| | |
|---|---|
| **Titre:** Title: | Applying Cognitive Mapping and Dependency Structure Modelling for Visual Analysis of Users and Stakeholders Needs: The Case of a New Application Development in the Transportation Industry |
| **Auteur:** Author: | Mitra Taraghi |
| **Date:** | 2023 |
| **Type:** | Mémoire ou thèse / Dissertation or Thesis |
| **Référence:** Citation: | Taraghi, M. (2023). Applying Cognitive Mapping and Dependency Structure Modelling for Visual Analysis of Users and Stakeholders Needs: The Case of a New Application Development in the Transportation Industry [Thèse de doctorat, Polytechnique Montréal]. PolyPublie. https://publications.polymtl.ca/53390/ |



| | |
|---|---|
| **URL de PolyPublie:** PolyPublie URL: | https://publications.polymtl.ca/53390/ |
| **Directeurs de recherche:** Advisors: | Fabiano Armellini, & Daniel Imbeau |
| **Programme:** Program: | Doctorat en génie industriel |

**POLYTECHNIQUE MONTRÉAL**

affiliée à l'Université de Montréal

# Applying cognitive mapping and dependency structure modelling for visual analysis of users and stakeholders needs: The case of a new application development in the transportation industry

**MITRA TARAGHI**

Département de mathématiques et de génie industriel

Thèse présentée en vue de l'obtention du diplôme de *Philosophiæ Doctor*

Génie industriel

Mai 2023

**POLYTECHNIQUE MONTRÉAL**

affiliée à l'Université de Montréal

Cette thèse intitulée :

# Applying cognitive mapping and dependency structure modelling for visual analysis of users and stakeholders needs: The case of a new application development in the transportation industry

présentée par **Mitra TARAGHI**

en vue de l'obtention du diplôme de *Philosophiæ Doctor*

a été dûment acceptée par le jury d'examen constitué de :

**Catherine BEAUDRY**, PhD, présidente

**Fabiano ARMELLINI**, DSc, membre et directeur de recherche

**Daniel IMBEAU**, PhD, membre et codirecteur de recherche

**Carla Cristina AMODIO ESTORILIO**, PhD, membre

**Tyson BROWNING**, PhD, membre externe

# ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and appreciation to my research supervisors Dr. Fabiano Armellini and Dr. Daniel Imbeau for their untiring support, guidance, and mentorship throughout my PhD program. Their expertise, encouragement, and constructive feedback have been invaluable in shaping my research and has helped me grow both professionally and personally. I would also like to extend my thanks to Dr. Jean-Marc Robert for believing in me and for his support during my academic journey. His guidance has been instrumental in shaping my research interests.

I would like to express my sincere appreciation to the president and members of the jury who took the time to review the thesis, I am grateful for their valuable insights.

I would like to thank the Mitacs Accelerate program and the partner organization for funding my research project. Their support has enabled me to pursue my research goals and has been critical to the success of my work. I would also like to thank Lattix directors Frank Waldman and Sean Barow for their sponsorship. Their support has been crucial in enabling me to pursue my research goals.

I would also like to extend my sincere thanks to my managers throughout the internship at the partner organization, Benjamin Sherren, Mark MacSephney, and Sébastien Malo, for their trust, collaboration, and support. Additionally, I would like to express my gratitude to all the participants in the data collection process. Without their willingness to participate, my research would not have been possible.

I am deeply grateful to my therapist, Faegheh Razzaghi, for all her effort and support in helping me cope with dark days of depression. Her guidance has been instrumental in enabling me to overcome my personal struggles and focus on my goals.

Above all, I would like to thank my husband, Ehsan Mortazavi, for his unwavering dedication and support throughout this journey. His love and encouragement have been my constant source of strength, and I am grateful for his support every step of the way.

# RÉSUMÉ

La phase initiale de création d'un nouveau produit implique la gestion des besoins des utilisateurs. Examiner les besoins des parties prenantes et des utilisateurs est important lorsqu'il s'agit de traiter de nouveaux marchés et technologies. Analyser les besoins peut être difficile lorsqu'il s'agit de systèmes complexes, c'est pourquoi des méthodes visuelles sont utilisées pour simplifier le processus en fournissant un aperçu des besoins et de leurs connexions à l'aide de différents outils. Il existe différentes méthodes d'analyse des besoins à choisir en fonction de la portée et de la complexité du projet, mais toutes ne fournissent pas un soutien efficace à la prise de décision pour les concepteurs qui doivent catégoriser et hiérarchiser les besoins. La prise de décision et la hiérarchisation efficaces sont cruciales dans le processus de développement d'un nouveau produit, il est donc important de mener une analyse approfondie des besoins et d'établir un modèle mental partagé au sein de l'équipe.

Cette thèse adopte un approche méthodologique basée sur la science de la conception composée de quatre étapes : clarification de la recherche, étude descriptive, étude prescriptive et une deuxième étude descriptive. La première étape de clarification de la recherche consistait à mener une revue systématique de la littérature pour identifier les méthodes actuelles d'analyse visuelle des besoins utilisées dans le développement de produits. La revue a permis l'identification de quinze méthodes qui ont été classées en cinq groupes en fonction de douze critères. L'analyse a révélé que les méthodes existantes avaient tendance à se concentrer sur les besoins des parties prenantes et des utilisateurs, mais pas sur les deux. Cela a présenté une opportunité d'explorer de nouvelles méthodes qui évaluent les interrelations et les dépendances entre les besoins des parties prenantes et des utilisateurs. L'étude a également révélé que les techniques de cartographie et d'analyse matricielle étaient couramment utilisées, la cartographie cognitive étant la plus ancienne et la plus puissante. En outre, la combinaison de différentes méthodes d'analyse des besoins est une tendance émergente pour les adapter à des fins plus ciblées.

La deuxième étape de la recherche visait à étudier l'utilisation de la cartographie cognitive en tant que méthode d'analyse visuelle des besoins pour une analyse efficace des besoins et de leurs interrelations. Cette étape a impliqué la réalisation d'une étude empirique avec l'équipe UX d'une entreprise de transport bien établie en Amérique du Nord. Les retours de plusieurs groupes impliqués dans l'analyse des besoins ont montré que la technique de cartographie des besoins était

perçue comme utile et pourrait être utilisée comme outil de prise de décision. L'étude a également révélé certaines exigences de l'équipe de développement de produits, ainsi que les défis associés à l'application de la cartographie cognitive en tant que méthode d'analyse des besoins. Les résultats ont suggéré que la gestion de la complexité de la carte est considérée comme un risque pouvant affecter négativement le rôle de la carte cognitive en tant qu'outil de prise de décision pour l'équipe.

Pour répondre aux défis découverts lors de la phase précédente, nous avons mené une étude prescriptive en menant une autre étude empirique. Dans cette phase, nous avons étudié l'utilisation de la matrice de structure de conception et de l'analyse de réseaux sociaux comme outils d'analyse de données pour gérer la complexité de la carte cognitive. La recherche a utilisé la cartographie cognitive comme technique d'analyse des besoins visuels, et nous avons exploré l'application de la matrice de structure de dépendance et de l'analyse de réseaux sociaux dans une étude de cas. Nous avons utilisé des mesures d'analyse de réseaux pour analyser et hiérarchiser les besoins identifiés.

La quatrième étape implique une deuxième étude descriptive qui évalue l'utilité des outils d'analyse de données utilisés dans la phase précédente. Les résultats suggèrent que la mise en place de métriques d'analyse de réseaux peut aider dans le processus d'analyse des besoins, la priorisation et la prise de décision pour les équipes de développement de produits. Ces métriques ont aidé l'équipe à évaluer l'importance des différents besoins et fonctionnalités du produit, à examiner la connexion entre les objectifs commerciaux et à estimer les effets des contraintes sur le développement du produit. L'intégration de la cartographie cognitive visuelle et des techniques ci-dessus a le potentiel de fournir aux équipes de développement de produits une meilleure compréhension de la façon dont les différents besoins sont interconnectés, ce qui conduit à des décisions plus éclairées sur le développement de produits.

# ABSTRACT

The initial phase of creating a new product involves managing user needs. Examining the needs of stakeholders and users is important when dealing with new markets and technologies. Analyzing needs can be challenging when it comes to complex systems, so visual methods are used to simplify the process by providing an overview of the needs and their connections using various tools. There are different needs analysis methods to choose from depending on the scope and complexity of the project, but not all of them provide efficient decision-making support for designers who have to categorize and prioritize needs. Effective decision-making and prioritization are crucial in the new product development process, so it is important to conduct a thorough needs analysis and establish a shared mental model within the team.

This thesis adopts a methodology approach based on the design science consisting of four stages: research clarification, descriptive study, prescriptive study, and a second descriptive study. The research clarification stage involved conducting a systematic literature review to identify current visual needs analysis methods used in product development. The review resulted in the identification of fifteen methods that were categorized into five groups based on twelve criteria. The analysis found that existing methods tended to focus on either user or stakeholder needs, but not both. This presented an opportunity to explore new methods that assess the interrelationships and dependencies between user and non-user stakeholder needs. The study also revealed that mapping and matrix analysis techniques were commonly used, with cognitive mapping being the oldest and most powerful. Furthermore, combining different needs analysis methods is an emerging trend to tailor them to more targeted purposes.

The second stage of the research aimed to investigate the use of cognitive mapping as a visual needs analysis method for efficient analysis of needs and their interrelationships. This stage involved conducting an empirical study with the UX team of a well-established transportation company in North America. The feedback from multiple groups involved in the needs analysis showed that the need mapping technique was perceived as useful and could be used as a decision support tool. The study also revealed some requirements of the product development team, as well as the challenges associated with the application of cognitive mapping as a needs analysis method. The results suggested that handling the complexity of the map is considered a risk that can negatively affect the role of the cognitive map as a decision support tool for the team.

To address the challenges discovered in the previous stage, we carried out a prescriptive study by conducting another empirical study. In this stage, we investigated the use of dependency structure modelling and social network analysis as data analysis tools to manage the complexity of the cognitive map. The research used cognitive mapping as a visual needs analysis technique, and we explored the application of dependency structure modelling and social network analysis in a case study. We employed network analysis metrics to analyze and prioritize the identified needs.

The fourth stage involves a second descriptive study that evaluates the usefulness of the data analysis tools used in the previous stage. The results suggest that the implementation of network analysis metrics can assist in the needs analysis process, prioritization, and decision-making for product development teams. These metrics aided the team in assessing the significance of different needs and product features, examining the connection between business objectives, and estimating the effects of constraints on product development. The integration of visual cognitive mapping and the above techniques has the potential to provide product development teams with a better understanding of how different needs are interrelated, leading to more informed decisions about product development.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LISTE OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| AHP | Analytic Hierarchy Process |
| CIA | Cross-Impact Analysis |
| DPB | Development Position Book |
| DSM | Dependency Structure Modelling |
| HoQ | House of Quality |
| INM | Ideation Need Mapping |
| JCR | Journal Citation Reports |
| NPD | New Product Development |
| PDP | Product Development Process |
| PSS | Product-Service System |
| QC | Quality Control |
| QFD | Quality Function Deployment |
| SJR | Scimago Journal Rank |
| SNA | Social Network Analysis |
| SLR | Systematic Literature Review |
| PRISMA | Preferred Reporting Items for Systematic Reviews and Meta Analysis |
| TQM | Total Quality Management |
| VPD | Value Proposition Design |
| UX | User Experience |
| UI | User Interface |

# LIST OF APPENDICES

# CHAPTER 1 INTRODUCTION

The rapid evolution of user needs has ushered in a new era of personalized product and service developments in the twenty-first century. To remain competitive, companies must be dynamic and innovative, offering cutting-edge products and services. This has resulted in a focus on user well-being and satisfaction in the majority of innovations (Chong & Chen, 2010).

In the context of product and service development, acquiring a comprehensive understanding of user needs is a fundamental component (Cagan & Vogel, 2002). This is particularly vital for ensuring the success of forthcoming products and services in the marketplace by precisely meeting the aforementioned needs (W. Song, 2017; von Hippel & Katz, 2002). In addition to user needs, the needs and requirements of other stakeholders can also have an impact on product development, and thus influence the overall quality of the product and the satisfaction of the users (Griffin, 2012; W. Song, 2017). While it may appear straightforward, the task of understanding needs can prove to be highly complex. Neglecting to prioritize this aspect of product and service development can result in wasted resources spent on solutions for non-existent problems or issues for which users have already found alternative solutions. Conversely, seeking input from users on their needs is not without its challenges, as their capabilities and limitations must be carefully considered to avoid potential inaccuracies (Griffin, 2012). Therefore, achieving successful innovation in the development of new products and services requires a comprehensive approach to analysis and management of needs.

Human needs can be classified into various levels ranging from low-level to high-level, whereas the former corresponds to the basic biological needs, the latter corresponds to esteem needs or self-actualization and the other needs lie in between (Bonapace, 2003; Stenmark & Lilja, 2014). The existing needs analysis models primarily concentrate on the fundamental and functional requirements while neglecting the high-level needs; and only a few models account for the interdependencies among various levels of needs (Stenmark & Lilja, 2014). Nevertheless, in the current age of technology, it is imperative to consider all levels of needs and their interdependencies to aptly manage and satisfy them, particularly when operating in new technological and market contexts (Nelson et al., 2013).

Successful innovation depends on accurately identifying, comprehensively analyzing, and interpreting present and future needs (W. Song, 2017; Stenmark & Lilja, 2014). Additionally, decision-making and prioritization play a crucial role in design, sprint planning, and conflict resolution. A decision support system that can provide the required information to facilitate prioritization is indispensable (del Sagrado & del Águila, 2021; Ghozali et al., 2019). In the decision-making process, applying a visual analysis technique, such as mapping, can enhance project managers' comprehension of decision outcomes and complexities, enabling them to make better-informed decisions (Shaw et al., 2009). Nonetheless, project managers may exhibit a preference for relying on their subjective perceptions to evaluate the needs and demands of end-users (Ittner and Larcker, 2003).

In the domain of design research, visualization of information can help with the analysis and interpretation of collected data (Basole, 2014; Eppler & Platts, 2009; Fox & Hendler, 2011). Visualization presents information in a manner that enables decision-makers to perceive patterns, connections, and correlations that might have eluded them otherwise. Emerging technologies can be deployed to visualize information in maps, graphs, diagrams, and other visual forms that expedite data analysis and interpretation (Thoring et al., 2015). These visual applications enable product development teams to grasp the problem statement and synthesize copious amounts of data in a single view (Sperano et al., 2018). Visual aids serve as external cognitive resources that facilitate problem-solving, decision-making, and conflict detection (Card et al., 1999).

## 1.1 Research Problematic and Scope

The present study defines "need" as a broad term that encompasses various types of needs expressed by individuals, such as wants, requirements, attributes, preferences, values, and more. Needs management is an integral stage in the product development process, and it involves several steps, including elicitation, analysis, and specification of the needs (Jiao & Chen, 2006). The initial stage of needs management is elicitation, which involves identifying the target population, specifying the primary requirements and nature of the needs, and determining the elicitation techniques that will be employed (Kalbach, 2016; T. Ulwick, 2013). Needs analysis involves classifying, structuring, and prioritizing the needs, while considering their impact on each other and making compromises if conflicts arise (X. Liu et al., 2008). After analysis, prioritized structured needs are transformed into functional requirements through specification, which is then used for design and development (Bayus, 2008; Harris, 2002).

Despite the extensive coverage and presentation of needs elicitation and specification in the literature, there is no commonly accepted definition for “user needs analysis”, which is an integral part of user needs management. Studies have often considered user needs analysis to be equivalent to needs identification or elicitation or defined it as the interpretation of needs into product functions. Some studies have also considered the interactions between needs – See (Agassi et al., 2018; Kukich et al., 1993; Lindgaard et al., 2006; Naseem, 2005), but no comprehensive approach exists that categorizes needs, identifies links, prioritizes needs, investigates consequences, and resolves conflicts while fully considering their interactions.

In order to achieve a comprehensive approach in needs analysis, it is also important to involve all relevant stakeholders in the process. This can foster empathy among team members and facilitate the development of a shared mental model (Sperano et al., 2018; Village et al., 2016). However, due to the complexity of user and stakeholder needs, conflicts may arise (Griffin, 2012).

Visualization of data can be an effective tool in design research for analyzing and interpreting information (Basole, 2014; Eppler & Platts, 2009; Fox & Hendler, 2011). Visual representations can highlight patterns, connections, and correlations that may not be apparent through other means, aiding decision makers in identifying areas of conflict and facilitating problem solving and decision making (Card et al., 1999).

The scope of the study is limited to the analysis phase of user needs management, and the elicitation and specification of needs are excluded. However, since the elicitation phase is a prerequisite for the analysis phase, the thesis briefly explains the elicitation phase before presenting each case.

## 1.2 Research Objectives

The primary goal of this research is to examine the use of a comprehensive needs analysis methodology that incorporates visual representation techniques and data analysis tools to thoroughly analyze interactions among different needs and support decision-making. To achieve this objective, several sub-objectives need to be addressed:

- Perform a comprehensive analysis of visual tools and techniques employed in product or service development to analyze needs and evaluate existing needs analysis methodologies.
- Explore the application of visual needs analysis techniques in an actual new product development context to analyze and represent needs in innovation projects.

– Investigate the use of advanced data analysis tools in analyzing needs using visual needs analysis technique in a product development case study.

## 1.3 Thesis Organization

Chapter 1 establishes the backdrop, research problem, and objectives of the study. A review of the literature pertaining to needs analysis in product development is presented in Chapter 2. Chapter 3 outlines the research methodology in a step-by-step manner, which is subsequently expounded upon in three distinct articles in Chapters 4 to 6. The first paper (Chapter 4) presents a systematic literature review of visual needs analysis methods currently used in needs analysis. The second paper (Chapter 5) reports on an empirical study that explores the application of cognitive mapping in a real product development project in a case study. The third paper (Chapter 6) describes an exploratory case study that investigates the use of dependency structure modelling and social network analysis in needs analysis with a cognitive approach in a new product development project. The thesis continues with a general discussion synthesizing the findings from the three articles, followed by a conclusion in Chapters 7 and 8.

# CHAPTER 2 LITERATURE REVIEW

The genesis of an industry is rooted in understanding the needs of the customer, and not in a patent, raw material, or selling skill (Levitt, 1960). Deviating from traditional business models, product designers are obligated to prioritize user satisfaction when developing new products and services, based on the users' needs (Kalbach, 2016). The adoption of a market-pull approach is expected to reduce risks, as opposed to a technology-push approach, where new products are developed with novel capabilities and subsequently examined in the market to determine whether they can solve adequate problems and meet user needs (Griffin, 2012). In the forthcoming section, we will explore the significance of needs management in the new product development process. We will first clarify the meaning of the term 'need', which is essential to manage needs effectively. Additionally, we will discuss how visual needs analysis methods can be utilized to analyze needs.

## 2.1 New Product Development

New Product Development (NPD) is a multifaceted process that begins with identifying a market opportunity and culminates in the delivery of a product or service (Ulrich & Eppinger, 2011). Although the original definition focused on new product development, it can be adapted to encompass new service development (NSD) as well. In the case of NSD, the customer is actively involved in the co-production of the service, necessitating the inclusion of a customer interface mechanism. However, a firm's NPD activities must not only concentrate on developing individual products, but also account for a steady flow of multiple ideas and products, as well as selection among them and their evolution over generations (Loch & Kavadias, 2008).

In a further step, Product-Service System (PSS) is a combination of tangible products and intangible services that are integrated to meet the final customer's needs (Tukker & Tischner, 2006). In today's world, customers are seeking comprehensive solutions rather than individual products or services. As a result, product developers must offer their users a combined package of products and services known as product-service systems or hybrid products (Mont, 2002). Manufacturers can improve their competitive advantages by providing a range of hybrid products. However, accurately analyzing the requirements for PSSs is more challenging due to the subjective, intangible, and ambiguous nature of services (W. Song et al., 2013; W. Song, 2017). For the sake of brevity, hereafter we use the word 'product' meaning product, service and product-service systems.

The product development process involves three distinct stages: predevelopment, development, and post-development. During the predevelopment stage, product planning and portfolio management activities are carried out to assess project risks and determine which projects should proceed. The development stage involves the detailed elaboration of technical, commercial, and production-related information. This is also the phase where needs analysis is performed, and requirements are translated into product specifications. The post-development stage involves monitoring product performance, conducting evaluations, and identifying opportunities for improvement or enhancement (Amaral Capaldo & Rozenfeld, 2007).

In a new product development project, users demand high-quality products and possess knowledge about their tasks, jobs, preferences, feelings, environment, and context of use. They appreciate having their viewpoints and ideas incorporated into the development of new products. Gathering information from users can aid in identifying their needs and product specifications, leading to higher quality, greater customer satisfaction, and more usable systems. However, user involvement is not limited to information gathering. Users should be involved throughout the entire development process, with a focus on understanding, analyzing, and integrating their needs and interests with those of designers to achieve consensus. (Kujala, 2008).

To date, the primary emphasis has centered on the end-users, who are responsible for the purchase, usage, and overall experience of the final product. However, by expanding our focus, we can recognize that a diverse array of stakeholders, including designers, experts, product owners, functional designers, maintenance and security staff, and even in some cases, users' family members or coworkers, engage with the product during various stages of development and use (Cagan & Vogel, 2002). As such, it is not only the end-users who possess needs and requirements that must be addressed, but also other stakeholders whose requirements and needs should not be neglected (W. Song, 2017). While the development process's primary objective is to meet the end-users' satisfaction, the satisfaction levels of other stakeholders may significantly impact the end-users' experience, customer satisfaction, and project success (Nuseibeh & Easterbrook, 2000). Despite this, the majority of research has overlooked the involvement of other stakeholders. It is essential to handle both users and stakeholders simultaneously to obtain a complete understanding of the requirements' framework in the project (W. Song et al., 2013). The following section elucidates the management of needs in the product development process.

## 2.2 Needs Management

A thorough understanding of user needs is crucial for developing successful innovations (Robert et al., 2018). However, eliciting and analyzing needs can be expensive for firms since needs possess a complex structure that conventional market research methods are unable to explore in depth (von Hippel & Katz, 2002). Moreover, prioritizing various needs is essential to differentiate the most crucial user needs and avoid overlooking critical user needs and vital product requirements (Lindgaard et al., 2006). Thus, a structured approach is imperative for needs analysis.

One study has identified four key objectives of requirements engineering, which include capturing and understanding users’ requirements, Anayzing the requirements, specifying how requirements are met, and considering time and cost constraints for requirements analysis. The primary objective is to transform users’ informal, imprecise statements into formal, standardized terms that all stakeholders can easily comprehend (Sutcliffe, 2002). In a user-centered design approach, the primary objectives of user needs analysis are to collect users’ informal statements, articulate their needs, categorize and analyze their requirements, and translate them into prototypes (Lindgaard et al., 2006). As needs encompass a broad range of requirements, combining requirements engineering/management with user needs analysis as complementary approaches can provide a more comprehensive perspective. Additionally, in "Needs Management," needs analysis is just one of the phases of needs management, and much more is required than merely analyzing needs.

User needs management entails a number of stages such as elicitation, analysis, specification, interpretation, and so forth (Jiao & Chen, 2006). Various authors have proposed different structures or hierarchies to depict the different phases of needs (or requirements) management, some of which are outlined in Table 2.1.

Table 2.1 Instances of authors' proposed models for requirements management

| | | |
|---|---|---|
| **Requirements Engineering (Sutcliffe, 2002)** | 1- To capture a complete set of requirements from users. | |
| | 2- To analyze the users' requirements accurately and understand all the implications inherent in those requirements. | |
| | 3- To specify how those requirements should be met in a design. | |
| | 4- To complete requirements analysis within acceptable constraints of time and cost. | |
| **Customer requirement management process (Jiao & Chen, 2006)** | 1- Requirement elicitation | Effective capturing and systematic elicitation of requirements, making an inventory of customer requirements. |
| | 2- Requirement analysis | Interpreting the statements of the customers into explicit requirements by means of classification, prioritization and negotiation of the customer needs. |
| | 3- Requirement specification | Defining concrete product specifications (functional requirements). |
| **Requirement Engineering (Pandey et al., 2010)** | 1- Requirement elicitation and development | 1.1- Requirement analysis |
| | | 1.2- Allocation and flow-down of requirements |
| | 2- Documentation of requirements | 2.1- Requirements identification |
| | | 2.2- Requirements specification |
| | 3- Requirements verification and validation | |
| | 4- Requirement management and planning | |
| **PSS Requirement management (W. Song, 2017)** | 1- Stakeholders' requirement elicitation | • Requirement elicitation for customer and other stakeholders. |
| | 2- Stakeholders' requirement analysis | • Requirement classification<br>• Requirement prioritization<br>• Requirement negotiation |
| | 3- Requirement specification | • Requirement transformation<br>• Prioritization of design requirements<br>• Conflict resolution of design requirements |
| | 4- Requirement forecast | • Customer preference forecast<br>• Requirement changing trend forecast |

To summarize the table, we have outlined three key stages in the needs management process: Elicitation, Analysis, and Specification. Elicitation involves identifying needs through examination of statements made by users and stakeholders. Once needs have been elicited, the analysis stage begins, which includes categorization, prioritization, and potentially resolving conflicts and evaluating consequences. The final stage, specification, involves interpreting needs into functional requirements and specific product specifications, which may require further conflict resolution. This process is further illustrated in Chapter 5, Section 5.2.1.

Before delving into the various stages of needs management, it is essential to provide a clear definition of the term ‘need’. The subsequent sections will then explore the different stages involved in managing needs.

### 2.2.1 Definition of Need

In the literature, the term ‘need’ lacks a precise and standardized definition. However, firms aiming to achieve success in product development and innovation must define the needs originating from diverse sources with utmost precision (Bayus, 2008; A. W. Ulwick & Bettencourt, 2008). Various terms such as ‘needs’, ‘requirements’, ‘demands’, ‘wants’, ‘objectives’ and so on, have been used to denote ‘needs’ in the literature, often interchangeably and with similar meanings (Bayus, 2008). Here, we aim to examine the different definitions of needs and related concepts.

Table 2.2 presents a non-exhaustive list that outlines the wide range of definitions for needs and associated terms with a number of examples from the literature.

Table 2.2 Instances of the definition of different types of needs

| Term | Definition | Reference |
|---|---|---|
| **Need** | "A description, in the customer's own words, of the benefit to be fulfilled product or service." | (Griffin & Hauser, 1993, p. 4) |
| | The lack of something necessary for survival or well-being. | (Antonides & van Raaij, 1998) |
| | "What a customer **wants**; a lack of something; future–oriented; lead to *tomorrow's* dominant product; long term. Cannot always be recognized or described by the customer." | (Shillito, 2001, p. 12) |
| | "**Problems** that hinder users in achieving their **goals** in a specified context of use." | (Kujala, 2008, p. 460) |
| | "The **problems** that a product or service solves and the **functions** it performs." | (Griffin, 2012, p. 216) |
| **Requirement** | "What a system is supposed to do, as opposed to how it should do it" | (Yu, 1997, p. 8) |
| | "Engineering technical solution to meet a customer's **need**." | (Shillito, 2001, p. 12) |
| | "a **property** that must be exhibited in order to solve some **problem** in the real world" | (Abran et al., 2004, pp. 1–3) |
| | "a statement that identifies a **capability** or **function** that is needed by a system in order to satisfy its customer's **needs**" | (Bahill & Dean, 2009, p. 205) |
| | "A requirement is a feature of a design object that is necessary to achieve a **goal**." | (Ralph, 2013, p. 294) |
| **Want** | "Something a person believes will fulfill a known **need**; short-term orientation and temporary; quick fix. Can quickly change with time." | (Shillito, 2001, p. 12) |
| | "Something that a customer believes will satisfy an acknowledged **need**, is short-term and temporary, and can be altered based on psychosocial cues." | (Bayus, 2008, p. 119) |
| **Problems** | "**Wants** or **needs** stated in negative terms." | (Shillito, 2001, p. 12) |
| **Product characteristics** | "The **properties** of a product that are relevant to consumer choice; characteristics are quantitative in nature, can be measured objectively, and are universal." | (Bayus, 2008, p. 119) |
| **Product attributes** | "Product attributes are more abstract and generally fewer in number than product **characteristics** and are based on the perceptual dimensions that consumers use to make purchase decisions." | (Bayus, 2008, p. 119) |
| **Specifications (Specs)** | "Quantitative engineering measure, limit, or range developed to meet a **requirement**." | (Shillito, 2001, p. 12) |

User needs are concerned with the desired outcome of a product or service, while attributes, features, requirements, and specifications pertain to the specific means by which a need is met (Bayus, 2008). General needs are typically stable over time, and undergo gradual and insubstantial changes (Griffin, 2012). In contrast, wants are typically more temporary and are susceptible to influence from psychosocial factors such as advertising and social recommendations. Needs comprise both utilitarian and hedonic benefits, while wants are associated with the perceived means by which a particular need can be fulfilled (Bayus, 2008).

This section's definitions of different types of needs suggest that they have similar meanings, and there may be some overlap. Despite the subtle distinctions, the report will use the term "Need" to encompass all levels and types of user needs, wants, and requirements for the sake of clarity and simplicity.

### 2.2.2 Eliciting the Needs

In User Needs Management, the initial phase involves eliciting the needs, which is a crucial step. The term 'elicitation' is preferred over other terms such as identification and capturing, as it underscores the fact that needs and requirements cannot be simply collected (Nuseibeh & Easterbrook, 2000). To elicit appropriate needs for new products, a structured process is required (T. Ulwick, 2013). This process should consider the individuals from whom needs are being elicited, as well as the key factors, such as goals, jobs to be done, and outcomes that must be taken into account. Furthermore, it is important to determine appropriate methods for eliciting these needs (Kalbach, 2016).

***From Whom to Obtain the Needs.*** When determining stakeholders to participate in the needs elicitation process, it is critical to consider the goal of understanding the diverse needs of the entire target market, including individuals with varying characteristics (Griffin, 2012). The process of needs elicitation is a collaborative effort involving multiple stakeholders who interact with each other to expand the scope of needs identification (W. Song, 2017).

The elicitation process requires the participation of individuals with varying levels of expertise, including emergent users and experts. All individuals involved in the product development process, such as designers, analysts, developers, business experts, and end-users, should be considered in the needs elicitation process (Schirr, 2012; Stenseke & Soderholm, 2017). This is not only necessary to develop a successful innovative product by considering the needs and requirements of all stakeholders, but also to leverage the tacit knowledge of all stakeholders to elicit more needs. Moreover, since many users are unaware of future technologies and not all stakeholders can imagine future circumstances, involving individuals with professional experiences and knowledge in the elicitation and analysis of future needs can help generate representations of the future. This, in turn, can improve the quality and quantity of identified needs and product requirements (Brangier et al., 2018).

***Examples of Methods used for Eliciting the needs.*** The primary methods used for eliciting the needs in the literature could be divided into some categories (Blasco et al., 2016; Nuseibeh & Easterbrook, 2000). They include traditional techniques (e.g.  interviews, questionnaires, surveys and observation), group techniques (e.g., brainstorming, focus groups, workshops and Delphi technique.), cognitive techniques (e.g., laddering, card sorting and repertory grids) and contextual techniques (e.g., ethnography and contextual inquiry). Selecting an elicitation technique depends on the available resources, the nature of the product and the types of information being sought (Nuseibeh & Easterbrook, 2000). For instance, the observation method is well-suited to uncover process-related needs, while in-depth interviews are more effective in obtaining detailed information. Although many firms tend to use a combination of these methods, not all can afford to do so (Griffin, 2012).

### 2.2.3 Analyzing the Needs

Needs analysis is an indispensable component of user needs management, and it involves the classification of needs into various levels and categories, as well as the investigation of interactions between different needs at different levels (W. Song, 2017). The subsequent step involves prioritizing the needs to facilitate decision-making and compromise, given that requirements and needs can be complex and conflicting, and designers may not be able to consider all needs due to resource constraints (Griffin, 2012). To assign relative importance weights, stakeholders or designers' preferences, and the extent to which each need affects other needs are considered (W. Song et al., 2013). The importance weights represent the future share of customer value, making the results of the analysis a useful tool for managers and product developers to make informed decisions about investments (Borgianni & Rotini, 2015). It is also essential to assess the consequences of considering each need during product design and to use importance weights to facilitate trade-offs in case of conflicts between user needs or product requirements. However, sometimes, designers can resolve conflicts without degrading any of the user needs (W. Song, 2017), but compromise is often necessary as a perfect product that satisfies all needs does not exist (Griffin, 2012).

Inclusive design requires an in-depth needs analysis, which is critical not only for product and service design but also for creating knowledge that can help designers meet the needs of those often excluded from product use (Coleman, 2001). Additionally, it is useful for building risk management frameworks to select devices that match the needs and wishes of particular individuals, and setting benchmarks for device procurement outcomes (Fuhrer et al., 2003; Monk et al., 2006). Previous studies often jump from user, activity, or product analysis to requirements without considering user needs in detail (Blasco et al., 2016).

While various needs elicitation methods exist, most studies consider needs analysis equivalent to needs identification, and there is no needs analysis method that covers all the stages of the analysis process. Therefore, further research is necessary to develop inclusive analysis methods that meet all the requirements of the needs analysis process. However, some studies have used Kano model, mapping techniques, Analytical Hierarchy Process (AHP), neural network and so forth to analyze needs (W. Song, 2017).

### 2.2.4 Specifying the Needs

Once user needs have been analyzed, the next step in the product development process is to convert these needs into functional requirements (Harris, 2002). However, users and stakeholders often have difficulty expressing their needs in a way that is suitable for designers to use in creating design specifications. Thus, it is necessary to standardize all user needs and stakeholders' statements by interpreting them into technical information. Designers must also be aware of potential conflicts that may arise among the final functional requirements (Bayus, 2008; W. Song, 2017).

***Shared Mental Model.*** In order to facilitate the specification process, it is important for all members of the product development team to share a common understanding of user needs and requirements. A shared mental model helps to support a safe and effective exchange of information between users, stakeholders, and designers (Nelson et al., 2013). However, few studies have examined the methods by which designers can construct and utilize mental models of users.

One way to establish a shared mental model is to involve stakeholders in the process. Mapping techniques that engage stakeholders in conversations and idea exchange can help to create a shared understanding (Kalbach, 2016). Through negotiation and collaboration, a shared cognition can be developed among group members (Fiore & Schooler, 2004).

It is worth emphasizing the importance of a shared mental model, as its absence may result in designers and analysts relying on their subjective knowledge to translate user needs into functional requirements. This subjectivity can lead to inaccuracies and imprecision in the final design specifications, ultimately resulting in lower user satisfaction (W. Song, 2017).

***Examples of Methods used for Requirement Specification.*** Quality Function Deployment (QFD) is a widely used method for requirement specification, and is considered a key process of Total Quality Management (TQM) (Akao, 1997). The QFD approach involves using "houses of quality" matrices to convert user needs into product functions, with input from different groups of stakeholders (Griffin & Hauser, 1993).

In a different approach, "innovation toolkits" were utilized to allow users to customize products according to their needs and to innovate. This approach facilitated the identification of functional requirements by directly engaging users, without the need to translate their needs into standard technical statements. As a result, designers could better understand user requirements and mental models (Franke & von Hippel, 2003). Although this method could be somewhat effective to satisfy the customers, it may not be applicable to all product development projects.

Alternatively, conversion methods such as fuzzy mapping, artificial neural networks, and data mining have been used to specify user needs (W. Song, 2017). These methods allow for the transformation of qualitative user needs into quantitative requirements, facilitating the specification process.

Overall, a variety of approaches and methods exist for requirement specification in product development. These methods should be carefully considered based on the specific needs of each project to ensure the most effective outcomes.

Managing needs is a complex undertaking and involves numerous challenges, as noted by various authors (Jiao & Chen, 2006; Lindgaard et al., 2006). These challenges include:

- Ambiguity and imprecision of needs and requirements due to their linguistic origins.

- Conflicting needs and requirements that require trade-offs.
- Lack of clarity regarding the starting and stopping points of the analysis.
- Difficulty in transferring requirement information effectively from users to other stakeholders due to differences in terminology.
- Difficulty in estimating the consequences of different requirements.
- Challenges in dynamically updating the needs analysis process as needs and requirements change over time.
- Difficulty in converting all user needs into standard product requirements that designers can fully comprehend.

In the upcoming section, we will discuss how visualization techniques can aid in the analysis of needs.

