considered unlawful nursing practice.

Consequently, we proceeded to create the task slippage coefficient "Cgt" by drawing an analogy to slippage in the case of an asynchronous motor (Fayyad & Al-Rawashdeh, 2020). The formula presented in Figure 30 below elucidates the analogy made and the devised ratio used to calculate the extent of task slippage during an individual's daily job time. Our proposal involves dividing the number of tasks accomplished per milestone by the number of planned tasks for the same milestone by a specific employee to determine the task slippage rate.

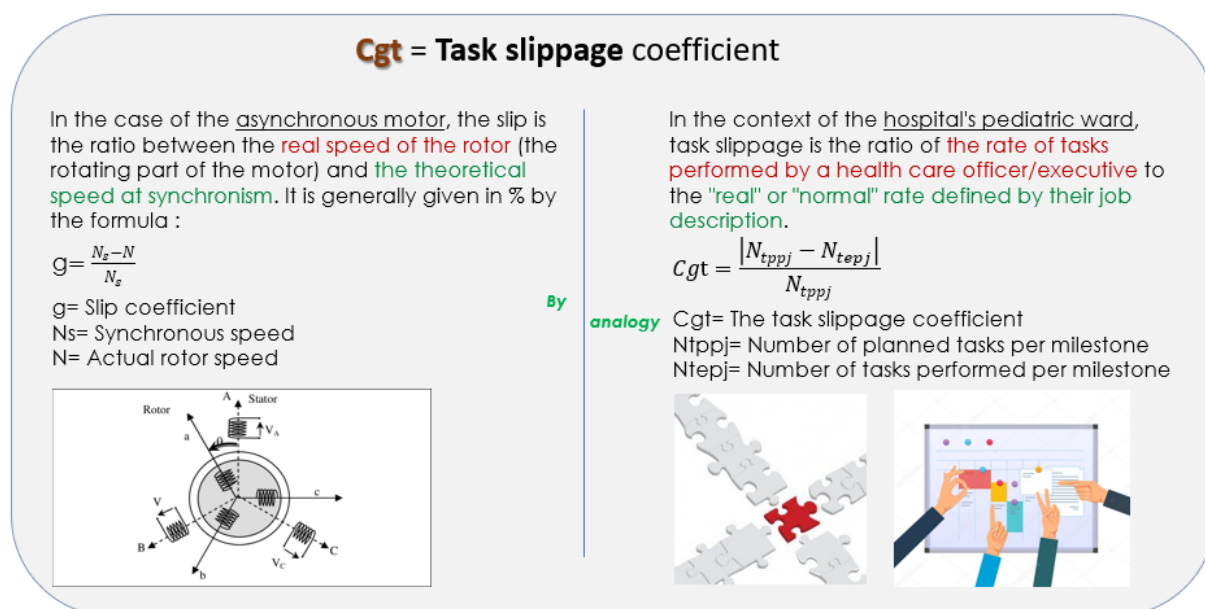


Figure 30. The task slippage coefficient



## 2.2. Case study (2): Security Operations Center of an urban transportation company

The key findings of this study can be summarized in the following points:

- Metrics for the company's BC
- An overall evaluation of company's BC
- Metrics for the SOC(Security Operations Center)'s BC. In fact the SOC is the "special unit" mentioned in Chapter III.7.4 of Chapter III.
- An evaluation of the SOC's BC
- Recommendations for both metric-based evaluations

The recommendations concern basically:

- The company's BC regulations, standards and requirements.
- The SOC's BC standards and requirements.

The metrics that were used to evaluate the overall BC of the company are given in Table 1 below:

Table 1. Case study 2: the overall BC metrics

• <b>Infrastructure and transport characteristics BC indicators</b>
○ Supplier due diligence result
○ Roadway Congestion Index (RCI)
○ Supply demand zone
○ Railroad lines total length in km
○ Supply demand timeframe
○ Road Density
○ Electricity service interruption indicators
• <b>Crime statistics BC indicators</b>
○ Ecoterrorism attack per year
○ Robberies per year
○ Homicides per year
○ Thefts per year
○ Chemical biological attack per year
○ Number of arson offenses
○ Hijackings per year
○ Fire brigades per year
○ Kidnappings per year
○ Bombing attack per year
○ Data exfiltration number of attacks per year
○ Database Read Volume
○ Cyber theft signature per year
○ Credential theft per year
○ Percentage of phishing emails
○ Malware number per year
○ Ransomware number per year
○ Cyber Attack incident per year
○ Outbound traffic sizes
○ Tampering physical devices attacks
• <b>Natural Catastrophes Weather BC indicators</b>
○ Daily Weather Records temperature low min
○ Rain frequency
○ Global mean surface temperature
○ Average number of tornados

○ Mean annual precipitation
○ Magnetic Fields
○ Flooding resilience
○ Number of Tornadoes and Related Deaths per year
○ Foreshocks
○ Number of lightning per year per area
○ Electromagnetic fluctuations
○ Humidity percentage
○ Land surface status impact on fires per year
○ Daily Weather Records temperature precipitation
○ Number of rainfalls per year per area
○ Fog density
○ Wind speed
○ Rain intensity
○ Rain duration
○ Seismic Waves
● Energy and environment BC indicators
○ Dependency on primary energy index
○ Energy consumption per year
○ Hazard World Risk Index
○ Fuel Price
○ Energy price
○ Alternative and nuclear energy
○ ISO standards
● Pandemic BC indicators
○ Covid positivity rate
● Social BC indicators
○ Number of protests per year
○ Number of vandalism actions
○ Number of migrants per year
○ Staff attendance rate
○ Number of strikes by area per month
● Macroeconomic BC indicators
○ Inflation
○ Tarif measurement
○ Security threats index
○ Economic decline index
○ Variation in demand for product
○ Cost volatility raw materials and transport
○ Raw material availability
○ Coefficient of variation (CV) of the annual sales
○ Interest rates on bank credit to the private sector
○ Cash flow forecasting
○ Credit Card Testing
○ Cash flow value
○ Bank robbery arrest rate
○ Company profit margin
○ Total % of revenue lost to fraud
○ Banking system z-scores
○ Market liquidity
○ Machinery and equipment prices
○ Vehicle prices
○ GDP per capita
○ Economic growth forecast
○ Economic growth
○ Net exports
○ Turnover rate
○ Driver position unfilled rate

○ <b>Unemployment rate</b>
○ <b>Labor cost index</b>
○ <b>Low pay rate</b>
○ <b>Cyber defense unfilled position rate</b>
○ <b>Unemployment rate forecast</b>
○ <b>Employment by weekly hours worked</b>
○ <b>Inflation forecast</b>
● <b>Governance business environment BC indicators</b>
○ <b>Political stability index</b>
○ <b>Control of corruption</b>
○ <b>Corruption Perceptions Index (CPI)</b>
○ <b>Government Stability Index</b>

Following the methodology application (illustrated by Figure 21), a “special” case study within the second use-case of this work (the transportation company) was considered. This allowed applying the ontology-supported methodology to first evaluate the general BC state of the use-case and then a particular unit. For this “special unit” which consists of the SOC (Security Operations Center) that contains as well the data center of the company, the following metrics were considered:

1. **Availability Metrics:** Availability metrics can help us track how often the data center is up and running. These metrics can include uptime percentage, downtime frequency, and mean time between failures (MTBF). By monitoring these metrics, trends and patterns can be identified, which helps to optimize the data center's performance and reduce downtime.
2. **Security Metrics:** Security metrics can help us track the level of security in the data center. These metrics can include the number of security incidents, the number of security vulnerabilities, and the level of compliance with security regulations. By monitoring these metrics, potential security risks can be identified and thus mitigated.
3. **Power Consumption Metrics:** Data centers consume a significant amount of energy, and an urban transportation company may have sustainability goals that require to reduce its energy consumption. Monitoring power consumption metrics such as power usage effectiveness (PUE) and energy consumption per server can help to identify opportunities to reduce your energy consumption and lower your operating costs.
4. **Disaster Recovery Metrics:** Given the critical nature of the data center for the operation of the transportation company, it is important to have a robust disaster recovery plan in place. Monitoring disaster recovery metrics such as recovery point objective (RPO) and recovery time objective (RTO) can help to ensure that the disaster recovery plan is effective and that the company can quickly recover from any disruptions.

Based on these metrics provided in Table 1 for the overall BC of the company and the previous paragraph for the company’s SOC an assessment and recommendations for the BC are obtained and even a more particular case study was held within the company’s SOC. These findings will be detailed and discussed in the next section.

### 3. Results analysis

In this section, the results of this study are explored in two different situations: (1) the Pediatric ward of a public hospital, and (2) the Security Operations Center of an urban transportation company. The main goal here is to explore the data's analysis results, which is like the foundation for careful recommendations and assessment.

#### 3.1. Case study (1): Pediatric ward of a public hospital

After formulating the robustness indicators intended to evaluate the BCP of the pediatric ward, the subsequent step involved categorizing them within the BCP robustness assessment grid, as described before in section 6 of the last chapter.

The assessment grid consists of three distinct layers, namely the physical layout, internal management, and external satisfaction, and is further defined by four axes denoted as operation, commitment, support, and policy. This configuration results in a total of 12 points of intersection, referred to as "classification patches," as illustrated in Figure 15. These patches serve as the designated positions for placing the sociological indicators, offering a visual representation of their alignment. For instance, the "Operation" axis contains the indicator denoting the capacity of the pediatric ward, labeled as "Csp," situated between the physical layout and internal management layers. Conversely, the relative staff attendance rate, labeled as "Trpp," is associated with the commitment axis and situated between the internal management and external satisfaction layers. In a nutshell, this relationship can be conveyed as follows:

- $Trpp = O_{IM-ES} = (\text{Internal management, External satisfaction})_{\text{Commitment}}$
- $Csp = O_{PL-IM} = (\text{Physical layout, Internal management})_{\text{Operation}}$

Following this approach, all of the indicators and the classification patches can be assigned and represented as shown in Figure 31.

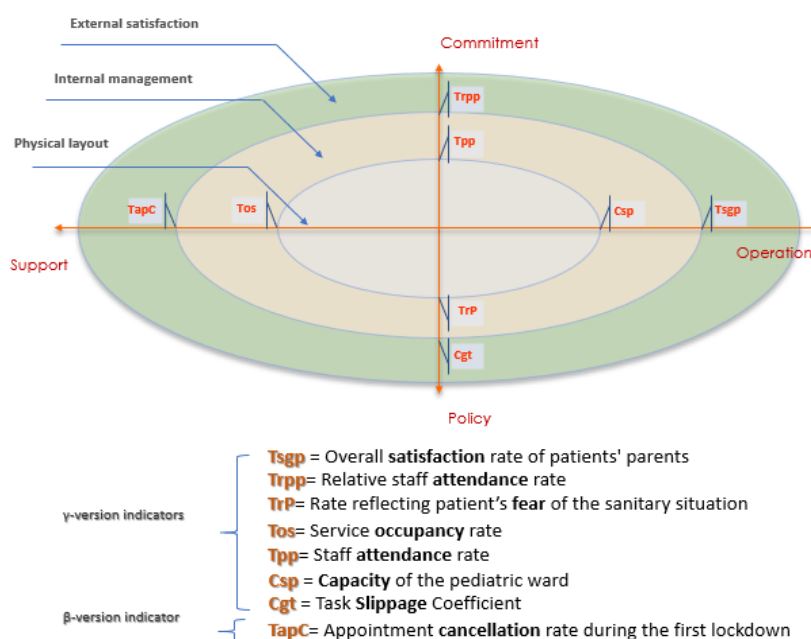


Figure 31. The classification of the sociological robustness indicators in the assessment grid

Whereas the robustness indicators, explained in 2.1 of this chapter, helped with assessing the pediatric ward's BC. Further data analysis and visualization performed on Tableau (a data visualization tool) led to obtaining the most impacted patient's along with staff's sociological profiles. In fact, three interactive dashboards were created for the patients including:

1. Dashboard 1: Economic situation | Domiciliation (see Figure 32 below)
2. Dashboard 2: Social situation | Domiciliation
3. Dashboard 3: Professional situation | Domiciliation

While:

**Social situation = f(number of children, level of education | impression % at service)**

**Economic situation = f(income (situation/values) | impression % at service)**

**Professional situation = f(employment/income status | impression % at service)**

And “|” stands for “filtered by”.

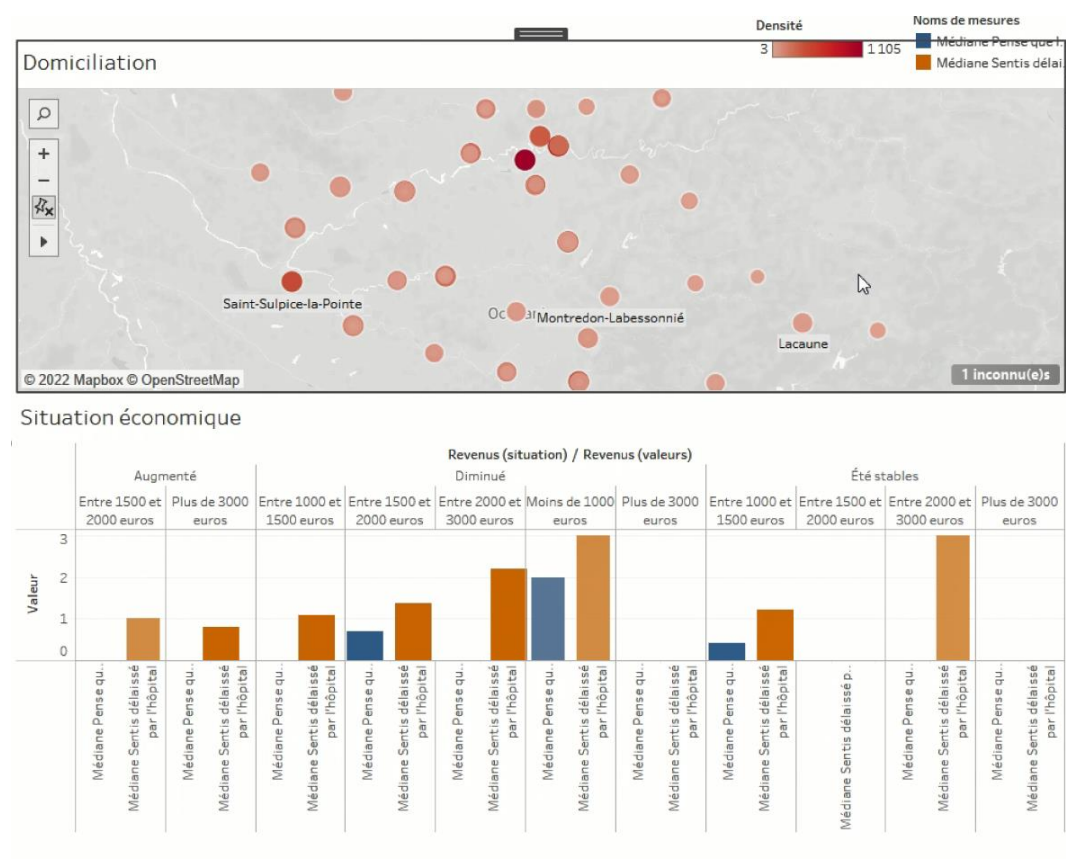


Figure 32. Example of an interactive dashboard created filtering results based on Economic situation | Domiciliation

In fact, these dashboards reflect the following:

1. **Economic Situation | Domiciliation:** This situation refers to the economic well-being of the patients and staff, and how it relates to their place of residence or domiciliation. The economic situation could involve factors such as income levels, financial stability, and access to resources. By examining this situation in relation to domiciliation, the study likely aimed to

understand whether there is a correlation between economic status and where individuals live. For example, it explores whether people with higher incomes tend to live in certain areas or if there's a disparity in economic conditions based on geographic locations.

**2. Social Situation | Domiciliation:** The social situation pertains to the social aspects of patients' and staff members' lives, and it is considered in conjunction with domiciliation, or where they reside. This could encompass factors like family size (number of children), education levels, and the overall impression percentage at the service (which could indicate their level of satisfaction or well-being). The study likely sought to uncover any patterns or relationships between these social variables and the places people call home. It reveals insights such as whether individuals with higher education levels tend to live in certain neighborhoods or if family size influences the overall impression of the pediatric ward's services.

**3. Professional Situation | Domiciliation:** The professional situation involves the employment or income status of patients and staff members, considered alongside their domiciliation. This situation explores how people's work-related factors interact with where they live. The study could analyze whether employment status or income levels have any bearing on the geographic locations of individuals. It also investigates whether job stability or income plays a role in their perception of the pediatric ward's services. For instance, the research could uncover whether those with stable employment are more satisfied with the services compared to those with uncertain job situations.

Overall, these three situations—economic, social, and professional—were studied in relation to domiciliation to gain insights into how different aspects of individuals' lives intersect and potentially impact their experiences within the pediatric ward. The use of Tableau and the creation of interactive dashboards likely helped visualize these complex relationships, allowing for a deeper understanding of the multifaceted dynamics at play.

These visualizations allow analyzing with depth the sociological profiles of the patients in order to identify the most impacted profiles within the considered scenario and accordingly its data set: first lockdown period in France due to the COVID-19 pandemic resulting in parents neglecting their children's appointments at the pediatric ward.

Table 2. The sociological profiles according to the financial situation of the parents

The most impacted profiles	The least impacted profiles	Interpretations
Those who earn less than 1000 euros/month with weakened income during the lockdown <b>[SE1+]</b>	Those who had stable incomes between 1500 and 2000 euros/month <b>[SE1-]</b>	Revenues that were stable or increasing imply less dissatisfaction (felt more neglected) with the service. This may be the result of anxiety that parents experience.
Those who earn between 2000 and 3000 euros/month with weakened income during the lockdown <b>[SE2+]</b>	Those who had incomes between 1500 and 2000 euros/month but increased during the lockdown <b>[SE1-]</b>	

Table 3. The sociological profiles according to the social situation of the parents

The most impacted profiles	The least impacted profiles	Interpretations
Employees with a BTS/DUT or a CAP/BEP <b>[SS1+]</b>	Industrialists, craftsmen or traders with a dependent child <b>[SS1-]</b>	Ordinary employees were more impacted than shopkeepers or executives. This can be explained by the state aid that has been provided to traders and/or the redundancies that have taken place. In addition, the number of children is a very important factor. It is noticeable that those who were in charge of only one child had better impressions.
Employees with more than 3 children <b>[SS2+]</b>	Middle or senior managers with a dependent child <b>[SS2-]</b>	

Table 4. The sociological profiles according to the professional situation of the parents

The most impacted profiles	The least impacted profiles	Interpretations
Employees with declining incomes <b>[SP1+]</b>	Those who were disabled or ill for a long time with stable income <b>[SP1-]</b>	The parents' income situation (stable or weakened) matters about their employment situation (unemployed, employed, on parental leave or other).
Those who were unemployed, at home and/or on parental leave with income that decreased <b>[SP2+]</b>	Those who were unemployed with incomes that increased <b>[SP2-]</b>	

Through the analysis of these profiles shown in Table 2, Table 3, and Table 4 resulting from the patient's survey data and interactive dashboards' visualization and analysis, the classification within the Figure 33 below was made.

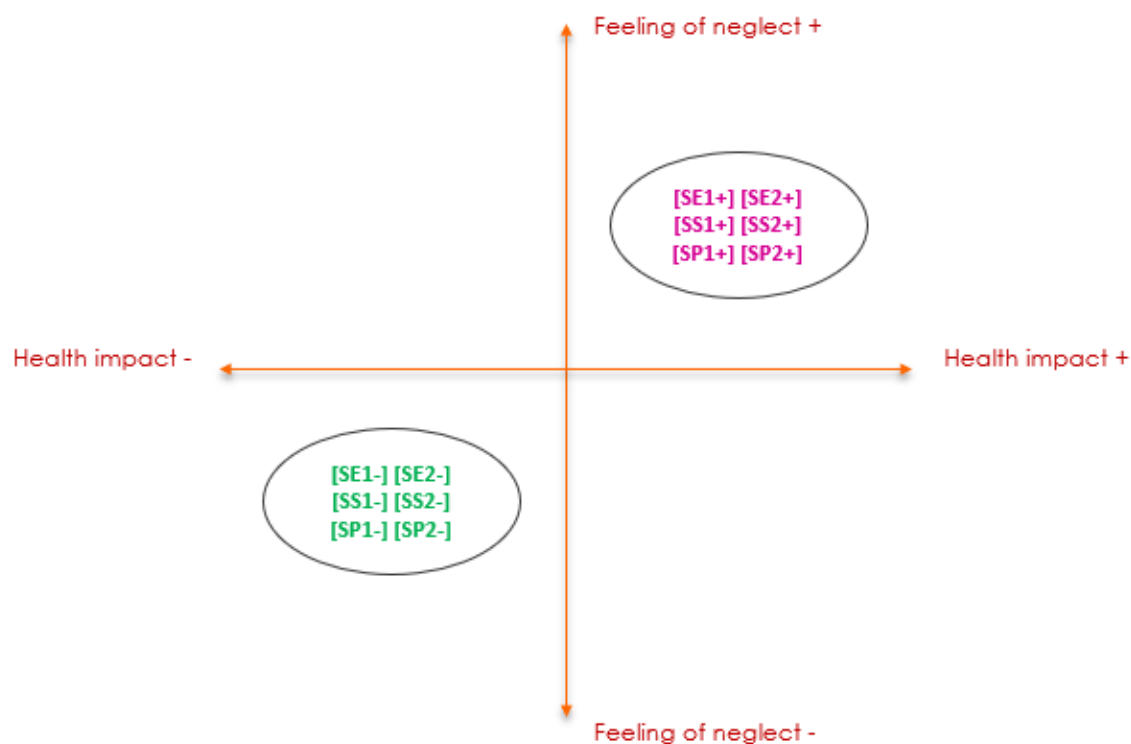


Figure 33. Patient's sociological profiles classification

The same types of analysis and visualizations were performed on the data set resulting from the staff's data set obtained through surveys, HR data requests and onsite visits for a total of 10 days. This resulted into obtaining the following sociological profiles for the pediatric ward's personnel.

1. **Personal situation = f(age/gender, absence over the three periods)**
2. **Professional situation = f(grade/seniority, absence over the three periods)**

Please note that absence\* refer to the absence only during the first lockdown period in France due to the COVID-19 pandemic while “absence over the three periods” refers to the absence during the first lockdown in France (2020), the same period in the year 2021, and the same period in the year 2019. This helps comparing the evolution of absence rates and a fair way of comparing them.