## 2.3 Application of Visualization

The utilization of interactive visual representations of data has been shown to enhance cognitive processes. In scientific computing, the primary objective is to gain insight rather than just numerical results. Similarly, the purpose of visualization is to gain insights, rather than just display images. Therefore, visualization techniques can play a crucial role in facilitating decision-making and explanations (Card et al., 1999).

In the domain of new product development, various visualization techniques have been employed, particularly in the analysis of needs. Diagrams and maps are among the most commonly used visualization techniques that provide valuable insights into product development and innovation (Kalbach, 2016). Consequently, our study aims to examine the use of mapping techniques in this context.

### 2.3.1 Mapping Techniques

The term "Map" typically refers to illustrations of the spatial location of objects, while "diagram" refers to illustrations of how objects function (Kalbach, 2016). However, these terms are often used interchangeably (Kalbach, 2016). In this study, we use the term “Map” to refer to all types of maps and diagrams.

Maps and visual representations are powerful tools for exploring different aspects of complex issues at various scales. They provide a comprehensive view of the situation and facilitate the analysis of large amounts of information (Iliinsky & Steele, 2011). For instance, a 20-page interview can be depicted in a single large map (Daley, 2004). Maps also serve as external memory, distributing cognition among individuals and reducing the mental workload required for decision-making and negotiation (Card, 2004). The ultimate goal of mapping techniques is to achieve coherence in system design and conception, provide balanced perceptions, and involve all stakeholders in the development process. Furthermore, mapping techniques allow stakeholders to select the aspects and dimensions to include in the map, providing an opportunity for them to contribute to the overall development process (Kalbach, 2016).

***Different Types of Maps.*** Various structures, such as chronological, hierarchical, spatial, and network, can serve as the basis for developing maps and diagrams. Additionally, the purpose of the task or project can determine the type of map to be used (Kalbach, 2016). The following are some examples of commonly used mapping techniques - Table 2.3.

Table 2.3 Examples of mapping techniques (Kalbach, 2016)

| **Title** | **Description** |
|---|---|
| *Service blueprints* | Service blueprints, which depict the service offerings, share similarities with flowcharts. They are among the earliest formal techniques. |
| *Customer journey maps* | One of the most widely used diagram types is the customer journey map, which portrays an individual’s experiences as a customer of an organization. These maps generally encompass various touchpoints, and explore different options available to the customer. |
| *Experience maps* | Experience maps are a relatively novel technique, depicting the experiences of individuals within a particular domain. Although they share similarities with service blueprints and customer journey maps, there are some notable differences. |
| *Mental model diagrams* | Mental model diagrams delve into human behaviors, emotions, and motivations, and are usually extensive diagrams that can cover an entire wall. |
| *Cognitive maps* | It refers to a depiction of the perceived connections between the elements present in a specific environment. These cognitive constructs are based on past experiences, beliefs, and assumptions. |

***Benefits of Mapping techniques.*** Numerous advantages of mapping techniques have been cited by authors. The following is a summary of these benefits.

- Maps offer a comprehensive perspective and can help eliminate organizational silos (Kalbach, 2016; Kaplan, 2016).
- They can exhibit multiple facets of an issue concurrently, with information presented at different layers and levels. Moreover, they take into account the interactions among various elements of the map (Quispe Vilchez & Pow-Sang Portillo, 2019; Swan, 1997).
- They offer a graphical summary of experiences, presenting a composite view (Kalbach, 2016).
- Maps are powerful analytical tools due to their capacity to display vast amounts of information in a single view. The comprehensive visualization enables the identification of areas for improvement and innovation (Kalbach, 2016; Sperano et al., 2018).
- Visualization techniques can aid in transforming implicit concepts and tacit knowledge into tangible representations (Kalbach, 2016; Sperano et al., 2018; Village et al., 2016).
- Maps and diagrams are compelling and quite easy to understand (Kalbach, 2016).
- Maps are typically created by groups of individuals, which implies that they are based on research and generate valid outcomes (Village et al., 2013).
- The engagement of various stakeholders fosters empathy among them and facilitates the creation of a shared mental model (Sperano et al., 2018; Village et al., 2016).
- Maps offer flexibility and can be updated dynamically, enabling teams to monitor changes (Swan, 1997; Village et al., 2016).
- Mapping techniques aid managers in thinking critically, broadly, and deeply, and can serve as decision support (Shaw et al., 2009; Sperano et al., 2018; Village et al., 2016).

### 2.3.2 Examples of Mapping Techniques in Needs Analysis

Visualization and mapping techniques have been recognized as effective approaches to analyze user needs and expand the strategic aperture of organizations (Kalbach, 2016). These techniques can also guide product innovation by representing future experiences. One of the first need mapping approaches is ‘attribute-value mapping’, where product attributes are linked to user values in a bottom-up approach (Goldenberg et al., 2009).

‘Customer roadmapping’ is a planning process that assists in identifying and selecting critical customer needs to be incorporated as input in the product development and innovation process. This method utilizes customer needs’ dimensions as a reference point for collecting user needs and as a starting point for building a hierarchy of user needs specific to a particular context or customer segment (Bayus, 2008).

Customer journey maps are graphical representations that depict the relationship between the user and the organization, product, or brand over time, from the user’s perspective (Grocki, 2014). This method considers multiple aspects, such as timeline, emotions, touch points, moments of truth, personas, and characters, and can represent the future state of a product (Kalbach, 2016).

Ideation Need Mapping (INM) method is a comprehensive approach to need mapping. It focuses on high-level needs of the users and aims to meet or even exceed various product attributes to achieve a high level of customer satisfaction. The INM methodology prepares a map of user needs where different levels of needs are situated on a vertical axis and linked together according to the way they influence each other (Stenmark & Lilja, 2014). Although the INM methodology could support the identification of new attributes that could enhance the related values for the customer in the future, it could be criticized for not suggesting a clear way of obtaining new attributes according to user values and high-level needs and for the lack of prioritization of the needs.

Cross-Impact Analysis (CIA) is a matrix-based method used to interpret and analyze constructs obtained from repertory grid methodology (Süner & Erbuğ, 2016), which is a type of interviewing method used to elicit personal constructs (Eden & Jones, 1984). CIA provides a holistic view of the impact of various dimensions, allowing the effects of potential changes to be observed. The matrix lists personal constructs (dimensions) both vertically and horizontally, with the impact and dependency levels of each dimension shown in the cells based on participant statements’ frequencies. The dimensions can be categorized based on their impact/dependency levels using a cross-impact chart or visually displayed in a network structure, showing the impact/dependency levels through shapes, links, and colors (Kuru, 2015; Süner & Erbuğ, 2016). While CIA can evaluate the interrelationships (impacts/dependencies) among dimensions, its use is limited to specific elicitation methods. Moreover, it does not support the analysis of dimensions in multiple levels.

The Value Proposition Design (VPD) canvas is a business design tool that employs visual representations to address user needs. It comprises two main blocks of “value proposition” and “client segment” and facilitates the generation of minimum viable product propositions quickly and easily. VPD supports both the technology-push and market-pull approaches in product development and enhances the accuracy of value propositions by posing questions that identify users’ jobs, pain points, and desired gains, as well as painkillers, gain creators, and the key product features associated with the product (Osterwalder et al., 2014; Pelicioni et al., 2017). However, VPD canvas has certain limitations. It only highlights two main categories of needs, making it more suitable for providing a general overview of the product development project. It may not be useful for complex products that require a focus on details. All needs are categorized on one level, making it difficult to examine the details of each category and investigate product functions’ details. Additionally, the technique does not provide a structured method for prioritizing needs, relying mainly on designers’ subjective judgments. Furthermore, stakeholders other than users and designers are not involved in the needs analysis process.

Recent research emphasizes the importance of understanding users’ mental models to empathize with them and comprehend their needs. However, there is currently no consensus on how to capture and accurately represent users’ mental models for use in the product development process. This issue has been addressed in several studies (Delugach et al., 2016; Kang et al., 2015; Olaverri-Monreal & Gonçalves, 2014; Young, 2008). Thus, there is a need for a more advanced needs analysis method that can act as a decision support system, facilitate the understanding of users’ mental models, encourage team empathy (Gibbons, 2019), and provide designers with the input they require.

Given the significance of needs analysis in product development, the need for an effective analysis method is crucial. Needs analysis is expected to help design teams understand the mental model of the target group, make informed decisions, and plan for future steps. Despite various methods proposed by researchers, there is still no comprehensive needs analysis method that can support design teams in prioritization and decision-making. Visualization and mapping techniques have advantages in information representation, data analysis, and decision support, making them useful tools for needs analysis in innovation projects (Kalbach, 2016; Shaw et al., 2009). Cognitive mapping has been utilized in organizations to assist in planning and decision-making (Village et al., 2016). It enables the representation of the network of needs, identification of their interrelationships, categories, and clusters (Castellano & Del Gobbo, 2018; Village et al., 2013). However, it is still necessary to present the various user and stakeholder categories, as well as the consequences and priorities of their needs.

In the following chapter, the methodology employed in this study will be presented.

# CHAPTER 3 METHODOLOGY OVERVIEW

This chapter outlines the research methodology adopted to accomplish the objectives and respond to the research questions proposed previously in section 1.2.

## 3.1 Design Research Methodology

In this thesis, we employed the design research methodology (DRM) to explore the application of cognitive mapping as a visual needs analysis technique in product development. DRM is a widely recognized approach to formulating and verifying models and theories pertaining to the field of design. This methodology also includes the development and validation of knowledge, methods, and tools based on these models and theories. Ultimately, the goal of DRM is to enhance the quality of design by increasing the likelihood of producing a successful product (Blessing & Chakrabarti, 2009). DRM utilizes the term “design” to encompass all activities associated with the process of developing an artefact, from the conception of product ideas or technologies to the comprehensive documentation required to materialize the product and meet the perceived needs of users and other stakeholders. The overall objective is to improve design with the intention of having an impact on both theory and practice (Blessing & Chakrabarti, 2009).

DRM consists of four stages of research clarification, first descriptive study, prescriptive study and the second descriptive study (Blessing, 1995). We have covered the four steps in three papers presented in the next three chapters. The DRM framework is presented in Figure 3.1.

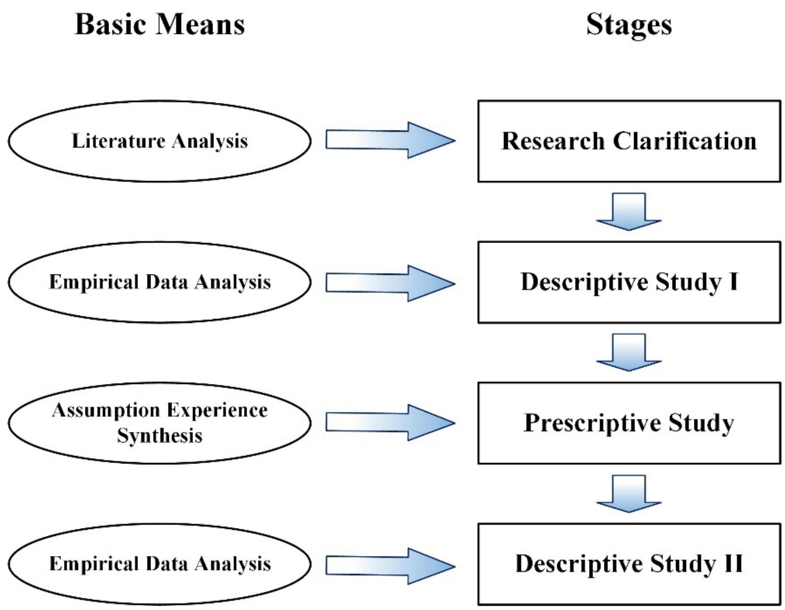



Figure 3.1 DRM Framework - Adapted from (Blessing & Chakrabarti, 2009) with permission

## 3.2 Research Structure

The subsequent explanation outlines how the three papers are structured to cover the four stages of DRM and address their intersections. In a stepwise depiction, Figure 3.2 provides an overview of the methodology adopted in the thesis.

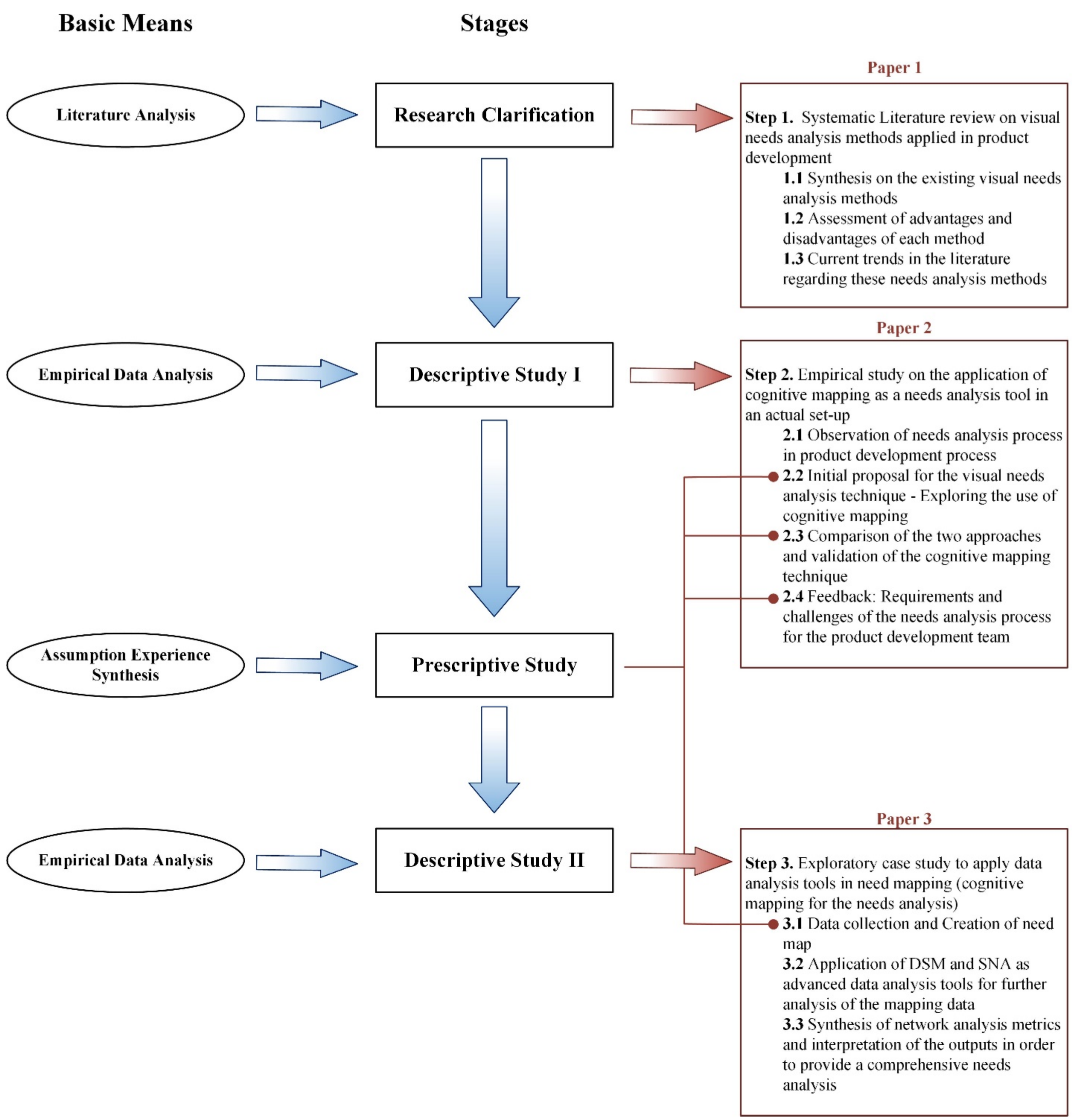



Figure 3.2 Breakdown of thesis methodology in the three articles

### 3.2.1 Research Clarification

For research clarification, a literature review is often conducted to provide an initial understanding of the current and desired state of the research problem for the purpose of clarification. To this end, a systematic literature review was conducted using the preferred reporting items for systematic reviews and meta-analysis (PRISMA) methodology, aimed at providing a comprehensive overview of various visual needs analysis techniques. The results of this analysis provided valuable insights into the main characteristics of different needs analysis methods employed in product development. Furthermore, our review facilitated identification of recent trends and complementarities between needs analysis methods, enabling us to explore possible combinations for optimal outcomes.

### 3.2.2 First Descriptive Study

In the second stage, the initial description of the situation is further elaborated using the findings of the literature review. Researchers then analyze empirical data to gain a deeper understanding of the current situation. The findings of the SLR showed that cognitive mapping is one of the most inclusive visual needs analysis techniques, offering the potential for simultaneous user and stakeholder engagement and facilitating identification of interconnections among needs (Quispe Vilchez & Pow-Sang Portillo, 2019; Villafranca & Loureiro, 2013). In the subsequent phase, we sought to examine the feasibility of applying cognitive mapping as a needs analysis technique in a product development process, through an empirical investigation. Our primary objective was twofold: firstly, to propose this novel visual analysis technique, and secondly, to gain insights into the challenges and obtain feedback from the product development team. The validation of cognitive mapping by the participants underscored its efficacy in providing a comprehensive needs analysis, including the prioritization of needs and offering decision support for the team. This step also facilitated identification of the key requirements and challenges for an optimal needs analysis method.

### 3.2.3 Prescriptive Study

A prescriptive study builds on the descriptive study to deepen researchers' understanding of the current situation, allowing them to refine and expand upon their initial portrayal of the ideal situation. This portrayal reflects their view of how addressing one or more factors of the current state could lead to the realization of the desired, improved state. During this stage, potential solutions for enhancing the current situation are explored. In the third paper, our objective was to investigate the use of data analysis tools (such as dependency structure modelling and social network analysis) in managing the intricacies of cognitive mapping in an exploratory case study within the context of new product development, with the aim of addressing the challenges identified in a previous study.

### 3.2.4 Second Descriptive Study

The final stage involves conducting an empirical study to evaluate the effectiveness of the proposed methodology. Based on the feedback gathered from the empirical study, the results of the exploratory case study revealed that by utilizing DSM and SNA, researchers were able to compute network analysis metrics that aided in interpreting the map and prioritizing needs. The use of data analysis tools enhanced the flexibility of the needs analysis method to better suit the needs of the product development team. This comprehensive approach is particularly beneficial in managing the complexity of the cognitive map as a visual needs analysis method, empowering the product development team to make informed decisions and plan ahead by leveraging a variety of metrics tailored to their specific requirements.

The following three chapters will detail the three papers that constitute the primary phases of the methodology used in this thesis.

## 3.3 Methodology of Articles

The subsequent sections present a comprehensive overview of the methodology employed in each article, outlining the specific steps taken to address the research questions posed in each study.

### 3.3.1 Article 1

The primary aim of the systematic literature review (SLR) is to thoroughly examine the visual tools and techniques utilized in the development of products or services for needs analysis. The SLR seeks to address the following research questions:

1. What visual/mapping techniques are currently employed in product/service development for needs analysis?
2. What are the strengths and weaknesses of these techniques and how can they complement one another?
3. What are the emerging trends in the literature concerning the utilization of these needs analysis techniques?

Through the SLR, we aim to provide a comprehensive analysis of the existing literature to enhance our understanding of the visual approaches used in needs analysis within the context of product or service development.

**Systematic Literature Review Strategy**

To conduct a comprehensive literature review on visual needs analysis methods, we adhered to the PRISMA methodology (Moher et al., 2009; Page et al., 2021). The articles examined were sourced from highly reputable academic databases, namely "Compendex" and "Web of Science." Given the novelty of the review topic and to ensure inclusivity, no specific time criteria were applied during the search process. However, the language requirement was limited to English, and only journal and conference articles were considered.

The initial search yielded 206 results from Compendex and 158 results from Web of Science. After removing 68 duplicates, the remaining 296 articles underwent abstract review. At this stage, 218 articles were excluded, leaving us with a pool of 78 papers for full-text review. Following the thorough evaluation of the full-text articles, 59 papers were further excluded, resulting in a final selection of 19 papers.

To ensure the comprehensiveness of the review, an additional 9 articles were included through snowball sampling. In total, the review encompassed 28 articles, providing a robust foundation for our analysis of visual needs analysis methods.

**Data Analysis**

To conduct a mixed-method systematic review, encompassing both quantitative and qualitative analyses, a two-stage data analysis approach was employed. The first stage involved a descriptive analysis utilizing graphs and tables to examine the data. In the second stage, a qualitative analysis was conducted, involving the categorization of visual representations for needs analyses, a comparative assessment of needs analysis methods, exploration of their complementary nature, and trend analyses.

To ensure a comprehensive evaluation, three academic experts with over 10 years of experience in new product development, needs analysis, and user experience dedicated a total of five hours to rate each method. The rating process was based on comparison criteria derived from the existing literature. Each method was assessed and assigned a rating indicating its level of capability: strong, medium, or poor, for each criterion. In cases where there was an odd number of voters, the dominant vote was selected to determine the final rating. Notably, no conflicts arose during this process, as there were no instances where all three options were selected simultaneously.

### 3.3.2 Article 2

The methodology for this research project was inspired by combining action research (Coughlan & Coghlan, 2002) with intervention research (Fraser & Galinsky, 2010). The researcher is involved in action to analyze the needs for an actual project, while the possibility of using cognitive mapping as a needs analysis technique is investigated. This allows for an analogy of what is currently being done to analyze the needs and what the researcher proposes in order to provide a comparison of the two approaches and draw conclusions based on the benefits of each method. The methodology can be divided into three steps.

1. Observation of current needs analysis procedure
2. Exploring the use of cognitive mapping
3. Comparison of the two approaches and validation of the cognitive mapping technique

**1- Observation of the Current Needs Analysis Procedure**

The researcher participated in the needs elicitation and analysis process facilitated by the UX team. Based on the documentation provided by the UX team, their research methodology for user experience (UX) encompasses four distinct phases: Definition, Execution, Synthesis, and Output.

**Participation in Needs Analysis**

The researcher was engaged in 10 meetings, which focused on various aspects such as workshop planning, interview script development, protocol establishment, participant recruitment, and the documentation of research questions for interviews and data processing. Additionally, three workshops were conducted to facilitate coordination with project stakeholders, generate innovative research questions, and arrange subsequent sessions for data analysis. The researcher was present throughout all 15 interview sessions with stakeholders and users, actively participating and observing the process.

**2- Mapping Exercise**

The process of needs elicitation remained consistent for this step, with the needs identified by the UX team being utilized for the subsequent mapping exercise. The mapping phase commenced after the Definition and Execution phases. The key steps involved in the mapping process are outlined below. Initially, the needs were grouped into different categories (such as user needs, business requirements, project manager's needs, constraints, etc.) and assigned levels (high, medium, and low). Two UX/UI designers conducted a one-hour session to cluster the needs. Subsequently, a mapping workshop lasting approximately three hours was conducted by a group comprising one UX/UI designer, two users, and two stakeholders. The ACV (Attribute/low-level, Consequence/medium-level, Value/high-level) structure was utilized to identify the levels (Costa et al., 2004; Leão & Mello, 2007). In the ACV structure, Attributes lead to Consequences, and Consequences lead to Values. However, this does not imply that there are no horizontal connections between nodes. The interrelationships and connections among user needs were identified based on the Means-End Theory, allowing for the generation of nodes and links without limitations. Any two nodes could be connected by a link if the former leads to (i.e., is the means to) the latter (the end) (Reynolds & Gutman, 1988; Woodall, 2013).

The resulting need map consists of nodes and links, where nodes represent the identified needs, and links denote the relationships between each pair of nodes. For instance, if node A is connected to node B by a link, it signifies that A has an impact on or leads to B. Nodes can be distinguished using different colors or shapes to represent various groups. Each pair of nodes can be connected by a link. However, since the ACV structure dictates that attributes lead to consequences and consequences lead to values, the directionality of the links must be respected. In other words, the only limitation for the connections (links) is that a value cannot lead to a consequence, and a consequence cannot lead to an attribute. It is important to note that, for simplicity, all the links are assumed to be of the same type. Once the nodes (i.e., needs/requirements from users/stakeholders) are established, the connections between the needs are identified using arrows. Following the completion of the map, the analysis phase commences. The count of links and nodes in the network provides an estimate of the importance of each node. Prioritization of the needs is based on their connections and impact on higher-level values. Once the map is finalized, its structure should be validated by the users and/or project stakeholders who participated in the mapping workshop. In this paper, the cognitive mapping technique utilizing an ACV structure for needs analysis is referred to as "need mapping."

**3- Comparison and Validation**

The primary outcome of both needs analysis approaches is the generation of a prioritized list of needs. In this step, the lists of prioritizations, the criteria for prioritization, and the advantages and disadvantages of each approach are compared. The comparison is based on how well the approaches fulfill the requirements for needs analysis in the project, such as stakeholder involvement, prioritization criteria, result validity, and potential benefits of the analysis method.

To validate the need mapping technique, after completing the need mapping exercise, the methodology and benefits of the technique were presented to the UX team and other groups engaged in needs analysis activities, consisting of 23 participants. These participants were asked to provide their opinions on the outcomes of the need mapping technique and the value it brings to the team. An online survey, administered by the UX team of the partner organization, was used for this purpose. The potential benefits of the maps and cognitive mapping, as extracted from the literature, were presented. The respondents were then asked to rate their level of agreement with each statement using a five-point Likert scale, including options such as "Strongly agree," "Somewhat agree," "Neither agree nor disagree," "Somewhat disagree," and "Strongly disagree."

### 3.3.3 Article 3

In order to explore the application of DSM (Design Structure Matrix) and SNA (Social Network Analysis) in a real-world context of product development, we conducted a case study as part of our research methodology (Yin, 2018). Case studies are considered comprehensive approaches for investigating data analysis in a needs analysis process within a practical setting (Stoecker, 1991; Yin & Davis, 2007).

The case study was conducted in a large transportation company in North America, specifically for a software development project. The project involved a diverse team consisting of business sponsors, product managers, functional designers, business analysts, UX designers, quality assessment specialists, and developers. This team collaborated to elicit needs, document requirements, plan design sprints, prepare user stories, and develop and test the product.

The research methodology for this case study was divided into three main steps: 1) data collection, 2) application of cognitive mapping, and 3) data analysis using DSM and SNA.

**Data Collection**

The initial stage of the needs analysis process involves gathering data pertaining to the needs and requirements expressed by users and project stakeholders. Eliciting needs is a fundamental component of the broader needs management process, which encompasses the elicitation, analysis, and specification of needs (Nuseibeh & Easterbrook, 2000; A. W. Ulwick, 2013).

In this research, the primary focus lies in the analysis of needs, with the elicited needs serving as the input for the analysis process. We obtained secondary data from various sources such as release planning documents, business planning documents, and functional design documents. These sources provided us with approximately 100 needs of different types. Once the data was collected, we proceeded to clean, sort, and cluster the needs into multiple groups in preparation for the subsequent cognitive mapping exercise.

**Cognitive Mapping**

In the initial phase, the needs were organized into distinct groups, including user needs (such as usability issues, specific feature requests, and user complaints), business objectives (such as safety, operational efficiency, environmental impact, and cost reduction), project manager's needs (involving planning, scheduling, and resource management), product attributes (such as search functions, menus, and displayed information), and constraints (including technical and time constraints). This clustering task was carried out by the researcher during a two-hour session.

Following the clustering step, the mapping process was conducted through a series of four workshops. The workshops involved a group consisting of a business analyst and three product owners, all of whom played crucial roles in the product development process, particularly in planning, prioritization, and decision-making. The researcher acted as the facilitator in all four workshops, which were held consistently with the participation of all members.

To create a collective map and establish the network structure, the participants were instructed to connect the nodes within the structure using links. Originally planned as a single four-hour session, the workshop had to be divided into four separate one-hour sessions due to the limited availability of participants and their geographic locations. The workshops were conducted using Microsoft Teams and Mural as virtual collaboration tools.

At the conclusion of the fourth session, the participants were asked to validate the group map, ensuring that it aligned with the team's shared understanding.

**Data Analysis Using DSM and SNA**

To examine the network of needs using DSM (Design Structure Matrix) and SNA (Social Network Analysis), several metrics and measures can be employed, including centrality, density, and brokerage, among others (Browning, 2016). However, in this particular paper, we focused on a select few measures that aligned with the project's characteristics and the context of its application. These specific measures will be detailed in the subsequent subsection.

**Network Structure and Adjacency Matrix**

A network consists of nodes or vertices, which are interconnected by edges. Mathematically, a network can be represented using an adjacency matrix called A. In its simplest form, the adjacency matrix is a symmetric matrix of size $n \times n$, where n represents the number of vertices in the network.

After constructing the adjacency matrix based on the network derived from mapping workshops, Lattix 2022.0, an advanced tool for analyzing DSMs (Jamal & Jenkins, 2006), was used for further analysis. Lattix allowed us to calculate degree centrality (indegree and outdegree), as well as impact and dependency rates for the nodes (needs) (Lattix CP, 2023). Furthermore, social network analysis (SNA) provides centrality measures like betweenness and eigenvector centrality, which can enhance the analysis of needs (Freeman, 2002; M. E. Newman, 2008). Network analysis tools such as Gephi 0.10 were employed in this paper to facilitate the calculation of these measures and visually represent the network. Chapter 6 presents the theory and computation of metrics for network analysis.

# CHAPTER 4 ARTICLE 1: APPLICATION OF VISUAL NEEDS ANALYSIS METHODS IN PRODUCT DEVELOPMENT – A SYSTEMATIC REVIEW

Mitra Taraghi, Fabiano Armellini, Ehsan Mortazavi, Daniel Imbeau

Article submitted to the Journal of Requirements Engineering on January 27, 2023 (under review).

## Abstract

One of the first steps in new product development is user needs management. When addressing new markets and technologies, analyzing users and stakeholders' needs is an essential part of the process. Needs analysis can be an especially difficult task for complex systems. Visual methods aim to manage the complexity by providing an overview of the needs and their connections using different tools found in the literature. To facilitate the use of the visual needs analysis methods that are applied in product development, we have conducted a systematic literature review using the preferred reporting items for systematic reviews and meta-analysis (PRISMA) methodology. Through this review of 28 journal articles and conference papers, 15 visual needs analysis methods were identified and organized into five categories. Next, a framework was established based on 12 criteria to compare the identified methods and provide a general overview of the visual needs analysis methods studied. The classification system used was validated by experts in the field. Our findings indicate that existing methods focus either on user or non-user stakeholder needs, but never both. Therefore, our review presents an opportunity to explore new methods that assess the interrelationships and dependencies between user and non-user stakeholder needs. Our results show that among recent trends, the most commonly used visual analysis tool applied mapping and matrix analysis techniques, among which cognitive mapping was the oldest and most powerful. Moreover, we identified an emerging trend in which different needs analysis methods are combined to tailor them to more targeted purposes.

**Keywords:** Needs analysis, Visual methods, Need mapping, New Product Development

## 4.1 Introduction

Needs analysis is an essential part of new product development. The design and development of a project starts with the elicitation and analysis of the needs of the user and the requirements of the business (Ferrari et al., 2022). Although terms such as needs, requirements, objectives, values and wants may have different definitions, they all share the commonality of being rooted in the concept of needing or seeking something (Bayus, 2008; Shillito, 2001). In this paper, we use the word “need” as an umbrella term that encompasses all varieties of necessities, including requirements, wants, preferences, values, desires and so on. Needs analysis is part of a more complex process of need management and it involves the categorization and prioritization of the needs as well as the identification of consequences and making compromises (W. Song, 2017). The needs of users and other stakeholders can be highly complex, making it likely that different needs conflict with each other (Griffin, 2012).

The errors that occur in needs identification and validation in the critical, early stages of product development are more consequential than those that occur during later stages. One of the main causes of error is the lack of communication and understanding among users and project stakeholders (i.e., business experts, business analysts, developers, managers, etc.). These issues can be addressed by investigating needs early in the process (Oran et al., 2021; Quispe Vilchez & Pow-Sang Portillo, 2019).

Decision-making and prioritization are required in design, sprint planning and conflict resolution. A decision support system should provide the necessary information to help with prioritization (del Sagrado & del Águila, 2021; Ghozali et al., 2019). When making a decision, a visual needs analysis method (e.g., a mapping technique) can help project managers gain a better understanding of the outcomes of a decision and the associated complexities, allowing them to make more informed decisions (Shaw et al., 2009). Strategic planning is another area that relies on the analysis and prioritization of needs from users and project stakeholders. However, managers may be inclined to use their own subjective perceptions to judge the needs and requirements of customers or end users. They may therefore neglect to apply a needs analysis process for information that might seem evident to them (Ittner and Larcker, 2003).

In design research, visualizing the information can aid the analysis and interpretation of the collected data (Basole, 2014; Eppler & Platts, 2009; Fox & Hendler, 2011). A visual representation presents information in the form of visually discernable patterns, connections, and correlations for decision makers who may not be able to recognize them otherwise. New technologies can be used to visualize information and facilitate the analysis and interpretation of the data through maps, graphs, diagrams, and other visuals (Thoring et al., 2015). These visual applications allow users to understand the problem statement and synthesize a vast amount of data in a single view (Sperano et al., 2018). The visual aids play the role of external cognition, facilitating problem solving and decision making, and identifying points of conflict (Card et al., 1999).

The main objective of our study is to conduct a comprehensive analysis of the visual tools and techniques applied in product or service development for the purpose of analyzing needs and investigating current needs analysis methods. The research questions are as follows:

1. What are the current visual/mapping techniques used in product/service development for needs analysis?
2. What are the advantages and disadvantages of these techniques and how might they complement each other?
3. What are the trends in the literature regarding the use of these needs analysis techniques?

Studies have investigated needs analysis (sometimes called requirements analysis) methods in different domains for the purpose of product or service development (Quispe Vilchez & Pow-Sang Portillo, 2019; W. Song, 2017). However, these studies focus on a specific methodology or specific context. In this paper, we aim to provide a general review on all visual needs analysis methods that have been reported in the literature for the development of products, services, and product-service systems. The following section explains the research method used to conduct the systematic literature review. The ensuing sections provide the results of the literature review, including the descriptive and qualitative analyses of the results, and the discussion.

## 4.2 Research Method

### 4.2.1 Planning the review

As the focus of the research project was visual methods for needs analysis, we aimed to use the main concepts (visual, needs, analysis) as the keywords in our search. However, this combination of keywords was too general and produced an extremely large number of results. We therefore collected keywords from relevant papers and clustered them over multiple iterations to generate the best conceptual framework and search strategy. This step was reviewed by a subject-specialist librarian. We found that we needed to address users and stakeholders separately, as "needs analysis" is a general term that can be applied to too many cases. We also applied the proximity functions in the query to yield more relevant results (see Appendix B). The conceptual framework is presented in Figure 4.1.

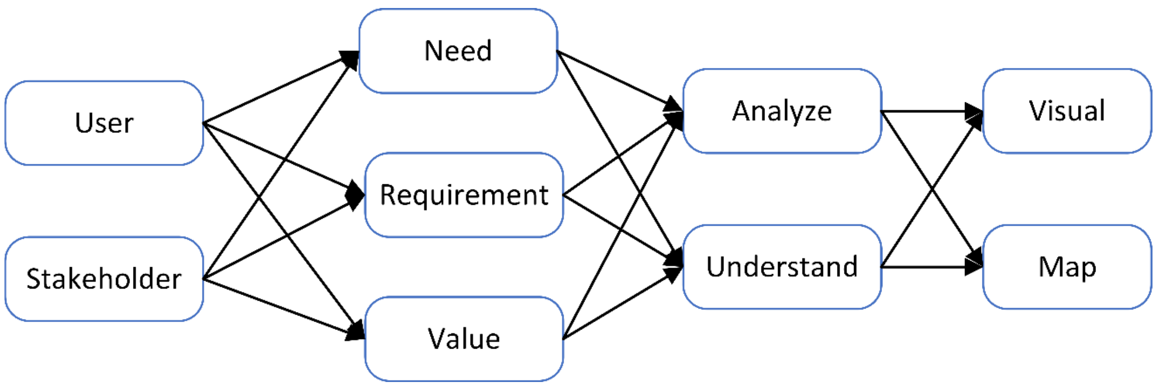



Figure 4.1 Conceptual framework

### 4.2.2 The systematic literature review strategy

We used the PRISMA methodology (Moher et al., 2009; Page et al., 2021) to conduct a rigorous literature review on visual needs analysis methods. The articles reviewed were retrieved from "Compendex" and "Web of Science," which are among the most renowned academic databases. Given that, to the best of our knowledge no similar review has been conducted on this topic, we did not apply any time criteria in our search. However, the language criterion was limited to English and the document type to "Journal and Conference articles." The search protocol is presented in Table 4.1.