Table 5. The sociological profiles according to the personal situation of the staff

The most absent* profiles	The least absent* profiles	Interpretations
Women between 27 and 47 years old. [SPE1+]	Women/Men between 24 and 52 years old. [SPE1-]	During the first lockdown schools were closed, hence the absenteeism of women and mothers.



Table 6. The sociological profiles according to the professional situation of the staff

The most absent* profiles	The least absent* profiles	Interpretations
Non-medical degree with an average of 37 years of seniority. <b>[SPR1+]</b>	Medical degree with 6 years of seniority on average. <b>[SPR1-]</b>	Doctors, having a large share of responsibility in the activity of the service, were heavily solicited during the first confinement.

The sociological profiles of the staff as shown by Table 5 and Table 6 demonstrate these who were the most affected by the COVID-19 pandemic and thus led to their lack of engagement and absenteeism. In fact, the findings underscore the specific challenges faced by certain groups during the COVID-19 pandemic. Women aged between 27 and 47 years old experienced higher absenteeism due to the closure of schools, which increased caregiving responsibilities. Meanwhile, doctors with non-medical degrees and extensive seniority faced higher absenteeism due to their critical roles in the service's operations during the initial lockdown. These findings offer some insights into the nuanced impacts of the pandemic on various staff demographics, with emphasis on the factors contributing to engagement and absenteeism within the paediatric ward. These analyses resulting from the staff's survey data and interactive dashboards' visualization made it possible to realize the classification within the Figure 34.

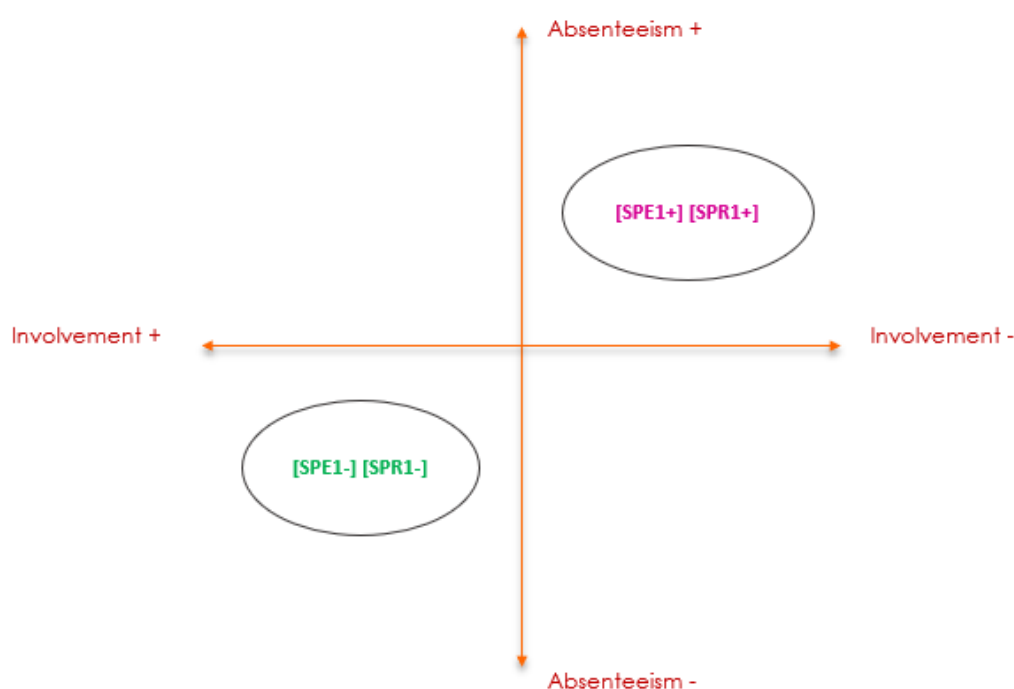


Figure 34. Personnel's sociological profiles classification

For the realization of the figure above the following hypothesis was made: absence (without compelling reason) under the conditions of the first confinement represents for this study a lack of involvement.

### 3.2. Case study (2): Security Operations Center of an urban transportation company

The metrics presented previously in 2.2 resulted in recommendations regarding the overall BC of the use-case company but also its SOC.

For instance, here are some of the evaluation and recommendations based on the BC overall evaluation for the **Infrastructure and transport characteristics BC indicators** (Figure 35):

#### Evaluation:

- The traffic intensity in Rome has been consistently high, leading to congestion on roadways. The current level of traffic intensity should be closely monitored to identify any areas of concern that require immediate attention, such as road expansions or alternative transportation solutions.
- The business inventory in Rome has experienced a loss of 44,904,084 euros. The significant loss in business inventory indicates a decline in sales or operational inefficiencies. It is crucial to identify the root causes and take corrective measures to prevent further losses
- The absence caused by injury rate for employees is 0.82% (Rome). The absence caused by injury rate provides insights into the occupational health and safety of employees. Monitoring this rate over time helps identify areas of concern and implement measures to improve workplace safety.
- The current ratio of paved roads per inhabitant is 0.00002210442047 (Rome) which is quite average. The ratio of paved roads per inhabitant indicates the level of infrastructure development and accessibility. Monitoring this ratio allows for identifying areas that require improvements to enhance transportation connectivity.
- The smoothness of ride on roads in Italy was rated as 4.4 on a national level in 2019. The quality of roads directly affects the safety and comfort of road users. Monitoring and improving road smoothness is crucial for providing a positive user experience and minimizing vehicle damage.
- Compliance with Inspection Plans (Rome): The Corps is developing operational procedures and inspection/supervisory reports in line with legislative and regulatory changes. Compliance with inspection plans is crucial for ensuring the safety and proper functioning of infrastructure. Adherence to established procedures and reporting guidelines enhances transparency and regulatory compliance.
- Supplier Due Diligence Result: No specific information provided. Supplier due diligence is essential to assess the overall risk associated with doing business with specific suppliers. A robust evaluation process minimizes operational and financial risks.
- Roadway Congestion Index (RCI): The current Roadway Congestion Index is 33% (Italy). The Roadway Congestion Index provides insights into the level of traffic congestion on roads. Monitoring this index over time helps identify congested areas and supports the implementation of traffic management strategies.
- Supply Demand Zone in Rome: Business events are taking place in Garbatella area. Understanding the supply and demand balance in relevant zones is crucial for efficient operational planning and resource allocation.

- **Railroad Lines Total Length (Rome) in km:** The total length of the railroad lines is 672 km. The length of railroad lines is an important indicator of infrastructure development and accessibility. Monitoring changes in this indicator helps assess the growth and connectivity of the transportation network.
- **Road Density:** Italy had a road density of 161.8 km per 100 sq.km. Road density reflects the level of infrastructure development and accessibility in an area. Monitoring changes in road density helps identify areas that require improvements to enhance connectivity.
- **Electricity Service Interruption Indicators (central region of Italy):** Long unannounced outages: 1.85 / Short unannounced outages: 1.73 (0 being the best indicator value that corresponds to no interruptions). The quality and reliability of the energy distribution network impact the continuity of operations. Regular assessment and maintenance are required to minimize service interruptions.

BC indicator		Description	Questions	Value
Infrastructure and transport characteristics BC indicator				
	Traffic Intensity	Traffic intensity is a measure of how much traffic is on a particular road or network. It is typically measured as the number of vehicles per unit of length or area per unit of time. The higher the traffic intensity, the more congested the road or network is.	What is the current traffic intensity on our roadways and how does it compare to previous months/years? Are there any areas of concern that we should address?	On average it takes 25min and 40s to drive 10km in Rome in 2022 (12th world rank)
	Increase Business inventory % per year	This indicator measures the rate at which a business's inventory is increasing over time. It is calculated as the percentage change in inventory levels over a certain period of time, typically one year. A high percentage increase in inventory may indicate strong sales and a growing business, while a low percentage increase may indicate weaker sales and a stagnant business.	What is the current rate of increase for our business inventory and how does it compare to previous years? Are there any concerns or areas for improvement?	a loss of 44,904,084 euros
	Road Infrastructure Quality			
		Absence caused by injury rate	What is the current absence caused by injury rate for our employees and how does it compare to previous months/years? Are there any areas of concern that we should address?	0.82% in 2022

Figure 35. An extraction of the company's overall BC indicators-questions-values sheet

### Recommendations resulting from the assessment of the metrics:

- ✓ Conduct periodic analyses of traffic volume to spot problem regions and put congestion-relief plans into action. This may entail streamlining traffic, putting in place intelligent transportation systems, and encouraging the use of different modes of transportation.
- ✓ Maintain a check on how quickly the company's inventory is growing and handle any problems or potential improvements. This could entail enhancing forecasting precision, streamlining supply chain operations, and optimizing inventory management procedures.
- ✓ Create a detailed plan for maintaining and improving the road infrastructure. To guarantee the quality and security of road networks, this should involve routine inspections, prompt repairs, and strategic investments in road improvement projects.
- ✓ Continuously monitor and evaluate the absence rate due to injury to detect trends and areas of concern. Implement employee safety measures, give adequate training and resources, and establish systems for reporting and treating injuries.

- ✓ Assess the ratio of paved roads per inhabitant and identify locations that need to be improved to improve accessibility. Collaborate with appropriate authorities to prioritize road construction projects and guarantee effective transportation connectivity.
- ✓ Implement efforts to increase the smoothness of road rides, hence improving road users' safety and comfort. This can include routine road maintenance, resurfacing, and repairing road surface defects.
- ✓ Evaluate the overall appearance of infrastructure and identify areas that need to be improved in order to retain aesthetic appeal and a positive public image. Collaborate with city planners, architects, and designers to improve the visual appeal of the company's infrastructure.
- ✓ Maintain the safety and proper operation of infrastructure by ensuring compliance with inspection plans. Inspection methods should be reviewed and updated on a regular basis, workers involved in inspections should be trained, and legislative and regulatory changes should be included into inspection protocols.
- ✓ Create a strong supplier due diligence procedure to evaluate potential vendors and mitigate operational and financial risks. Monitor supplier performance, conduct periodic reassessments, and define explicit supplier selection criteria.
- ✓ Monitor the Roadway Congestion Index on a regular basis and execute traffic management methods to address congestion issues. Develop long-term strategies for infrastructure growth and upgrades in crowded areas in collaboration with local governments and transportation agencies.
- ✓ Analyze supply and demand balance in key zones on a regular basis to enhance operational planning and resource allocation. Adjust service offerings and resources in response to market trends and fluctuations in demand.
- ✓ Assess the length of railroad lines and explore expansion or enhancements in light of population development and transportation needs. Plan and execute railroad improvements that improve connectivity and accessibility in collaboration with transportation authorities.
- ✓ Supply and demand balance should be monitored throughout time to aid in demand planning and resource allocation. Based on market dynamics, implement forecasting models and alter operational strategy.
- ✓ Assess road density on a regular basis and prioritize road network expansion and improvements in underserved areas. Develop methods for increasing road density and connectivity in collaboration with urban planning agencies.
- ✓ Invest in modernizing and improving the power distribution infrastructure to improve reliability and reduce service interruptions. Create contingency planning and communication methods to successfully handle power disruptions.

#### **Particular case study:**

To further apprehend this application case, a particular case study was considered within the company's SOC. In fact, this situation analyses how the SOC can effectively manage energy-related obstacles and adjust flexibly to guarantee the uninterrupted functioning of vital subsystems, depending on the specific events and the energy resources at hand. The objective

is to strike a harmonious balance between proficient security operations and the efficient utilization of resources when faced with demanding circumstances.