Table 4.1 Search Protocol

| | |
|---|---|
| Search String* | (user* OR stakeholder*) AND (need* OR requirement* OR value*) AND (Analy* OR Understand*) AND (map* OR visual*) |
| Database | Compendex and Web of Science |
| Period | 1981–2022 |
| Language | English |
| Document Type | Journal and Conference papers |

*The search query with all the applied functions is presented in Appendix 1.

Running the search query generated 206 search results from Compendex and 158 results from Web of Science. Next, 68 duplicates were removed, and 296 articles were subjected to abstract review. At this stage, 218 articles were excluded (Reasons R1, R2 and R3 in Table 4.2), resulting in a total of 78 papers for full-text review. After full-text review, 59 papers were excluded (Reasons R4, R5 and R6 in Table 4.2) and 19 remained. We added 9 articles which were found by snowball sampling to ensure that the review was comprehensive. In the end, a total of 28 articles were included in the review (final list of sample publications is provided in Appendix C). The search strategy is presented in Figure 4.2.

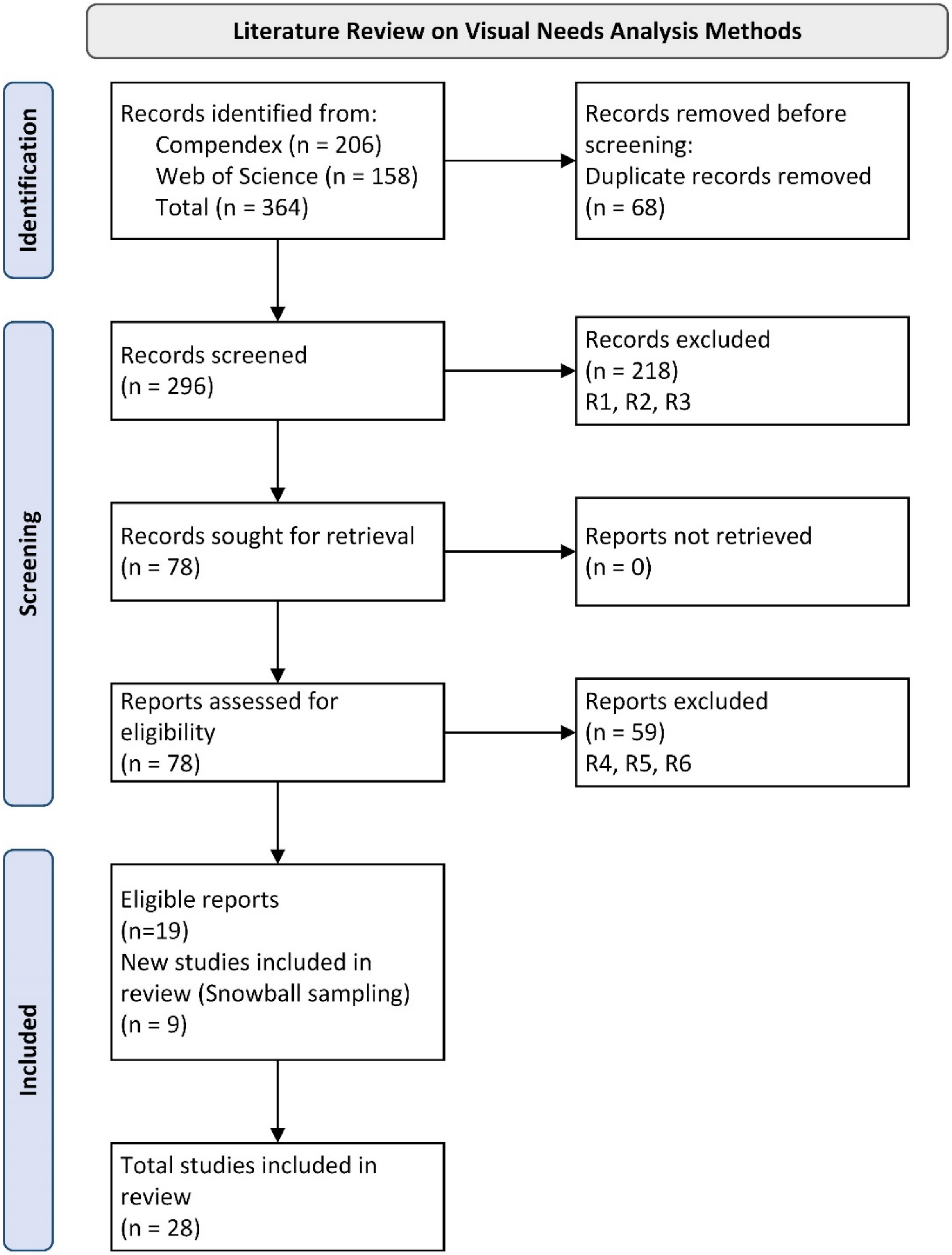



Figure 4.2 Systematic literature review strategy

Table 4.2 List of reasons for excluded reports

| No. | Reason |
|---|---|
| R1 | The topic is not relevant to the objective of the study. |
| R2 | The paper does not provide any needs analysis methodologies. |
| R3 | The terms “visual” and “map” are defined differently than in our study (e.g., visual senses, geographical maps, etc.). |
| R4 | There is no mention of any visual or mapping needs analysis methods in the paper. |
| R5 | The methodology is not explained well and is unclear. |
| R6 | The visual/mapping technique is used for a purpose other than needs analysis (e.g., elicitation, specification, functional analysis, etc.). |

### 4.2.3 Data analysis

Our study employs both quantitative and qualitative analyses in a mixed-method systematic review. A two-stage data analysis was therefore carried out. In the first stage, we performed a descriptive analysis using graphs and tables. In the second stage, we conducted a qualitative analysis, which involved the categorization of visual representations for needs analyses, the comparison of needs analysis methods, investigation of how these methods complement each other, and combinations and trend analyses.

Three academic experts, each with more than 10 years of experience in new product development, needs analysis and user experience spent a total of five hours rating each method based on the comparison criteria derived from the literature. Each method was evaluated and assigned a rating of either strong, medium, or poor capability for each criterion. As there was an odd number of voters, the dominant vote was selected for each case. It is worth noting that no conflicts arose as there were no instances where all three options were chosen simultaneously.

## 4.3 Results

The results from our literature review are presented into two sections: a descriptive analysis and a qualitative analysis. The descriptive analysis presents the evolution and origin of publications, the research type and methodological approach used, a ranking of the journals and their topic area, a keyword analysis, and a summary of the needs analysis methods and their applications. The qualitative analysis presents the categorization of the needs analysis methods along with a brief description for each category.

### 4.3.1 Descriptive analysis

**Evolution and origin of publications**

The distribution of publications over time is shown in Figure 4.3. Although the average number of papers published per year is low, the slight increase in the number of publications could be perceived as a growing interest in this topic among researchers. The low number of annual publications may be due to two main reasons. First, the topic is general and there are many variations in the keywords chosen for the relevant papers. Therefore, there could be a good number of publications that have not been discovered due to the differences in keywords. Second, although many studies claim to have analyzed needs, what they have actually done is identified needs without providing any further analyses. These studies therefore did not meet our acceptance criteria.

The increase in the number of publications over the past 16 years shows that there is growing interest in this topic among the research community.

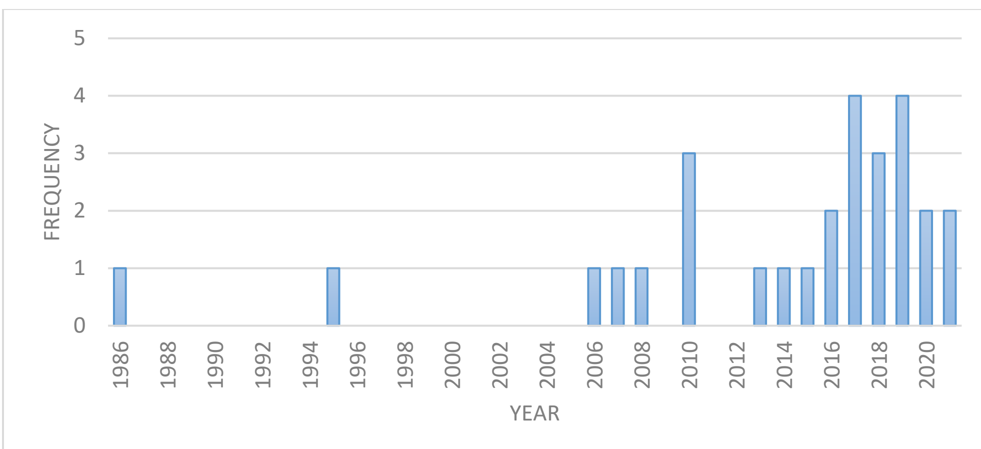



Figure 4.3 Number of Publications per year

Figure 4.4 shows the geographical distribution of the publications based on the affiliation of the first author. Most contributing authors were from China, Brazil and South Korea with three papers each. Next, there were authors from Canada, France, India, UK and USA with two each. Other authors were from countries mainly in Asia and Europe and have only one contribution each.

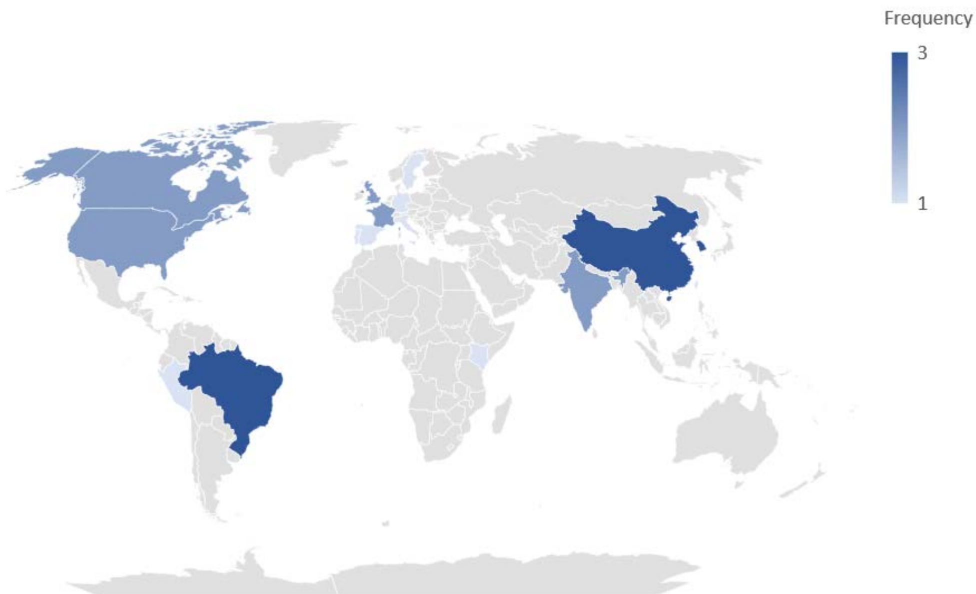



Figure 4.4 Geographic distribution of the papers

**Research type and methodological approach**

Most of the papers we collected were empirical studies (46%). Approximately 25% used a mixed approach (theoretical–empirical) while another 25% were theoretical. Given that needs analysis is a practical research topic, we expected the empirical approach to be dominant; 68% of the papers used qualitative methodology, whereas 28% applied a combination of qualitative and quantitative methodologies. Research based on qualitative analyses may be unavoidable for needs analyses due to the qualitative nature of human needs and the way these needs are expressed by users and stakeholders (see Table 4.3).

Table 4.3 Research Type and Methodological Approach

| Research Type | No. | % | Methodological Approach | No. | % |
|---|---|---|---|---|---|
| Theoretical | 7 | 25 | Qualitative | 18 | 64 |
| Theoretical-Empirical | 6 | 21 | Qualitative-Quantitative | 9 | 32 |
| Empirical | 14 | 50 | Quantitative | 0 | 0 |
| Literature Review | 1 | 4 | Literature Review | 1 | 4 |
| Total | 28 | 100 | Total | 28 | 100 |

**Ranking and topic area of journals**

Of the 28 publications, half were journal articles, and the other half were conference papers. The top 10 journals ranked according to impact factor (according to Journal Citation Reports - JCR) and SCImago Journal Rank (SJR) are presented in Table 4.4.

Table 4.4 Journal rankings

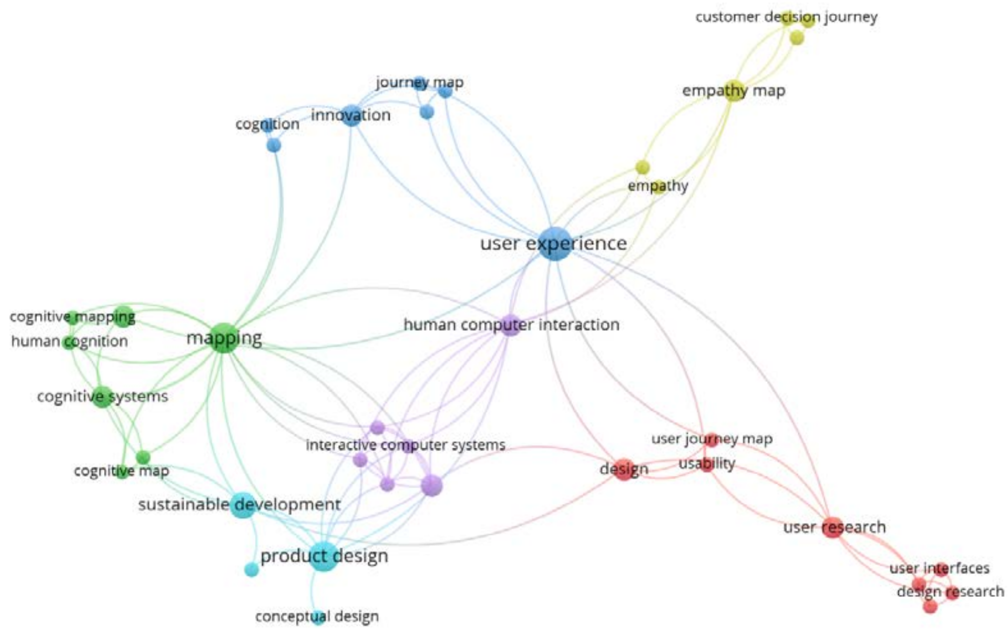
| Name of Journal | IF | SJR |
|---|---|---|
| MIS Quarterly | 8.513 | 4.50 |
| Human Relations | 5.658 | 2.90 |
| Business Horizons | 10.56 | 2.38 |
| Energy for Sustainable Development | 5.655 | 1.44 |
| Management Decision | 5.589 | 1.16 |
| International Journal of Medical Informatics | 4.73 | 1.14 |
| Public Health | 4.984 | 0.97 |
| BMC Medical Informatics and Decision Making | 3.298 | 0.83 |
| Journal of Computer Information Systems | 3.317 | 0.82 |
| International Journal of Industrial Ergonomics | 2.884 | 0.76 |
| The TQM Journal | N/A | 0.65 |

The journal's subject area was analyzed based on the categories provided by Scimago for 25 records out of 28 (four records were not indexed). Half of the papers were published in journals or proceedings that are associated with computer science (computer science, computer science applications and computer networks and communications). The second most popular area was business management (business management accounting, business, and international management) and the rest belonged to miscellaneous categories (arts and humanities, geography, planning and development, health informatics, etc.). From this, we can see that needs analysis methods are widely used in software development and computer science, and the results of these needs analyses are mainly of interest to managers who use that information for decision making.

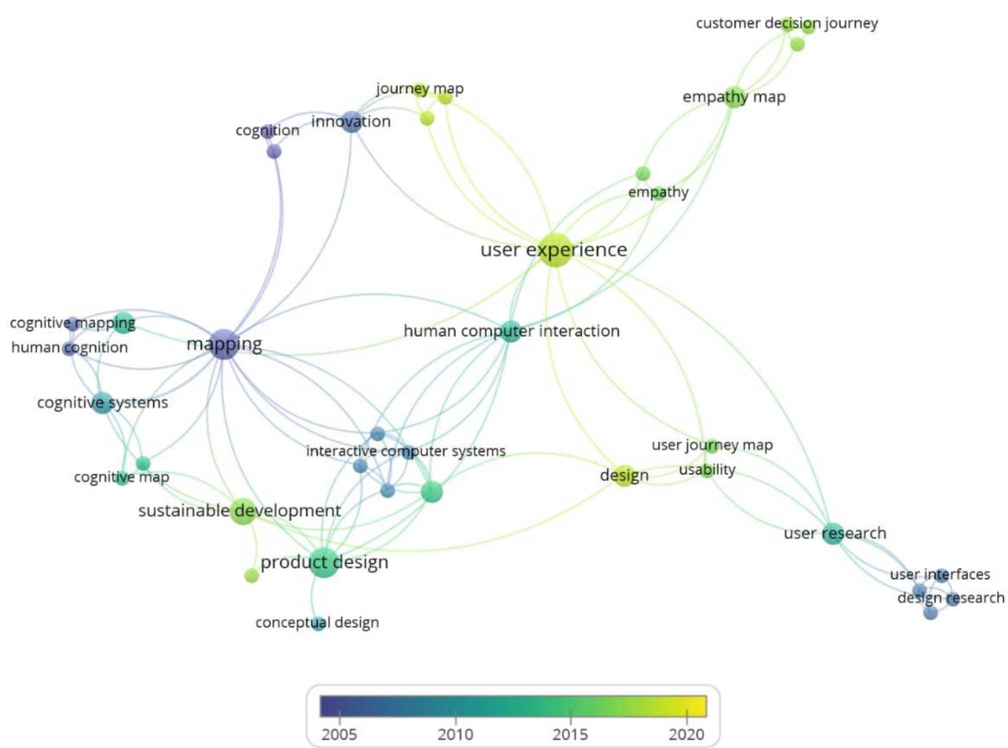
**Keyword analysis**

A network of keywords based on the number of co-occurrences in the sample publications was created using the VOSviewer 1.6.18 software. Figure 4.5(a) shows the keyword clusters by color. The main keywords were: user experience, human-computer interaction, product design, sustainable development and mapping. Other less common keywords included empathy map, user research and customer, among others. The word “user” very frequently appeared as a keyword, suggesting that researchers are particularly interested in this aspect of needs analysis. The fact that the term "stakeholder" or other types of stakeholders are not mentioned, implies that the methods that we analyzed were predominantly focused on users. The keyword network also revealed that mapping methods, specifically cognitive mapping, are directly connected to user experience and product design. However, no direct connection could be established between the mapping methods and user research. This might imply that cognitive mapping methods have not been used for user research and consequently, for the analysis of user needs.

Figure 4.5(b) shows the year of publication for each cluster. While user experience, journey mapping, design and development were the most recent concepts discussed in the literature, human computer interaction, user interface and cognitive mapping have been mentioned in older publications.




(a)




(b)

Figure 4.5 (a) Cluster analysis of key words, (b) keyword clusters by year

**Needs analysis methods and applications**

A list of needs analysis methods and their respective fields of applications from the sample publications is presented in Table 4.5. The most popular needs analysis method is the cognitive map. Although cognitive mapping has been used for needs analysis for many years (Montazemi & Conrath, 1986), it was not recognized as one of the primary tools for needs analysis until more recently. The user journey map method is widely used in UX (User Experience) design and agile development (Endmann & Keßner, 2016; Patton & Economy, 2014). Quality Function Deployment (QFD) is ranked next, followed by the Kano model, experience map, network analysis and need matrix. The other methods were reported only once. Needs analysis methods can be used in a large variety of fields, but the most popular is design and development of products and services. Health care and environment are next, according to our sample of publications.

Table 4.5 Needs analysis methods and applications

| **Methodology** | **Frequency** | **Field(s) of Application** | **References** |
|---|---|---|---|
| Cognitive map | 9 | Design and development, Management and decision making, Healthcare | (Castellano & Del Gobbo, 2018; Driss et al., 2010; Montazemi & Conrath, 1986; Olaverri-Monreal & Gonçalves, 2014; Quispe Vilchez & Pow-Sang Portillo, 2019; Siau & Tan, 2006; Swan, 1995; Villafranca & Loureiro, 2013; H. Yang et al., 2010) |
| Journey map | 6 | Design and development, Energy, Environment, Health care, Project planning | (Endmann & Keßner, 2016; Grenha Teixeira et al., 2019; K.-H. Liu & Wang, 2020; Ogeya et al., 2021; Rosenbaum et al., 2017; Sperano et al., 2018) |
| QFD | 5 | Design and development, Environment, Automotive industry | (K.-H. Liu & Wang, 2020; Sambandan et al., 2018; K. Song & Lee, 2008; Wulandari et al., 2017) |
| Kano model | 2 | Health care, Environment | (Deng et al., 2021; Xie & Han, 2019) |
| Experience map | 2 | Design and development, Health care, Transportation | (Deng et al., 2021; Xie & Han, 2019) |
| Network analysis and need matrix | 1 | Energy, Design and development | (Pahk & Baek, 2017) |
| Empathy map | 1 | Design and development | (Ferreira et al., 2016) |
| E3 (economic, ecological and experience) value classification | 1 | Design and development | (Cho et al., 2010) |
| Multidimensional scaling and cluster analysis | 1 | Health care, Sports | (Johnson et al., 2020) |
| Ideation need mapping | 1 | New product development | (Stenmark & Lilja, 2014) |
| Fishbone analysis | 1 | Design and development | (Rao, 2007) |
| Customer value constellation | 1 | Health care | (Grenha Teixeira et al., 2019) |
| Analytic Hierarchy Process (AHP) | 1 | Health care | (Fico et al., 2019) |
| Value Proposition Design | 1 | New product development | (Pelicioni et al., 2017) |

### 4.3.2 Qualitative analysis

The needs analysis methods identified in the literature were grouped into five categories: (i) ***mapping*** (9 methods), (ii) ***matrix analysis*** (1 method), (iii) ***network analysis*** (2 methods), (iv) ***multidimensional scaling*** (2 methods) and (v) ***cluster analysis*** (2 methods). Table 4.6 presents the methods that belong to each category. The methods are briefly introduced in the following subsections.

Table 4.6 Categories of Needs Analysis Methods in the Sample Publications

| | |
|---|---|
| Methods based on *Mapping* | User/Customer Journey Maps<br>Experience Map<br>Empathy Map<br>Value Proposition Design (VPD)<br>Cognitive Map<br>Ideation Need Mapping<br>Fishbone Analysis<br>MEASUR<br>MAP |
| Methods based on *Matrix Analysis* | QFD |
| Methods based on *Network Analysis* | Need Network Analysis<br>Customer Value Constellation |
| Methods based on *Multidimensional Scaling* | AHP<br>E3 Value Classification |
| Methods based on *Cluster Analysis* | Cluster Analysis<br>Kano Model |

**Methods based on mapping**

Data can be better understood by using visual representations (Card et al., 1999). One of the most popular visualization techniques is mapping. Maps and other types of visual representation help researchers explore the different aspects of a particular issue in different scales by providing a holistic perspective. They are effective tools for analyzing massive amounts of complex information (Iliinsky & Steele, 2011).

Journey maps and experience maps are usually sequentially structured and display multiple dimensions of an experience (Grenha Teixeira et al., 2019; Sedig & Parsons, 2016; Sperano et al., 2018). The main purpose of a journey map is to uncover gaps in user experiences and identify opportunities for innovation and improvement (Grocki, 2014; Kaplan, 2016).

Empathy maps were first designed by Xplane as a human-centered design toolkit. These maps provide a predesigned canvas with 7 sections in numerical order (1. Who, 2. Do, 3. See, 4. Say, 5. Do, 6. Hear, 7. Think & Feel). Each section comes with a set of guiding questions to help with the mapping process (Gray, 2018). Similarly, Value Proposition Design (VPD) is another method that uses a canvas to analyze user needs. Inspired by the business model canvas, VPD is comprised of two main blocks called "value proposition" and "client segments." Each block is divided into 3 sections (painkillers, gain creators and product features for value proposition, and pains, gains and customer jobs for client segments), with a set of questions to help the mapping process. Empathy Maps offer a fast and simple way to generate minimum viable product propositions (Osterwalder et al., 2014; Pelicioni et al., 2017).

Cognitive maps are network structures that provide a visual representation of a person's beliefs and their views on a particular issue (Eden et al., 1992; Tegarden & Sheetz, 2003). These maps can be produced using various techniques such as causal mapping, semantic mapping and concept mapping (Siau & Tan, 2006). Other needs analysis methods such as Ideation Need Mapping (INM), Fishbone analysis, MEASUR and MAP have similar structures and can also be categorized as cognitive maps. In general, cognitive maps help with subjective information and allow for in-depth understanding of a topic, evaluation and analysis of complex structures, decision making, and team mental models (Eden et al., 1992; Montazemi & Conrath, 1986; Siau & Tan, 2006; Village et al., 2016). All these qualities make cognitive mapping a good technique for needs analysis, stakeholder analysis and strategic planning (Quispe Vilchez & Pow-Sang Portillo, 2019; Villafranca & Loureiro, 2013).

**Methods based on matrix analysis**

Analyses based on matrices have long been used in a variety of fields. For example, in plant layout design, they are typically used to determine the proximity requirements of different machines, equipment, and workers or the connections between them. Some needs analysis methods also use matrices to demonstrate the interrelationship between needs. These matrices help reveal the connections that exist while quantifying and prioritizing the needs. Our systematic literature review identified just one method (QFD) that is currently being used for needs analysis. However, because of the potential for other matrix-based methods in needs analyses, we have retained it as a category.

The QFD method is one that is popular for specifying customer requirements, which is one of the main processes of Total Quality Management (TQM). In this method, different groups of stakeholders use a number of matrices, known as "Houses Of Quality", to convert user needs into product functions by comparing correlations (Griffin & Hauser, 1993; K.-H. Liu & Wang, 2020).

The matrix structure simplifies data analysis. The QFD method is a collaborative tool that requires the involvement of all team members in decision making and discussions. The multiple sections and correlations are all based on a collective consensus (Wulandari et al., 2017). As it is not always possible to identify the connections between all needs, other data analysis techniques should be used for further analysis. However, matrices compromise the "visualization" aspect of analysis, as they are not very easy to interpret by those who are less familiar with them (normally the case for project management professionals).

**Methods based on network analysis**

Network structures, which help with data analysis by revealing correlations, have been long used in areas such as social sciences, management, health systems, and engineering, among others (Barabási & Pósfai, 2016; Caldarelli & Catanzaro, 2012). Network analysis offers another way to visualize the needs and the connections between them. Network structures are flexible and can display various types of interrelationships.

One type of network analysis is the Customer Value Constellation. In this method, the service concept is first defined, and then the stakeholders participate in a design workshop to prioritize the various components of the service. The service concept is displayed as a network and the feedback from the participants can be visualized. For each stakeholder involved in the service concept, one specific network representing that stakeholder's point of view is created. This method allows for the collaboration between designers and stakeholders and extracts the most relevant information (Grenha Teixeira et al., 2019).

Needs network analysis is a tool used to demonstrate the relationships between social entities with structural attributes. To create a social network, data is collected (needs elicitation) from customers/stakeholders, the relevant attributes are defined, and data are analyzed and transferred into measurable metrics. This method identifies links that represent a need that exists between each pair of stakeholders. For example, a link from stakeholder A to stakeholder B shows that stakeholder A has a need that could be met by stakeholder B. The network structure provides a qualitative analysis of the capacity of different stakeholders and helps identify those that have the biggest impact (Pahk & Baek, 2017).

**Methods based on multidimensional scaling**

Multidimensional scaling uses hierarchical mathematical modeling to show the multiple factors that contribute to the main objective. By simplifying problem solving and data analysis, hierarchical structures can help with decision making. Hierarchical structures and multidimensional scaling are the basis of needs analysis methods such as AHP and E3 value classification.

Analytic Hierarchy Process (AHP) is a tool that combines a hierarchical structure with mathematical modeling for the analysis of factors involved in reaching a specific goal (Brunelli, 2014; W. Wang et al., 2020). In this method, the main objective, the contributing factors and their alternatives are presented as levels within a hierarchy. Each element is connected to all the items below it in the hierarchy. The importance of each element is measured using pairwise comparisons with the other elements in the same level. The potential for each element to influence those in the higher level is thus quantified (Saaty, 1980). In product development, AHP can provide a scale to assess the relative importance of design factors (W. Wang et al., 2020). Additionally, AHP can help with the analysis of a user's needs by providing structured, specific requirements (Fico et al., 2019).

The E3 value classification addresses product-service systems (PSS) by considering three values: economic, ecological and experiential. Economic values are related to product/service providers and include cost reduction and income enhancement. Ecological values address environmental issues such as limiting the use of resources, reducing hazardous materials and recycling. Experiential values are associated with product/service users as well as utilitarian and hedonic aspects of user experience. This method provides a modular and predefined structure for needs in order to assess stakeholder requirements in a PSS (Cho et al., 2010).

**Methods based on cluster analysis**

Classification and clustering is an efficient data analysis method that simplifies complex structures by breaking them down into groups (Landau et al., 2011). Clustering and categorization significantly help with qualitative analysis methods. Needs analysis requires a great deal of qualitative analysis due to fuzzy statements of users and stakeholders. A popular approach that is used to cluster needs is the Kano model which is an effective tool for classification and prioritization of users' needs (Berger, 1993; Kano, 1984). This model categorizes user needs into five groups: attractive, must-be, one-dimensional, indifferent and reverse requirements. However, in some cases, the indifferent and reverse requirements categories can be avoided and only the first three are used for the needs analysis (Deng et al., 2021; Xie & Han, 2019). To categorize and prioritize the user needs, one could simply use the five categories above to cluster the needs based on the subjective judgements of the design team or users (Xie & Han, 2019). The Kano evaluation form is mainly used for the further analysis of needs (Deng et al., 2021; Kano, 1984; Sauerwein et al., 1996).

Another method is the hierarchical cluster analysis, which can be used to cluster product/service attributes according to stakeholder statements. Prior to cluster analysis, stakeholder statements should be sorted and rated based on stakeholder perceived values, importance and feasibility. In one example, the data was statistically analyzed using the Concept Systems Global Max™ *groupwisdom*® web platform to generate visual maps and a cluster analysis (Johnson et al., 2020). The clustering of data facilitates needs analysis and provides a better overview of the main concerns raised by stakeholders.

## 4.4 Discussion

The main objective of our study is to analyze the visual tools and techniques applied in product/service development. In this section, we aim to answer the research questions by assessing the visual needs analysis methods to understand their characteristics, their strengths, and how they contribute to the quality of needs analyses.

### 4.4.1 Comparison of visual needs analysis methods

First, we will discuss the visual/mapping needs analysis methods that are currently used in product and service development, and the advantages and disadvantages of each method. This question has been partially answered in Section 4.3.2. To further assess the needs analysis methods, we have extracted their main characteristics from the analyzed publications to be later used as comparison criteria. We have defined the criteria based on the main capabilities, advantages, and disadvantages of the methods (see Table 4.7). In some cases, other references that were not included in the sample publications of this literature review have been added to the table for a clearer definition of the criteria. These references are indicated with an asterisk (*) in the table.

Table 4.7 Definition of the comparison criteria (references with an asterisk are not from the sample publications)

| **Criteria** | **Definition** | **References** |
|---|---|---|
| *Categorization of needs* | The needs analysis method can display needs in multiple categories. The categorization could be according to the type of need, its source, or other criteria. | (Deng et al., 2021)<br>(Johnson et al., 2020)<br>(Quispe Vilchez & Pow-Sang Portillo, 2019)<br>(Fico et al., 2019)<br>(Xie & Han, 2019)<br>(Cho et al., 2010) |
| *Interrelationships between needs* | The needs analysis method can show any type of connection between each pair of needs. | (Quispe Vilchez & Pow-Sang Portillo, 2019)<br>(Stenmark & Lilja, 2014)<br>(K. Song & Lee, 2008)<br>(Rao, 2007)<br>(Siau & Tan, 2006)<br>(Montazemi & Conrath, 1986) |
| *Impacts/dependencies* | The needs analysis method can demonstrate the dependencies (causal relationships) between each pair of needs. | (Sambandan et al., 2018)<br>(Stenmark & Lilja, 2014)<br>(K. Song & Lee, 2008)<br>(Rao, 2007)<br>(Montazemi & Conrath, 1986) |
| *Prioritization of needs* | The needs analysis method can prioritize needs in the analysis process. | (Deng et al., 2021)<br>(K.-H. Liu & Wang, 2020)<br>(Johnson et al., 2020)<br>(Fico et al., 2019)<br>(Xie & Han, 2019)<br>(Sambandan et al., 2018)<br>(Wulandari et al., 2017) |
| *Display of needs in multiple levels* | The needs analysis method can display the needs in multiple levels. | (Quispe Vilchez & Pow-Sang Portillo, 2019)<br>(Fico et al., 2019)<br>(Sperano et al., 2018)<br>(Stenmark & Lilja, 2014) |
| *Involvement of different parties* | The needs analysis method can consider the needs of users and other stakeholders (product manager, business analyst, developer, designer, etc.) during the analysis process. | (Castellano & Del Gobbo, 2018)<br>(Sambandan et al., 2018)<br>(Wulandari et al., 2017)<br>(Pahk & Baek, 2017)<br>(Endmann & Keßner, 2016) |
| *Provide general overview* | The needs analysis method provides a holistic overview of the needs and their interrelationships. | (Sperano et al., 2018)<br>(Kalbach, 2016)*<br>(Iliinsky & Steele, 2011)* |

Table 4.7 Definition of the comparison criteria (references with an asterisk are not from the sample publications) (Cont'd)

| **Criteria** | **Definition** | **References** |
|---|---|---|
| *Help to empathize with users* | The needs analysis method can help team members to understand users and empathize with them. | (Deng et al., 2021)<br>(Ogeya et al., 2021)<br>(K.-H. Liu & Wang, 2020)<br>(Sambandan et al., 2018)<br>(Quispe Vilchez & Pow-Sang Portillo, 2019)<br>(Xie & Han, 2019)<br>(Castellano & Del Gobbo, 2018)<br>(Sperano et al., 2018)<br>(Wulandari et al., 2017)<br>(Ferreira et al., 2016)<br>(Stenmark & Lilja, 2014) |
| *Help to empathize with the team* | The needs analysis method can help team members to understand project stakeholders and empathize with them. | (Castellano & Del Gobbo, 2018)<br>(Sambandan et al., 2018)<br>(Sperano et al., 2018) |
| *Quantifiability* | The analyses can be translated into quantifiable measures to facilitate further data analysis. | (Pahk & Baek, 2017)<br>(Village et al., 2016)*<br>(Kalbach, 2016)* |
| *Customizability/Flexibility* | The needs analysis method is flexible and can be adapted and customized to the context of use and project requirements (e.g., flexibility in defining the categorization criteria). | (Sperano et al., 2018)<br>(K. Song & Lee, 2008)<br>(Kalbach, 2016)* |
| *Ease of interpretation of outputs* | The output generated by the needs analysis method is easy to understand. | (Sperano et al., 2018)<br>(Kalbach, 2016)* |

Table 4.8 shows the comparison of the reviewed needs analysis methods, conducted by experts. The experts compared the methods according to the comparison criteria provided in the previous table.

Table 4.8 Comparison of visual needs analysis methods

| Methods | Categorization of needs | Interrelationships among needs | Impacts/ dependencies | Prioritization of needs | Display of needs in multiple levels | Involvement of different parties | Provide general overview | Help to empathize with users | Help to empathize with the team | Quantifiability | Customizability / Flexibility | Ease of interpretation of outputs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Journey maps | o | o | o | - | o | - | ✓ | ✓ | o | - | ✓ | ✓ |
| Empathy map | o | - | - | - | - | - | o | ✓ | o | - | - | ✓ |
| VPD | o | ✓ | - | ✓ | - | o | ✓ | ✓ | ✓ | - | ✓ | ✓ |
| Cognitive map | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | o | ✓ | - |
| INM | o | o | ✓ | o | ✓ | o | ✓ | o | - | - | o | o |
| Fishbone analysis | ✓ | o | o | - | ✓ | o | ✓ | ✓ | o | - | o | ✓ |
| QFD | o | o | ✓ | ✓ | - | - | ✓ | o | - | ✓ | o | ✓ |
| Need Network analysis | - | - | - | - | - | ✓ | o | - | - | o | o | ✓ |
| Customer value constellation | - | ✓ | o | - | - | o | ✓ | ✓ | - | o | o | o |
| AHP | ✓ | o | o | ✓ | ✓ | - | ✓ | o | o | ✓ | - | ✓ |
| E3 value classification | ✓ | - | - | o | ✓ | - | ✓ | o | o | o | - | ✓ |
| Hierarchical cluster analysis | ✓ | - | - | o | - | ✓ | ✓ | o | o | o | - | ✓ |
| Kano model | ✓ | - | - | ✓ | - | - | o | ✓ | - | o | - | ✓ |

(✓): Strong capability (o): Medium Capability (-): Poor capability

Our results showed that most needs analysis methods can provide a general overview, the outputs are easy to interpret, and they encourage empathy with users. Despite being an advantage, ease of interpretation of the results was sometimes due to the limited structure of the visual tool and the restricted functionality of the needs analysis method. For instance, an empathy map may have very simple outputs, but it is not an extensive needs analysis tool.

Some of the needs analysis methods were better able to categorize and quantify needs than others. Some methods were not able to categorize needs, such as the need network analysis method, and some provided very limited categorizations, such as the QFD or journey mapping - see (Grenha Teixeira et al., 2019; Ogeya et al., 2021; Sambandan et al., 2018; K. Song & Lee, 2008). However, methods based on network structures such as cognitive maps or network analysis can offer a variety of categorization structures. These include categorization by level of need or its source (user or stakeholder) - see (Castellano & Del Gobbo, 2018; Pahk & Baek, 2017; Quispe Vilchez & Pow-Sang Portillo, 2019; Stenmark & Lilja, 2014).

Connections and dependencies cannot be adequately identified in all needs analysis methods. Some methods, such as empathy maps, the Kano model and the hierarchical cluster analysis, do not have the means to show any connections between needs. Others such as journey maps, AHP or QFD can only specify particular types of connections - see (Wulandari et al. 2017; Fico et al. 2019). For example, the journey map mainly focuses on establishing a chronological order - see (K.-H. Liu & Wang, 2020). It is thus difficult to show any other dependencies.

For methods based on hierarchical structure such as AHP, fishbone analysis, E3 value classification and INM, the hierarchical structure only allows for vertical connections (Cho et al., 2010; Fico et al., 2019; Rao, 2007; Stenmark & Lilja, 2014). However, in the real world, needs might not only impact each other vertically, but also horizontally. Methods based on a network structure like cognitive map and network analysis can best demonstrate the different types of interrelationships among needs.

Including all the parties involved in the project is another important criterion for analysis. We were not able to identify a needs analysis method that integrated needs from users and other stakeholders at the same time in order to analyze the more general connections and dependencies between them. However, some methods such as cognitive mapping and network analysis have the potential to include all involved parties and display their interrelationships.

Finally, it is important that the needs analysis be customizable, as the nature of the needs, and their relationships and categories could vary depending on the context. Methods with a predefined structure such as the Kano model, INM or E3 value classification do not have the flexibility to cover all possible contexts.

### 4.4.2 Complementarities between needs analysis methods

The second research question targeted the possible complementarities among needs analysis methods. According to the results of our review, it is possible to combine needs analysis methods. In this section, we discuss the possible combinations of methods found in the literature, as shown in Figure. 4.6.

**Combinations of mapping methods**

It is possible to combine the use of a journey map with QFD. User journey maps help with scenario analysis as well as the analysis of user needs. Going through multiple different scenarios provides an opportunity to empathize with users, learn about their pain points and identify their needs. In a later step, QFD then helps to organize these needs and prioritize them. The matrix structure in HoQ provides better visibility for the team to understand the connections and correlations between user needs and product requirements. Quantifying the correlations between the requirements leads to the prioritization of technical features by offering a better understanding of the complexity of the project (K.-H. Liu & Wang, 2020).

Another possibility is to combine the journey map with methods based on network analysis, such as a customer value constellation. Journey maps help to elicit customer needs, while customer value constellations display the product or service solutions provided by stakeholders to meet those customer needs (Grenha Teixeira et al., 2019).

As already explained in the previous section, an experience map is very similar to a journey map. Combining these with the Kano model can provide a more comprehensive needs analysis methodology that is capable of both elicitation, categorization and prioritization (Xie & Han, 2019).

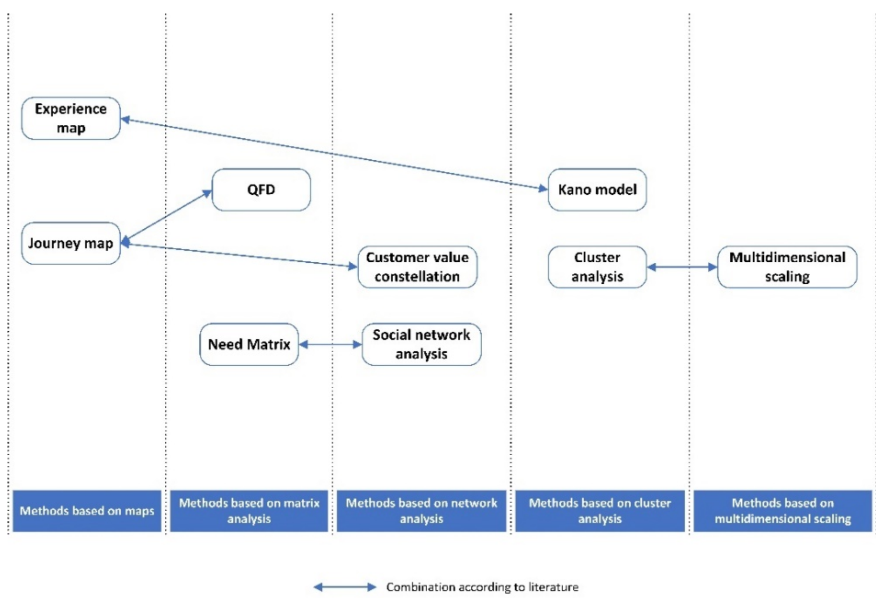



Figure. 4.6 Combinations of methods according to literature

**Combinations of methods based on network and matrix analysis**

In addition to the experience map, the Kano model can also be paired with QFD. While QFD helps to elicit the needs and link them to product features, the Kano model can help with categorizing, prioritizing and better understanding the needs (Sireli et al., 2007). Hierarchical cluster analysis is another method in the same category that has been combined with multidimensional scaling. As such, multidimensional scaling can help with the cluster analysis. This can be achieved by clustering scattered stakeholder statements over a two-dimensional map using proper visual software that groups together those that are most closely related (Johnson et al., 2020).

The literature showed evidence of network analysis being combined with need matrix analysis. All the needs and requirements among multiple stakeholders were first quantified in a matrix. Then, the matrix was dichotomized (using only zeroes and ones to represent the presence or absence of needs). The matrix simplified the data analysis and provided the input for generating a network, where the relationship between stakeholders could be visualized. Combining a matrix and network is helpful in that the matrix provides a simple overview with quantifiable information, while the network gives a better overview of the connections for a qualitative analysis (Pahk & Baek, 2017). It is also possible to combine network analysis with cluster analysis. One of the advantages of network structures is that they allow for the visualization of the connections and interrelationships within a group of needs. The network structure also helps identify clusters according to proximity, dependency or other criteria (Kalbach, 2016).

### 4.4.3 Trends in the application of needs analysis methods

The third research question focused on trends in the most frequently used visual needs analysis methods according to our review. In the previous section (4.3.2), visual techniques in needs analysis were introduced in five different categories. Figure. 4.7 shows the distribution of each category over the past few decades to show the frequency with which they have appeared in our sample publications. Even though our sample is too small for a trend analysis, some interesting trends could be observed.

Our results reveal that mapping techniques (especially cognitive mapping) have been a practical tool for analyzing needs throughout the period of analysis, with a growing number of publications using them in recent years.

Since 2008, quantitative methods based on matrix analysis, such as QFD, have appeared in the sample. It is important to mention that the scope of QFD is broader than just the concept of needs. Especially in the last five years, some studies have explored the capabilities of matrix methods, more particularly QFD and its variations, for needs analysis.

The same can be said about the other three types of methods. In the last five years, a broader variety of methods have been used for needs analysis. Analytic methods such as network analysis, multidimensional scaling and cluster analysis have enhanced the needs analysis process.

The practice of combining different needs analysis methods has been growing in recent years. The triangulation of methods provides a more comprehensive approach towards needs analysis while compensating for the shortcomings of each method. This also calls for further investigation into the possible combinations of needs analysis methods and data analysis techniques, which can improve understanding of the needs.

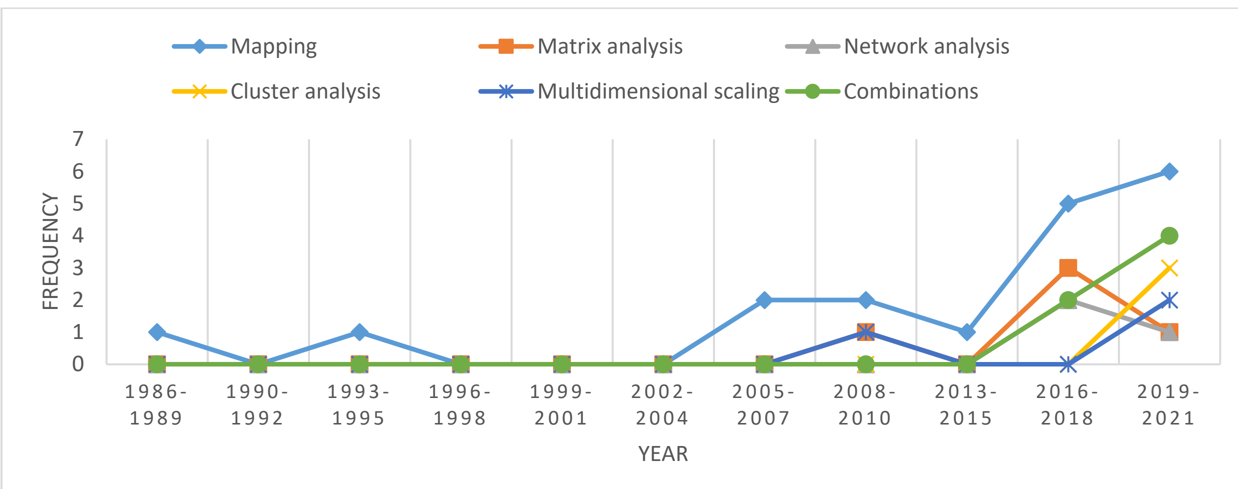



Figure. 4.7 Trends on needs analysis methods

### 4.4.4 Research Limitations

We faced various challenges during this study. The most difficult step was creating a comprehensive search query. The variety of terms used to describe needs and analyses, which are also commonly used words in many other fields, made it very difficult to come up with a search query that produced relevant results. Although we attempted to generate the best possible combination of terms, we know that some methods or papers may not have appeared in our search results. Furthermore, our search protocol only covered journal and conference papers in English and in two specific databases (Compendex and Web of Science). Therefore, books, dissertations and other sources as well as papers written in other languages have been excluded.

The descriptive analysis provided in this paper was also impacted by the aforementioned challenges associated with the search query. It should be noted that we are aware that all the needs analysis methods likely occur elsewhere in the literature beyond the instances identified here. However, considering our research limits, we were restricted to the occurrences that appeared within our sample.

### 4.4.5 Implications for theory and practice

The results of this study provide a comprehensive overview of various needs analysis methods that have been proposed for new product development. This review benefits researchers by providing the current trends on needs analysis methods with a particular focus on visual techniques. This paper describes a classification for needs analysis methods and provides comparison criteria for evaluating those methods.

The assessment of needs analysis methods based on their weaknesses and strengths can provide practitioners with insights on how best to leverage the current methods in their projects. According to our results, combinations of existing methods offer the potential to customize tools to the specific objectives of a practitioner.

### 4.4.6 Future research

The assessment of visual needs analysis methods, their fields of application and the various ways in which they can be combined may inspire other researchers to be creative and propose better solutions for needs analysis processes in large or complex projects. Through empirical studies or quantitative research (e.g., surveys), future research could aim to understand the possible challenges that might arise when incorporating visual needs analysis methods in complex product development projects. This information could then facilitate the industry’s adoption of such methods.

Researchers in the field could also empirically test the combination of visual needs analysis methods with other techniques. They could explore how complementary methods might enhance the results of the needs analysis process, which could potentially contribute to improving the quantification and prioritization of needs. We suggest investigating matrix-based models, such as the Dependency structure modelling (DSM) (Browning, 2016), as well as social network analysis methods (e.g., (Yuan et al., 2018) and other mapping methods from the domain of creativity and design thinking, such as mind maps (Kelley & Kelley, 2013).

## 4.5 Conclusion

In this paper, we have conducted a systematic literature review using the PRISMA methodology to determine the current state of visual needs analysis methods and recent trends in the field. Our results revealed 28 publications that use 15 different needs analysis methods that have been categorized into five groups according to the visualization tool being used: maps, matrix analysis, network analysis, cluster analysis, and multidimensional scaling.

We discovered that maps and matrix analyses are the most popular visualization tools used for needs analysis. Among all methods, the cognitive map is the most frequently used visualization method to analyze needs. The flexible nature of cognitive maps helps to reveal the needs from different parties across multiple levels, as well as their interrelationships and dependencies. Cognitive maps provide a holistic overview of the structure of the needs and thus act as a good support for decision making.

We identified a recent upward trend in authors using combinations of multiple needs analysis tools. Combining tools can create more powerful needs analysis methods. Certain tools can compensate for some of the shortcomings of other tools and provide more flexibility in needs analysis. Ultimately, the combination of various visual tools with data analysis techniques or other needs analysis methods could provide a creative way to improve and enhance the current needs analysis methods.

# CHAPTER 5 ARTICLE 2: AN EXPLORATORY INVESTIGATION OF COGNITIVE MAPPING FOR ANALYZING NEEDS IN UX DESIGN

Mitra Taraghi, Fabiano Armellini, Daniel Imbeau

Article submitted to the Journal of Transactions on Engineering Management on June 21, 2022 (under review).

The version below is a revised version resubmitted on January 20, 2023, after comments from the journal peer reviewers.

**Abstract**

Needs analysis is a major concern in innovation projects both for organizations pursuing business objectives and for the users whose needs should be satisfied. Different needs analysis methods can be used, depending on the scope and complexity of the project. However, not all the existing methods provide efficient decision-making support for designers whose task is to categorize and prioritize the needs. The aim of this paper is to explore the application of cognitive mapping as a needs analysis method that will more efficiently analyze the nature of the needs and their interrelations. This analysis will provide a different perspective for understanding needs and thus contribute to decision making and prioritization. To this end, the proposed method was tested with the UX team of a large established North American transportation company. The feedback from the multiple groups involved in needs analysis indicated that the need mapping technique was perceived as useful and could be applied as a decision support.

**Keywords:** Needs analysis, Cognitive mapping, Need mapping, User experience, New product development

**Managerial Relevance Statement**

Based on cognitive mapping, the new needs analysis method proposed in this paper could help with the analysis of numerous stakeholders' needs by highlighting the connections between the needs of the various parties participating in the project (users, designers, managers, and other stakeholders). Furthermore, employing cognitive mapping in the development of a new product enhances understanding of the needs and represents the collective mental model associated with using this product. In practice, it can provide decision support for UX designers, back-end and front-end developers, project managers, product owners and other members of the team, supporting strategy planning, decision making and project management. The collaborative nature of the mapping workshops improves communication between project stakeholders and end users, promoting empathy and mutual understanding. Additionally, maps could be updated and used in the design and development process in a dynamic way.

## 5.1 Introduction

One of the main reasons for innovation failure is negligence of a broad range of users' needs which leads to failure in creating a positive experience for them (Melgarejo & Malek, 2018). Developing a better understanding of user needs is a major component of product and service development. More specifically, if future products and services are to succeed in the marketplace, they have to accurately respond to user needs (W. Song, 2017; von Hippel & Katz, 2002). Thus, successful innovation in new product and service development requires a holistic approach to user needs analysis and management.

While studies have concentrated on a user-centred approach, a broader perspective could indicate that diverse groups of stakeholders (designers, experts, developers, product managers, information security specialists, etc.) interact with the product in different development stages (Cagan & Vogel, 2002). End users are not the only ones whose needs and requirements have to be met, those of other stakeholders must also be taken into consideration (W. Song, 2017).

The first step of the product development process is the needs assessment, where information and feedback are sought from multiple groups of potential users and stakeholders. This information is later aggregated to identify the useful features of the product. The feedback gained from the users and stakeholders displays a considerable level of heterogeneity and dispute due to the inherent complexity of product characteristics, personal preferences, and levels of respondents' motivation (Rashid et al., 2012; Y. Wang & Tseng, 2014). Consequently, an inclusive needs analysis method is required to determine all the needs, along with a good visual representation to further analyze these needs and facilitate decision making.

UX (User eXperience) is a process that begins with research and ends with UX/UI (User Experience/User Interface) design (Karr, 2015). The main goal of the research phase is to identify the needs through assessing potential user experiences and analyzing them in order to transform them into design features (Slegers et al., 2015). However, in large companies with complicated large-scale projects, analyzing the needs of different parties, resolving possible conflicts between any two needs/requirements, and prioritizing needs could be a real challenge. It could be difficult to analyze large amounts of information to pave the way for decision making by providing an overview of the big picture and defining the main values of the users and stakeholders. Studies show that visualization techniques like cognitive mapping could be effective tools in such circumstances to help organizations deal with complicated projects (Sperano et al., 2018; Swan, 1997; Village et al., 2016).

Accordingly, this research project is geared towards the application of cognitive mapping to more effectively analyze and represent the needs in innovation projects. Research was conducted on the application of the cognitive mapping technique to analyze users and stakeholders' needs. It is worth noting that for the sake of simplicity, in this paper, the term "need" is defined as an umbrella term encompassing all types of needs such as requirements, wants, values, preferences, desires, and so on. The paper continues with a theoretical background on needs management and its components, mapping techniques and cognitive mapping (Section 5.2); the methodology used for the investigation of the outcome of implementing a new needs analysis method based on cognitive mapping in a large transportation company (Section 5.3); and presentation of the results and discussion of the different steps of the research conducted in the company (Section 5.4). The conclusion is presented in Section 5.5.

## 5.2 Theoretical Background

First the process of Needs Management and, more specifically, needs analysis in new product development is explained. The steps to be taken to analyze the needs are illustrated and the importance of this analysis is outlined. In the next step, visualization techniques, including cognitive mapping as an analysis tool that could be used for needs analysis in different contexts for innovation projects are explored.

### 5.2.1 Needs Management

Even though this paper is about needs analysis, it is important to look at the whole process of needs management as a comprehensive approach that entails a number of stages, including elicitation, analysis and specification of the needs (see Figure 5.1) (Jiao & Chen, 2006).

**Eliciting needs.** Eliciting needs is the first step in Needs Management. A structured process is required to be able to elicit the needs for new products (T. Ulwick, 2013). One needs to know the people from whom he elicits the needs, the main factors (goals, jobs to be done and outcomes) to be considered, and the methods to do so (Kalbach, 2016). Various elicitation methods, such as surveys, interviews, contextual inquiries, focus groups, ethnography, are already available (Beyer & Holtzblatt, 1997; Korjonen-Close, 2005; McDonagh-Philp & Bruseberg, 2000; Savage, 2006; Schirr, 2012). Once the needs are elicited from users and stakeholders, a list or pool of needs is generated that require analysis.

**Analyzing needs.** The second step, needs analysis, involves classifying, structuring and prioritizing the needs. While conducting the analysis, the impact of the needs on each other should also be considered and compromises should be made if conflicts arise. Such trade-offs require the design team to make decisions based on the results of the needs analysis (X. Liu et al., 2008).

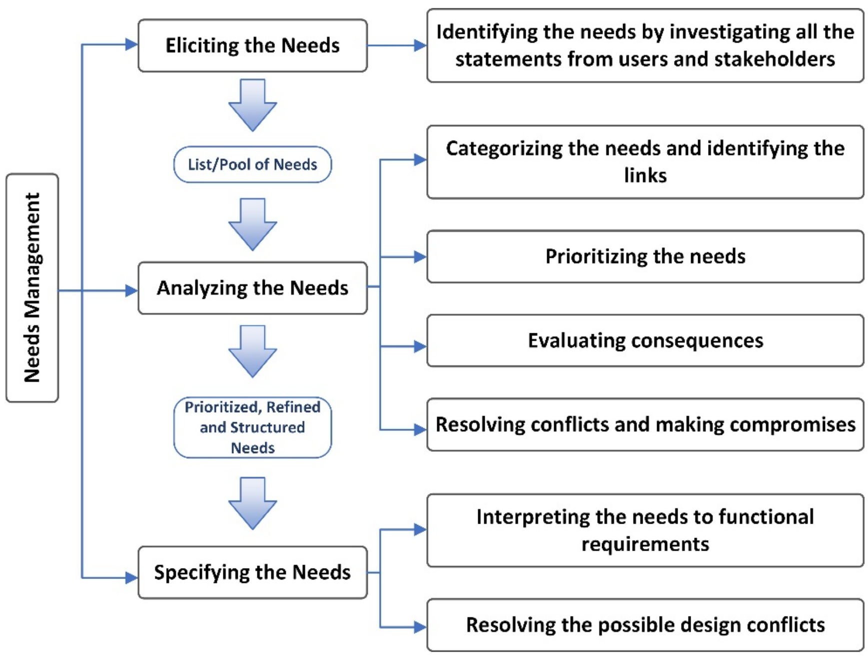



Figure 5.1 Needs Management Structure

The end user is the one who pays for the final product, uses it, and experiences it. However, with a broaden focus, it can be seen that diverse groups of stakeholders (various user groups in multipurpose products, designers, experts, users' relatives, maintenance, safety and security, distribution staff, and so on) interact with the product in different development stages (Cagan & Vogel, 2002). For instance, in the process of developing an application software, business requirements also need to be considered as well as the users' needs. Although users may prefer to have access to a wide variety of features, the business may have to restrict their access for regulatory and safety reasons. Furthermore, the user is not the only one who is supposed to interact with the product. UX/UI designers, functional designers, product owners, business analysts and developers also interact with the product and are involved in the design and development process. Each of these groups has requirements and mandates that should also be considered. During the development process, needs such as the outcome-driven requirements of the business (business rules, business values, priorities, etc.), the technical constraints of the development, and the design principles for UX/UI designers should all be taken into account. For instance, the data that needs to be displayed to the user through the interface must be fed into the system supporting the application. However, this data might need to go through some processing steps, where technical constraints affect the data processing in the back-end. Therefore, the user is not the only one with needs and requirements to be met, other stakeholders also have needs and requirements that must be considered (W. Song, 2017). Although the main goal of the development process is to satisfy the user, the satisfaction level of other stakeholders could severely affect the project's success (Nuseibeh & Easterbrook, 2000), given that the satisfaction of business and product owners is important to make sure that the users are appropriately interacting with the product. However, the majority of studies have overlooked other stakeholders (W. Song et al., 2013).

One major problem with needs analysis is the decision as to where to begin and where to end the analysis. Once the list of needs from users and stakeholders is available, it is important to know how to analyze these needs and how to document and present the outcomes to ensure seamless translation into user interface design and design completeness. Existing methodologies and techniques appear to be helpful in some, but not all, aspects of the needs analysis process (categorization, prioritization, evaluation of consequences and making compromises).

Given the lack of a needs analysis method that can meet all our expectations such as categorization, prioritization, evaluation and resolution of conflicts (W. Song, 2017), it is essential to have access to an advanced needs analysis method that can produce prioritized needs in different clusters. Such a method acts as a decision support for designers to help them plan for the next steps.

**Specifying needs.** This is the third step after analyzing and organizing the prioritized needs in clusters. Specifying needs is the process of converting needs into functional requirements (Harris, 2002). Users and other stakeholders are not usually able to express their needs in terms of standard end-states that are suitable for the designers to generate the design specifications. It is thus essential to standardize all the needs by translating them into technical information to be used in design and development. Additionally, the designers must resolve possible conflicts among the final functional requirements (Bayus, 2008; Da Silva et al., 2020; W. Song, 2017).

### 5.2.2 Visual Mapping Techniques

The utilization of interactive visual representations of data enhances cognition. Thus, visualization techniques could be widely used to help discover and make decisions (Card et al., 1999). One of the most popular visualization techniques is mapping, which is beneficial to product development and innovation. Maps and other visual representations provide a holistic overview of the situation that helps explore the various aspects of a particular issue in different scales. They are effective tools in analyzing massive amounts of complex information (Iliinsky & Steele, 2011). A list of advantages of the mapping techniques derived from the literature is presented below:

- Maps provide a holistic view and help breaking silos in an organization (Kalbach, 2016; Kaplan, 2016).
- They simultaneously demonstrate multiple aspects of an issue. The information can be presented in different layers and various levels. They also consider the interactions among the different elements of the map (Quispe Vilchez & Pow-Sang Portillo, 2019; Swan, 1997).
- They display a composite view of experiences in a graphical overview(Kalbach, 2016).
- Maps are powerful tools for analysis because of their ability to present massive amounts of information in a single view. This all-at-once visualization facilitates the identification of improvement and innovation points (Kalbach, 2016; Sperano et al., 2018).
- The visualization techniques can help convert tacit knowledge and implicit concepts into tangible representations (Kalbach, 2016; Sperano et al., 2018; Village et al., 2016).
- Maps and diagrams are compelling and quite easy to understand (Kalbach, 2016).
- Maps are made by groups of people, which means they are made based on consensus achieved through group discussions and produce valid results (Village et al., 2013).

- The involvement of different stakeholders fosters empathy among the stakeholders, leading to a shared mental model (Sperano et al., 2018; Village et al., 2016).
- Maps are flexible and can be dynamically updated so that the team can track the changes (Swan, 1997; Village et al., 2016).
- Mapping techniques help managers think critically, broadly and deeply, and can provide decision support (Shaw et al., 2009; Sperano et al., 2018; Village et al., 2016).

The benefits of mapping techniques make them powerful tools for the analysis of needs in an innovation project. Visual representations help team members understand the needs, ideate on their structure and empathize with one another while seeing through the group mental model. The following section provides an overview of the mapping techniques that were used to analyze the users' needs.

### 5.2.3 Need Mapping

Mapping techniques appear to be an effective means to support needs analysis. They can also be used to raise the visibility of future experiences and guide product innovation in practice. A descriptive literature review was conducted that revealed a number of mapping techniques currently applied to needs analysis. Our findings are briefly presented in the following paragraphs.

One of the first mapping approaches is "attribute-value mapping," which is a simple tool comprised of two main components (product attributes and user values) for exploring the values proposed by a product or service. Each of the product attributes is linked to its corresponding values. A bottom-up approach indicates which user values would be met by each of the proposed product attributes ("Attribute Value Mapping," n.d.; Goldenberg et al., 2009). Although simplicity could be considered an advantage, this method does not help with the prioritization of needs.

"Customer road-mapping is a customer planning process to help identify and select key customer needs to be used as input into the innovation and product development process" [32]. Customer journey maps are graphical representations that narrate the relationship between the user and the organization, product or brand over time from the user's perspective. Using a customer journey map, the timeline, emotions, touch points, moments of truth, personas, characters and so forth must be taken into consideration (Grocki, 2014). This method can indicate the future state of a product (Kalbach, 2016) and the user's needs. However, it is not able to present the stakeholders' needs, the connections and impacts between the needs, or prioritizations.

The purpose of the "Ideation Need Mapping (INM)" method is to focus on the users' high-level needs and try to meet or even exceed the various product attributes to reach a high level of customer satisfaction. In this approach, a map of user needs is prepared situating the different levels of user needs on a vertical axis, including low-level needs (product attributes), medium-level needs (functions) and high-level needs (values and complex psychological needs). The needs are linked according to how they influence each other. When moving top-down from high-level to low-level needs, INM methodology could support the identification of new attributes that could enhance the related values for the customer in the future (Stenmark & Lilja, 2014). Although the map facilitates the innovation process, this technique could be criticized for failing to prioritize the needs and to suggest a clear path to obtain new attributes according to user values and high-level needs. In addition, this technique has not been validated.

Cross-Impact Analysis (CIA) is a matrix-based analysis method which is used for the interpretation and analysis of constructs derived from repertory grid methodology (Süner & Erbuğ, 2016). Repertory grid is an interviewing method that is used to elicit personal constructs (Eden & Jones, 1984). CIA displays the impact of various dimensions in a holistic way, making it possible to see the effects of potential changes. In the matrix, personal constructs (dimensions) are listed both vertically and horizontally and the cells show the impact and dependency levels of each dimension based on the frequencies of the participant statements. The dimensions can be categorized based on impact/dependency levels using a cross-impact chart or visually displayed in a network structure to show the impact/dependency levels by shapes, links and colors (Kuru, 2015; Süner & Erbuğ, 2016). Although CIA provides the means to assess the interrelationships (impacts/dependencies) among dimensions, it has its own limitations being dependent on specific elicitation methods. Furthermore, it does not support the analysis of dimensions in multiple levels.

VPD canvas, a business design tool, is another method that uses visual representations to address user needs. Inspired by the business model canvas, VPD is comprised of two main blocks of "value proposition" and "client segments." It offers a fast and simple way to generate minimum viable product propositions. This method supports both the technology-push and market-pull approaches in product development (moving from client canvas to product canvas and vice versa) and improves the accuracy of value propositions by triggering questions that help identify users’ jobs, the pains and gains associated with users, as well as pain killers, gain creators and the main product features associated with the product (Osterwalder et al., 2014; Pelicioni et al., 2017). Although the VPD canvas is an innovative tool to analyze users’ needs, it has some major disadvantages. For example, it highlights only two main categories of needs and is more suitable for providing a general overview of the product development project. It may therefore not be that useful for complicated products where the focus is mainly on details. All the needs are categorized on one level, which makes it difficult to examine the details of each category and consequently investigate details of product functions. Moreover, the technique does not support a structured method of prioritizing the needs. Prioritization is mainly based on the designers’ subjective judgments. Last but not least, those involved in the needs analysis process are users and designers; other stakeholders are not involved in the development process.

Recent studies show that it is essential to understand users’ mental model to empathize with them and understand their needs. However, to the best of our knowledge, there is no consensus on how to capture users’ mental models, how to make sure that they have been truly understood and how to present them (See (Delugach et al., 2016; Kang et al., 2015; Olaverri-Monreal & Gonçalves, 2014; Young, 2008)) so that designers could use them in a new product development process. Neither is it clear what type of information could be elicited from representations of users’ mental models. It is thus needed to have a more advanced needs analysis method that acts as a decision support system, helps understand users’ mental models, promotes team empathy (Gibbons, 2019), and produces the input required by the designers.

Cognitive maps are graphic representations that display the content and structure of concepts and thoughts that individuals hold implicitly (Swan, 1995). They have certain benefits and characteristics that make them very relevant tools to analyze user needs. In particular, they can provide important information about users’ unarticulated and implicit needs. Cognitive maps can capture complexity and can be represented comprehensibly (Eden et al., 1979). In addition, they are not limited to a hierarchical structure and can cover the network structure required for the analysis of needs. The visual nature of the map also simplifies the complex structure of personal concepts and thoughts and facilitates the transmission of complex mental structures (Village et al., 2016). Enabling a systematic and detailed exploration of the cognitions of teams, cognitive mapping helps negotiate to reach a consensus and make commitments to a portfolio of actions. This way, the team's cognition helps manage the complexity and acts as a decision support (Eden, 1988; Swan, 1995). This method could also be used to investigate decision makers' cognitions. Furthermore, cognitive maps improve understanding of complex decision environments by making it possible to build a complex, interactive system based on simple, understandable components and simple data collection and analysis techniques (Montazemi & Conrath, 1986; Swan, 1995). Ultimately, cognitive maps maintain a dynamic relationship between the individuals' mental model and their environment. They could thus be used dynamically to reflect the variations in the need map structure over time (Swan, 1995; Village et al., 2016).

Given the importance of needs analysis for product development, the necessity for a powerful analysis method is undebatable. A needs analysis is supposed to help the design team understand the group mental model, make better decisions, and plan for the next steps. Although researchers have attempted to propose different methodologies for needs analysis, there is no comprehensive needs analysis method that can support the design team. The advantages of visualization and mapping techniques in information representation, data analysis and decision support make them practical tools for needs analysis in innovation projects (Kalbach, 2016; Shaw et al., 2009). Cognitive mapping has been specifically used in organizations to assist in planning and decision making (Village et al., 2016). Cognitive maps make it possible to represent the network of needs and identify their interrelationships, categories and clusters (Castellano & Del Gobbo, 2018; Village et al., 2013). Nonetheless, it is still necessary to present the different categories of users and stakeholders, the consequences and the priorities.

## 5.3 Methodology

The methodology for this research project was inspired by combining action research (Coughlan & Coghlan, 2002) with intervention research (Fraser & Galinsky, 2010). The researcher is involved in action to analyze the needs for an actual project, while the possibility of using cognitive mapping as a needs analysis technique is investigated. This allows for an analogy of what is currently being done to analyze the needs and what the researcher proposes in order to provide a comparison of the two approaches and draw conclusions based on the benefits of each method. The methodology can be divided into three steps, which are summarized in Figure 5.2.

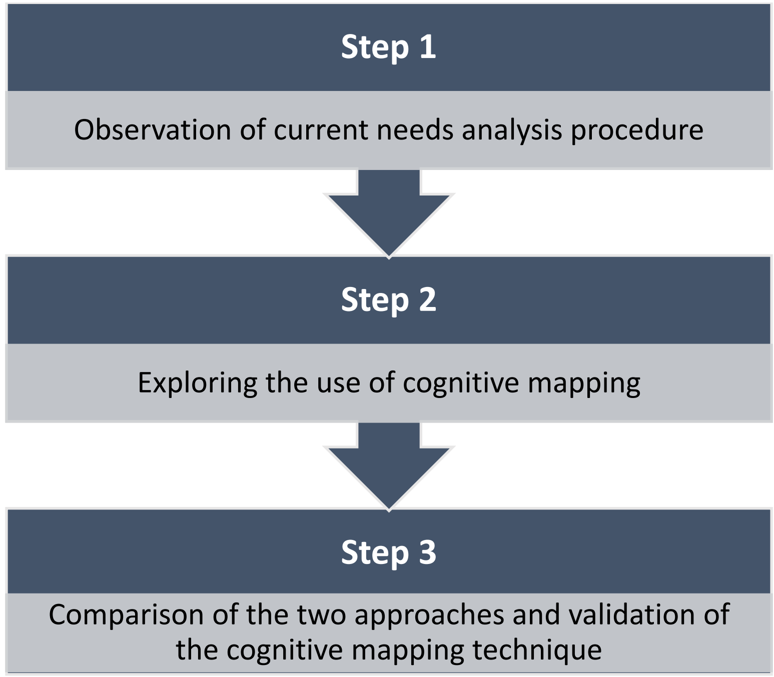



Figure 5.2 Research Methodology

First, to explore the possibility of using cognitive mapping in a product development context, it was observed that the needs analysis process currently in place at the I&T department of a large Canadian transportation company. While working with the UX team (including two UX managers and a UX research lead), the author observed the methodology they used to analyze users' needs and proposed using the same data to create cognitive map for a specific project.

Evaluating the portfolio of ongoing projects within the team, the authors were looking for a project that was still in its primary phases and had not been the focus of a needs analysis. The author also needed easy access to the project stakeholders and users to facilitate the data collection and analysis. The Development Position Book (DPB) was ultimately chosen as an internal project to set the ground for our exploratory research. As part of an exploratory approach, the initial step involved following the company's current technique. Subsequently, cognitive mapping was implemented, and a comparison was made between the outcomes of both approaches. Finally, the project stakeholders were asked to provide feedback about the usefulness of cognitive mapping to validate the results.

### 5.3.1 Observation of the Current Needs Analysis Procedure

**UX Research Methodology at the Partner Organization**

The researcher was involved in the entire needs elicitation and analysis process conducted by the UX team. According to the UX team's documents, UX research methodology is comprised of four phases: Definition, Execution, Synthesis and Output.