This case study was considered for the following main reasons: **(i) it explains how the BC threats/metrics can be used in a real-life scenario** (namely three), **(ii) it explores one of the most challenging disruptions for the company's SOC BC (upon the company's request), which is the regulating the consequences of energy drop**, and **(iii) it associates a real comprehension of an internal unit with external threats and goes beyond BC consultant recommendations by investigating some possible technical solutions, such as algorithm exploitation.**

The SOC is composed mainly of:

- a. **SIRES** (System for Insertion of Risky Events): This subsystem is associated with one server and likely deals with security incident reporting and management.
- b. **CCTV** (Closed-Circuit Television): Seven servers are allocated to the CCTV subsystem, which is responsible for monitoring closed-circuit television cameras across the termini station (an area where transportation modes meet, such as a railway station, bus terminal, or airport shuttles).
- c. **Anti-intrusion subsystem**: One server is dedicated to the anti-intrusion subsystem, which involves protecting the SOC's network and resources from unauthorized access attempts or cyber intrusions.
- d. **SOS Points**: The SOS points subsystem has one server and could relate to emergency response systems or critical communication points within the station.

### 1. *The considered scenario:*

The focus is on a considered scenario that involves studying the impact of a drop in the energy on the four subsystems of the SOC (Security Operations Center). The scenario is centered around making decisions about which servers to keep on or switch off based on the nature of the event and the subsystems they require. This process is referred to as dynamic adaptation.

To elaborate further, let's break down the key components of this scenario:

- I. **Drop of Energy Consequences**: The scenario assumes that there is a reduction in available energy, which could be due to power outages, system failures, or any other energy-related issues. This drop-in energy supply can potentially affect the functioning of the SOC's servers.
- II. **Four Subsystems of the SOC**: SIRES, CCTV, Anti-intrusion and SOS points.
- III. **Dynamic Adaptation**: The main objective of the scenario is to perform dynamic adaptation based on the type of event and the energy degradation level. In other words, when there is a drop in available energy, it becomes essential to decide which servers to keep operational and which ones to shut down temporarily, considering the specific requirements of the events being handled.
- IV. **Function  $f(x, y, z)$** : The decision-making process for dynamic adaptation can be represented by a function  $f(x, y, z)$ , where:
  - $x$  represents the degradation of energy (i.e., the level of energy drop) of a subsystem in case of an event. It could be measured in percentage or some other unit. In Table 7 it spans the  $[0,5]$  range.

- $y$  represents the importance rate of an event for a subsystem (e.g., the degree of relevance of having CCTV working in case of a terrorist attack) (see Table 8).
- $z$  represents the type of event (e.g., a security incident, a power outage, a cyber-attack, etc.).

By analyzing the combination of energy degradation and event type, the function  $f(x, y, z)$  can suggest the appropriate servers to keep running and those that can be turned off to optimize resource utilization while ensuring critical functions are maintained.

Overall, this scenario explores how the SOC can handle energy-related challenges and adapt dynamically to ensure the continuous operation of critical subsystems based on the nature of events and the available energy resources. The goal is to maintain a balance between effective security operations and resource efficiency during challenging situations.

## 2. *The approach*

Table 7 and Table 8 show an example of some risky events to the data center along with their respective subsystem importance rates, which have been established through heuristic methods. All of the values above in the following tables are **estimations of the parameters  $x$ ,  $y$  and  $z$** . The importance rates help deciding how to manage the energy degradation within the four subsystems of the data center.

Table 7. Degradation of energy ( $x$ ) for subsystem function by event type ( $z$ )

Subsystem function	Big strike	Terrorist Attack	Roadside fire
SIRES			
1. <b>Incident Detection and Alerting</b>	4	5	5
2. <b>Incident Triage and Categorization</b>	3	5	4
3. <b>Incident Investigation and Forensics</b>	3	5	3
4. <b>Personnel management</b>	3	5	4
CCTV			
1. <b>Camera Monitoring and Control</b>	5	5	5
2. <b>Video Analytics and Anomaly Detection</b>	4	4	3
3. <b>Camera Maintenance and Quality Assurance</b>	3	3	4
Anti-intrusion			
1. <b>Intrusion Detection System (IDS) Management</b>	4	5	3
2. <b>Threat Intelligence Analysis</b>	4	5	2
3. <b>Vulnerability Assessments and Patch Management</b>	3	4	2

<b>4. Incident Response and Containment</b>	5	5	5
SOS points			
1. <b>Emergency Alert Handling</b>	5	5	5
2. <b>Emergency Communication Management</b>	5	5	5
3. <b>Location Tracking and Incident Coordination</b>	5	5	5
4. <b>Post-Emergency Assessment and Feedback</b>	2	3	3

Table 8. Importance rates (y) by event type (z)

	Big strike	Terrorist Attack	Roadside fire
Importance rates	0.7	0.9	0.8

### 3. *Algorithm*

#### Scenario: Data Center Energy Optimization

In this scenario, the objective is to optimize energy usage in a data center during different events (e.g., big strike, terrorist attack, roadside fire) while ensuring essential functions are maintained. The algorithm utilizes a function  $f(x, y, z)$  that evaluates the combination of energy degradation (x) by event type (y) and importance rate (z). The algorithm then suggests the server that should be kept running to achieve optimal resource utilization while preserving critical operations.

#### Function Explanation:

- $f(x, y, z)$ : This subfunction takes three parameters, x (energy degradation), y (importance rate) and z (event type), and returns the decision to make for the dynamic adaptation process (i.e **the most important server to keep running**) based on the provided function table. The importance of the server is calculated by summing the values corresponding to the combination of degradation and event type from the table.
- `optimize_resource_utilization(server_list)`: This function takes a list of servers as input, where each server is represented by a dictionary containing its energy degradation (degradation) and event type (event\_type). The function iterates through the servers, calculates the importance rate using  $f(x, y)$ , and identifies the server with the highest importance rate. The identified server is the one recommended to be kept running.

#### Result Explanation:

For each scenario, a list of servers with their respective degradation and event type information is provided. The `optimize_resource_utilization` function is called for each scenario to find the server with the highest importance rate. The recommended server is the one that should be kept operational during the specific event, ensuring optimal resource utilization and the continuation of critical functions.

This algorithm (see Figure 36) evaluates the importance of each server based on energy degradation and event type and provides recommendations for keeping the most crucial servers

running during different events. It aims to strike a balance between energy efficiency and maintaining essential data center operations.

```

1  # Fixed importance rates for specific event and subsystem function combinations
2  fixed_importance_rates = {
3      ('Big strike', 'SIRES'): 0.7,
4      ('Big strike', 'CCTV'): 0.7,
5      ('Big strike', 'Anti-intrusion'): 0.7,
6      ('Big strike', 'SOS points'): 0.7,
7      # ... (add other combinations)
8  }
9
10 # Define the function f(x, y, z) using the fixed importance rates
11 def f(x, y, z):
12     return fixed_importance_rates.get((z, y), 0)
13
14 # Function to optimize resource utilization
15 def optimize_resource_utilization(server_list):
16     # Initialize variables to track the best server to keep running and its importance rate
17     best_server = None
18     best_importance = 0
19
20     # Iterate through the servers
21     for server in server_list:
22         # Extract degradation, importance rate, and event type for the server
23         degradation = server['degradation']
24         importance_rate = server['importance_rate']
25         event_type = server['event_type']
26
27         # Calculate the importance rate using function f(x, y, z)
28         importance_rate_for_server = f(degradation, event_type, importance_rate)
29
30         # Update the best server if the current server has higher importance rate
31         if importance_rate_for_server > best_importance:
32             best_importance = importance_rate_for_server
33             best_server = server
34
35     return best_server
36
37 # List of servers with degradation, importance rate, and event type information
38 server_list = [
39     {'degradation': 3, 'importance_rate': 0.7, 'event_type': 'Big strike'},
40     {'degradation': 4, 'importance_rate': 0.9, 'event_type': 'Terrorist Attack'},
41     {'degradation': 2, 'importance_rate': 0.8, 'event_type': 'Roadside fire'},
42     # Add more servers here...
43 ]
44
45 # Optimize resource utilization and get the best server to keep running
46 best_server_to_keep_running = optimize_resource_utilization(server_list)
47
48 # Print the result
49 print("Best server to keep running:", best_server_to_keep_running)

```

Figure 36. Data Center Energy Optimization Algorithm

#### 4. *Instantiations*

The algorithm identifies the server that should remain operational during each of the following events.

##### **Scenario 1: Data Center Energy Optimization During a Big Strike Event**

In this scenario, a big strike event has occurred, and the data center needs to optimize its energy usage while ensuring critical functions are maintained. The algorithm evaluates the degradation of energy and event type for each server and recommends the best server to keep running.

*# List of servers with degradation and event type information for Scenario 1*

```
server_list_scenario1 = [
```



```

{'degradation': 3, 'importance_rate': 0.7, 'event_type': 'Big strike'}, # Server A=SIRES
{'degradation': 4, 'importance_rate': 0.7, 'event_type': 'Big strike'}, # Server B=CCTV
{'degradation': 2, 'importance_rate': 0.7, 'event_type': 'Big strike'}, # Server C=SOS points
]
# Optimize resource utilization for Scenario 1
best_server_to_keep_running_scenario1 = optimize_resource_utilization(server_list_scenario1)
# Print the result for Scenario 1
print("Scenario 1: Best server to keep running:", best_server_to_keep_running_scenario1)

```

### Scenario 2: Data Center Energy Optimization During a Terrorist Attack Event

In this scenario, a terrorist attack event has occurred, and the data center needs to optimize its energy usage while ensuring critical functions are maintained.

```

# List of servers with degradation and event type information for Scenario 2
server_list_scenario2 = [
    {'degradation': 3, 'importance_rate': 0.9, 'event_type': 'Terrorist Attack'}, # Server X=SIRES
    {'degradation': 5, 'importance_rate': 0.9, 'event_type': 'Terrorist Attack'}, # Server Y=SOS points
    {'degradation': 2, 'importance_rate': 0.9, 'event_type': 'Terrorist Attack'}, # Server Z=Anti-intrusion
]
# Optimize resource utilization for Scenario 2
best_server_to_keep_running_scenario2 = optimize_resource_utilization(server_list_scenario2)
# Print the result for Scenario 2
print("Scenario 2: Best server to keep running:", best_server_to_keep_running_scenario2)

```

### Scenario 3: Data Center Energy Optimization During a Roadside Fire Event

In this scenario, a roadside fire event has occurred, and the data center needs to optimize its energy usage while ensuring critical functions are maintained.

```

# List of servers with degradation and event type information for Scenario 3
server_list_scenario3 = [
    {'degradation': 3, 'importance_rate': 0.8, 'event_type': 'Roadside fire'}, # Server P=CCTV
    {'degradation': 1, 'importance_rate': 0.8, 'event_type': 'Roadside fire'}, # Server Q=SOS points
    {'degradation': 2, 'importance_rate': 0.8, 'event_type': 'Roadside fire'}, # Server R=SIRES
]
# Optimize resource utilization for Scenario 3
best_server_to_keep_running_scenario3 = optimize_resource_utilization(server_list_scenario3)
# Print the result for Scenario 3
print("Scenario 3: Best server to keep running:", best_server_to_keep_running_scenario3)

```

In each scenario, the algorithm analyzes the degradation of energy and event type for the servers and suggests the best server to keep running to optimize resource utilization while maintaining critical functions. The output provides the specific server recommendation for each scenario.