**Participation in Needs Analysis**

The researcher was involved in a total of 10 meetings to plan and prepare for the workshops, interview scripts and protocols, participant recruitment, and documenting the research questions to be used in the interviews and data processing. Three workshops were held to coordinate with the project stakeholders, brainstorm on the most important research questions, and organize follow up sessions for data analysis. The researcher also observed and was involved in all the interviews with stakeholders and users (a total of 15 interview sessions), the details of which are presented in Section 5.4.1.

### 5.3.2 Mapping Exercise

The elicitation phase remained the same for this step and the needs elicited by the UX team were also used for the mapping exercise. The mapping started after the Definition and Execution phase. Once the needs were elicited from the users and other stakeholders, the mapping exercise began. The main steps are outlined below.

The first step involved clustering the needs in different groups (user needs, business requirements, project manager's needs and constraints, etc.) and levels (high, medium, and low), which was done by two UX/UI designers in a one-hour session. In the next step, the mapping was done by a group composed of one UX/UI designer, two users, and two stakeholders through a mapping workshop that took about three hours. The levels were identified based on the ACV (Attribute/low-level, Consequence/medium-level, Value/high-level) structure (Costa et al., 2004; Leão & Mello, 2007). In the ACV structure, Attributes lead to Consequences and Consequences lead to Values. However, this does not mean that there is no horizontal connection between nodes. The interrelationships and connections between the user needs are identified according to the Means-End Theory with no limitations in generation of nodes and links, where any two nodes could be connected by a link as long as the former leads to (i.e., is the means to) the latter (the end) (Reynolds & Gutman, 1988; Woodall, 2013).

The need map is comprised of nodes and links, where nodes represent the needs and links identify the relationship between each pair of nodes. For example, if node A is connected to node B by a link, it means that A leads to or has an impact on B. Nodes could be coded by colour or shape to represent different groups. Each pair of nodes could be connected to each other by a link. However, since in the ACV structure, attributes lead to consequences and consequences to values, the direction must be respected. In other words, the only limitation for the connections (links) is that a value cannot lead to a consequence and a consequence cannot lead to an attribute. It is worth noting that for simplicity, we have assumed that all the links are of the same type.

Once the nodes (ie., need/requirement from users/stakeholders) are available, the connections between the needs can be identified with links (arrows). Once the map is shaped, the analysis begins. The count of links and nodes in the network gives an estimate of the importance of each node. Prioritization of the needs is made based on their connections and impact on higher-level values. Once the map is complete, the structure should be validated by users and/or project stakeholders who participated in the mapping workshop. This mapping method for needs analysis using cognitive mapping with an ACV structure is hereafter referred to as “need mapping” in the paper.

### 5.3.3 Comparison and Validation

The most important outcome for both needs analysis approaches is a list of prioritized needs. At this step, the lists of prioritizations, the prioritization criteria, and the pros and cons of each approach should be compared. The two approaches are compared based on their capability to fulfill the requirements for needs analysis in the project, such as the involvement of stakeholders, prioritization criteria, validity of the results and the potential benefits of the analysis method.

To validate the need mapping technique, once the need mapping exercise was completed, the methodology and the advantages of the technique were presented to the UX team and other groups involved in needs analysis activities (23 participants). The participants were asked to express their opinion about the outcomes of the need mapping technique and the value it brings to the team. An online survey was conducted by the UX team of the partner organization. The possible benefits of the maps and cognitive mapping are listed below (extracted from the literature). The respondents were asked to rate their level of agreement with each statement on a five-point Likert scale (Strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, strongly disagree).

1. Maps **provide a holistic view**, presenting the information in different layers and various levels along with the interactions among the elements (Kalbach, 2016; Kaplan, 2016; Swan, 1997).
2. Maps are able **to demonstrate massive amounts of information in a single view** and facilitate the identification of points of improvement (Kalbach, 2016; Sperano et al., 2018).
3. The visualization can help to **convert tacit knowledge and implicit concepts into tangible representations** (Kalbach, 2016; Sperano et al., 2018; Village et al., 2016).
4. Maps and diagrams are **compelling and quite easy to understand** (Kalbach, 2016).
5. Maps are made by groups of people, which **promotes empathy among the stakeholders leading to a shared mental model** (Village et al., 2013).
6. Mapping techniques help managers think critically, broadly and deeply, and could act as a **decision support** (Shaw et al., 2009; Sperano et al., 2018; Village et al., 2016).
7. Cognitive maps **could capture complexity and are not limited to a hierarchical structure**. Thus, they could cover the network structure required for the analysis of the needs (Eden et al., 1979).
8. Cognitive mapping **facilitates the transmission of complex mental structures** and implicit knowledge among the individuals (Village et al., 2016).
9. Cognitive maps enable us to **systematically explore the cognitions of teams in detail, negotiate to reach consensus and make commitments to a portfolio of actions** (Eden, 1988; Swan, 1995).
10. Cognitive mapping helps developing a subjective representation of the relationships between factors in **semi- or unstructured decision problems** (Montazemi & Conrath, 1986; Swan, 1995).
11. **Interactions presented in cognitive maps improve understanding** (Kalbach, 2016; Montazemi & Conrath, 1986; Swan, 1995).

12. Cognitive maps **could be used dynamically and be updated whenever necessary** (Swan, 1995; Village et al., 2016).

## 5.4 Results and Discussion

Here, the results of the exploratory research are presented in two main sections. The first is the observation of the UX research methodology for the DPB project; the second is the implementation of cognitive mapping as an alternative approach for analyzing the needs and exploring the possibilities. The comparison of the needs analysis results produced by each approach is presented in the discussion (Section 5).

### 5.4.1 Development Position Book - Observation

The observation encompassed the UX team's data collection process and their progression through the four phases of UX research (definition, execution, synthesis, and analysis) specifically for the DPB project. The Development Position Book (DPB) is a software engineering development framework and definitive guide to customized development at the company. The DPB is considered as a repertory of the information required by different groups of developers and includes development pillars (Java, Mulesoft, Web, Mobile, etc.), development patterns (technology and infrastructure alignment, high-level patterns and reference application), development accelerators (frameworks, libraries, scaffolding tooling), and standards (security and vulnerability standards, coding standards, unit test standards and non-functional requirements).

The DPB is maintained by the software engineering development architecture team. Developers are encouraged to contribute to it by leaving comments in the comment section at the bottom of each page. Developers can also contact the development architecture team if they have any questions or suggestions about the DPB or technical blueprint reviews.

**Definition**

At this stage, the kick-off workshop was held with the project’s main stakeholders (DPB managers, developers, development architects) and UX/UI designers to brainstorm on the research questions. All the research questions were subsequently refined and clustered as themes to be prioritized by the participants. Information structure and content, usability and contribution to the DPB were considered to be the most important themes, while efficiency, navigation, usefulness, compliance and enforcement were deemed to be moderately important.

According to the current needs analysis procedure, the plan for this project was defined as follows:

1- Interview sessions with product stakeholders (unstructured interview sessions – not recorded)
2- Interview sessions with the developers from different disciplines, plus an observation activity where users are given a set of tasks that will inform the researcher about the user flow and probable challenges. (structured interview sessions – recorded and transcribed)
3- An online survey targeting a much larger number of developers to collect more data and evaluation of the user experience with the current version of the DPB.
4- Analysis of findings from the interview sessions, observation activity and the online survey. Identification of the themes, patterns and insights resulting from the data analysis.
5- Recommendations for each of the pain points found.
6- Preparation of a report of the proposed recommendations and possible solutions.
7- Presentation of the results to the project stakeholders.

**Execution**

UX research activities were defined and carried out in this phase. Interview sessions with end users and other project stakeholders, an online survey and a need mapping exercise were defined to collect and analyze the data on the needs of end users and project stakeholders.

**DPB Stakeholders' Feedback**

Research questions that were ideated and prioritized in the previous step should be answered at the execution phase. Some are to be answered by stakeholders and the rest by end users. In addition, it is important to involve stakeholders in the needs elicitation process and consider their input for product improvement. To this end, five stakeholders were interviewed: two managers of the DPB and three quality control specialists (QC specialists).

**Interview Sessions with Stakeholders**

One of the major concerns was the level of compliance of development projects with the DPB guidelines and standards. Since the QC Specialists were in charge of assessing the level of compliance for development projects, 30-minute unstructured interview sessions were conducted with three of these specialists. In addition, two managers were interviewed (30-minute unstructured interviews) to provide their point of view.

**Interview sessions with the DPB end users (developers)**

At this stage, 10 semi-structured interview sessions (1 hour each), including an observation activity, were conducted. The questions, a combination of open-ended and closed, were derived from the research questions, while the observation tasks were provided by the DPB managers responsible for each field of development. Description of the target population is as follows:

- Of the10 participants, seven were Java developers, two Mobile developers and only one RPA/.NET developer. Web developers were not accessible and were consequently eliminated from the target users.
- Most of the participants were development leads who needed the DPB on a regular basis for their work.
- Half the target population were internal employees; the other half were external consultants.
- The average working experience as a development lead was five years.
- The preferred method of contribution by interviewees was to reach out to colleagues or an architecture enterprise, which is an indirect way of contributing to the DPB.
- Only half the users used the search bar to navigate through the DPB content and find the desired information.

**Synthesis**

Once the interview sessions with users and project stakeholders were completed, the UX team collected the notes and highlights from each interview session. Next, all the findings were clustered by a UX researcher and the patterns (the frequency with which a need is mentioned by users) were identified. The clusters/themes, findings/needs and the frequency with which one was mentioned by the interviewees was thus determined. Based on the findings and insights derived, the UX team presented the recommendations, which could be new ideas for development or suggestions for improvement. A summary of the most important needs (top 10%) is presented in the following table.

Table 5.1 Table of findings - Interview sessions with end users and stakeholders' feedback

| Theme | User's need | User/Provider | Pattern/Frequency | Recommendations |
|---|---|---|---|---|
| 1- Inclusiveness | The DPB should cover all the project requirements and approved development technologies. | User | #7, #11, #12, #15 | The feedback system will help with inclusiveness once users feel that they can easily forward their input to the providers. |
| 2- Awareness | Being notified about the latest updates and recent changes (minor changes) | User | #1, #4, #11, #12 | Email notifications for minor updates |
| 3- Training | Online course, recorded videos for training (saving time for presentations) | User, Provider | #10, #11, #12, P | • Training workshops in fixed time intervals (based on time or number of onboardings).<br>o The session should be recorded for absent participants or other users in need. |
| | Interactive sessions for training (group calls, workshops, etc.) | User | #1, #3, #4, #7, #10, #15 | |
| 4- Findability | User needs to trust the search results and the results must be in the DPB space, not from all over the Confluence; the filtering must be effective. | User | #1, #4, #5, #7, #10, #12 | • A fully functional search engine with various filtering options. |
| | Need to be able to find the desired information in the DPB with minimal time and effort | User | #4, #5, #10, #11 | Improving the efficiency, information structure and the search function. |
| 5- Contribution | User prefers indirect contribution to avoid scattered information all over the DPB. If everyone tries to directly contribute to the DPB, the reliability of the information would be compromised. | User | #4, #5, #12, #15 | Indirect contribution is preferred so that the reliability of the information will not be compromised.<br>• Direct link for contribution on the main page.<br>• Contact list. |

### 5.4.2 Need Mapping – Implementation of cognitive mapping

In the need mapping exercise, elicitation of the needs is based on the feedback from users and other stakeholders collected from interview transcripts, which is the method used by the UX researchers at the organization.

For the DPB project, the need map is comprised of 151 nodes connected with 180 links, among which there are 17 Values (Green), 73 Consequences (Blue), 56 Attributes (Pink) and 4 identified as Constraints (Red). Additionally, different colours were used for different need levels (ACV clustering) and different shapes to represent different groups of people (rectangles for users and circles for stakeholders). Figure 5.3 shows the final map for the DPB project to give a broad idea of the project scale, shape and color coding.

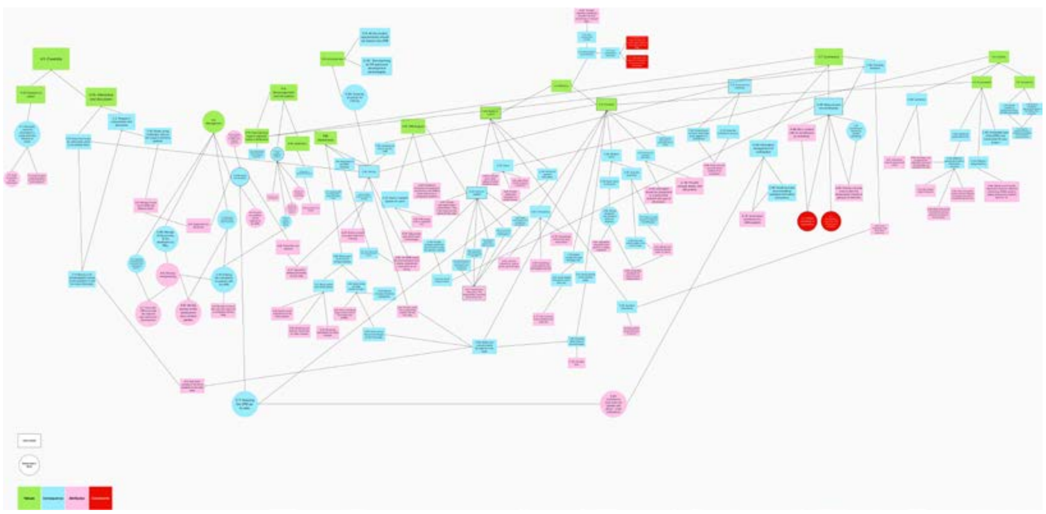


Figure 5.3 An overview of the need map presented for the DPB

**Need Mapping Exercise**

Once the map is complete and validated by users and/or stakeholders, all the nodes should be coded, and the data transferred to an Excel Worksheet. The links and nodes are registered in the form of an adjacency matrix. Figure 5.4 shows the structure of the map along with the adjacency matrix (Table 5.2) for a map of 10 nodes and 12 links.

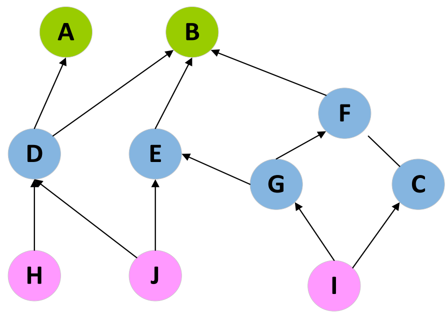



Figure 5.4 Example of a map

Table 5.2 Example of adjacency matrix

| | A | B | C | D | E | F | G | H | I | J | Sum (output) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| D | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| E | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| F | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| G | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| H | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| I | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| J | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Sum (input) | 1 | 3 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 12 (Total No. of links) |

Cognitive maps are mainly analyzed based on their shape and structure (Ruiz-Primo, 2004). Expert maps resemble networks with many links, whereas novice maps are linear or spoke-shaped (with multiple concepts originating from a single concept) (Hay & Kinchin, 2006). The number of links and nodes can be used to further analyze how the nodes are connected and to interpret the map. The ratio of heads to tails can also be investigated. The "heads" of the map (values) are at the top, with concepts leading into them. The action items leading upward are represented by the "tails" (attributes) at the bottom of the map. A high heads-to-nodes ratio can imply numerous potentially conflicting objectives or values, which can reflect the problem's complexity. A high ratio of tails-to-nodes, or the shape's relative flatness, can imply a broad number of possibilities for achieving a specific goal. It is also possible to calculate the centrality of the nodes and investigate patterns such as clusters and loops(Eden, 2004; Village et al., 2013).

In our case, we were interested in the way different needs affect each other. The analysis and interpretation of the need map are presented below.

*User needs with most inputs - Influenceables*

Nodes with the greatest number of inputs are the most demanding. This means that they are affected by many factors (other nodes), there is more than one way to respond to this need, and several improvements must be made to meet it. These nodes are called the most influenceable needs. In an ACV clustering where attributes lead to consequences and consequences lead to values, it is expected, and it makes sense, that there are no attributes among the most influenceable. For example, in the need map developed for the DPB project, “Findability” was the most influenceable node, being influenced by nine others (See Figure 5.5).

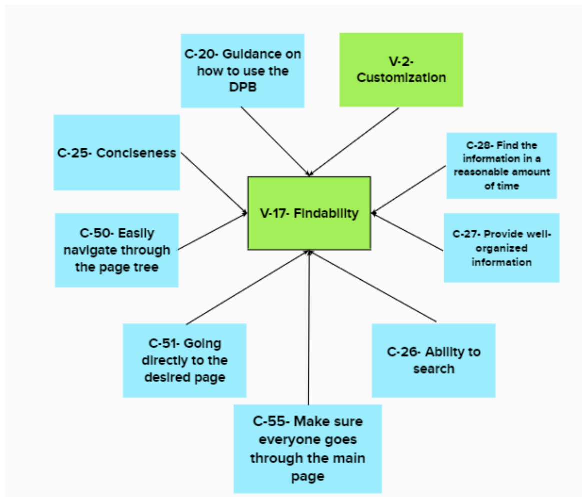



Figure 5.5 The most influenceable node in the DPB need map

The list of most influenceable nodes (with the most inputs) in the DPB example is provided in Table 5.3.

Table 5.3 List of most influenceable needs

| Code | Title | Input |
|---|---|---|
| V-17 | Findability | 9 |
| C-22 | Decision support | 7 |
| V-7 | Contribution | 5 |
| C-5 | Managing the workload | 5 |
| C-35 | Easy process for contribution | 5 |
| V-6 | Usability | 4 |
| V-8 | Management | 4 |
| V-11 | Quality of content | 4 |
| C-9 | Ensuring that all developers use the DPB in a proper way | 4 |
| C-45 | Different granularity levels in information structure | 4 |

*User needs with most outputs - Influencings*

Nodes with the greatest number of outputs have the largest impact on other user needs and values, and thus on user satisfaction. Since it is very important that these needs be met, they should be prioritized as they have the most influencing. According to the ACV structure, attributes and consequences are more likely to be in this category. In the DPB example, “Training” has the most influence on the six others (See Figure 5.6).

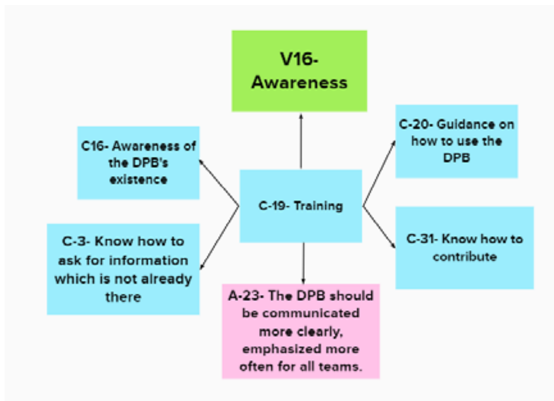



Figure 5.6 The most influencing node in the DPB need map

Table 5.4 sets out the most influencing nodes in the DPB example.

Table 5.4 List of most influencing needs

| Code | Title | Output |
|---|---|---|
| C-19 | Training | 6 |
| C-55 | Make sure everyone goes through the main page | 5 |
| A-25 | Provide clear instructions. Interpretation shouldn’t be up to the user. | 5 |
| A-6 | Process reengineering | 4 |
| V-14 | Feeling that their input is required/makes a difference | 3 |
| C-35 | Easy process for contribution | 3 |

*Calculation of Output/Input Ratio*

When it comes to deciding which needs to work on, the output/input ratio could also be an indicator. Nodes with maximum output and minimum input have the highest ratio. Since they are the ones that have the most significant impact and could be met with minimal effort, they can make for quick wins in terms of improving user satisfaction.

The nodes with the maximum Output/Input Ratio are listed in Table 5.5. It is worth noting that the first three are at the bottom of the map (attributes and consequences) with no inputs. This has led to an infinite ratio. However, in this case, since the number of inputs is equal for all of them (zero), the number of outputs could be considered instead (See Figure 5.7).

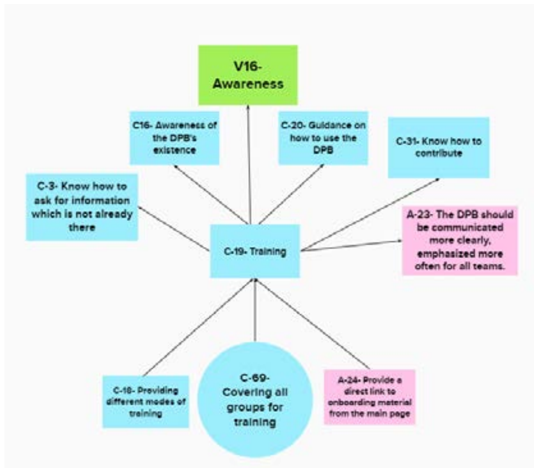



Figure 5.7 Example of a node with an Output/Input ratio of 2 (6/3)

Table 5.5 List of most important needs based on Output/Input Ratio

| Code | Title | Input | Output | Ratio |
|---|---|---|---|---|
| C-55 | Make sure everyone goes through the main page | 0 | 5 | ∞ |
| A-25 | Provide clear instructions. The interpretation shouldn't be up to the user. | 0 | 5 | ∞ |
| A-6 | Process reengineering | 0 | 4 | ∞ |
| V-14 | Feeling that their input is required/makes a difference | 1 | 3 | 3.00 |
| C-19 | Training | 3 | 6 | 2.00 |
| C-3 | Know how to ask for information that is not already there | 1 | 2 | 2.00 |
| C-6 | Managing communications with third parties | 1 | 2 | 2.00 |
| C-7 | Keeping the DPB up to date. | 1 | 2 | 2.00 |
| A-43 | Effective and functional filtering option for search | 1 | 2 | 2.00 |

Depending on the management strategy in responding to a project's different needs and requirements, the decision criteria could change. It is evident that meeting all of these needs contributes to increasing the value delivered to the organization and enhances the satisfaction of both end users and other stakeholders. However, in most cases it will not be possible to respond to all needs, at least not all at once. That is why it is necessary to prioritize the needs and have a plan to decide which needs to tackle first. Different criteria could be employed in different contexts to prioritize needs, based on their importance. For example, when seeking needs that have the greatest impact on our high-level values, one may choose to prioritize those that exert the most influence. Similarly, when searching for needs that can be readily fulfilled in tight constraints and limited resources, one might consider focusing on those with minimal input or the least influenceability. Depending on the circumstances, other criteria could also be used. In the DPB case, the management decided to go with the sum of inputs and outputs to address the most complicated needs (the ones with the maximum number of links). Ultimately, it is possible to target certain values and focus on specific parts of the map connected to those needs.

### 5.4.3 Comparison and Validation

With the analysis results from the three research activities of the synthesis phase, one can compare the list of prioritized needs.

To compare the results, the most important needs to be considered for the DPB project, derived from the two methodologies are set out in Table 5.6.

Table 5.6 Comparison of the prioritizations from the Need Mapping exercise and the current methodology

| No. | Need Mapping | | Analysis of interview transcripts | |
|---|---|---|---|---|
| | **Need** | **Impact level** | **User need** | **Frequency** |
| 1 | Decision Support | 9 | Interactive and recorded sessions for training | 8 |
| 2 | Training | 8 | Trusting the search results | 6 |
| 3 | Findability | 7 | Workload management | 5 |
| 4 | Easy process for contribution | 6 | Indirect contribution | 4 |
| 5 | Managing the workload | 6 | Inclusiveness | 4 |
| 6 | Quality of content | 5 | Being notified about the recent changes and updates | 4 |
| 7 | Providing clear instructions. | 5 | Finding information with minimal effort | 4 |
| 8 | Knowing how to contribute | 5 | Decision support | 4 |

Comparing the two lists of prioritized needs, it is first evident that transcript analysis considers only the users' needs, while need mapping considers needs from other stakeholders as well. Another difference is the distinction between needs. There are five different impact levels in the need mapping list, whereas there are four different frequency rates in the transcript analysis. In the latter, the last five (out of eight) needs followed a pattern of four and appear to be of equal significance, making decision making difficult and defeating the goal of prioritization.

It is also worth noting that the prioritization criteria for the analysis of the transcripts is the frequency with which a certain need was mentioned by users. Such a pattern may not necessarily reveal the importance of the need. High frequency could occur in other circumstances as well. For example, something may be mentioned by a large number of users because it is too obvious or annoying. However, there can be times when one user may see something really important that the other users do not. In this case, a very important need would not be considered because of its low frequency.

However, in the need mapping technique, the impact level, based on the number of needs or values a certain need has impacted, is considered as the prioritization criteria. The prioritization results are thus more reliable. Furthermore, once a need has been prioritized, the need map indicates the steps to be taken, based on the needs and requirements leading to that node, which clears the path for decision making and strategy planning.

Above all, need mapping offers value and flexibility, which the current needs analysis method does not. Need mapping provides the option of further analyzing the needs, visualizing them and adopting various strategies. The current method offers one single criterion (frequency), which cannot be used for further analysis. The advantages of need mapping thus make it a better needs analysis method that could provide decision support for project managers and UX/UI designers.

To validate the usefulness of the need mapping technique, the author used the aggregated data collected in an internal procedure by the company in which 23 people were asked to express their opinion about the outcomes of the new needs analysis method and the value it brings to the team, on a five-point Likert scale. The average response for each statement was calculated based on the median in the respective category (all responses for a particular statement). The results are set out in Figure 5.8. The box plot visualizes several statistical measures, including the minimum and maximum values, the mean (x), the median (represented by a horizontal line in the center of the box), and the quartiles (the 2nd and 3rd quartiles displayed within the box, and the 1st and 4th quartiles represented outside the box).

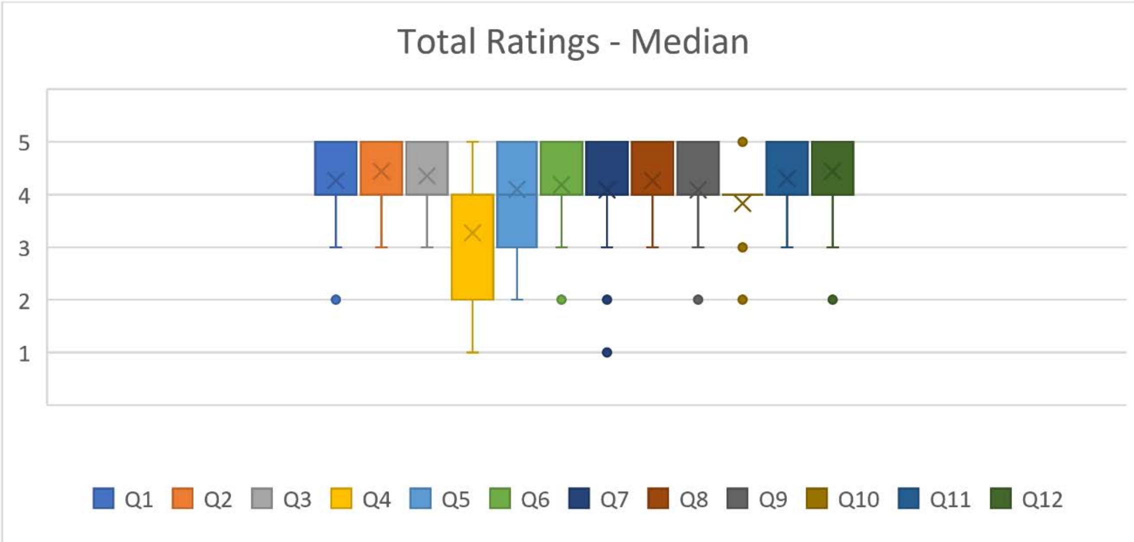



Figure 5.8 Total Ratings - Box Chart

The results show that respondents agreed with almost all the statements and acknowledged the benefits of the need mapping technique. However, concerns were expressed about the complexity of the map using a visual representation tool and data analysis. The lowest rated statement is number 4, which is about the maps being compelling and easy to understand. Given the large number of needs elicited from users and stakeholders, the complexity of the map is to be expected. It is quite understandable that respondents would be concerned about this complexity compromising the map's usability and efficiency. However, complex maps are required to solve complex problems and complexity is something to be managed rather than avoided.

The respondents also raised certain other concerns as to whether the map was capable of acting as a decision support, was useful in negotiations. and promoted empathy to create a shared mental model (statements number 5, 9 and 10). Nevertheless, once the complexity of the map has been managed using data analysis techniques (e.g., Dependency Structure Modelling) and appropriate representation tools, its usability and usefulness in other areas, such as decision making, negotiation and creating a shared mental model, will increase.

## 5.5 Conclusion

We explored the application of cognitive mapping as a needs analysis method for UX/UI designers in a large transportation company. A comprehensive needs analysis method should be able to categorize and prioritize the needs, identify the interrelationships and consequences, act as a decision support while resolving the conflicts and ultimately help to understand the users' mental model, as well as promote empathy and mutual understanding in the team. Given all the benefits of cognitive mapping as a visual representation for analyzing needs, its application was studied for UX/UI designers, business analysis and business process optimization specialists who are directly or indirectly involved in needs analysis in a large organization.

Implementing the need mapping technique in an actual project setting showed that cognitive mapping can reveal the clusters, conflicts, interrelationships, constraints, and consequences of the needs from end users and other project stakeholders. Its flexible structure allows for further analysis of the needs in an innovation project and represents the collective mental model of the users and stakeholders. Another advantage is that designers and project managers can adopt different strategies, according to the design stage, to prioritize the needs. The map also allows for the investigation of connections between the needs, illustrating the impact they have on each other, which in turns helps to identify the steps to be taken to meet each major need or value. The cognitive mapping technique could thus be applied in a needs analysis method to provide decision support for the team and facilitate project management.

The results indicate that the advantages and benefits of the need mapping technique are mainly acknowledged by the UX/UI designers, business analysis specialists and business process optimization specialists. Concerns were expressed that the complexity of the need map could compromise its usability in decision making and negotiation and in creating a shared mental model in the team. Accordingly, handling the complexity of the need map by means of data analysis techniques and better visual representation tools constitutes the next step in the enhancement and development of the new needs analysis method.

### 5.5.1 Limitations

First, since not all the organization's current projects fit into our research scope, the application of cognitive mapping was investigated and explored for only one project (Development Position

Book), which was still in the first phase of UX research. A wide range of users and project stakeholders were accessible for this project. However, the primary intention was to be involved in three projects, which proved not to be possible owing to various constraints.

Second, the mapping workshops were supposed to be held in a room with a large whiteboard where the participants could actively collaborate to build the map for three hours. However, because of the work-from-home policies sparked by the COVID-19 pandemic, the workshops had to be held remotely. The UX team had to adapt to the new circumstances and use MURAL to create the maps. The clustering and first draft of the maps were created by the facilitator. The stakeholders were able to validate the map in separate video calls using a shared screen.

Third, due to specific conditions regarding the DPB project at the partner organization, we were not able to carry out the online survey for the validation of the need mapping technique independently. Hence the validations results presented in the paper are part of an aggregated report from the partner organization which prevented us from verifying if the questions are biased or standardized.

### 5.5.2 Suggestions for future research

Since we explored this new method of needs analysis in only one particular project in a large transportation company, it should also be tested in other contexts and different industries to explore the extendibility of the need mapping method to projects with different stakeholders, context of use, complexity, and so on.

Future research could also use more advanced visual representation tools or software to create and present the maps, as well as data analysis tools to further analyze the data driven from the maps (e.g., impact/dependency levels, multiple dependencies, dependency type, importance weights, centrality index, etc.).

Ultimately, since this method is intended to respond to the needs of UX/UI designers, product designers, developers, and everyone involved in the design process, as well as to act as a decision support for project stakeholders, it is highly recommended that stakeholders’ and designers’ needs and requirements be examined.

### 5.5.3 Implications for Theory and Practice

In theory, this novel needs analysis method could help with the analysis of numerous stakeholders' needs by highlighting the connections between the needs of the various parties participating in the project (users, designers, managers, and other stakeholders). Furthermore, employing cognitive mapping in the development of a new product enhances understanding of the needs and the representation of the collective mental model associated with using the product in question.

In practice, very often there are discussions around conflict resolutions between users' and stakeholders' needs. Business stakeholders and UX designers as users' advocates end up being against each other rather than being on the same side. Cognitive mapping can present a holistic overview to show users' as well as stakeholders' needs in a single view depicting how they impact each other. The mapping can promote empathy and help the team to collaborate for any conflict resolution. Cognitive mapping can provide decision support for UX designers, back-end and front-end developers, project managers, product owners, and other members of the team, supporting strategy planning and project management. The collaborative nature of the mapping workshops improves communication between project stakeholders and end users, promoting empathy and mutual understanding.

# CHAPTER 6 ARTICLE 3: A COGNITIVE APPROACH FOR ANALYZING NEEDS IN PRODUCT DEVELOPMENT USING DEPENDENCY STRUCTURE MODELLING AND SOCIAL NETWORK ANALYSIS

Mitra Taraghi, Fabiano Armellini, Daniel Imbeau

Article submitted to the Journal of Product Innovation Management on March 17, 2023 (under review).

## Abstract

Effective decision-making and prioritization are crucial components of the new product development (NPD) process. In order to understand needs from users and stakeholders, it is important to conduct a thorough analysis and establish a shared mental model within the team. To achieve this, we used cognitive mapping as a visual needs analysis method and explored the application of dependency structure modelling (DSM) and social network analysis (SNA) in a case study. We utilized several metrics such as impact rate, cumulative dependency rate, degree centrality (indegree and outdegree), betweenness centrality, and eigenvector centrality to further analyze and prioritize the identified needs. Our research findings indicate that the application of network analysis metrics can facilitate the process of needs analysis, prioritization, and decision-making for the product development team. The metrics help the team to assess the importance of different needs or product features, evaluate the dependency of business objectives, and estimate the impact of constraints on product development. Additionally, these metrics can be modified to meet specific requirements, such as estimation of impact rates and dependencies for a specific group of needs. Even though further research is required to validate the effectiveness of this approach in different contexts, this case study demonstrated the potential of the combination of visual cognitive mapping with the aforementioned techniques to give NPD teams a better understanding of how various needs are interconnected and, therefore, enable them to make better-informed decisions regarding product development.

**Keywords:** Needs analysis, New product development, Cognitive mapping, Dependency structure modelling, Social network analysis

## 6.1 Introduction

Effective decision-making is a key factor in product management, ensuring product success (Krishnan & Ulrich, 2001; Lo Storto, 2010). The timing of decisions during product development and appropriate prioritization can impact performance. Making the right decisions early, when information is scarce and uncertainty is high, can boost performance (Ali et al., 2021; Ullman, 2009). In the same vein, waiting until later stages with more certain information and opportunities can have a negative impact on performance (Maier et al., 2014; Verganti, 1999). Product attributes are a consideration in critical decision-making, and the new product development process is strongly affected by the way the components are interconnected and coordinated (Lo Storto, 2010; Markham, 2013; Ulrich et al., 2008). Each of the product attributes is linked to its corresponding values with the goal of fulfilling a user's or stakeholder's need ("Attribute Value Mapping," n.d.; Goldenberg et al., 2009). Thus, it is important to analyze needs on various levels to assess the interrelationships and impacts to make decisions for design and development.

Truly successful innovations require a good understanding of the user needs (Evanschitzky et al., 2012; Robert et al., 2018). However, it is costly for firms to elicit and analyze needs, in that needs have a complicated structure and, therefore, conventional market research methods are not able to deeply investigate them (von Hippel & Katz, 2002). More importantly, to be able to analyze various needs, one must prioritize them. Otherwise, it would not be possible to distinguish the most important user needs, and there is a risk of overlooking the user's critical needs and essential product requirements (Lindgaard et al., 2006), not to mention the needs of other stakeholders. Thus, a structured approach is necessary to analyze needs.

The process of determining user and business requirements, also known as needs analysis, is crucial in the development of new products. The initiation of a project is centered on identifying and examining the needs of users and the expectations of the company (Ferrari et al., 2022). Although terms like needs, requirements, objectives, values, and wants may have distinct interpretations, they all stem from the notion of wanting or seeking something (Bayus, 2008; Shillito, 2001). This paper adopts the term "need" to encompass all types of necessities, including requirements, preferences, values, desires, and so on. Needs analysis is a component of a more comprehensive need management process and involves organizing and prioritizing needs, as well as recognizing potential consequences and making necessary compromises (W. Song, 2017). The needs of users and other stakeholders can often be intricate, making it likely that conflicting needs may arise (Andriopoulos et al., 2018; Da Silva et al., 2020; Griffin, 2012).

In design research, visualizing the information can aid the analysis and interpretation of the collected data (Basole, 2014; Eppler & Platts, 2009; Fox & Hendler, 2011). A visual representation presents information in the form of visually discernable patterns, connections, and correlations for decision-makers, who may not be able to recognize them otherwise. New technologies can be used to visualize information and facilitate the analysis and interpretation of the data through maps, graphs, diagrams, and other visuals (Thoring et al., 2015). These visual applications allow users to understand the problem statement and synthesize a vast amount of data in a single view (Sperano et al., 2018). The visual aids play the role of external cognition, facilitating problem-solving and decision-making, and identifying points of conflict (Card et al., 1999). However, in large companies with complicated large-scale projects, analyzing the needs of different parties, resolving possible conflicts between any two needs/requirements, and prioritizing needs could be a real challenge. It can be difficult to analyze large amounts of information to pave the way for decision-making by providing an overview of the big picture and defining the main values of the users and stakeholders. Studies show that visualization techniques like cognitive mapping can be effective tools in such circumstances to help organizations deal with complicated projects (Sperano et al., 2018; Swan, 1997; Village et al., 2016).

Cognitive maps can be applied in a variety of contexts. In general, they help users organize subjective information, evaluate and analyze complex structures, make decisions, gain in-depth understanding of a topic and, in addition, they help develop mutual understanding and a shared mental model in a team (Eden et al., 1992; Montazemi & Conrath, 1986; Siau & Tan, 2006; Village et al., 2016). All these qualities make cognitive mapping a good technique in needs analysis, stakeholder analysis, and even strategic planning (Quispe Vilchez & Pow-Sang Portillo, 2019; Villafranca & Loureiro, 2013).

The process of needs analysis in new product development (NPD) can be aided by visual techniques such as cognitive mapping, but the complexity of the maps can present a challenge in terms of interpretation and prioritization. Cognitive maps, like other graph-based representations, have a mathematical representation. To further analyze and go beyond the visual representation, advanced data analysis could be useful. To address this, advanced data analysis methods like the dependency structure modelling (DSM) and social network analysis (SNA) have been found to be effective (Chang et al., 2011). DSMs help simplify the system by prioritizing critical components and providing a clear visual representation of processes and stakeholder interrelations (Browning, 2016). SNA, on the other hand, is a flexible tool that can be used in large projects and that leverages computing technology to gather and analyze data on a massive scale, allowing for the discovery of generic properties of social networks (Albert & Barabási, 2002; M. E. Newman, 2001; Yan & Ding, 2009).

The main objective of this paper is to explore the application of DSM and SNA in analyzing needs using the cognitive mapping technique in a product development case study. The paper continues with a topic literature review on the application of DSM and SNA in product development (Section 6.2); the methodology used for the investigation of DSM and SNA in product development (Section 6.3); and presentation of the results of the different steps of the research and discussion (Section 6.4). The conclusion is presented in Section 6.5.

## 6.2 Literature Review

A cognitive map depict a person's beliefs in terms of their content and structure in a graphical representation (Eden et al., 1992; Tegarden & Sheetz, 2003). It seeks to obtain statements from individuals regarding subjectively meaningful concepts and relationships to a particular problem area and to illustrate these concepts and relationships using networks and diagrams (Swan, 1997). The network structure of the map is used to investigate cognitions in decision-making processes within an organization (Montazemi & Conrath, 1986; Swan, 1997). It presents the causal relationships among various constructs in a particular system. In other words, a construct is linked to others, with the link representing a cause-and-effect relationship (Castellano & Del Gobbo, 2018). A person's reasoning is gained by capturing the chains of causal argumentation (Eden et al., 1992; Siau & Tan, 2006).

The Dependency Structure Modelling (DSM) method is a powerful network modeling tool to represent the elements in a system and their interactions. It shows the system architecture in NPD, including the process architecture, the product architecture, and the organization architecture (Eppinger & Browning, 2012; Q. Yang et al., 2014). In an NPD process, graph-based techniques were successful in capturing relationships between tasks (Yassine & Braha, 2003). Network analysis techniques can be used to identify critical NPD tasks and interactions that constrain NPD process execution (Browning, 1999; Collins et al., 2010).

### 6.2.1 DSM in Needs Analysis and Product Development

The dependency structure modelling, also referred to as the dependency structure modelling (DSM), is a widely adopted modeling approach ~~across many fields~~. Its simplicity and succinctness make it an appealing choice and, when analyzed properly, it can reveal significant patterns within system architectures, including modules and cycles (Browning, 2016).

A DSM is a matrix that is arranged in a square format, where the cells along the diagonal generally correspond to the system elements, such as components in a product, individuals in an organization, or steps in a process. The off-diagonal cells, on the other hand, reflect relationships or dependencies among the elements. DSMs that have a single type of off-diagonal mark are known as binary DSMs, while those with numerical values in the off-diagonal cells are referred to as numerical DSMs. Furthermore, the format of a DSM allows for customization using symbols, markings, and color coding. The matrix orientation can also be flexible and allow the inputs in rows and outputs in columns or vice versa. This makes the basic DSM equivalent to a directed graph since the regions above and below the diagonal distinguish the directionality of any relationship (Eppinger & Browning, 2012).

The DSM representation offers a number of benefits over a graph, including a more compact and readable format, better scalability, and the ability to highlight key architectural features, such as iterations and loops (Browning, 2001, 2016). By measuring interaction strength, overlap, and clustering of organizational units, DSMs can help reduce and simplify the complexity of systems (Q. Yang et al., 2014). The growing popularity of DSMs is due to their many advantages, which have led to their use in a range of applications, including product development, project planning and management, systems engineering, and organizational design. In product design, DSMs can be used to model the relationships between design decisions, parameters, and subroutine parameter exchanges through the use of parameter-based or process-based models (Browning, 2001), which also allows the analysis of the sensitivity to NPD changes (Biazzo, 2009).

The DSM may offer several advantages, but it falls short in its representation of a rich process model. Some important aspects of activities (e.g., duration), are typically not depicted in a DSM. The compact nature of the DSM format means that it cannot show all the attributes of activities.

Display tools could be utilized to fill in the missing elements and better illustrate the information, such as highlighting disconnected workflows (Browning, 2016; Kumar & Mocko, 2007).

### 6.2.2 SNA in Needs Analysis and Product Development

Graphs or networks provide a universal method for representing and examining the interplay between nodes. Among the many types of networks, social networks are the most recognized and have been the subject of research for many years (Bringmann et al., 2019; M. Newman, 2018). When the focus of a system is on individual components and their relationships, social network analysis offers an effective method for interpretation and analysis (Hanneman & Riddle, 2005). By drawing on the concepts, visualization methods, and mathematical tools of graph theory, social network analysis provides a means to visualize and measure the relationships, information, and knowledge transmission among individuals and units within an organization (Barabási, 2003; Lo Storto, 2010).

In a network structure, the connections between the nodes are called *edges* or *links*, which can be identified through questionnaires, interviews, observations, or databases (Wasserman & Faust, 1994). Once the network is built using an adjacency matrix, connections between nodes $i$ and $j$ can be captured. When there is an edge between nodes $i$ and $j$, the entry equals one, otherwise it equals zero. As well as visualizing such relationships, statistical tools are used to examine a network's structural properties (Bringmann et al., 2019; Collins et al., 2010).

Social network analysis uses the concept of centrality to investigate a network's properties. In order to estimate a node's structural importance or power, a measure of centrality provides a rough indication of how well it is connected to other nodes (Lo Storto, 2010). Defining a centrality index has been a contentious issue throughout history because there is no universally accepted understanding of what it represents. While centrality indices aim to quantify the relative importance of vertices or edges in a network, the definition of importance is far from straightforward and has been a subject of debate. In most networks, there is a sense that some vertices or edges are more central than others. Centrality indices quantify that intuitive feeling (Brandes & Erlebach, 2005).

The SNA metrics enable the analytical determination of essential relationships in complex NPD settings without depending on an individual or group to have a precise understanding of the entire NPD process (Collins et al., 2010). The main measurements of centrality in a social network are degree centrality, closeness centrality, betweenness centrality, and eigenvector centrality

(Freeman, 2002). In a network, centrality describes how each node is involved in all subgraphs. An important property of centrality measures is their ability to display clear rankings of nodes and characteristics, such as criticality (Collins et al., 2009; Yan & Ding, 2009). In the NPD literature, SNA is commonly employed to investigate the relationship and relative position of actors within interorganizational NPD setups (Kratzer et al., 2016; Leenders & Dolfsma, 2016), but it is also used to assess the relationship of other NPD attributes, such as ideas management (Björk & Magnusson, 2009).

### 6.2.3 Combination of DSM and Network Analysis

DSM and SNA can be used in tandem to effectively analyze and improve product development behavior, providing a powerful analytical tool for NPD performance investigation (Lo Storto, 2010). A DSM can be a powerful tool for identifying critical features of a product (Eppinger & Browning, 2012). Identifying critical features in a complex iterative system can be challenging. However, DSM utilizes network analysis to identify and prioritize such critical features. By doing so, DSM enables the analysis of the activities of the complex system and allows for resource allocation for the necessary activities based on the criticality of the features (Chang et al., 2011).

Additionally, network analysis metrics help identify constraints on NPD execution by measuring properties of information flow. The data can be used by project managers to develop team integration mechanisms and identify coordinating mechanisms for concurrent projects. It is also possible to identify important or critical tasks for functional managers and process architects. It provides managers with a practical decision-support tool for adjusting ideal task sequences when scheduling, budget, and expertise constraints prevent them from performing tasks in the ideal order (Collins et al., 2009).

## 6.3 Methodology

We have used a case study for the purpose of exploratory research (Yin, 2018), in order to investigate the application of DSM and SNA in an actual setting of product development. Case studies are comprehensive methods of inquiry to examine the analysis of data in a needs analysis process in a real-world setting (Stoecker, 1991; Yin & Davis, 2007).

The case study takes place in a large North American transportation company for a software development project. In this setting, a large team comprising business sponsors, product managers, functional designers, business analysts, UX designers, quality assessment specialists and developers elicited needs, documented requirements, planned for the design sprints, prepared user stories, and developed and tested the product. The research methodology is divided into three main steps: 1) data collection, 2) application of cognitive mapping, and 3) data analysis using DSM and SNA. Each step is explained in the following three subsections.

### 6.3.1 Data Collection

The first step for the needs analysis process is to collect data regarding the needs and requirements coming from users and project stakeholders. Elicitation of the needs is part of the needs management process, which includes elicitation, analysis, and specification of needs (Nuseibeh & Easterbrook, 2000; A. W. Ulwick, 2013). In this paper, with an inclusive approach, we refer to needs as an umbrella term including all types of needs, such as requirements, objectives, values, attributes, and so on.

In this study, the focus of the research is on analysis of the needs, and the elicited needs have been the input for the analysis process. We used secondary data collected from release planning documents, business planning documents and functional design documents (about 100 needs of various types). Once the data was collected, the needs were cleaned, sorted, and clustered in multiple groups to prepare them for the cognitive mapping exercise.

### 6.3.2 Cognitive Mapping

During the first step, the needs were clustered into various groups such as user needs (usability issues, complaints, specific features asked for by users), business objectives (safety, operational efficiency, environmental impact, cost reduction), project manager’s needs (planning and scheduling, resource management), product attributes (search functions, menus, information to be displayed), and constraints (technical constraints, time constraints). This task was done by the researcher in a two-hour session. The mapping process was next carried out in a series of four mapping workshops (according to the availability of participants) involving a group consisting of a business analyst and three product owners. All participants were present in all four sessions. These individuals were directly involved in the product development process, playing critical roles in planning, prioritization, and decision-making. The mapping workshops were consistent in nature, with the researcher acting as the facilitator in all instances. The participants were tasked with collaborating and creating a collective map to identify the necessary elements required to shape the network structure. They were instructed to connect the various nodes within the structure through links. While it was initially planned to conduct a single four-hour group mapping workshop, due to the limited availability of the participants, it was necessary to divide the workshop into four separate one-hour sessions. Given that the participants were geographically located in multiple places, the workshops were held using Microsoft Teams and Mural. Ultimately, at the end of the fourth session, the participants were asked to validate the map to make sure that the group map (comprising needs in a network structure with nodes and links) was aligned with the team mental model.

The final group map was structured based on the ACV (Attribute/low-level, Consequence/medium-level, Value/high-level) structure (Costa et al., 2004; Leão & Mello, 2007). The ACV structure follows the sequence of attributes leading to consequences, which in turn lead to values. It should be noted that there may be horizontal connections between nodes, and it is also possible to add more categories (e.g., constraints, conditions) according to the NPD requirements. The interrelationships and connections between user needs are identified according to the means-end theory, which does not impose any limitations on the generation of nodes and links. This means that any two nodes can be linked together as long as one node serves as a means to the other node (Reynolds & Gutman, 1988; Woodall, 2013).

***Structure of the Map.*** The cognitive map is composed of nodes and links, where the nodes represent needs, and the links indicate the relationship between each pair of nodes. For instance, if node A is linked to node B, it signifies that A has an impact on or leads to B. To represent different groups, nodes can be coded using color or shape. While any two nodes can be linked to each other, it is crucial to maintain the directionality specified in the ACV structure, where attributes lead to consequences and consequences lead to values. Therefore, the only limitation for the connections or links is that a value cannot lead to a consequence, and a consequence cannot lead to an attribute. For simplicity, it’s essential to note that all the links are assumed to be of the same type.

After shaping the map, the analysis phase begins. Network analysis metrics are calculated to determine the significance of each node based on the number of links and nodes present in the network. The prioritization of needs is determined based on their connections and influence on higher-level values. To validate the structure, the completed map should be reviewed by users and/or project stakeholders who took part in the mapping workshop. In this paper, this method of needs analysis, which utilizes cognitive mapping with an ACV structure, is referred to as “need mapping”.

The network structure of the need map can be analyzed using a DSM, and SNA can advance the analysis of needs. In the next section this approach is further discussed.

### 6.3.3 Data Analysis Using DSM and SNA

To analyze the network of needs using DSM and SNA, various measures (such as centrality, density, brokerage, etc.) and architecture metrics can be used (Browning, 2016). However, in this paper, we used a few measures that were in line with the nature of the project and the context of use. These measures are presented in the following subsection.

**Network Structure and Adjacency Matrix**

A network is made up of points called *nodes* or *vertices* and lines connecting them called *edges*. Mathematically, a network can be represented by a matrix called the *adjacency matrix* **A**, which in the simplest case is a $n\times n$ symmetric matrix, where $n$ is the number of vertices in the network. The adjacency matrix has elements $A_{ij}$ as defined below – Eq. 1. Directed networks are represented by an asymmetric matrix in which $A_{ij} = 1$ implies the existence of a directed edge pointing from $i$ to $j$ (M. E. Newman, 2008).

$$A_{ij} = \begin{cases} 1 & \text{if there is an edge between vertices } i \text{ and } j, \\ 0 & \text{otherwise.} \end{cases} \quad 6,1$$

Once the adjacency matrix has been built according to the network that resulted from the mapping workshops, it can be further analyzed using Lattix 2022.0, which is an advanced tool for analyzing DSMs (Jamal & Jenkins, 2006; Xiao et al., 2014). Using Lattix, degree centrality (indegree and outdegree) and impact and dependency rates were calculated for the nodes (needs) (Lattix CP, 2023). Additionally, SNA provides centrality measures, such as betweenness and eigenvector centrality, that could further the analysis of needs (Freeman, 2002; M. E. Newman, 2008). Network analysis tools can also facilitate the calculation of such measures and provide a visual representation of the network. In this paper, we used Gephi 0.10 for this purpose. Each measure is briefly introduced in the following four subsections.

**Degree Centrality**

A node's degree centrality is determined by its number of direct edges (Freeman, 2002). The degree of node *i* is defined below.

$$d_i = \sum_{ij} A_{ij} \quad 6,2$$

The node with the highest number of connections is considered the most central in a network. In a directed network, degree centrality can be measured through two distinct measures: indegree and outdegree. Indegree reflects the number of incoming edges directed towards the node, representing the number of links it receives. On the other hand, outdegree represents the number of outgoing edges directed from the node to others, reflecting the number of links it originates (Lo Storto, 2010). Nodes with more connections tend to be more central to the structure and have a greater influence on other nodes (Yan & Ding, 2009).

**Impact and Dependency Rates**

Degree centrality is a local measure, as a node's centrality is derived from its neighbors (Brandes & Erlebach, 2005). However, Lattix allows for further analysis on the adjacency matrix by providing impact rates (average impact) and cumulative dependency rates (average cumulative dependency). A node's impact rate is calculated as the total number of nodes that are affected by that particular node (directly or indirectly – a transitive closure of all elements that could be impacted) divided by the total number of nodes. From the other way round, the cumulative dependency rate is calculated as the total number of direct and indirect dependencies in the network (Breivold et al., 2008; Lattix CP, 2023). The two measures are illustrated in the following example.

Figure 6.1 shows examples of the impact and dependencies of a node within a graph. In this example, the network has a total number of 8 nodes and 8 links. Consequently, the impact rate for node H would be 50% (4/8*100) and the cumulative dependency rate for node G would be 37.5% (3/8*100).

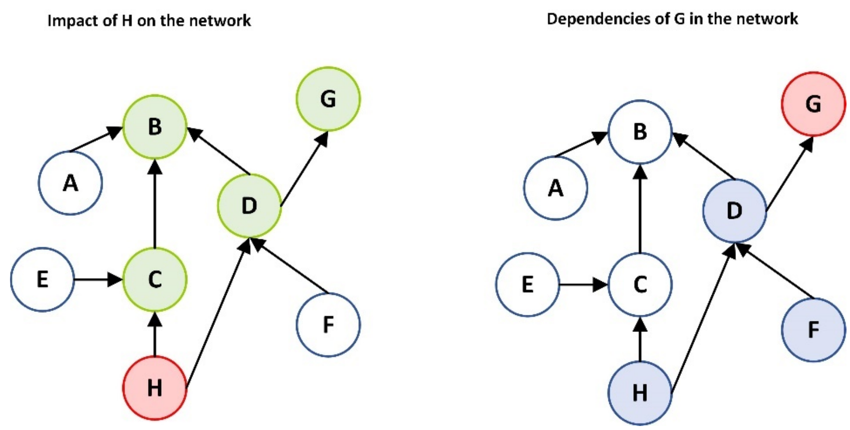



Figure 6.1 Examples of impact and dependency in a network

**Betweenness Centrality**

Betweenness centrality is a commonly used metric in network analysis that assesses the number of shortest paths that traverse a particular node. A node that exhibits a high betweenness centrality has a crucial intermediary or gatekeeper role as it can affect the flow of information between nodes that are not directly connected. This metric can be computed by determining how frequently a node appears on the shortest path connecting any two given nodes (Wasserman & Faust, 1994). When calculating shortest paths, betweenness centrality considers the direction of the edges, so results may differ when networks are directed and undirected (Bringmann et al., 2019; White & Borgatti, 1994).

Mathematically, betweenness centrality is expressed as the ratio of the number of shortest paths from node *i* to node *j* that pass through node *k* ($g_{ikj}$) to the total number of shortest paths from *i* to *j* ($g_{ij}$). The denominator is used to assign a weight to node *k*, such that it is only considered as a significant central point when it lies on the sole shortest path between *i* and *j* (Lo Storto, 2010).

$$b_k = \sum_{i\,j} \frac{g_{ikj}}{g_{ij}} \qquad 6,3$$

Betweenness centrality reflects the significance of a node in facilitating the flow of information to other nodes in the network. Specifically, nodes with high betweenness centrality are deemed to have a greater ability to direct, organize, and exert influence over the network than others (Lo Storto, 2010).

**Eigenvector Centrality**

A node's degree is often used as a reliable metric to determine its influence or importance within a network. In social settings, for instance, individuals with a greater number of connections generally wield more power. A more advanced variation of this concept is known as eigenvector centrality. Unlike degree centrality, which simply counts a node's connections, eigenvector centrality recognizes that not all connections hold the same weight. In general, links to nodes that themselves possess a considerable amount of influence confer greater importance to a given node than links to less influential nodes. If the centrality of node *i* is represented as $x_i$, this effect can be accounted for by scaling $x_i$ in proportion to the average centralities of node *i*'s network neighbors (M. E. Newman, 2008).

$$x_i = \frac{1}{\lambda}\sum_{j=1}^{n} A_{ij}x_j \qquad 6,4$$

Here, λ is a constant. Assuming that *x* is the centrality vector $\mathbf{x} = (\mathbf{x_1}, \mathbf{x_2}, \ldots)$, the equation can be written in vector form as below.

$$\lambda x = A, x \qquad 6,5$$

Therefore, it can be observed that *x* serves as an eigenvector of the adjacency matrix, with the corresponding eigenvalue of λ. To ensure that the centralities remain nonnegative, the Perron-Frobenius theorem can be employed to demonstrate that λ must be the principal eigenvalue of the adjacency matrix, and *x* must be its associated eigenvector (Pillai et al., 2005).

In measures of eigenvector centrality, while having numerous connections still carries some weight, a node with fewer but high-quality connections may outrank another one with a larger number of connections (M. E. Newman, 2008).

## 6.4 Results and Discussion

Here we present the result of our exploratory case study in three sections: data collection and need mapping, data analysis with DSM, and data analysis with SNA. It should be noted that, as a precaution to protect the confidentiality of the data, the nodes are displayed as codes instead of the actual values.

### 6.4.1 Data Collection and Need Mapping

The result of the group need map, which was created by a team of product owners and a business analyst, is a complicated network of needs from different levels comprised of 129 nodes and 192 links, which is presented in Figure 6.2 for general illustrative purposes only (to maintain confidentiality, details about the map nodes cannot be disclosed). In this map, the nodes have been color coded to facilitate the visual interpretation of the map. The different categories presented as nodes are main business objectives, secondary objectives, product attributes, backend requirements, functional design requirements and solution integration constraints, development requirements and constraints, and operational constraints. The guide for color coding is provided in Table 6.1.

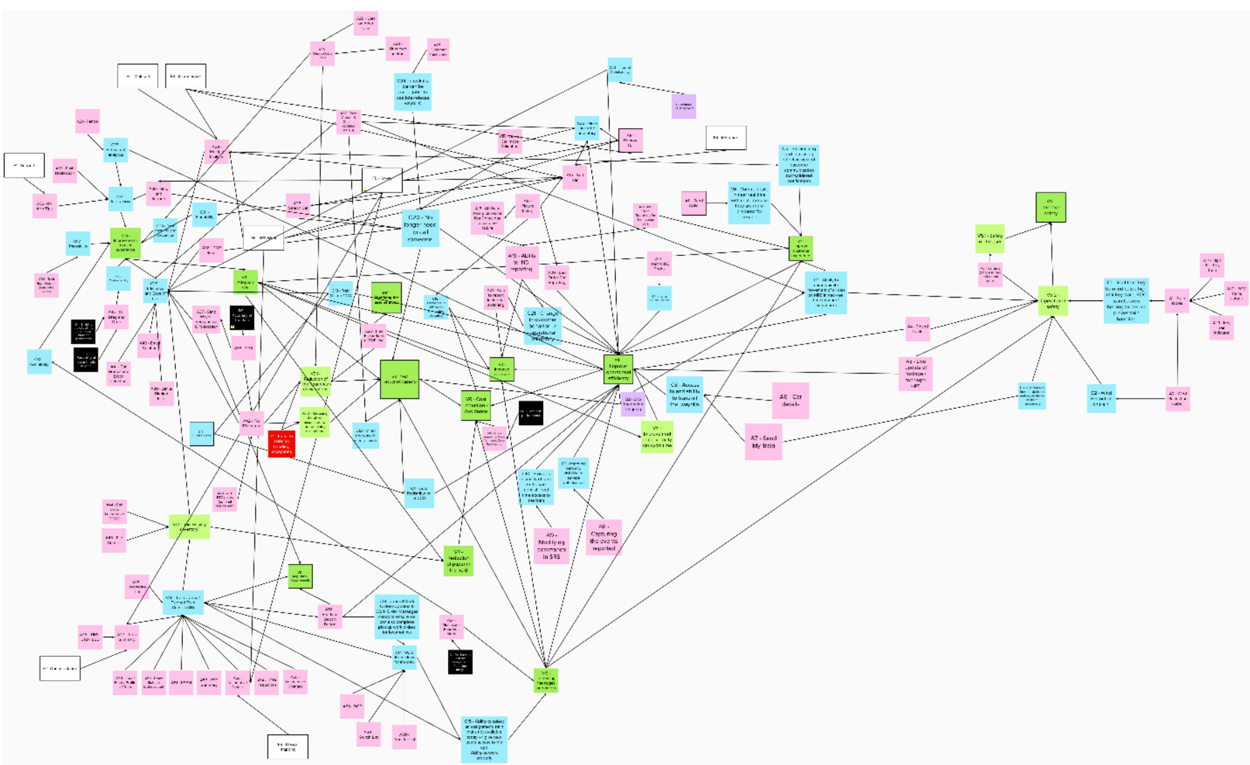


Figure 6.2 General overview of the need map for the NPD case study

Table 6.1 Color coding for the need map

| Color | | Category of needs | Code |
|---|---|---|---|
| | **Green** | Business objectives | V |
| | **Blue** | Secondary objectives | C |
| | **Pink** | Product attributes | A |
| | **Purple** | Backend requirements | B |
| | **Black** | Development requirements and constraints | D |
| | **White** | Functional design requirements and solution integration constraints | F |
| | **Red** | Operational constraints | L |

Once the map was validated and participants confirmed the network structure, using Microsoft Excel, the adjacency matrix was created based on the network structure provided in the need map. An overview of the adjacency matrix is presented in Figure. 6.3. The adjacency matrix used the same color coding as the need map.

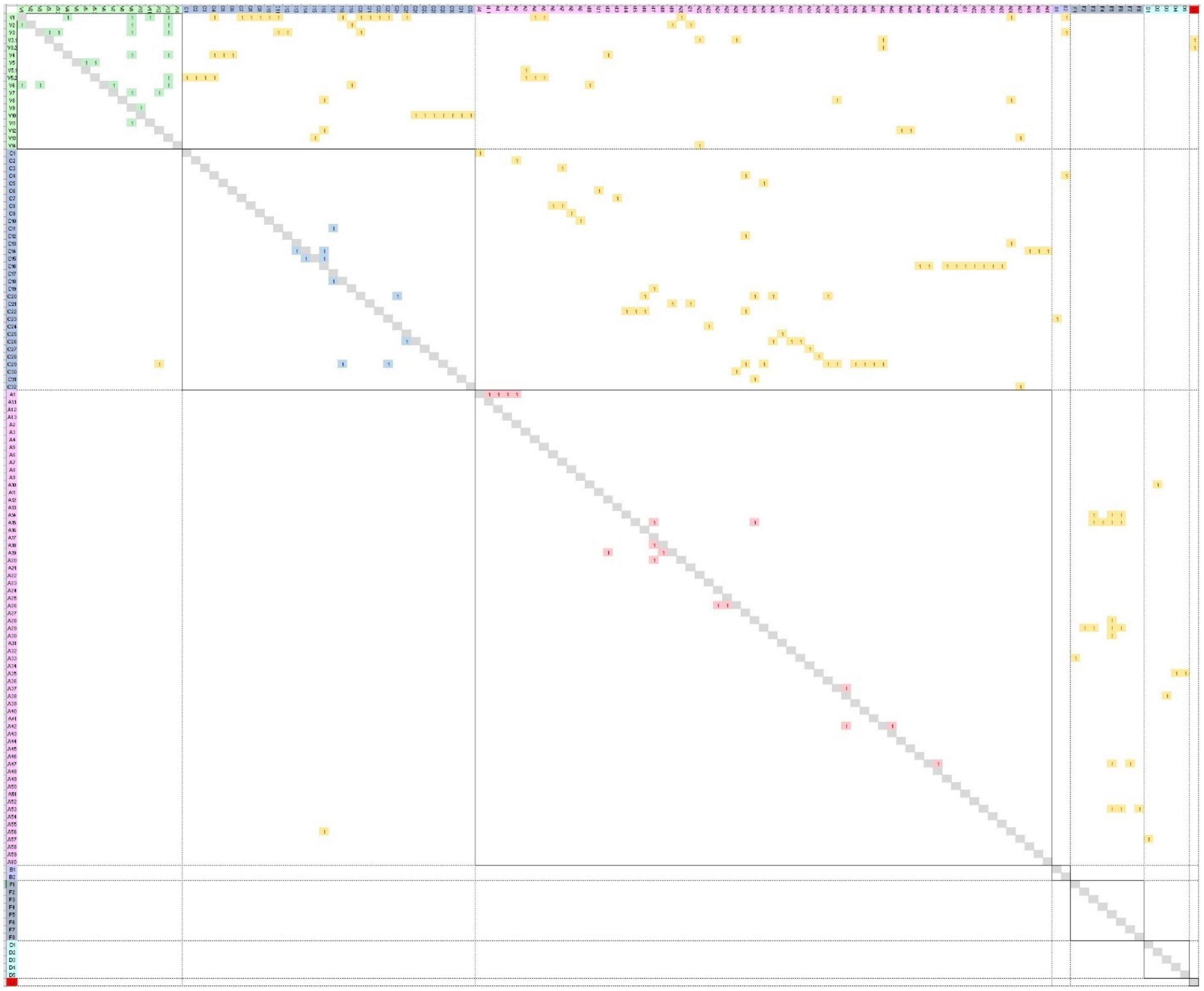


Figure. 6.3 General overview of the adjacency matrix

In the adjacency matrix (129x129), inputs are displayed on rows, whereas outputs are displayed on columns. The squares in Figure. 6.3 show the main categories of needs. The categories were not very interconnected except for the business objectives (green), which seem to be closely related. In fact, the interrelationships between the categories were much more noticeable. In addition, the ACV structure has been respected as there were mainly feedbacks above the diagonal and very few feedforwards below, meaning that the attributes impact consequences, and consequences impact values. The four bottom categories that are mainly related to constraints and technical requirements showed as fully independent from one another as there were no connections between them. They only impacted other categories (all above the diagonal).

### 6.4.2 Data Analysis with DSM (Lattix)

Using Lattix for analyzing the data, degree centrality (indegree and outdegree), impact rates and dependency rates were calculated. The results are presented in the following.

**Degree Centrality**

Given that the need map is a directed network, degree centrality is calculated in two sections, indegree and outdegree. The results for the top ten nodes with the most indegree and outdegree values are presented in Table 6.2. The nodes with the most indegree value have been directly impacted by other nodes the most; and the ones with the most outdegree value have impacted other nodes the most. The indegree and outdegree values indicate the direct impacts in the network.

Table 6.2 Nodes with the most indegree and outdegree values

| **Nodes with the most indegree value** | | **Nodes with the most outdegree value** | |
|---|---|---|---|
| **Node** | **Indegree value** | **Node** | **Outdegree value** |
| V1 | 21 | F5 | 7 |
| C29 | 11 | V13 | 6 |
| C16 | 9 | V9 | 6 |
| V3 | 8 | C16 | 5 |
| V5.2 | 8 | A17 | 4 |
| V10 | 7 | A27 | 4 |
| V2 | 6 | F6 | 4 |
| V4 | 6 | C4 | 3 |
| V6 | 6 | A42 | 3 |
| A15 | 6 | A28 | 3 |

The nodes with the most indegree value (impacted by many other nodes) are related to operational efficiency and safety, improvements to user and customer experience, financial benefits, and specific product features; and the nodes with the most outdegree value (impacting many other nodes) are related to adoption rates, functional design requirements, backend support, and key product features.

**Impact Rates and Dependency Rates**

Similarly, the top ten nodes with the most impact rates and most cumulative dependency rates are presented in Table 6.3. The nodes with the most cumulative dependency rates were all values and the nodes with the most impact rates were all product attributes and functional constraints. This result is explained by the direction of the network based on the ACV clustering. Attributes and constraints should have the greatest impact on the values, while values should be most dependent on them.

Table 6.3 Nodes with most impact and dependency rates

| **Nodes with the most impact rates** | | **Nodes with the most cumulative dependency rates** | |
|---|---|---|---|
| **Node** | **Impact rate** | **Node** | **Cumulative dependency rate** |
| F5 | 25.60% | V6 | 88.37% |
| F6 | 20.90% | V2 | 81.40% |
| A48 | 17.10% | V1 | 79.84% |
| F7 | 17.10% | V3 | 62.02% |
| F8 | 17.10% | V4 | 58.14% |
| A47 | 16.30% | V11 | 47.29% |
| A53 | 16.30% | V7 | 47.29% |
| A46 | 16.30% | V9 | 46.51% |
| A49 | 16.30% | V10 | 45.74% |
| A50 | 16.30% | V5 | 33.33% |

The nodes with the most impact rates are related to functional design requirements, backend support, and specific product features, while the nodes with the most cumulative dependency rates are related to operational efficiency and safety, financial benefits, adoption rates, user experience, and environmental factors. The outcomes are consistent with the preceding table, indicating a correlation between the nodes with the highest outdegree values and the most significant impact rates, as well as between the nodes with the highest indegree values and the cumulative dependency rate.

### 6.4.3 Data Analysis with SNA (Gephi)

Using Gephi, we were able to calculate the betweenness and eigenvector centrality measures. The top ten nodes with the most betweenness and eigenvector centralities are presented in Table 6.4. According to the findings, nodes that have the highest eigenvector centrality values are primarily associated with values. On the other hand, nodes with the highest betweenness centrality values are distributed across all types of needs, including values, consequences, and attributes. Since values are highly connected, it is reasonable that they have higher eigenvector centrality values. In contrast, betweenness centrality targets nodes that frequently appear on the shortest paths in the network, and this leads to a more diverse set of nodes being identified as having high betweenness centrality values.

Table 6.4 Nodes with the most betweenness and eigenvector centralities

| **Nodes with the most betweenness centrality** | | **Nodes with the most eigenvector centrality** | |
|---|---|---|---|
| **Node** | **Betweenness centrality** | **Node** | **Eigenvector centrality** |
| V10 | 297.5 | V6 | 1.00 |
| C16 | 248.5 | V1 | 0.86 |
| V9 | 246.5 | V2 | 0.79 |
| C29 | 176.5 | V3 | 0.40 |
| C15 | 127.3 | V10 | 0.34 |
| V13 | 127.3 | V4 | 0.28 |
| V1 | 105.2 | V9 | 0.23 |
| V12 | 91.3 | C29 | 0.23 |
| A47 | 51 | C15 | 0.23 |
| C26 | 45 | V7 | 0.21 |

The nodes with the most betweenness centrality are related to user experience, adoption rates, and operational efficiency, while the nodes with the most eigenvector centrality are related to financial benefits, operational efficiency, user and customer experience, and environmental factors. Nodes that appear in both groups are deemed highly central, as they have achieved top rankings on both centrality metrics.

***Filtering Options.*** Gephi offers tools to filter and rank nodes in the network based on specific criteria such as centrality measures and degree. This functionality is useful for visually analyzing the map and making changes as needed. With this feature, it is possible to filter out a particular node and its neighbors by selecting it for modification. Figure 6.4 shows the graph ranked according to the eigenvector centrality of nodes. The incorporation of filtering features can aid in the visual identification of highly central nodes and facilitate a qualitative assessment of the map.

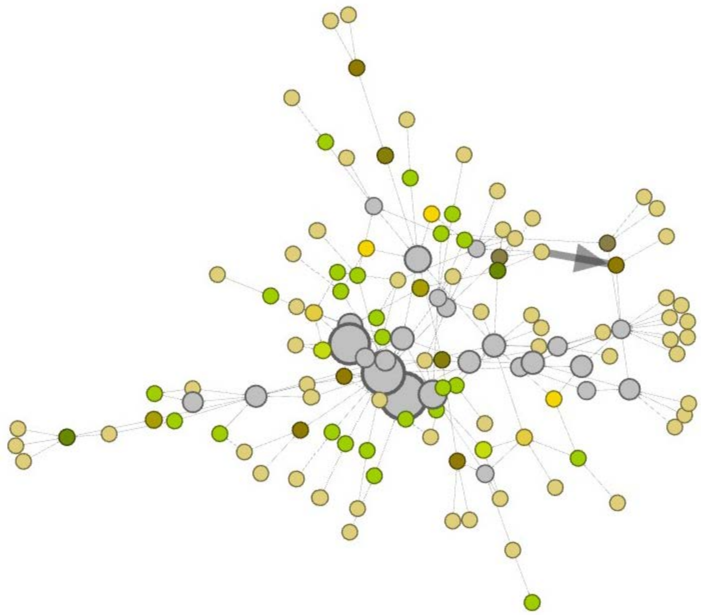


Figure 6.4 Example of the need map ranked by eigenvector centrality of the nodes

### 6.4.4 Complementary Analysis of the Metrics

By examining the information obtained from the map, it is possible to improve decision-making in the NPD process. In our specific example, we utilized network analysis metrics to aid in determining which needs should be given priority.