The main discoveries from this case study can be condensed into the following categories:

- Measurement criteria for the company's BC
- A comprehensive assessment of the company's BC
- Metrics for the SOC's BC
- An evaluation of the SOC's BC
- Suggestions for metric-based evaluations for both areas

## 4. Hypothesis testing

To test the hypotheses previously explained in section 4 of Chapter II of this thesis, some use-case indicators are used as examples to illustrate the hypotheses and test them. Three indicators of each use case are used in this explanation.

### 4.1. Case Study 1: Pediatric Ward of a Public Hospital

#### 1. *Economic Situation and Absenteeism Hypothesis:*

- Hypothesis: Parents with lower incomes experienced higher absenteeism rates among the staff during the lockdown.
- Null Hypothesis (H1): There is no significant difference in absenteeism rates among staff members based on parents' income levels.
- Alternative Hypothesis (H2): Parents with lower incomes have significantly higher absenteeism rates among staff members during the lockdown.

#### 2. *Social Situation and Patient Satisfaction Hypothesis:*

- Hypothesis: Parents' social situations, such as education levels and family size, are related to their satisfaction with the pediatric ward's services.
- Null Hypothesis (H1): There is no significant relationship between parents' social situations and their satisfaction with the pediatric ward's services.
- Alternative Hypothesis (H2): Parents' social situations are significantly associated with their satisfaction levels with the pediatric ward's services.

#### 3. *Professional Situation and Parental Attendance Hypothesis:*

- Hypothesis: Parents' employment and income status are linked to their attendance of appointments for their children.
- Null Hypothesis (H1): There is no significant relationship between parents' employment and income status and their attendance of appointments for their children.
- Alternative Hypothesis (H2): Parents' employment and income status significantly affect their attendance of appointments for their children.

### 4.2. Case Study 2: Security Operations Center of an Urban Transportation Company

#### 1. *Road Density and Traffic Congestion Hypothesis:*

- Hypothesis: Areas with higher road density experience lower levels of traffic congestion.
- Null Hypothesis (H1): There is no significant correlation between road density and traffic congestion levels.
- Alternative Hypothesis (H2): Higher road density is significantly associated with lower levels of traffic congestion.

#### 2. *Supplier Due Diligence and Business Inventory Hypothesis:*

- Hypothesis: Strengthening supplier due diligence processes reduces business inventory losses.
- Null Hypothesis (H1): There is no significant impact of supplier due diligence on business inventory losses.

- Alternative Hypothesis (H2): Strengthening supplier due diligence processes leads to a significant reduction in business inventory losses.
3. ***Electricity Service Interruptions and Employee Absenteeism Hypothesis:***
- Hypothesis: Frequent electricity service interruptions are related to increased employee absenteeism rates.
  - Null Hypothesis (H1): There is no significant relationship between the frequency of electricity service interruptions and employee absenteeism rates.
  - Alternative Hypothesis (H2): Frequent electricity service interruptions lead to a significant increase in employee absenteeism rates.

These hypotheses provide a **basis for conducting statistical tests to validate or reject the stated relationships**. By collecting more data and applying appropriate statistical methods such as t-tests that determine whether there is a statistically significant difference between the means of two groups or populations (Rojewski et al., 2012), ANOVA (Analysis of Variance) which is used to determine whether there are statistically significant differences between the means of three or more groups or populations (Emerson, 2017), or correlation analysis, one can determine whether the observed patterns are statistically significant or merely coincidental (Park, 2009).

To move beyond conjecture and ascertain the true significance of these hypotheses, statistical testing is imperative. Statistical methods such as t-tests, ANOVA, and correlation analysis provide systematic frameworks to assess the observed patterns in the data. These tests allow for precise quantification of the relationships suggested by the hypotheses, helping to **distinguish between patterns that are statistically significant and those that could arise by chance**.

The accuracy of these hypotheses depends on gathering further information to support the study. The findings of the statistical tests will be more solid and compelling the more varied and comprehensive the data. The statistical techniques can produce measurable evidence that either supports or disproves the assumptions given enough data.

## 5. Discussion of the results

In this section, the focus will be on contextualizing the findings within the existing body of literature, thereby illuminating the alignment and disparities with prior research efforts. This discussion aims to provide a comprehensive understanding of how the identified patterns and insights from the case studies involving a pediatric ward in a public hospital and a Security Operations Center (SOC) of an urban transportation company resonate with, and potentially diverge from, established knowledge. This helps clarifying the significance of the contributions made by the ontological frameworks, threat generation methodologies, and data-driven indicators. Moreover, this section will offer an exploration of the implications of these findings on their respective domains and contribute to understanding the practical implications of the research outcomes.

### 5.1. Indicators and assessment grid (use-case 1):

Once computed, these indicators enable the assessment of Business Continuity Plan (BCP) robustness across the four distinct axes. As these indicators essentially encompass ratios within the 0 to 1 range, they readily facilitate gauging the extent of robustness of individual pillars within specific axes, thereby aiding the customization of business continuity strategies. Consequently, an "evaluation" or "qualification" of pivotal BCP elements becomes feasible, with the indicators critically appraising the quality of these components. Functioning as gauges of the "condition" of specific elements, essentially the four axes within the evaluation grid, these indicators provide insights into the state of affairs. The gradation of organizational facets translates to an appraisal of the influence these factors wield, directly or indirectly, over BCP, as governed by the three layers within the grid. Moreover, this also raises the prospect of devising an evaluation tool for the assessment grid itself, ensuring its efficacy and perpetuating a continuous mode of self-enhancement. such as in (Caffyn, 1999).

It's important to note that the proposed assessment tool put forth in this study is inherently adaptable and expandable. While currently composed of four axes and three layers, resulting in 12 classification patches as elucidated earlier, it can readily accommodate the integration of additional sub-factors inherent to its foundational design. Should supplementary elements be considered, the axes and layers could be augmented, consequently amplifying both the number of classification patches and the indicators necessitated for formulation and placement. For instance, drawing inspiration from the risk assessment and mapping framework proposed by (Girgin & Krausmann, 2013), which encompasses an extensible substance database detailing chemical properties, a similar approach could be adopted. By employing property estimation methodologies, such as in the estimation of 'missing property' data, the tool could identify 'missing subfactors' pertinent to BCPs and their robustness. Similarly, the research conducted by (G. Zhao et al., 2020) explores a thorough examination of risks within the agri-food supply chain, encompassing the identification of diverse risk factors, the establishment of inter-relationships among these factors, and the differentiation of pivotal risks. Through the implementation of an "estimating" framework for absent data, this proposal could be further extended, establishing a thoroughly adaptable assessment grid grounded in the qualifying factors prevalent within the BC literature.

Furthermore, it's essential to acknowledge that the illustrated case study in this thesis represents a singular application of the assessment grid, exemplified through its instantiation in a real-world context like the COVID-19 pandemic. By incorporating a reasoner and an ontology, it becomes possible to semantically generalize item attributes, thereby enhancing the decision tree's effectiveness, as evidenced in the work of (Bouza et al., 2008). This approach could be extended to the generalization of indicator sets and the potential threats they signify, aligning with the insights provided by (Daniel L. Costa et al., 2014).

This research introduces an assessment grid aimed at evaluating the robustness of Business Continuity Plans (BCPs), with its validation undertaken through the utilization of sociological indicators developed via a societal data collection and interpretation framework. While the present study focuses on one specific case and the corresponding societal data, it's important to highlight that diverse datasets can be employed to generate alternative robustness indicators. Beyond sociological data, various other data types (financial, technical, etc.) could be harnessed to assess BCP robustness, although these aspects are not explored within the scope of this work.

Furthermore, a limitation of this work, and a potential avenue for future improvement, lies in the relatively modest composition of the evaluation grid, comprising four axes (operation, policy, commitment, and support) and three layers (physical layout, internal management, and external satisfaction), thus yielding 12 classification patches. However, the inclusion of sub-factors within the robustness elements or sub-pillars of BCPs could substantially expand these axes and layers, resulting in a proliferation of classification patches. This expansion would facilitate a more refined assessment of BCP robustness, encompassing diverse types of designed robustness indicators spanning various subfactors, such as those of technical, financial, or social nature.

At this stage, the current research provides a means to assess BCP robustness exclusively through sociological indicators. In parallel, it introduces a comprehensive evaluation model applicable to a broad spectrum of indicators, which can be readily extended along the lines of its existing design framework. This opening up of possibilities lays the groundwork for three potential avenues of future research: (a) the augmentation of the BCP robustness evaluation grid, (b) its validation using dissimilar data types and consequently indicators, including technical, social network, and financial aspects, and (c) its application within an alternative use-case context of disparate nature.

## **5.2. The ontological framework and knowledge graph exploitation (use-case 2):**

The application of an ontological framework for threat generation and subsequent development of indicators, questions, and a knowledge graph within the urban transportation context provides valuable insights into business continuity assessment. However, the approach is subject to limitations. Data availability and quality could compromise the reliability of threat identification and knowledge graph construction, while subjectivity in threat generation might lead to variations in threat representation. In fact, the complexity of urban dynamics and the dynamic nature of threats might challenge the framework's ability to capture evolving risks comprehensively. The limited scope of indicators could leave gaps in the analysis, and assumption dependency may affect the accuracy of threat assessments. Real-time data integration and resource intensiveness could impact the practicality of implementation, and

generalization to different transportation systems could be constrained by contextual variations. Ethical considerations should also be addressed.

In fact, the evolution of knowledge graphs and ontologies has introduced promising prospects for enhancing AI systems and diverse sectors across society. Yet, these advancements are accompanied by noteworthy technical limitations that warrant careful consideration. Within the realm of knowledge graphs, the challenge lies in harmonizing information from disparate sources into cohesive structures, which can impede the seamless integration and holistic depiction of complex relationships. This obstacle may affect the potential benefits of knowledge graphs in delivering accurate and comprehensive insights. On the other hand, ontologies face their own set of constraints, including concerns regarding the availability and quality of data. The subjective nature of knowledge representation in ontologies can give rise to variations in interpretation, potentially compromising the reliability and precision of the information conveyed. Furthermore, the sophisticated dynamics of the real world introduce complexities in capturing evolving phenomena comprehensively, underscoring the need for adaptive approaches. To overcome these limitations and fully leverage the capabilities of knowledge graphs and ontologies, sustained efforts are required. This entails ongoing validation of data, real-time updates, active engagement with domain experts, and continuous refinement of methodologies. By addressing these challenges head-on, the potential benefits of these knowledge representation frameworks can be harnessed more effectively in AI systems and real-world contexts alike (Cheng et al., 2022; Dai et al., 2020; Hogan et al., 2021; Ji et al., 2022; Ko et al., 2021; Kong et al., 2022; C. Peng et al., 2023).

Despite these challenges, the approach offers a structured means to assess BC and guide the urban transportation company's strategic decisions, contingent upon thorough data validation, real-time updates, and ongoing collaboration with domain experts.