**Impact Analysis of the Constraints**

In our need map, we identified a specific group of needs categorized as constraints (codes B, D, F, and L). A key objective was to determine the constraints that carry the greatest weight in terms of impact. To do so, we can narrow down the relevant nodes involved in the decision-making process and make comparisons in similar situations. The impact rates of the constraints are presented in Table 6.5. The results show that the functional design requirements (indicated by code F) have the most impact among others, with an average impact of 14.7%.

Table 6.5 Impact rates for constraints

| **Node** | **Impact rate** | **Node** | **Impact rate** |
|---|---|---|---|
| B1 | 9.3% | F7 | 17.1% |
| B2 | 7.0% | F8 | 17.1% |
| F1 | 9.3% | D1 | 11.6% |
| F2 | 10.1% | D2 | 2.3% |
| F3 | 12.4% | D3 | 13.2% |
| F4 | 4.7% | D4 | 9.3% |
| F5 | 25.6% | D5 | 9.3% |
| F6 | 20.9% | L1 | 3.9% |

**Counting the Nodes that Matter**

Our analysis revealed another significant finding: not all nodes carry equal weight for the NPD team. Specifically, we noticed that this was true for consequences that served only as intermediaries between values and attributes. In other words, the team was particularly interested in understanding the impact of attributes on values and the dependency of values on attributes. To address this need, we introduced two new metrics: *attribute dependency* and *value impact*. These metrics helped the team measure and evaluate the relationship between attributes and values. Attribute dependency is the number of attributes a value is dependent on (directly or indirectly) and is indicated by *Ad*. Value impact is the number of directly or indirectly impacted values by a certain attribute and is indicated by *Vi*. It is also possible to calculate the rates by dividing the *Ad* and *Vi* metrics by the total numbers of attributes or values respectively. For example, V1 (related to operational efficiency) had a cumulative dependency rate of 79.8% (103 nodes out of 129) but the attribute dependency rate is 87.3% (55 attributes out of 63). The comparison for other values is presented in Figure 6.5, in which the rates have been calculated for values and consequences. Another example is A17 (related to a key product feature) with an impact rate of 8.5% (11 nodes out of 129) and a value impact of 16.7% (3 values out of 18). The comparisons for other attributes are presented in Figure 6.6. While the removal of consequences did not consistently result in significant changes, it did lead to more precise outcomes.

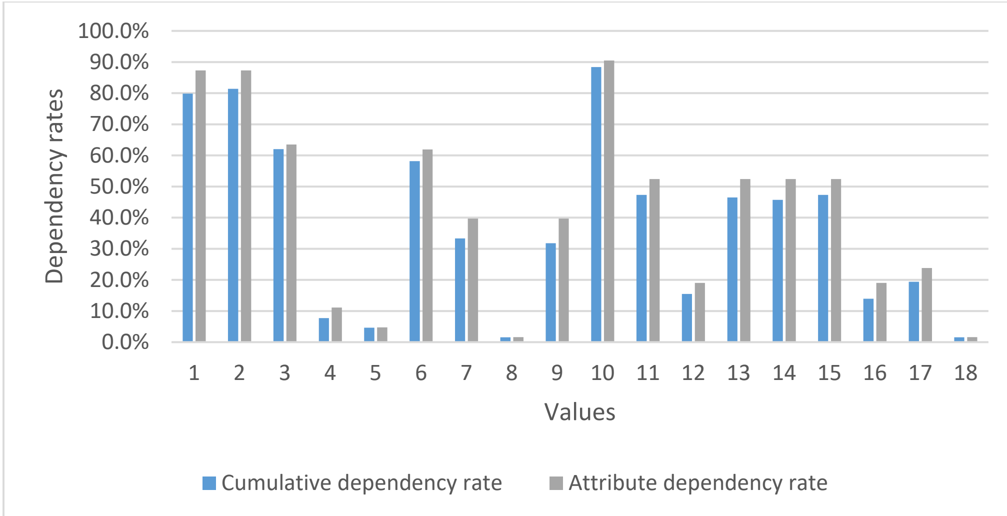



Figure 6.5 Comparison of cumulative dependency rates and attribute dependency rates

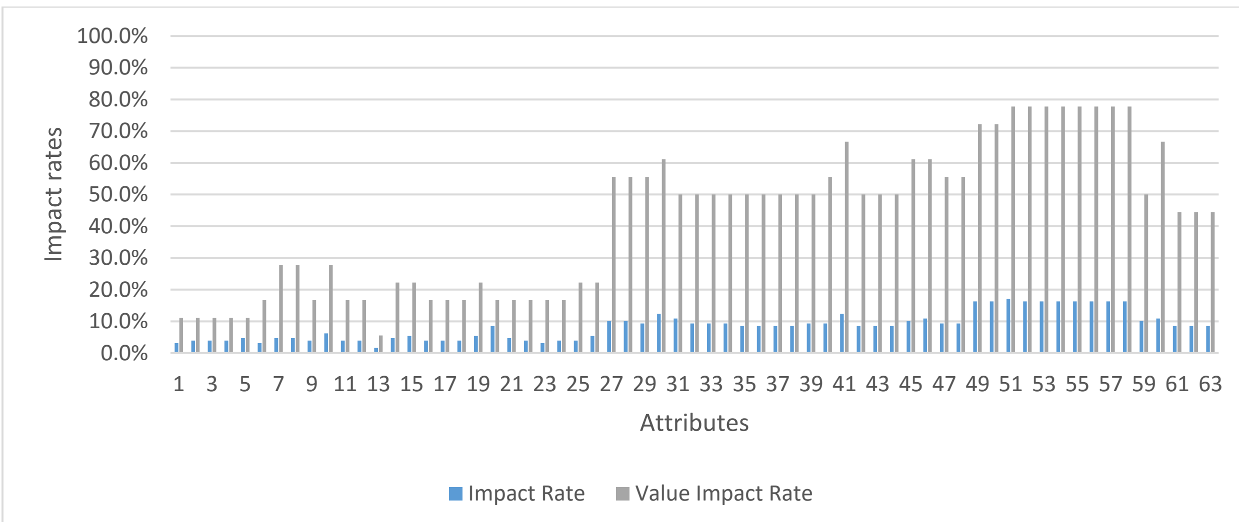



Figure 6.6 Comparison of impact rates and value impact rates

**Eigenvector Centrality and Cumulative Dependency**

During our case study, we discovered that advanced data analysis tools might not always be r user-friendly for product development team to utilize. As a result, it may be more practical to rely on simpler metrics. For instance, we observed a correlation between cumulative dependency rates and eigenvector centralities (spearman correlation coefficient is 0.99) - Figure 6.7. While we cannot generalize this as a universal principle due to limited data, we suggest that, in this case, cumulative dependency rate can be considered as a viable prioritization criterion instead of eigenvector centrality.

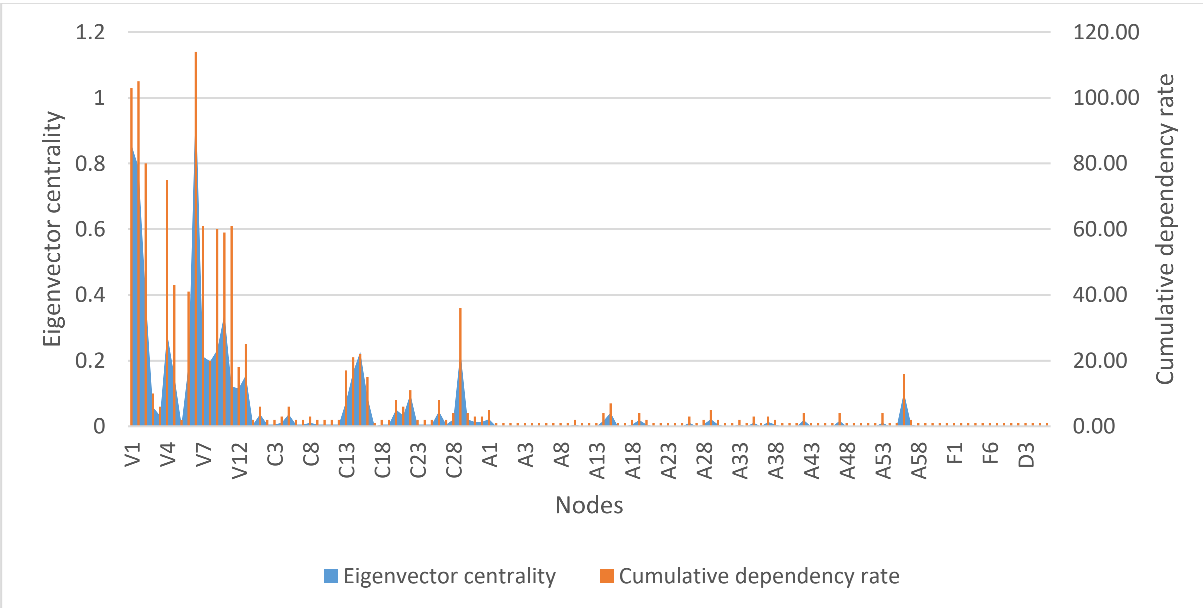



Figure 6.7 Correlation between cumulative dependency rate and eigenvector centrality

## 6.5 Conclusion

Our investigation involved examining the use of DSM and SNA for a more thorough analysis of the results obtained from utilizing cognitive mapping as a technique for needs analysis. Although need mapping allows for the visualization of diverse needs from various sources and their interconnections, the results can be too complex for a qualitative evaluation, and data analysis tools can assist in interpreting the map.

We conducted an exploratory case study in which we utilized a blend of DSM and SNA to provide network analysis metrics for scrutinizing the need map. The DSM approach presented a matrix view of the map that highlighted the density of connections between multiple levels, providing an overall perception of the map’s structure. The calculation of metrics such as degree centralities, impact rates, and cumulative dependency rates was performed with the assistance of Lattix. Additionally, we employed another network analysis tool, namely Gephi, to generate measures of betweenness and eigenvector centrality. To identify the most critical nodes within the network, we employed network metrics as prioritization criteria, both locally and globally within the network.

Our case study revealed that, in addition to needs, it is possible to evaluate the impact of constraints on the project. These constraints can also affect the nodes in the map, and assessing their significance in relation to the primary objectives enables managers to plan and make appropriate compromises. However, it is essential to note that not all nodes are equally important from a project management perspective. By eliminating the consequences (in the ACV structure) from the equation, it is feasible to measure the impact of attributes on values and the dependency of values on attributes more accurately. This modification resulted in more precise results for the purpose of prioritization and decision-making.

Furthermore, we discovered that working with advanced data analysis tools may not always be straightforward for practitioners. In our case, as a solution, we proposed using cumulative dependency rate instead of eigenvector centrality. Our case results indicated that the cumulative dependency rate and eigenvector centrality provided comparable ratings for the nodes.

We believe that the need mapping technique's flexibility, coupled with network analysis metrics, enhances the results of needs analysis. This approach can be tailored to accommodate a wide array of product development projects. It serves as a valuable resource for managers and decision-makers, offering multiple options for prioritization, planning, and informed decision-making.

### 6.5.1 Research Limitations

To make processing of the need map more manageable, we had to simplify the analysis similar to other network analysis methods. We recognized that there were various types of dependencies and not all connections carried the same level of impact. However, we did not have access to detailed information on each connection, and, given our resources and the participants' limited capacity, it was not feasible to process the different dependency types for the 192 links on the map. As a result, we assumed that all connections were of equal importance. Similarly, the nodes in the map could have varying levels of significance and diverse objectives. However, it was difficult to prioritize these nodes due to a lack of information, and we aimed for simplicity in our case study by not considering node importance weights.

One more limitation was that we were unable to validate the new needs analysis method with participants from the partner organization, as it was outside the scope of our research.

### 6.5.2 Implications for Theory and Practice

In theory, the newly proposed needs analysis approach has the potential to assist with the needs analysis process in complex development projects. By using a need map to visually illustrate the needs from various sources across multiple levels and their interrelationships, this method can offer valuable insights to researchers. Additionally, utilizing advanced data analysis tools can further enhance the analysis process by providing a range of network analysis metrics that can be useful for prioritization and decision-making. In an exploratory study of needs analysis in NPD, the implementation of DSM and SNA has yielded valuable insights for researchers who may wish to conduct similar analyses. Additionally, empirical data supports the complementarity of DSM and SNA in this context.

In this case study, the application of need mapping technique facilitated the identification of interrelationships among diverse types of needs and the evaluation of their dependencies and impacts. Group mapping workshops enabled team collaboration and promoted a shared mental model. Furthermore, these workshops aided in the identification and mapping of constraints and risks related to development and functional design solutions. Network analysis metrics were used to establish prioritization criteria that facilitated analysis and decision-making processes. Managers were able to assess the significance of product features in terms of their impact on business objectives and evaluate business objectives based on their dependency rates on other needs. In practice, need mapping can be an effective tool for various members of the product development team, including managers, UX researchers, and business analysts, to develop a shared understanding of the product and identify any missing requirements. Assessing the impact and interdependence of different needs and constraints helps with resource management, and the data generated by network analysis metrics can assist the team in making informed decisions, prioritizing tasks, and planning projects.

### 6.5.3 Suggestions for Future Research

While DSM and SNA are frequently used for network analysis, there is a need to explore the potential application of more advanced analysis techniques, such as multidomain matrix (MDM) and heuristic and metaheuristic algorithms. Additionally, it is beneficial to take needs analysis one step further and examine the significance of both needs (nodes) and their interrelationships (links) in different contexts. Further exploration in diverse domains can uncover additional challenges and analysis requirements that should be taken into account.

To effectively analyze complex data and increase the adoption rate of the need mapping technique, it is important to consider the design and development of user-friendly software tools. These tools should feature simple and intuitive interfaces that are accessible to novice users. By prioritizing ease of use, we can lower the barriers to entry for those unfamiliar with the process, thereby encouraging broader adoption of the technique. Ultimately, this will help to ensure that decision-makers have access to the insights they need to make informed choices.

# CHAPTER 7 GENERAL DISCUSSION

This chapter presents a general discussion of the research, summarizing the main takeaways from the three papers. In addition, some complementary topics are discussed regarding the lessons learned from the research project.

## 7.1 Summary of the Research Results Presented in the Papers

*The first paper* was a systematic literature review that comprehensively analyzed visual tools and techniques used for product or service development in order to evaluate the application of existing visual needs analysis methodologies in product development. The results of this review revealed that visual needs analysis methods can be classified into five categories: mapping, matrix analysis, network analysis, multidimensional scaling, and cluster analysis. The review also indicated that each visual needs analysis method has its own advantages and disadvantages, and not all methods can meet the requirements of the product development team.

The review found an emerging trend in which different needs analysis methods are combined to tailor them to more targeted purposes, as Table 4.8 shows that different methods can complement each other's disadvantages and improve the needs analysis process. For example, combining the journey map with methods based on network analysis, such as a customer value constellation, has been found effective for eliciting customer needs and displaying product or service solutions provided by stakeholders to meet those needs (Grenha Teixeira et al., 2019). Other possible combinations from the literature include the use of journey maps with QFD (K.-H. Liu & Wang, 2020), experience maps with Kano model (Xie & Han, 2019), Kano model with QFD (Sireli et al., 2007), hierarchical cluster analysis with multidimensional scaling (Johnson et al., 2020), and network analysis with need matrix analysis or cluster analysis (Kalbach, 2016; Pahk & Baek, 2017).

Additionally, the review revealed that mapping techniques, especially cognitive mapping, have been practical tools for analyzing needs throughout the period of analysis, with a growing number of publications using them in recent years. Since 2008, quantitative methods based on matrix analysis, such as QFD, have appeared in the literature. Although the scope of QFD is broader than just the concept of needs, recent studies have explored the capabilities of matrix methods, particularly QFD and its variations, for needs analysis. The practice of combining different needs analysis methods has been growing in recent years, as it provides a more comprehensive approach to needs analysis while compensating for the shortcomings of each method. Further research into possible combinations of needs analysis methods and data analysis techniques is needed to improve understanding of the needs.

*The Second paper* aimed to explore the application of cognitive mapping as a needs analysis method in a real-life new product development context. Specifically, the UX design team employed cognitive mapping and compared its results with those obtained using the team's original method. The cognitive mapping exercise facilitated the identification of the nodes with the highest impact and dependency levels and provided a visual representation of the interrelationships between various needs, offering an overview of the overall picture. Additionally, the need map enabled the inclusion of stakeholders' and users' needs and constraints that were previously overlooked in the team's original methodology. The feedback from multiple groups involved in the needs analysis revealed that the need mapping technique was perceived as a useful decision support tool. However, concerns were expressed regarding the complexity of the visual representation tool and data analysis techniques required for complex maps. Despite these concerns, in should be noted that managing complexity is essential for addressing complex problems, and that appropriate data analysis techniques (e.g., Dependency Structure Modelling) and representation tools can enhance the usability and usefulness of cognitive maps in various areas such as decision-making, negotiation, and creating a shared mental model.

*In the third paper*, we sought to address the concerns raised in the previous study about the complexity of need mapping data by exploring the application of DSM and SNA as advanced data analysis tools to further analyze and interpret the data. Specifically, we used various network analysis metrics, including degree centrality (indegree and outdegree), impact rate, cumulative dependency rate, betweenness centrality, and eigenvector centrality, to analyze the needs in the map (Lo Storto, 2010; Yan & Ding, 2009). Degree centrality measures the nodes' direct inputs and outputs, while impact rate and cumulative dependency rate measure the number of nodes that have been impacted or depended on directly or indirectly (Breivold et al., 2008; Lattix CP, 2023). The significance of a node in facilitating the flow of information to other nodes in a network is reflected by its betweenness centrality. Nodes with high betweenness centrality are deemed to have a greater ability to direct, organize, and exert influence over the network than others (Lo Storto, 2010). Eigenvector centrality, on the other hand, recognizes that not all connections hold the same weight.

In general, links to nodes that themselves possess a considerable amount of influence confer greater importance to a given node than links to less influential nodes. Measuring the eigenvector centrality, while having numerous connections still carries some weight, a node with fewer but high-quality connections may outrank another one with a larger number of connections. This property makes eigenvector centrality a useful measure in various scenarios (M. E. Newman, 2008).

Our case study showed that we could use these metrics to evaluate both the needs and constraints in the project, enabling managers to plan and make appropriate compromises. However, it is crucial to note that not all nodes are equally important from a project management perspective. By eliminating the consequences in the ACV (Attributes, Consequences, and Values) structure, we could measure the impact of attributes on values and the dependency of values on attributes. This modification resulted in more precise results for prioritization and decision-making in the case study. We also found that, in our case where advanced data analysis tools are not available, cumulative dependency rate can be used as a substitute for eigenvector centrality. Our case results showed that the cumulative dependency rate and eigenvector centrality provided comparable ratings for the nodes.

Overall, we conclude that the flexibility of the need mapping technique and the assortment of network analysis metrics make it a robust needs analysis method that can be customized to suit numerous product development projects, assisting managers and decision-makers.

## 7.2 Lessons Learned from the Empirical Studies

In our empirical studies (second and third papers), valuable lessons were learned about the challenges of implementing advanced needs analysis methods in practice. The main lessons learned are outlined below.

### 7.2.1 Complexity of the Map and the Adjacency Matrix

Our experimental results revealed that the large number of links and nodes can be overwhelming and confusing for product development teams. It is crucial to have a facilitator who can guide the mapping workshop and keep the team members focused on the mapping exercise (Village et al., 2013). To facilitate our mapping workshops, we used MURAL, but we found that a better visualization tool with a more efficient layout for nodes and links would be beneficial.

Additionally, team members expressed concerns about processing the map and deriving data regarding dependencies for the adjacency matrix. While we were able to process the data manually for our project, this may not be feasible for larger projects.

We utilized an Excel spreadsheet to create the adjacency matrix for both Lattix and Gephi but encountered the issue of the two tools using different formats for the matrix, which required double the work for data processing. The inability to calculate all network analysis metrics using a single tool highlighted the need for software to evolve to meet the requirements of needs analysis in product development. Alternatively, a new software designed solely for the purpose of needs analysis using cognitive mapping could be introduced. Practitioners need an easy-to-use tool, as it can significantly affect the adoption rate of the new needs analysis method.

### 7.2.2 DSM and SNA in Needs Analysis

The dependency structure modelling (DSM) is a widely adopted modeling approach used in various fields due to its simplicity, which allow for the revealing of significant patterns in system architectures, including modules and cycles (Browning, 2016; Piccirillo et al., 2017). Compared to a graph, DSM representation offers several benefits, including better scalability, a more compact and readable format, and the ability to highlight key architectural features like iterations and loops (Browning, 2001, 2016). In product design, DSMs can model the relationships between design decisions and parameters, which also allows the analysis of the sensitivity to NPD changes (Biazzo, 2009; Browning, 2001; Piccirillo et al., 2017). Moreover, DSMs provide means to analyze existing dependencies in the process, schedule management, and risk anticipation. They can also examine the impact of any potential change to the project plan and visually represent and organize project tasks (Gualberto & Melhado, 2012).

However, DSM falls short in representing a rich process model since it typically does not depict some crucial aspects of activities such as duration and dependencies. Due to the compact nature of the DSM format, it cannot show all the attributes of activities, and display tools can be used to fill in the missing elements and better illustrate the information. Highlighting disconnected workflows is an example of such tools (Browning, 2016; Kumar & Mocko, 2007). Additionally, DSMs do not replace the other practices of planning and estimation in projects but improve their reliability. Despite the development of DSM in the last few decades, the theory and mathematical methods still require further improvements to deal with the increasing complexity and dynamic in project environments (Piccirillo et al., 2017).

Graphs and networks are widely used in representing and analyzing the relationships and interactions among nodes in various fields (Bringmann et al., 2019; M. Newman, 2018). (Hanneman & Riddle, 2005). Social network analysis (SNA) utilizes the visualization methods, concepts, and mathematical tools of graph theory to examine the transmission of information, knowledge, and relationships among units and individuals within an organization (Barabási, 2003; Lo Storto, 2010).

SNA employs centrality metrics to investigate a network’s properties and estimate the structural importance or power of nodes (Brandes & Erlebach, 2005; Lo Storto, 2010). Degree centrality, closeness centrality, betweenness centrality, and eigenvector centrality are the primary measurements of centrality in a social network (Freeman, 2002). Centrality measures also enable the clear ranking of nodes and the identification of characteristics such as criticality (Collins et al., 2009; Yan & Ding, 2009). Although SNA is commonly used to investigate the relationships and relative position of actors within interorganizational NPD setups (Kratzer et al., 2016; Leenders & Dolfsma, 2016), it is also used to assess the relationship of other NPD attributes such as ideas management (Björk & Magnusson, 2009).

In this study, we used both DSM and SNA to enhance the analysis of needs, facilitate decision-making for the team, and prioritize requirements. DSM is a powerful tool for identifying critical features of a product (Eppinger & Browning, 2012), but it can be challenging to use in the context of a complex iterative system. Therefore, SNA complements DSM by identifying and prioritizing critical features in such systems. DSM and SNA enable the analysis of complex system activities and resource allocation for necessary tasks based on feature criticality (Chang et al., 2011).

Additionally, network analysis metrics help identify constraints on NPD execution by measuring properties of interdependencies. It is also possible to identify important or critical tasks for functional managers and process architects and works as a practical decision-support tool (Collins et al., 2009).

### 7.2.3 Tools Utilized in the Empirical Study

In the second empirical study the analysis of needs assessment was enhanced using cognitive mapping through the utilization of Dependency Structure Modelling (DSM) and Social Network Analysis (SNA). Although cognitive mapping is a valuable tool for representing and interconnecting diverse needs from various sources, the resulting maps can be complex for qualitative evaluation. To assist with the interpretation of these maps, we employed a combination of DSM and SNA to provide network analysis metrics.

The DSM approach provided a matrix view of the map that highlighted the density of connections between multiple levels, providing an overall perception of the map's structure. We used Lattix to calculate metrics such as degree centralities, impact rates, and cumulative dependency rates. However, we found that Lattix did not support other centrality measures of interest, such as betweenness and eigenvector centralities. To address this, we employed Gephi, another network analysis tool, to generate measures of betweenness and eigenvector centrality.

Gephi provided a better visual representation of the network with a broader range of customizability and filtering features, which facilitated the qualitative analysis of the need map. Additionally, it enabled us to apply centrality measures to the map, such as adapting the size of nodes to their centrality. This helped to highlight nodes with higher centrality rankings as larger in size.

Although Gephi offered superior visual representation and centrality measures, Lattix presented the matrix structure in a more comprehensive way and was capable of generating detailed reports on impact rates and dependency measures. These reports allowed us to track the impacts and dependencies across multiple levels.

In general, we found that neither of the tools we used were user-friendly and required a high level of knowledge and familiarity with both theory and software interfaces. While these tools can be well adopted by researchers, they are not intuitive enough for practitioners to use effectively. The use of multiple tools, including MURAL, Excel, Lattix, and Gephi, to thoroughly analyze the needs in the PDP created a serious limitation for our research project's validation of the new needs analysis method. The complexity of the map, matrix, software tools, and data analysis methods may be very intimidating for practitioners.

However, in practice, practitioners need not be involved in all of these complexities, and it is possible to present the new needs analysis method in a simple and easy-to-use tool. Practitioners do not need to process the data manually or be familiar with the theoretical background of centrality measures. To validate the new method, it is essential to ensure that the final product is presented in a proper format for the target audience. Therefore, we decided not to proceed with the validation to prevent biased feedback due to the unnecessary complexity of the method in its current state. To make these tools more accessible to practitioners, it is suggested that they should be evolved to incorporate greater simplicity and intuitiveness. Alternatively, the development of a new tool with this specific purpose appears to be a feasible solution.

# CHAPTER 8 CONCLUSION AND RECOMMENDATIONS

This chapter presents the conclusion of the thesis, the implications for theory and practice, limitations of research and suggestions for future research.

## 8.1 Conclusion

The primary objective of our study was to examine a comprehensive needs analysis methodology that utilizes visual representation techniques and data analysis tools to thoroughly analyze interactions among different needs and support decision-making. To achieve this goal, we divided our study into three steps: a literature review to understand the current state of visual needs analysis tools in product development, exploration of the use of cognitive mapping in a product development context, and investigation of the use of data analysis tools to analyze needs using cognitive mapping.

Through our systematic literature review, we identified that maps and matrix analyses are the most popular visualization tools used for needs analysis. Additionally, we found that the cognitive map is the most frequently used visualization method to analyze needs. We also noted an upward trend in authors using combinations of multiple needs analysis tools, which could improve and enhance the current needs analysis methods.

In the second step of our study, we explored the application of cognitive mapping in an actual product development context. We found that while the need mapping technique is mainly acknowledged by UX/UI designers, business analysis specialists, and business process optimization specialists, concerns were expressed about its complexity compromising its usability in decision-making and negotiation. Therefore, we proposed handling the complexity of the need map by means of data analysis techniques and better visual representation tools.

Finally, we investigated the use of data analysis tools such as DSM and SNA to provide a more thorough analysis of the results obtained from utilizing cognitive mapping as a technique for needs analysis. Our study found that network analysis metrics make cognitive mapping a robust needs analysis method that can be customized to suit numerous product development projects and assist managers and decision-makers. We also proposed a modification to the technique by eliminating the consequences from the equation to more accurately measure the impact of attributes on values and the dependency of values on attributes.

Overall, this thesis highlights the importance of visual tools in needs analysis, and the benefits of combining various visual tools with data analysis techniques or other needs analysis methods to provide decision support for the team and facilitate project management. The thesis also proposes a modification to the cognitive mapping technique and the use of network analysis metrics to improve the accuracy and usability of the method.

## 8.2 Implications for theory and practice

Researchers can benefit from a comprehensive overview of various methods for needs analysis, especially those that employ visual techniques. The first paper in this field presents a classification system for needs analysis methods and criteria for comparing and evaluating them. A proposed needs analysis method can help researchers analyze the needs of various stakeholders by emphasizing the connections between their needs. By using cognitive mapping in the development of a new product, researchers can better understand the needs and the collective mental model of those who use the product. This method can be particularly useful in complex development projects. The use of a need map to visually depict needs from multiple sources and levels and their interrelationships can provide researchers with valuable insights. Advanced data analysis tools can enhance the analysis process by providing network analysis metrics that are helpful for prioritization and decision making. An exploratory study of needs analysis in NPD has shown that implementing DSM and SNA can offer valuable insights to researchers conducting similar analyses. Empirical data also suggests that DSM and SNA complement each other in this context.

In practice, assessing the strengths and weaknesses of needs analysis methods can provide practitioners with insights on how to use them effectively in their projects. Our research shows that combining existing methods can be useful for tailoring tools to specific project objectives. When there are conflicts between the needs of users and stakeholders, cognitive mapping can present a holistic view of both parties’ needs and their impacts on each other. This approach can foster collaboration and empathy among team members and support decision-making for UX designers, developers, project managers, and product owners. Collaborative mapping workshops can facilitate communication and promote a shared mental model among team members. In the second case study, need mapping facilitated the identification of interrelationships among different types of needs and helped evaluate their dependencies and impacts. Network analysis metrics were used to establish prioritization criteria for analysis and decision-making processes. Need mapping can be a useful tool for various members of the product development team, including managers, UX researchers, and business analysts, to develop a shared understanding of the product and identify any missing requirements. The analysis of needs and constraints helps with resource management, and the data generated by network analysis metrics can assist the team in making informed decisions, prioritizing tasks, and planning projects.

## 8.3 Limitations

The systematic literature review encountered various challenges, with the most difficult being the creation of a comprehensive search query due to the multitude of terms used to describe needs and analyses. Despite our efforts to generate the best possible combination of terms, some methods or papers may have been missed, and our search protocol only covered English-language journal and conference papers in two specific databases. As a result, books, dissertations, other sources, and papers written in other languages were excluded from our analysis. These limitations affected the descriptive analysis presented in this paper, as we were only able to consider the occurrences of needs analysis methods within our sample.

For the empirical studies, the application of cognitive mapping was only investigated for one project due to constraints of the partner organization, and the mapping workshops had to be conducted remotely using MURAL instead of in a room with a large whiteboard (due to constraints because of Covid-19 pandemic). The online survey for validation of the need mapping technique was also aggregated, preventing us from verifying the questions' bias or standardization. Furthermore, to simplify the analysis of the need map, we assumed that all connections were of equal importance and did not consider node importance weights. Lastly, due to the complexity of the tools and methods involved, we were unable to validate the effectiveness of the new needs analysis approach with participants from the partner organization, and thus it fell beyond the scope of our study.

## 8.4 Future Research Directions

The purpose of this study is to inspire other researchers to develop better solutions for needs analysis in complex projects by assessing visual needs analysis methods, their application fields, and possible combinations. Future research could focus on identifying challenges that arise when incorporating visual needs analysis methods in complex product development projects and examine how complementary methods can improve quantification and prioritization of needs.

To further improve the need mapping technique, it is recommended that stakeholders' and designers' needs and requirements be examined, and more advanced analysis techniques be explored. In addition, the significance of needs and their interrelationships in different contexts should be studied.

To increase the adoption rate of the need mapping technique, user-friendly software tools with simple and intuitive interfaces should be designed. This will help to ensure that decision-makers have access to the insights they need to make informed choices. It is important to test this method in different contexts and industries to explore its extendibility. Ultimately, this method aims to respond to the needs of UX/UI designers, product designers, developers, and project stakeholders.

# REFERENCES

Abran, A., Moore, J. W., Bourque, P., Dupuis, R., & Tripp, L. (2004). Software engineering body of knowledge. *IEEE Computer Society, Angela Burgess*, *25*.

Agassi, T. N., Ushada, M., & Suyantohadi, A. (2018). User Needs Analysis for Industrial Design of Kansei Engineering-Based Sensor for Agroindustry (KESAN). *2018 4th International Conference on Science and Technology (ICST)*, 1–5. https://doi.org/10.1109/ICSTC.2018.8528697

Akao, Y. (1997). QFD: Past, present, and future. *International Symposium on QFD*, *97*(2), 1–12.

Albert, R., & Barabási, A.-L. (2002). Statistical mechanics of complex networks. *Reviews of Modern Physics*, *74*(1), 47.

Ali, H. B., Helgesen, F. H., & Falk, K. (2021). Unlocking the power of big data within the early design phase of the new product development process. *INCOSE International Symposium*, *31*(1), 434–452. https://doi.org/10.1002/j.2334-5837.2021.00846.x

Amaral Capaldo, D., & Rozenfeld, H. (2007). Integrating new product development process references with maturity and change management models. *Guidelines for a Decision Support Method Adapted to NPD Processes*.

Andriopoulos, C., Gotsi, M., Lewis, M. W., & Ingram, A. E. (2018). Turning the Sword: How NPD Teams Cope with Front-End Tensions. *Journal of Product Innovation Management*, *35*(3), 427–445. https://doi.org/10.1111/jpim.12423

Antonides, G., & van Raaij, W. F. (1998). *Consumer behaviour: A European perspective*. John Wiley.

Attribute Value Mapping. (n.d.). *Systematic Inventive Thinking*. Retrieved July 22, 2019, from http://www.sitsite.com/method/avm/

Bahill, A. T., & Dean, F. F. (2009). Discovering System Requirements. In A. P. Sage & W. B. Rouse (Eds.), *Handbook of Systems Engineering and Management* (pp. 205–266). John Wiley & Sons.

Barabási, A.-L. (2003). Linked: The New Science of Networks. *American Journal of Physics*, *71*(4), 409–410. https://doi.org/10.1119/1.1538577

Barabási, A.-L., & Pósfai, M. (2016). *Network Science*. Cambridge University Press.

Basole, R. C. (2014). Visual Business Ecosystem Intelligence: Lessons from the Field. *IEEE Computer Graphics and Applications*, *34*(5), 26–34. https://doi.org/10.1109/MCG.2014.104

Bayus, B. L. (2008). Understanding Customer Needs. In S. Shane, *The Handbook of Technology and Innovation Management* (pp. 115–141). John Wiley & Sons.

Berger, C. (1993). Kano’s methods for understanding customer-defined quality. *Center for Quality Management Journal*, *2*(4), 3–36.

Beyer, H., & Holtzblatt, K. (1997). *Contextual Design: Defining Customer-Centered Systems*. Elsevier.

Biazzo, S. (2009). Flexibility, Structuration, and Simultaneity in New Product Development. *Journal of Product Innovation Management*, *26*(3), 336–353. https://doi.org/10.1111/j.1540-5885.2009.00662.x

Björk, J., & Magnusson, M. (2009). Where Do Good Innovation Ideas Come From? Exploring the Influence of Network Connectivity on Innovation Idea Quality. *Journal of Product Innovation Management*, *26*(6), 662–670. https://doi.org/10.1111/j.1540-5885.2009.00691.x

Blasco, R., Blanco, T., Marco, A., Berbegal, A., & Casas, R. (2016). Needs identification methodology for inclusive design. *Behaviour & Information Technology*, *35*(4), 304–318. https://doi.org/10.1080/0144929X.2016.1149962

Blessing, L. T. M. (1995). Comparison of design models proposed in prescriptive literature. *The Role of Design in the Spaping of Technology, COST A3/COST A4 International Research Workshop, 1995*.

Blessing, L. T. M., & Chakrabarti, A. (2009). *DRM, a design research methodology*. Springer.

Bonapace, L. (2003). Linking Product Propertiesto Pleasure: The SensorialQuality Assessment Method—SEQUAM. In W. S. Green & P. W. Jordan, *Pleasure With Products: Beyond Usability* (pp. 184–211). CRC Press.

Borgianni, Y., & Rotini, F. (2015). Towards the fine-tuning of a predictive Kano model for supporting product and service design. *Total Quality Management & Business Excellence*, *26*, 263–283. https://doi.org/10.1080/14783363.2013.791119

Brandes, U., & Erlebach, T. (Eds.). (2005). *Network analysis: Methodological foundations*. Springer.