Moving forward, there are several avenues for future work to enhance the applicability and robustness of the ontological framework and knowledge graph-based business continuity assessment in the urban transportation domain. Firstly, expanding the scope of indicators and questions by incorporating additional data sources and diverse perspectives could provide a more comprehensive understanding of threats and vulnerabilities. Secondly, refining the ontology through continuous updates and validations against real-world events will contribute to its accuracy and relevance. Thirdly, exploring advanced data analytics techniques, such as machine learning and predictive modelling, could enable more accurate threat forecasting and proactive risk management. Fourthly, developing a scalable and adaptable framework that can accommodate different urban transportation systems and contexts would increase its versatility. Fifthly, addressing data privacy and security concerns while integrating real-time data streams could enhance the timeliness and effectiveness of threat assessments. Finally, collaborating with domain experts, stakeholders, and regulatory bodies can ensure the framework's alignment with industry standards and best practices. By considering these future directions, the ontological framework and knowledge graph approach can evolve into a better tool for sustainable and resilient urban transportation systems.

## 6. Key takeaways

Chapter IV explores the empirical testing of the proposed methodology, revealing findings that provide insights into its application. The section introduces two case studies, each designed to probe the methodology's robustness, using the multidimensional testing grid as a tool for structuring investigations. This framework enables a comprehensive examination of the cases, predicting outcomes that contribute to our understanding of Business Continuity Planning (BCP) robustness.

The chapter proceeds with the presentation of data from the two case studies. In the pediatric ward of a public hospital (Case Study 1), the interplay between sociological indicators is unveiled, providing insights into BCP robustness. Simultaneously, the Security Operations Center of an urban transportation company (Case Study 2) comes under investigation, demonstrating the methodology's adaptability to diverse domains and its capacity to analyze multidimensional data.

The results from these analyses are examined. Case Study 1 unveils sociological profiles underlying BCP robustness in a healthcare setting. Case Study 2 showcases the potential of an ontological framework and a knowledge graph to distill patterns within the urban transportation sector. Moreover, hypothesis testing is employed to validate relationships and assumptions made beforehand.

The ensuing discussion section interprets the implications of these results within the broader context of existing literature. It underscores how the methodology is manifested in the design of indicators and assessment grids, which offer tools for inspecting BCP robustness. Moreover, the exploitation of ontological frameworks and knowledge graphs reinforces the methodology's adaptability to diverse applications.

Furthermore, through a comprehensive analysis of both case studies, more insights emerge. In the pediatric ward context, the application of sociological indicators reveals nuanced patterns within economic, social, and professional situations, deeply influencing patient and staff experiences. By systematically categorizing sociological profiles, distinct vulnerable groups are identified, shedding light on the specific demographic segments most affected by crises. In the urban transportation scenario, the ontological framework's application demonstrates its potential to facilitate business continuity assessment. Nevertheless, limitations are evident, such as potential data quality issues and the subjectivity in threat identification. Furthermore, the dynamic and complex urban environment presents challenges in capturing evolving risks comprehensively. These observations demonstrate the need for continuous improvement, real-time data integration, and expert collaboration to enhance the effectiveness and practicality of the proposed approaches.

In conclusion, Chapter IV culminates with a succinct consolidation of key takeaways. The chapter underscores the significance of the empirical findings in confirming the methodological approach's efficacy. Moreover, it highlights the transferability of the approach across distinct domains and discusses its potential as a foundation for future research works. Through its exploration of case studies, data analyses, and validation techniques, Chapter IV offers insights that contribute to the discourse of BCP.



## DISCUSSION AND CONCLUSION

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The last section of this thesis is dedicated to summarizing the results, answer the research problem and its derived questions, recall and classify the contributions of this work, outline its limitations, and finally discuss the future works and perspectives.

**The main goal** of this study was to put some advancements about business continuity management. The creation of a thorough and flexible framework for the evaluation of BCP was the main issue addressed throughout this research work. The result this work offers a technique that makes use of robustness indicators and a data-driven model.

Throughout the course of this research, a literature review was conducted, uncovering critical insights into the landscape of BCM. This phase served as the foundation, allowing the identification of the existing gaps and challenges in assessing the effectiveness of BCP. One noteworthy finding was the need for a holistic perspective when evaluating these plans. Traditional methods often focused on internal processes and systems, neglecting external factors that could improve an organization's ability to withstand disruptions.

**The establishment of an efficient data collection procedure to evaluate the robustness of a business continuity plan using robustness indicators, with a focus on crucial infrastructures and organizations, was the main goal of this study.** The formation of multiple research questions (RQs) to comprehend the complex facets of BCP implementation across several domains, including environmental, technical, and organizational/human work areas, was initiated by this central topic.

The main set of study questions focused on the domains where BC principles were applied and how these principles linked to these particular areas. In essence, the RQs aimed to ascertain the degree to which **environmental, technological, and organizational/human work** areas BC is applied? In other terms, how do these areas address the BC question and/or are related with it.

Following that, the **research questions** essentially, and in a concise manner, concerned:

- **RQ1: BC and its relation with technology:** The complicated relationship between BC and technology inside companies was the focus of this study inquiry. It aimed to provide light on how technical aspects affected the formulation and implementation of BC strategies and whether technology was essential to maintaining the sustainability of crucial business processes.
- **RQ2: BC and its relation with organizational/human roles features:** At this point, the emphasis switched to the role that people play in organizations. Understanding how BC practices complemented people's jobs and responsibilities within the organizational structure was the goal of this study question. It looked at how human factors influence the efficacy of BC plans.
- **RQ3: BC and its relation with environmental features:** The environmental factors that might have an impact on BC planning were the focus of the third research question.

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It aimed to pinpoint the environmental elements and circumstances that firms considered when creating their BCPs. Natural catastrophes, geographic risks, and other external factors that can interfere with corporate operations were all included in this category.

In addressing these research questions, this work conducted some contributions to the field of BCP. Four primary contributions emerged from the research:

- **Ct1. The Data Collection Model and Approaches:** A first contribution was the creation of a generic data gathering approach that considered a variety of data kinds, including physical, sociological, and other elements. This model allowed for a thorough evaluation of BCPs, ensuring that both internal operations and outside factors were taken into consideration. The depth and scope of the evaluation process were reflected by the integration of different data collection approaches, including old and developing technologies.
- **Ct2. The BC assessment grid:** The development of a BC evaluation grid was another contribution of this work. This grid offers a methodical framework for reviewing the BCP's pillars and the elements that contribute to its resilience. It forms a methodical and uniform approach to BCP evaluation while including robustness indicators for BC as valuable insights on the efficacy of the plan.
- **Ct3. The BC ontology and knowledge graph:** A third contribution consists of the creation of a BC ontology and its transformation into a knowledge graph. This ontological framework made it easier to comprehend the connections between the BC elements and made it possible to use knowledge graphs to improve BCP assessment. It showed how a user-friendly (the graph) and generic-literature-based ontological framework could improve conventional BC evaluation techniques by addressing multiple threats and considering many organizational characteristics.
- **Ct4. The dynamic patients/staff data dashboards and the sociological profiles identification:** While it is a use-case application, this contribution analyzes sociological profiles for the staff and patients within the considered scenario (first French lockdown due the COVID-19 pandemic) and introduces dynamic data displays for them. The patient dashboards analyze their financial, social, and professional conditions, considering things like their income, level of education, and work status, and they give them real-time information about how easily they can access services during service interruptions. A fuller knowledge of how these factors affect worker availability during important events is provided by the sociological profiles of the personnel, which classify individuals based on personal and professional factors including age, gender, grade, and seniority. By adapting these visualizations of patients' and staff's sociological profiles, BCP evaluation is improved, considering the fact that it enables organizations to identify vulnerable groups among patients who may require additional support during disruptions and tailor BCPs accordingly. Additionally, it helps in pinpointing critical staffing factors, allowing organizations to address potential shortages and optimize workforce management strategies, which improves the overall resilience of critical operations.

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These contributions can be classified as it follows:

- **Technical Contributions:**

Ct1. The Data Collection Model and Approaches: This technical contribution involves the development of a generic data gathering approach that accommodates various data types, including physical and sociological data. It enables a comprehensive evaluation of BCPs by integrating both established and emerging data collection methods and technologies.

- **Conceptual Contributions:**

Ct2. The BC Assessment Grid: This contribution introduces a structured conceptual framework for evaluating BCPs. It provides a systematic approach to reviewing the pillars and elements contributing to BCP resilience, incorporating robustness indicators as conceptual tools for assessing plan robustness.

- **Semantic Contributions:**

Ct3. The BC Ontology and Knowledge Graph: A semantic contribution, this includes the creation of a BC ontology and its transformation into a knowledge graph. It enhances the semantic understanding of relationships between BC elements, offering a semantic framework to improve conventional BCP evaluation methods by considering multiple threats and organizational characteristics.

- **Applied Contributions:**

Ct4. The Dynamic Patients/Staff Data Dashboards and Sociological Profiles Identification: This applied contribution focuses on practical use cases. It delves into the analysis of sociological profiles for staff and patients during a specific scenario, using dynamic data dashboards. This application serves to enhance BCP evaluation by offering real-time insights into patients' conditions and vulnerabilities, as well as staff availability factors, contributing to the practical application of BCPs for improved resilience.

### How do these CTs contribute to the RQs stated previously?

- **Ct1. The Data Collection Model and Approaches:** Connected with **RQ1** (BC and its relationship with technology): This contribution deals directly with **RQ1**, delving into how technology influences BC strategies. The data collection model examines technological aspects, shedding light on how technology impacts the sustainability of vital business processes.
- **Ct2. The BC Assessment Grid:** Related to **RQ2** (BC and its relationship with organizational/human roles features): This contribution closely correlates with **RQ2** as it offers a structured framework for evaluating how BC practices align with human roles and responsibilities within organizations. It assesses how human factors contribute to the effectiveness of BC plans.
- **Ct3. The BC Ontology and Knowledge Graph:** Tied to **RQ1** (BC and its relationship with technology), **RQ2** (BC and its relationship with organizational/human roles features), and also **RQ3** (BC and its relationship with environmental features): This contribution has a dual significance. It addresses **RQ1** by exploring the technological facets of BC through ontology and knowledge graphs. Concurrently, it touches upon

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**RQ2** by considering how organizational and human roles are incorporated into BC planning and **RQ3** by exploring the environmental features' impact on BCP.

- **Ct4. The Dynamic Patients/Staff Data Dashboards and Sociological Profiles Identification:** Aligned with **RQ3** (BC and its relationship with environmental features): This contribution predominantly corresponds with **RQ3** as it centers on environmental factors impacting BC planning. It investigates sociological profiles related to environmental conditions and external variables such as natural disasters capable of disrupting corporate operations.

**These Cts are also linked to the hypotheses (H1, H2, and H3)** conducted previously in section 4 of Chapter II. These hypotheses with **(H1)** being “Some robustness indicators might not be significantly related to the implementation of a data-driven model for business continuity planning evaluation of a public hospital/urban transportation company”, **(H2)** being “There is a significant relationship between the implementation of a data-driven model for business continuity planning evaluation and the robustness indicators of a public hospital/urban transportation company.” Thus, it’s legit to compile some robustness indicators and link them to assessing the BCP”, and **(H3)** being “The creation of a generic metamodel, an ontology for business continuity assessment, and a knowledge graph significantly enhances the effectiveness of a data-driven model for business continuity planning evaluation in public hospitals/urban transportation companies” are linked to **Ct1, Ct2, Ct3** and **Ct4** as following:

- **Ct1 - The Data Collection Model and Approaches:**
  - 30% with H1: This indicates a moderate link with H1, suggesting that some robustness indicators might not be significantly related to the implementation of the data-driven model for BCP evaluation.
  - 70% with H2: Ct1 has a strong connection with H2, indicating that there is a significant relationship between the implementation of the data-driven model and robustness indicators in evaluating BCPs.
  - 0% with H3: There is no direct link to H3, as Ct1's focus is on the data collection model and approaches rather than the creation of an ontology.
- **Ct2 - The BC Assessment Grid:**
  - 0% with H1: Ct2 is not directly related to H1, as its main focus is on providing a systematic framework for reviewing BCP pillars and elements, rather than evaluating robustness indicators.
  - 60% with H2: Ct2 has a substantial link with H2, suggesting that the implementation of the BC assessment grid is significantly related to robustness indicators in BCP evaluation.
  - 40% with H3: Ct2 also has a notable connection with H3, indicating that the creation of a systematic BC assessment grid enhances the effectiveness of the data-driven model.
- **Ct3 - The BC Ontology and Knowledge Graph:**
  - 0% with H1: Ct3 is not directly related to H1, as its primary role is in creating a BC ontology and knowledge graph rather than evaluating robustness indicators.

- 20% with H2: Ct3 has a weaker link with H2, suggesting that the BC ontology and knowledge graph contribute, albeit to a lesser extent, to the relationship between the data-driven model and robustness indicators.
- 80% with H3: Ct3 has a strong connection with H3, indicating that the creation of a generic metamodel, ontology, and knowledge graph significantly enhances the effectiveness of the data-driven model for BCP evaluation.
- **Ct4 - Dynamic Data Dashboards and Sociological Profiles:**
  - 0% with H1: Ct4 is not directly related to H1, as its primary role is in the development of dynamic data dashboards and sociological profiles, which are distinct from robustness indicators.
  - 100% with H2: Ct4 has a strong and direct link with H2, indicating that the implementation of dynamic data dashboards and sociological profiles significantly contributes to the relationship between the data-driven model and robustness indicators in BCP evaluation.
  - 0% with H3: Ct4 is not directly related to H3, as its focus is on enhancing BCP evaluation through dynamic data displays rather than creating a BC ontology and knowledge graph.

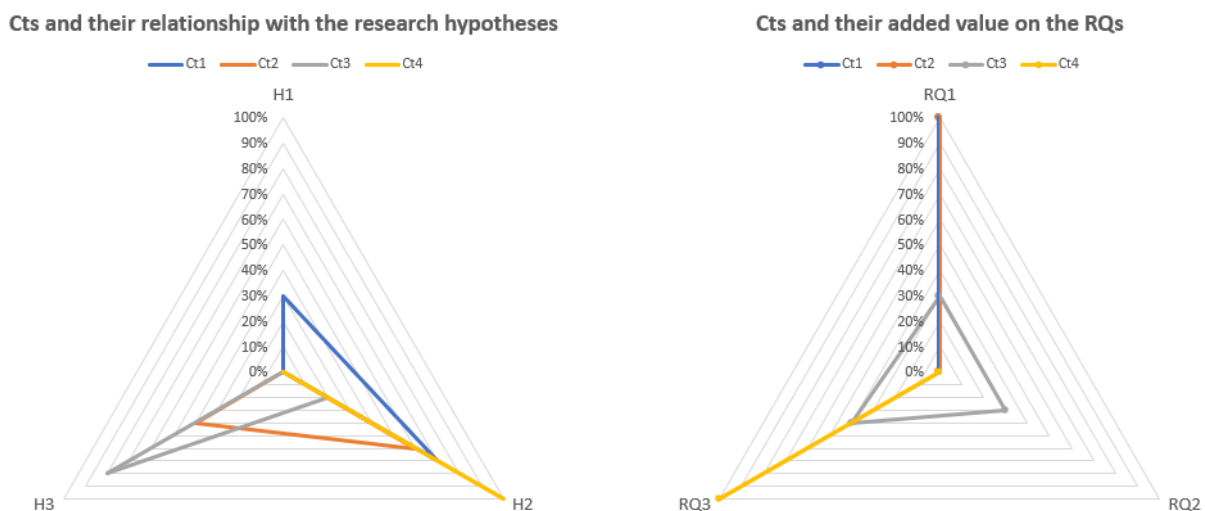


Figure 37. The contributions of this research work and their links to the RQs and (H1, H2, H3)

These contributions collectively offer insights into the intricate interplay between BC, technology, human roles, and environmental features within organizational contexts, addressing the research questions defined in this research work.

Overall, this research developed a novel data collection procedure leveraging robustness indicators to address a significant issue in the field of business continuity planning. It investigated the varied nature of BC implementation within two organizational domains. A thorough data collecting strategy, a structured BC assessment grid, and the incorporation of a BC ontology and knowledge graph were all included in the contributions. Together, these contributions improve the understanding of and assessment of BCPs by addressing new ways of identifying threats, classifying them, analyzing the organization's data and forming indicators to assess the BC's robustness. These assessment measures later on help providing recommendations and initiating the decision-making phase.

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While this research work provides the stated contributions and aims at answering the RQs expressed previously, it is still limited by many constraints such as:

- **Steering Methodology Constraints:** These boundaries emerge from the limitations imposed by the research's chosen methodology. The chosen sample and population may not wholly mirror the extensive BCP landscape, which might influence the relevance of the findings to RQ2 regarding the interplay between BC and organizational/human roles characteristics. Furthermore, the data collection methodologies could inherently possess constraints concerning data availability and completeness, potentially impacting the assessment of CT1, the Model and Approaches for Data Collection.
- **Ethical Boundaries:** Ethical considerations involve constraints linked to confidentiality and privacy. While upholding ethical guidelines is pivotal, limitations like restricted access to sensitive information may affect the comprehensiveness of findings concerning RQ3, which explores BC's association with environmental elements. Ethical concerns also have ramifications on the application of CT4, which delves into dynamic data dashboards for patients and staff and the identification of sociological profiles.
- **Conceptual Constraints:** These constraints stem from the intricacies involved in studying BCP. Diverse interpretations of BCP practices among individuals and organizations may introduce voids in the conceptualization of the research, potentially impacting the evaluation of CT2, the BC Assessment Grid. Additionally, the ontological framework might not encompass every facet or standpoint, aligning with CT3, which pertains to the BC Ontology and Knowledge Graph.
- **Practical Restrictions:** Practical limitations comprise factors such as time, resources, and technical intricacies. These limitations necessitate consideration when translating research findings into practical applications in real-world scenarios, especially concerning the pragmatic implications of CTs like CT1, CT2, and CT3, encompassing the Data Collection Model and Approaches, the BC Assessment Grid, and the BC Ontology and Knowledge Graph, respectively.

These constraints underscore the contextual intricacies influencing the research journey, interconnecting them with the research queries and contributions. They highlight the importance of a nuanced comprehension of research outcomes and their real-world applicability within the field of BCP and its associations with technology, organizational/human roles features, and environmental features.

Looking ahead, there are exciting possibilities to explore. One path involves diving deeper into using data and technology to make sure plans for business continuity are in good shape. This means using computers to help us understand these plans better and make the process of checking them faster and more accurate.

Smart computer programs can be developed to handle much of the evaluation work for these plans, thus saving time and providing a clearer understanding of their effectiveness. The impact of new technologies like the Internet of Things, blockchain, and smart machines on business continuity planning should be monitored due to the constant evolution of technology. This will ensure that plans can be adjusted to accommodate emerging technologies. Additionally, these ideas should be tested in various industries and real-life scenarios to verify their effectiveness for a wide range of users.

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In short, the future of studying business continuity planning means using data and technology in smarter ways, trying out new ideas with technology, and making sure they work in many different situations. This will allow us to better prepare for unforeseen issues and handle disruptions and emergencies once they occur.

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## APPENDICES

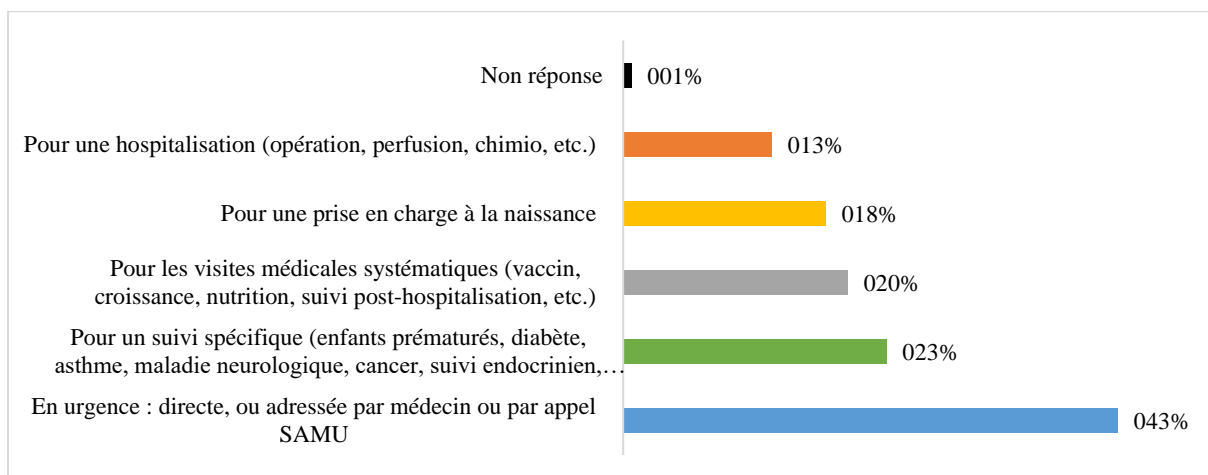
**Tab 1. En 2019-2020, vous avez fréquenté le service de pédiatrie de l'hôpital ?**

(plusieurs réponses possibles)

	Effectif	Pourcentage
En urgence : directe, ou adressée par médecin ou par appel SAMU	293	43,47%
Pour un suivi spécifique (enfants prématurés, diabète, asthme, maladie neurologique, cancer, suivi endocrinien, cardiologique, etc.)	156	23,15%
Pour les visites médicales systématiques (vaccin, croissance, nutrition, suivi post-hospitalisation, etc.)	133	19,73%
Pour une prise en charge à la naissance	120	17,80%
Pour une hospitalisation (opération, perfusion, chimio, etc.)	88	13,06%
Non réponse	5	0,74%

**Graph 1. En 2019-2020, vous avez fréquenté le service de pédiatrie de l'hôpital ?**

(plusieurs réponses possibles)

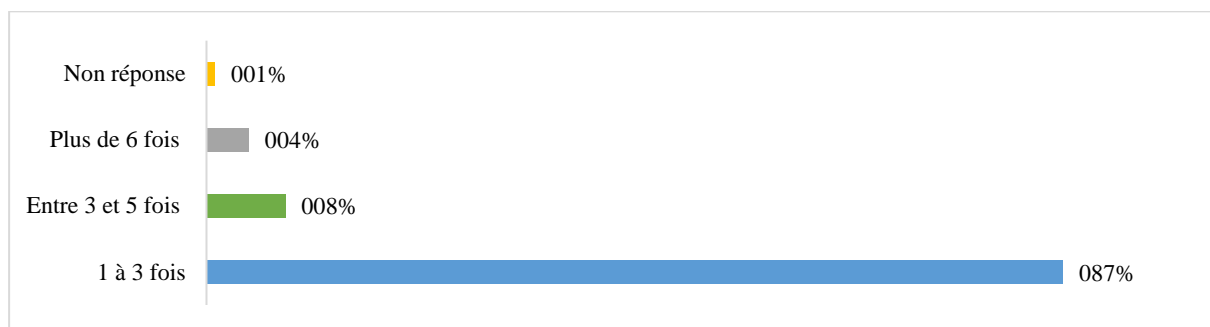


**Tab 2. Au cours des 12 derniers mois, vous vous êtes rendu dans le service de pédiatrie de l'hôpital (1 seule réponse)**

	Effectif	Pourcentage
1 à 3 fois (Q02A)	585	86,80%
Entre 3 et 5 fois (Q02B)	54	8,01%
Plus de 6 fois (Q02C)	29	4,30%

Non réponse	1	0,86%
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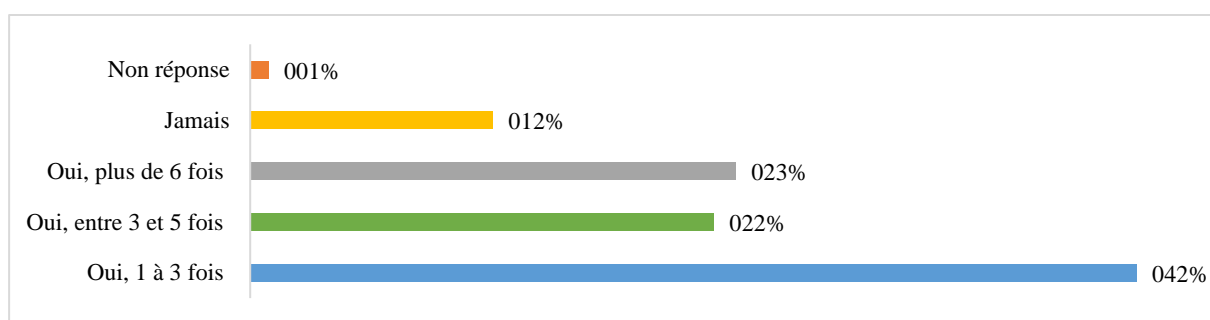
**Graph 2. Au cours des 12 derniers mois, vous vous êtes rendu dans le service de pédiatrie de l'hôpital (1 seule réponse)**



**Tab 3. Au cours des 12 derniers mois, vous vous êtes rendu pour le même enfant chez un pédiatre de ville, un médecin généraliste... (1 seule réponse)**

	Effectif	Pourcentage
Oui, 1 à 3 fois	285	42,28%
Oui, entre 3 et 5 fois	149	22,11%
Oui, plus de 6 fois	156	23,15%
Jamais	78	11,57%
Non réponse	6	0,86%

**Graph 3. Au cours des 12 derniers mois, vous vous êtes rendu dans le service de pédiatrie de l'hôpital (1 seule réponse)**



**Tab 4. Au cours des 12 derniers mois, vous vous êtes rendu pour le même enfant à la PMI ... (1 seule réponse)**

	Effectif	Pourcentage
Oui, 1 à 3 fois	34	5,04%
Oui, entre 3 et 5 fois	18	2,67%

Oui, plus de 6 fois	9	1,34%
Jamais	600	89,02%
Non réponse	13	1,93%

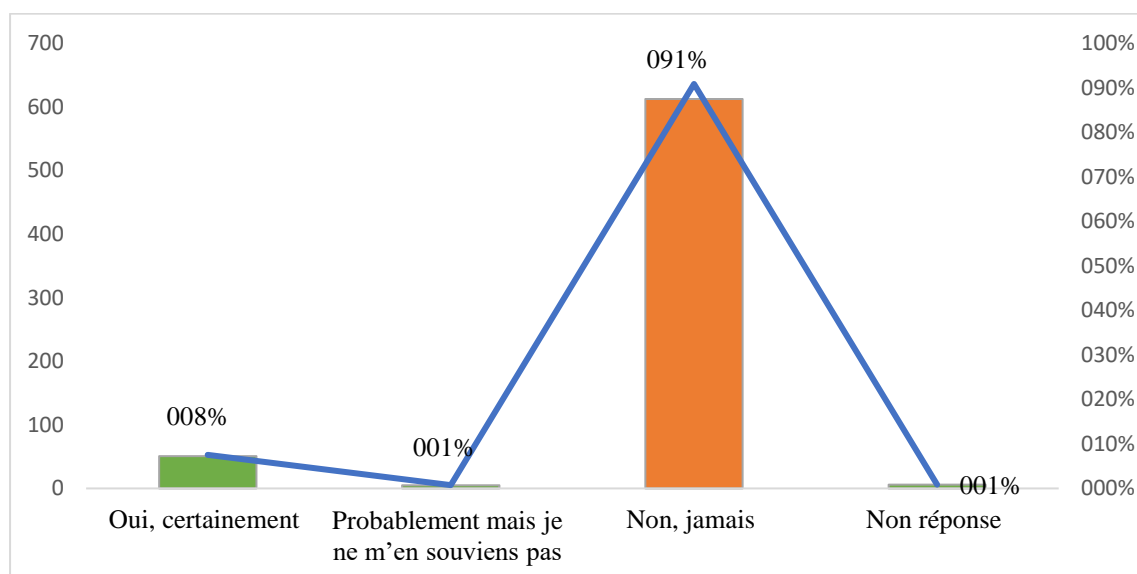
**Graph 4. Au cours des 12 derniers mois, vous vous êtes rendu dans le service de pédiatrie de l'hôpital (1 seule réponse)**



**Tab 5. En dehors des périodes de confinement, vous est-il déjà arrivé de renoncer à amener votre enfant à une consultation, un examen ou une hospitalisation ? (1 seule réponse)**

	Effectif	Pourcentage
Oui, certainement	51	7,57%
Probablement mais je ne m'en souviens pas	5	0,74%
Non, jamais	612	90,80%
Non réponse	6	0,89%

**Graph 5. En dehors des périodes de confinement, vous est-il déjà arrivé de renoncer à amener votre enfant à une consultation, un examen ou une hospitalisation ? (1 seule réponse)**







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# CONCEPTION D'UN MODELE BASE SUR LES DONNEES POUR L'EVALUATION DE LA PLANIFICATION DE LA CONTINUTE D'ACTIVITE A L'AIDE D'INDICATEURS DE ROBUSTESSE

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## Résumé :

L'importance de la planification de la continuité d'activité a été, consécutivement à l'augmentation d'événements à risque tels que les catastrophes naturelles et les pandémies, reconnue comme essentielle. Bien que cette planification soit discutable, l'évaluation de son efficacité demeure un défi. Cette thèse est consacrée aux données qui servent à évaluer différents Plans de Continuité d'Activité (PCAs) à partir de l'utilisation d'indicateurs de robustesse.

La question à laquelle tente de répondre cette thèse porte plus spécifiquement sur la conception d'un processus de collecte de données pour l'évaluation de PCAs. Afin de répondre à notre questionnement nous emprunterons un cheminement constitué de trois étapes. La première se présente sous la forme d'une revue systématique de la littérature qui permet de proposer un état de l'art de la gestion de la continuité d'activité. La seconde aborde un modèle de recueil de données qui associe différents types de données, aussi bien des facteurs physiques que sociétaux, et décrit les approches qui permettent de les collecter. Le modèle proposé intègre une approche prioritairement centrée sur les données dans l'objectif de renforcer l'exactitude et la fiabilité du processus d'évaluation. La troisième étape est consacrée à une preuve de concept (POC) effectuée pour démontrer la pertinence et l'impact des données collectées à propos de la continuité d'activité. Le POC implique de concevoir des indicateurs de robustesse pour l'évaluation des PCAs, alors que l'analyse fournit des informations précieuses à propos de l'intégralité du modèle proposé.

L'approche retenue vise à mesurer la capacité des PCAs à maintenir les fonctions critiques d'une organisation et à minimiser les perturbations dont elle souffre. L'introduction d'indicateurs de robustesse dans le cadre du processus d'évaluation représente une contribution au domaine de la gestion de la continuité d'activité. Le modèle de collecte de données proposé prend en compte différents types d'indicateurs afin de fournir une évaluation complète des PCAs. L'analyse du POC permet de simuler la faisabilité du modèle proposé et la pertinence des indicateurs de robustesse dans l'évaluation de l'efficacité des PCAs.

Les résultats de cette étude ont été traités à travers : (i) un modèle de collecte de données et ses approches, (ii) une grille d'évaluation de la continuité d'activité, (iii) une ontologie de la continuité d'activité et un graphe de connaissances, et (iv) des tableaux de bord dynamiques pour présenter les données des patients et du personnel ainsi que leurs profils sociologiques.

Ce travail ambitionne de contribuer à l'amélioration des PCAs en fournissant un modèle d'évaluation de la robustesse. Les résultats de la recherche souhaitent être utiles pour les organisations cherchant à améliorer leur planification de la continuité d'activité et leurs stratégies de gestion des risques.

**Mots clés :** Planification de la continuité d'activité, Indicateurs de robustesse, Approche axée sur les données, Gestion des risques, Préparation aux catastrophes, Évaluation de la continuité d'activité, Résilience.

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# DESIGNING A DATA-DRIVEN MODEL FOR BUSINESS CONTINUITY PLANNING EVALUATION USING ROBUSTNESS INDICATORS

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## **Abstract:**

The importance of business continuity planning (BCP) has been underscored by the increase in risky events such as natural disasters and pandemics. Despite the critical nature of these plans, evaluating their effectiveness has remained a challenge. This thesis project proposes a data-driven approach to evaluate BCPs through the use of robustness indicators.

To address the research question of how to design a data collection process for BCP evaluation, this project follows a three-step approach. Firstly, a comprehensive literature review establishes a state-of-the-art understanding of business continuity management. Secondly, a proposed data collection model considers different types of data, including physical and societal factors, and outlines approaches for their collection. The proposed model incorporates a data-driven approach to ensure accuracy and reliability in the evaluation process. This model is designed to address specific use cases within the scope of BCP, including a pediatric ward and an urban transportation company. Thirdly, a Proof of Concept (POC) analysis is conducted for these use cases to demonstrate the relevance and impact of the collected data on their respective business continuity strategies. The POC involves the design of robustness indicators for the evaluation of BCPs, and the analysis will provide valuable insights about the entire proposed model.

The proposed approach aims to measure the ability of BCPs to maintain critical business functions and minimize disruptions. Introducing robustness indicators as part of the evaluation process represents a contribution to the field of business continuity management. The proposed data collection model considers various data types to provide a comprehensive evaluation of BCPs. The POC analysis demonstrates the practical application of the proposed model and the value of robustness indicators in assessing BCP effectiveness.

The results of this study were examined through the following cases: (i) a data collection model and its approaches, (ii) a BC assessment grid, (iii) a BC ontology and a knowledge graph, and (iv) dynamic dashboards for presenting patients' and personnel's data along with their sociological profiles.

This thesis project aims at improving the BCP by providing a robustness evaluation model. The proposed model has the potential to improve the assessment of business continuity planning and improve organizations' ability to withstand disruptive events. The research findings can be reproduced within organizations seeking to enhance their business continuity planning and risk management strategies.

**Keywords:** Business continuity planning, Robustness indicators, Data-driven approach, Risk management, Disaster preparedness, Business continuity assessment, Resilience