Brangier, E., Brangier, B., Marache-Francisco, C., Kopp, S., & Clausse, J. (2018, August 26). An interview process to anticipate future needs: First analysis of an approach to explore future user experiences in the fields of business travel and tourism. *To Appear in Proceedings of the International Ergonomics Association (IEA) Conference*.

Breivold, H. P., Crnkovic, I., Land, R., & Larsson, S. (2008). Using dependency model to support software architecture evolution. *2008 23rd IEEE/ACM International Conference on Automated Software Engineering-Workshops*, 82–91.

Bringmann, L. F., Elmer, T., Epskamp, S., Krause, R. W., Schoch, D., Wichers, M., Wigman, J. T. W., & Snippe, E. (2019). What do centrality measures measure in psychological networks? *Journal of Abnormal Psychology*, *128*, 892–903. https://doi.org/10.1037/abn0000446

Browning, T. R. (1999). Designing system development projects for organizational integration. *Systems Engineering - SYST ENG*, *2*, 217–225. https://doi.org/10.1002/(SICI)1520-6858(1999)2:43.3.CO;2-0

Browning, T. R. (2001). Applying the design structure matrix to system decomposition and integration problems: A review and new directions. *IEEE Transactions on Engineering Management*, *48*(3), 292–306. https://doi.org/10.1109/17.946528

Browning, T. R. (2016). Design Structure Matrix Extensions and Innovations: A Survey and New Opportunities. *IEEE Transactions on Engineering Management*, *63*(1), 27–52. https://doi.org/10.1109/TEM.2015.2491283

Brunelli, M. (2014). *Introduction to the analytic hierarchy process*. Springer.

Cagan, J., & Vogel, C. M. (2002). *Creating Breakthrough Products: Innovation from Product Planning to Program Approval*. FT Press.

Caldarelli, G., & Catanzaro, M. (2012). *Networks: A Very Short Introduction*. Oxford University Press. https://doi.org/10.1093/actrade/9780199588077.001.0001

Card, S. K., Mackinlay, J. D., & Shneiderman, B. (1999). *Readings in Information Visualization: Using Vision to Think*. Morgan Kaufmann.

Castellano, N. G., & Del Gobbo, R. (2018). Strategic mapping: Relationships that count. *Management Decision*, *56*(4), 908–921. https://doi.org/10.1108/MD-03-2017-0224

Chang, C.-W., Chiang, D. M., Wu, A. W.-D., & Chang, Y.-C. (2011). Identifying critical features of complex systems under prior known conditions. *Computers & Industrial Engineering*, *61*(3), 788–793. https://doi.org/10.1016/j.cie.2011.05.011

Cho, C. K., Kim, Y. S., & Lee, W. J. (2010). Economical, ecological and experience values for Product-Service Systems. *7th International Conference on Design and Emotion 2010, October 4, 2010 - October 7, 2010*.

Chong, Y. T., & Chen, C.-H. (2010). Management and forecast of dynamic customer needs: An artificial immune and neural system approach. *Advanced Engineering Informatics*, *24*, 96–106. https://doi.org/10.1016/j.aei.2009.06.003

Coleman, R. (2001). *Designing for our Future Selves in Universal Design Handbook, WFE Preiser & E. Ostroff*. McGraw-Hill, New York.

Collins, S. T., Bradley, J. A., & Yassine, A. A. (2010). Analyzing Product Development Task Networks to Examine Organizational Change. *IEEE Transactions on Engineering Management*, *57*(3), 513–525. https://doi.org/10.1109/TEM.2009.2033047

Collins, S. T., Yassine, A. A., & Borgatti, S. P. (2009). Evaluating product development systems using network analysis. *Systems Engineering*, *12*(1), 55–68. https://doi.org/10.1002/sys.20108

Costa, A. I. A., Dekker, M., & Jongen, W. M. F. (2004). An overview of means-end theory: Potential application in consumer-oriented food product design. *Trends in Food Science & Technology*, *15*(7), 403–415. https://doi.org/10.1016/j.tifs.2004.02.005

Coughlan, P., & Coghlan, D. (2002). Action research for operations management. *International Journal of Operations & Production Management*, *22*(2), 220–240. https://doi.org/10.1108/01443570210417515

Da Silva, R. H., Kaminski, P. C., & Armellini, F. (2020). Improving new product development innovation effectiveness by using problem solving tools during the conceptual development phase: Integrating Design Thinking and TRIZ. *Creativity and Innovation Management*, *29*(4), 685–700. https://doi.org/10.1111/caim.12399

Daley, B. J. (2004). Using Concept Maps in Qualitative Research. In A. J. Cañas, J. D. Novak, & F. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proc. Of the First Int. Conference on Concept Mapping* (Vol. 1, pp. 191–199). Universidad Pública de Navarra. http://cmc.ihmc.us

del Sagrado, J., & del Águila, I. M. (2021). Assisted requirements selection by clustering. *Requirements Engineering*, *26*(2), 167–184. https://doi.org/10.1007/s00766-020-00341-1

Delugach, H. S., Etzkorn, L. H., Carpenter, S., & Utley, D. (2016). A knowledge capture approach for directly acquiring team mental models. *International Journal of Human-Computer Studies*, *96*, 12–21. https://doi.org/10.1016/j.ijhcs.2016.07.001

Deng, J., Yang, D., Yang, S., & Zhu, B. (2021). Research on Innovative Design Strategy of Intelligent Infusion Set Based on User Needs. *2nd International Conference on Intelligent Design, ICID 2021, October 19, 2021*, 412–416. https://doi.org/10.1109/ICID54526.2021.00087

Driss, M., Moha, N., Jamoussi, Y., Jezequel, J.-M., & Ben Ghezala, H. H. (2010). A requirement-centric approach to web service modeling, discovery, and selection. *Service-Oriented Computing - 8th International Conference, ICSOC 2010, Proceedings*, *6470 LNCS*, 258–272. https://doi.org/10.1007/978-3-642-17358-5_18

Eden, C. (1988). Cognitive mapping. *European Journal of Operational Research*, *36*(1), 1–13.

Eden, C. (2004). Analyzing cognitive maps to help structure issues or problems. *European Journal of Operational Research*, *159*(3), 673–686. https://doi.org/10.1016/S0377-2217(03)00431-4

Eden, C., Ackermann, F., & Cropper, S. (1992). The analysis of cause maps. *Journal of Management Studies*, *29*(3), 309–324.

Eden, C., & Jones, S. (1984). Using repertory grids for problem construction. *Journal of the Operational Research Society*, *35*(9), 779–790.

Eden, C., Jones, S., & Sims, D. (1979). *Thinking in organisations*. Macmillan. https://strathprints.strath.ac.uk/43640/

Endmann, A., & Keßner, D. (2016). User Journey Mapping – A Method in User Experience Design. *I-Com*, *15*(1), 105–110. https://doi.org/10.1515/icom-2016-0010

Eppinger, S. D., & Browning, T. R. (2012). *Design Structure Matrix Methods and Applications*. MIT Press.

Eppler, M. J., & Platts, K. W. (2009). Visual Strategizing: The Systematic Use of Visualization in the Strategic-Planning Process. *Long Range Planning*, *42*(1), 42–74. https://doi.org/10.1016/j.lrp.2008.11.005

Evanschitzky, H., Eisend, M., Calantone, R. J., & Jiang, Y. (2012). Success Factors of Product Innovation: An Updated Meta-Analysis: Success Factors of Product Innovation. *Journal of Product Innovation Management*, *29*, 21–37. https://doi.org/10.1111/j.1540-5885.2012.00964.x

Ferrari, A., Spoletini, P., & Debnath, S. (2022). How do requirements evolve during elicitation? An empirical study combining interviews and app store analysis. *Requirements Engineering*, *27*(4), 489–519. https://doi.org/10.1007/s00766-022-00383-7

Ferreira, B. M., Barbosa, S. D. J., & Conte, T. (2016). PATHY: Using empathy with personas to design applications that meet the users needs. *18th International Conference on Human-Computer Interaction, HCI International 2016, July 17, 2016 - July 22, 2016*, *9731*, 153–165. https://doi.org/10.1007/978-3-319-39510-4_15

Fico, G., Hernanzez, L., Cancela, J., Dagliati, A., Sacchi, L., Martinez-Millana, A., Posada, J., Manero, L., Verdu, J., Facchinetti, A., Ottaviano, M., Zarkogianni, K., Nikita, K., Groop, L., Gabriel-Sanchez, R., Chiovato, L., Traver, V., Merino-Torres, J., Cobelli, C., … Arredondo, M. (2019). What do healthcare professionals need to turn risk models for type 2 diabetes into usable computerized clinical decision support systems? Lessons learned from the MOSAIC project. *BMC MEDICAL INFORMATICS AND DECISION MAKING*, *19*(1). https://doi.org/10.1186/s12911-019-0887-8

Fiore, S. M., & Schooler, J. W. (2004). Process mapping and shared cognition: Teamwork and the development of shared problem models. *Team Cognition: Understanding the Factors That Drive Process and Performance*, 133–152.

Fox, P., & Hendler, J. (2011). Changing the Equation on Scientific Data Visualization. *Science*, *331*(6018), 705–708. https://doi.org/10.1126/science.1197654

Franke, N., & von Hippel, E. (2003). Satisfying heterogeneous user needs via innovation toolkits: The case of Apache security software. *Research Policy*, *32*(7), 1199–1215. https://doi.org/10.1016/S0048-7333(03)00049-0

Fraser, M. W., & Galinsky, M. J. (2010). Steps in Intervention Research: Designing and Developing Social Programs. *Research on Social Work Practice*, *20*(5), 459–466. https://doi.org/10.1177/1049731509358424

Freeman, L. C. (2002). Centrality in social networks: Conceptual clarification. *Social Network: Critical Concepts in Sociology. Londres: Routledge*, *1*, 238–263.

Fuhrer, M. J., Jutai, J. W., Scherer, M. J., & DeRuyter, F. (2003). A framework for the conceptual modelling of assistive technology device outcomes. *Disability and Rehabilitation*, *25*(22), 1243–1251.

Ghozali, R. P., Saputra, H., Nuriawan, M. A., Suharjito, Utama, D. N., & Nugroho, A. (2019). Systematic Literature Review on Decision-Making of Requirement Engineering from

Agile Software Development. *Procedia Computer Science*, *157*, 274–281. https://doi.org/10.1016/j.procs.2019.08.167

Gibbons, S. (2019, April 21). *Sympathy vs. Empathy in UX*. Nielsen Norman Group. https://www.nngroup.com/articles/sympathy-vs-empathy-ux/

Goldenberg, J., Levav, A., Mazursky, D., & Solomon, S. (2009). *Cracking the ad code*. Cambridge University Press.

Gray, D. (2018, July 21). Updated Empathy Map Canvas. *The XPLANE Collection*. https://medium.com/the-xplane-collection/updated-empathy-map-canvas-46df22df3c8a

Grenha Teixeira, J., Pinho, N. F. de, & Patricio, L. (2019). Bringing service design to the development of health information systems: The case of the Portuguese national electronic health record. *International Journal of Medical Informatics*, *132*. https://doi.org/10.1016/j.ijmedinf.2019.08.002

Griffin, A. (2012). Obtaining customer needs for product development. In K. B. Kahn (Ed.), *The PDMA Handbook of New Product Development* (3rd ed., pp. 213–230). John Wiley & Sons.

Griffin, A., & Hauser, J. R. (1993). The Voice of the Customer. *Marketing Science*, *12*(1), 1–27. https://doi.org/10.1287/mksc.12.1.1

Grocki, M. (2014, September 16). *How to Create a Customer Journey Map*. UX Mastery. https://uxmastery.com/how-to-create-a-customer-journey-map/

Gualberto, A. C. F., & Melhado, S. B. (2012). *Aplicação da ferramenta DSM-Design Structure Matrix ao planejamento do processo de projeto de edificações*.

Hanneman, R. A., & Riddle, M. (2005). *Introduction to social network methods*. University of California Riverside.

Harris, C. (2002). *Hyperinnovation: Multidimensional Enterprise in the Connected Economy*. Springer.

Hay, D. B., & Kinchin, I. M. (2006). Using concept maps to reveal conceptual typologies. *Education + Training*, *48*(2/3), 127–142. https://doi.org/10.1108/00400910610651764

Iliinsky, N., & Steele, J. (2011). *Designing Data Visualizations: Representing Informational Relationships*. O'Reilly Media, Inc.

Jamal, K., & Jenkins, C. (2006). *Tool Evaluation–Lattix LDM* (No. 17-654 Analysis of Software Artifacts).

Jiao, J. (Roger), & Chen, C.-H. (2006). Customer Requirement Management in Product Development: A Review of Research Issues. *Concurrent Engineering*, *14*(3), 173–185. https://doi.org/10.1177/1063293X06068357

Johnson, S., Van Hoye, A., Donaldson, A., Lemonnier, F., Rostan, F., & Vuillemin, A. (2020). Building health-promoting sports clubs: A participative concept mapping approach. *PUBLIC HEALTH*, *188*, 8–17. https://doi.org/10.1016/j.puhe.2020.08.029

Kalbach, J. (2016). *Mapping Experiences: A Complete Guide to Creating Value Through Journeys, Blueprints, and Diagrams*. O'Reilly Media, Inc.

Kang, R., Dabbish, L., Fruchter, N., & Kiesler, S. (2015). *"My Data Just Goes Everywhere:" User Mental Models of the Internet and Implications for Privacy and Security*. 39–52. https://www.usenix.org/conference/soups2015/proceedings/presentation/kang

Kano, N. (1984). Attractive quality and must-be quality. *Hinshitsu (Quality), The Journal of Japanese Society for Quality Control*, *14*, 39–48.

Kaplan, K. (2016, July 31). *When and How to Create Customer Journey Maps*. Nielsen Norman Group. https://www.nngroup.com/articles/customer-journey-mapping/

Karr, A. (2015). UX research vs. UX design. *Interactions*, *22*(6), 7. https://doi.org/10.1145/2834964

Kelley, T., & Kelley, D. (2013). *Creative confidence: Unleashing the creative potential within us all*. Currency.

Korjonen-Close, H. (2005). The information needs and behaviour of clinical researchers: A user-needs analysis. *Health Information & Libraries Journal*, *22*(2), 96–106. https://doi.org/10.1111/j.1471-1842.2005.00562.x

Kratzer, J., Lettl, C., Franke, N., & Gloor, P. A. (2016). The Social Network Position of Lead Users. *Journal of Product Innovation Management*, *33*(2), 201–216. https://doi.org/10.1111/jpim.12291

Krishnan, V., & Ulrich, K. T. (2001). Product development decisions: A review of the literature. *Management Science*, *47*(1), 1–21.

Kujala, S. (2008). Effective user involvement in product development by improving the analysis of user needs. *Behaviour & Information Technology*, *27*(6), 457–473. https://doi.org/10.1080/01449290601111051

Kukich, K., McKeown, K., Shaw, J., Robin, J., Lim, J., Morgan, N., & Phillips, J. (1993). *User-needs analysis and design methodology for an automated documentation generator*.

Kumar, P., & Mocko, G. (2007). Modeling and analysis of an ontology of engineering design activities using the design structure matrix. *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, *48043*, 559–571.

Kuru, A. (2015). Cross impact analysis: An alternative way of qualitative data analysis of repertory grid technique. *Journal of Design Research*, *13*(4), 362–380.

Landau, S., Leese, M., Stahl, D., & Everitt, B. S. (2011). *Cluster Analysis*. John Wiley & Sons.

Lattix CP. (2023). *Architecture Metrics | Customer Portal*. Lattix Customer Portal. https://cp.lattix.com/node/3832

Leão, A., & Mello, S. (2007). The Means-End Approach to Understanding Customer Values of a On-Line Newspaper. *BAR. Brazilian Administration Review*, *4*. https://doi.org/10.1590/S1807-76922007000100002

Leenders, R. T. A. J., & Dolfsma, W. A. (2016). Social Networks for Innovation and New Product Development: Social Networks for Innovation and New Product Development. *Journal of Product Innovation Management*, *33*(2), 123–131. https://doi.org/10.1111/jpim.12292

Levitt, T. (1960). Marketing Myopia. *Harvard Business Review*, 3–13.

Lindgaard, G., Dillon, R., Trbovich, P., White, R., Fernandes, G., Lundahl, S., & Pinnamaneni, A. (2006). User Needs Analysis and requirements engineering: Theory and practice. *Interacting with Computers*, *18*(1), 47–70. https://doi.org/10.1016/j.intcom.2005.06.003

Liu, K.-H., & Wang, S.-M. (2020). Design and Evaluation of Electric Scooter Innovative Service. *7th IEEE International Conference on Consumer Electronics - Taiwan, ICCE-Taiwan 2020, September 28, 2020 - September 30, 2020*. https://doi.org/10.1109/ICCE-Taiwan49838.2020.9258185

Liu, X., Zhang, W. J., Tu, Y. L., & Jiang, R. (2008). An Analytical Approach to Customer Requirement Satisfaction in Design Specification Development. *IEEE Transactions on Engineering Management*, *55*(1), 94–102. https://doi.org/10.1109/TEM.2007.912812

Lo Storto, C. C. (2010). Assessing product development performance analyzing the information flows structure using social network analysis measurements. *World Academy of Science, Engineering & Technology*.

Loch, C., & Kavadias, S. (2008). Managing new product development: An evolutionary framework. In *Handbook of New Product Development Management* (pp. 1–26). Routledge.

Maier, J. F., Wynn, D. C., Biedermann, W., Lindemann, U., & Clarkson, P. J. (2014). Simulating progressive iteration, rework and change propagation to prioritise design tasks. *Research in Engineering Design*, *25*(4), 283–307. https://doi.org/10.1007/s00163-014-0174-8

Markham, S. K. (2013). The Impact of Front-End Innovation Activities on Product Performance: Front-End Activities. *Journal of Product Innovation Management*, *30*, 77–92. https://doi.org/10.1111/jpim.12065

McDonagh-Philp, D., & Bruseberg, A. (2000). Using focus groups to support new product development. *Engineering Designer*, *26*(5), 4–9.

Melgarejo, R., & Malek, K. (2018). *Setting the Record Straight on Innovation Failure*. Nielsen Company. https://www.nielsen.com/us/en/insights/report/2018/setting-the-record-straight-on-innovation-failure

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *Annals of Internal Medicine*, *151*(4), 264–269. https://doi.org/10.7326/0003-4819-151-4-200908180-00135

Monk, A., Hone, K., Lines, L., Dowdall, A., Baxter, G., Blythe, M., & Wright, P. (2006). Towards a practical framework for managing the risks of selecting technology to support independent living. *Applied Ergonomics*, *37*(5), 599–606.

Mont, O. K. (2002). Clarifying the concept of product–service system. *Journal of Cleaner Production*, *10*(3), 237–245. https://doi.org/10.1016/S0959-6526(01)00039-7

Montazemi, A. R., & Conrath, D. W. (1986). The Use of Cognitive Mapping for Information Requirements Analysis. *MIS Quarterly*, *10*(1), 45–56. https://doi.org/10.2307/248879

Naseem, A. (2005). Dynamics of user needs analysis in redesigning an open learning website: A case from Pakistan. *Proceedings of ASCLITE 2005*, 4–7.

Nelson, J., Buisine, S., & Aoussat, A. (2013). Anticipating the use of future things: Towards a framework for prospective use analysis in innovation design projects. *Applied Ergonomics*, *44*, 948–956. https://doi.org/10.1016/j.apergo.2013.01.002

Newman, M. (2018). *Networks*. Oxford University Press.

Newman, M. E. (2001). Scientific collaboration networks. I. Network construction and fundamental results. *Physical Review E*, *64*(1), 016131.

Newman, M. E. (2008). The mathematics of networks. *The New Palgrave Encyclopedia of Economics*, *2*(2008), 1–12.

Nuseibeh, B., & Easterbrook, S. (2000). Requirements engineering: A roadmap. *Proceedings of the Conference on the Future of Software Engineering*, 35–46.

Ogeya, M., Muhoza, C., & Johnson, O. W. (2021). Integrating user experiences into mini-grid business model design in rural Tanzania. *Energy for Sustainable Development*, *62*, 101–112. https://doi.org/10.1016/j.esd.2021.03.011

Olaverri-Monreal, C., & Gonçalves, J. (2014). Capturing mental models to meet users expectations. *2014 9th Iberian Conference on Information Systems and Technologies (CISTI)*, 1–5. https://doi.org/10.1109/CISTI.2014.6877006

Oran, A. C., Santos, G., Gadelha, B., & Conte, T. (2021). A framework for evaluating and improving requirements specifications based on the developers and testers perspective. *Requirements Engineering*, *26*(4), 481–508. https://doi.org/10.1007/s00766-021-00352-6

Osterwalder, A., Pigneur, Y., Bernarda, G., & Smith, A. (2014). *Value proposition design: How to create products and services customers want*. John Wiley & Sons.

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … McKenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ*, *n160*. https://doi.org/10.1136/bmj.n160

Pahk, Y., & Baek, J. (2017). *NEED NETWORK ANALYSIS: A PROCESS TO UNDERSTAND THE STAKEHOLDER NEED STRUCTURE IN MULTI-ACTOR SERVICE SYSTEMS* (A. Maier, S. Skec, H. Kim, M. Kokkolaras, J. Oehmen, G. Fadel, F. Salustri, & M. VanDerLoos, Eds.; WOS:000455227200071; pp. 693–702).

Pandey, D., Suman, U., & Ramani, A. K. (2010). An Effective Requirement Engineering Process Model for Software Development and Requirements Management. *2010 International Conference on Advances in Recent Technologies in Communication and Computing*, 287–291. https://doi.org/10.1109/ARTCom.2010.24

Patton, J., & Economy, P. (2014). *User Story Mapping: Discover the Whole Story, Build the Right Product*. O’Reilly Media, Inc.

Pelicioni, R. A., Armellini, F., Kaminski, P. C., & Bassetto, S. (2017). Including the voice of the client in the creative process: A case study of the integration of Quality Function Deployment (QFD) to the Value Proposition Design (VPD) in the service sector. *Journal Modern Project Management*, *05*(02), 06–21. https://doi.org/10.19255/JMPM01401

Piccirillo, I. N., Almeida, L. F. M. de, Araújo, L. Q. de, & Silva, S. L. da. (2017). Design Structure Matrix and Project Management: Bibliometric analysis. *Product Management & Development*, *15*(2), 86–91. https://doi.org/10.4322/pmd.2017.008

Pillai, S. U., Suel, T., & Cha, S. (2005). The Perron-Frobenius theorem: Some of its applications. *IEEE Signal Processing Magazine*, *22*(2), 62–75.

Quispe Vilchez, E., & Pow-Sang Portillo, J. A. (2019). Mind Maps in Requirements Engineering: A Systematic Mapping. In A. Marcus & W. Wang (Eds.), *Design, User Experience, and Usability. Design Philosophy and Theory* (pp. 335–350). Springer International Publishing. https://doi.org/10.1007/978-3-030-23570-3_25

Ralph, P. (2013). The illusion of requirements in software development. *Requirements Engineering*, *18*(3), 293–296. https://doi.org/10.1007/s00766-012-0161-4

Rao, N. (2007). Entrepreneurial digital photography—A case study for design research method in the emerging Indian market. *2nd International Conference on Usability and Internationalization, UI-HCII 2007, July 22, 2007 - July 27, 2007*, *4560 LNCS*(PART 2), 193–200. https://doi.org/10.1007/978-3-540-73289-1_24

Rashid, M. M., Ullah, A., Sarker, M. A. R., Tamaki, J., & Kubo, A. (2012). Logical Aggregation of Customer Needs Assessment. *Proceedings of the Fifth International Symposium on Computational Intelligence and Industrial Applications (ISCIIA2012), Sapporo, Japan*, 20–26.

Reynolds, T. J., & Gutman, J. (1988). Laddering theory, method, analysis, and interpretation. *Journal of Advertising Research, 28*(1), 11–31.

Robert, J.-M., Maldar, M., Taraghi, M., & Seffah, A. (2018, August 26). User Innovation, Lead users and Crowdsourcing for the Design of new Products and Services: Why, What and How? *To Appear in Proceedings of the International Ergonomics Association (IEA) Conference*.

Rosenbaum, M. S., Otalora, M. L., & Ramírez, G. C. (2017). How to create a realistic customer journey map. *Business Horizons, 60*(1), 143–150. https://doi.org/10.1016/j.bushor.2016.09.010

Ruiz-Primo, M. A. (2004). *Examining concept maps as an assessment tool*.

Saaty, T. L. (1980). *The analytic hierarchy process: Planning, priority setting, resource allocation*. McGraw-Hill International Book Co.

Sambandan, S., Valencia, M., Khawaja, A., & Sathish Kumar, S. K. (2018). HVAC System Bench Test Analysis for TXV Tuning. *2018 SAE World Congress Experience, WCX 2018, April 10, 2018 - April 12, 2018, 2018-April*. https://doi.org/10.4271/2018-01-0070

Sauerwein, E., Bailom, F., Matzler, K., & Hinterhuber, H. H. (1996). The Kano model: How to delight your customers. *International Working Seminar on Production Economics*, *1*, 313–327.

Savage, J. (2006). Ethnographic evidence: The value of applied ethnography in healthcare. *Journal of Research in Nursing*, *11*(5), 383–393. https://doi.org/10.1177/1744987106068297

Schirr, G. R. (2012). User research for product innovation: Qualitative methods. In K. B. Kahn (Ed.), *The PDMA Handbook of New Product Development* (3rd ed., pp. 213–230). John Wiley & Sons.

Sedig, K., & Parsons, P. (2016). Design of visualizations for human-information interaction: A pattern-based framework. *Synthesis Lectures on Visualization*, *4*(1), 1–185.

Shaw, D., Eden, C., & Ackermann, F. (2009). Mapping causal knowledge: How managers consider their environment during meetings. *International Journal of Management and Decision Making*, *10*(5–6), 321–340. https://doi.org/10.1504/IJMDM.2009.026681

Shillito, M. L. (2001). *Acquiring, processing, and deploying: Voice of the customer*. Crc Press.

Siau, K., & Tan, X. (2006). Using cognitive mapping techniques to supplement UML and UP in information requirements determination. *Journal of Computer Information Systems*, *46*(5 SPEC. ISS.), 59–66. https://doi.org/10.1080/08874417.2006.11645924

Sireli, Y., Kauffmann, P., & Ozan, E. (2007). Integration of Kano's Model Into QFD for Multiple Product Design. *IEEE Transactions on Engineering Management*, *54*(2), 380–390. https://doi.org/10.1109/TEM.2007.893990

Slegers, K., Ruelens, S., Vissers, J., & Duysburgh, P. (2015). Using Game Principles in UX Research: A Board Game for Eliciting Future User Needs. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 1225–1228. https://doi.org/10.1145/2702123.2702166

Song, K., & Lee, S. (2008). Mapping user accessibility needs systematically to universal design principles. *8th Asia-Pacific Conference on Computer-Human Interaction, APCHI 2008, July 6, 2008 - July 9, 2008*, *5068 LNCS*, 446–456. https://doi.org/10.1007/978-3-540-70585-7_51

Song, W. (2017). Requirement management for product-service systems: Status review and future trends. *Computers in Industry*, *85*, 11–22. https://doi.org/10.1016/j.compind.2016.11.005

Song, W., Ming, X., Han, Y., & Wu, Z. (2013). A rough set approach for evaluating vague customer requirement of industrial product-service system. *International Journal of Production Research*, *51*, 6681–6701. https://doi.org/10.1080/00207543.2013.832435

Sperano, I., Roberge, J., Bénech, P., Trgalova, J., & Andruchow, R. (2018, August 26). Exploring New Usages of Journey Maps: Introducing the Pedagogical and the Project Planning Journey Maps. *International Ergonomics Association (IEA) Conference*.

Stenmark, P., & Lilja, J. (2014). Designing for the satisfaction of high-level needs: Introducing the Ideation Need Mapping (INM) methodology. *The TQM Journal*, *26*(6), 639–649. https://doi.org/10.1108/TQM-08-2012-0058

Stenseke, L., & Soderholm, A. (2017). *Finding Future Customer Needs for Smart Home Solutions* [Master's Degree, Chalmers University of Technology]. http://publications.lib.chalmers.se/records/fulltext/249698/249698.pdf

Stoecker, R. (1991). Evaluating and rethinking the case study. The sociological review. *Citado Na*, 47.

Süner, S., & Erbuğ, Ç. (2016). Evaluation of construct elicitation as a research method to obtain design-relevant data from children. *METU Journal of the Faculty of Architecture*, *33*(2).

Sutcliffe, A. (2002). *User-Centred Requirements Engineering*. Springer-Verlag. //www.springer.com/fr/book/9781852335175

Swan, J. A. (1995). Exploring Knowledge and Cognitions in Decisions About Technological Innovation: Mapping Managerial Cognitions. *Human Relations*, *48*(11), 1241–1270. https://doi.org/10.1177/001872679504801101

Swan, J. A. (1997). Using Cognitive Mapping in Management Research: Decisions about Technical Innovation. *British Journal of Management*, *8*(2), 183–198. https://doi.org/10.1111/1467-8551.0050

Tegarden, D. P., & Sheetz, S. D. (2003). Group cognitive mapping: A methodology and system for capturing and evaluating managerial and organizational cognition. *Omega*, *31*(2), 113–125. https://doi.org/10.1016/S0305-0483(03)00018-5

Thoring, K., Mueller, R. M., & Badke-Schaub, P. (2015). Technology-supported design research. *20th International Conference on Engineering Design, ICED 2015, July 27, 2015 - July 30, 2015*, *11*(DS 80-11), 31–40.

Tukker, A., & Tischner, U. (2006). Product-services as a research field: Past, present and future. Reflections from a decade of research. *Journal of Cleaner Production*, *14*(17), 1552–1556. https://doi.org/10.1016/j.jclepro.2006.01.022

Ullman, D. (2009). *The Mechanical Design Process* (4th ed.). McGraw Hill.

Ulrich, K. T., & Eppinger, S. (2011). *Product Design and Development*. McGraw Hill.

Ulrich, K. T., Eppinger, S. D., & Yang, M. C. (2008). *Product design and development* (Vol. 4). McGraw-Hill higher education Boston.

Ulwick, A. W. (2013, June 24). *Silence the Voice of the Customer*. InnovationManagement. https://innovationmanagement.se/2013/06/25/silence-the-voice-of-the-customer/

Ulwick, A. W., & Bettencourt, L. A. (2008). Giving Customers a Fair Hearing. *MIT Sloan Management Review; Cambridge*, *49*(3), 62–68.

Ulwick, T. (2013, June 25). *Silence the Voice of the Customer*. Innovation Management. http://www.innovationmanagement.se/2013/06/25/silence-the-voice-of-the-customer/

Verganti, R. (1999). Planned flexibility: Linking anticipation and reaction in product development projects. *Journal of Product Innovation Management: An International Publication of the Product Development & Management Association*, *16*(4), 363–376.

Villafranca, B. C. L., & Loureiro, G. (2013). Stakeholder analysis process using cognitive mapping. *19th ISPE International Conference on Concurrent Engineering, CE 2012, September 3, 2012 - September 7, 2012*, 1069–1080. https://doi.org/10.1007/978-1-4471-4426-7_90

Village, J., Salustri, F. A., & Neumann, W. P. (2013). Cognitive mapping: Revealing the links between human factors and strategic goals in organizations. *International Journal of Industrial Ergonomics*, *43*, 304–313. https://doi.org/10.1016/j.ergon.2013.05.001

Village, J., Salustri, F. A., & Neumann, W. P. (2016). Cognitive mapping links human factors to corporate strategies. *European Journal of Industrial Engineering*, *10*, 1. https://doi.org/10.1504/ejie.2016.075126

von Hippel, E., & Katz, R. (2002). Shifting Innovation to Users via Toolkits. *Management Science*, *48*(7), 821–833. https://doi.org/10.1287/mnsc.48.7.821.2817

Wang, W., Liu, Y., Wei, T., & Zhang, Y. (2020). Product service model constructing method for intelligent home based on positive creative design thinking. *International Journal of Intelligent Systems Technologies and Applications*, *19*(2), 141–154. https://doi.org/10.1504/IJISTA.2020.107223

Wang, Y., & Tseng, M. M. (2014). Identifying Emerging Customer Requirements in an Early Design Stage by Applying Bayes Factor-Based Sequential Analysis. *IEEE Transactions on Engineering Management*, *61*(1), 129–137. https://doi.org/10.1109/TEM.2013.2248729

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*.

White, D. R., & Borgatti, S. P. (1994). Betweenness centrality measures for directed graphs. *Social Networks*, *16*(4), 335–346.

Woodall, G. (2013, December 9). *Understanding Consumer Decision-Making with Means-End Research*. Rockbridge. https://rockresearch.com/understanding-consumer-decision-making-with-means-end-research/

Wulandari, L., Sularto, L., Yusnitasari, T., & Ikasari, D. (2017). User Requirements Analysis For Digital Library Application Using Quality Function Deployment. *Journal of Physics: Conference Series*, *818*, 012004. https://doi.org/10.1088/1742-6596/818/1/012004

Xiao, L., Cai, Y., & Kazman, R. (2014). Design rule spaces: A new form of architecture insight. *Proceedings of the 36th International Conference on Software Engineering*, 967–977. https://doi.org/10.1145/2568225.2568241

Xie, Y., & Han, T. (2019). *Future Personalized Autonomous Shared Car Design Based on User Experience* (H. Kromker, Ed.; WOS:000657973400006; Vol. 11596, pp. 76–91). https://doi.org/10.1007/978-3-030-22666-4_6

Yan, E., & Ding, Y. (2009). Applying centrality measures to impact analysis: A coauthorship network analysis. *Journal of the American Society for Information Science and Technology*, *60*(10), 2107–2118. https://doi.org/10.1002/asi.21128

Yang, H., Liu, K., & Li, W. (2010). Adaptive requirement-driven architecture for integrated healthcare systems. *Journal of Computers*, *5*(2), 186–193. https://doi.org/10.4304/jcp.5.2.186-193

Yang, Q., Yao, T., Lu, T., & Zhang, B. (2014). An Overlapping-Based Design Structure Matrix for Measuring Interaction Strength and Clustering Analysis in Product Development Project. *IEEE Transactions on Engineering Management*, *61*(1), 159–170. https://doi.org/10.1109/TEM.2013.2267779

Yassine, A., & Braha, D. (2003). Four Complex Problems in Concurrent Engineering and the Design Structure Matrix Method. *Concurrent Engineering: R&A*, *11*, 165–176. https://doi.org/10.1177/106329303034503

Yin, R. K. (2018). *Case study research and applications: Design and methods* (Sixth edition). SAGE.

Yin, R. K., & Davis, D. (2007). Adding new dimensions to case study evaluations: The case of evaluating comprehensive reforms. *New Directions for Evaluation*, *2007*(113), 75–93.

Young, I. (2008). *Mental Models: Aligning Design Strategy with Human Behavior*. Rosenfeld Media.

Yu, E. S. (1997). Towards modelling and reasoning support for early-phase requirements engineering. *Proceedings of ISRE'97: 3rd IEEE International Symposium on Requirements Engineering*, 226–235.

Yuan, J., Chen, K., Li, W., Ji, C., Wang, Z., & Skibniewski, M. J. (2018). Social network analysis for social risks of construction projects in high-density urban areas in China. *Journal of Cleaner Production*, *198*, 940–961. https://doi.org/10.1016/j.jclepro.2018.07.109

# APPENDIX A ETHICS CERTIFICATE

POLYTECHNIQUE MONTRÉAL
UNIVERSITÉ D'INGÉNIERIE

**CER-2122-13-M**

Montréal, le 8 avril 2022

Objet: Approbation éthique – « Design and development of a need analysis method based on cognitive mapping techniques » - Projet CER-2122-13-D

Mme Mitra Taraghi,

J'ai le plaisir de vous informer que le Comité d'éthique de la recherche, selon les procédures en vigueur, en vertu des documents qui lui ont été fournis, a examiné le projet de recherche susmentionné et conclu que ce dernier répond aux normes en vigueur au chapitre de l'éthique de la recherche énoncées dans la *Politique en matière d'éthique de la recherche avec des êtres humains* de Polytechnique Montréal.

Veuillez noter que le présent certificat est valable pour une durée d'un an, soit du 8 avril 2022 au 1er mai 2023, pour le projet tel qu'approuvé au Comité d'éthique de la recherche avec des êtres humains.

Veuillez noter que conformément aux exigences auxquelles l'institution et son personnel sont assujettis afin d'être admissibles aux fonds des organismes subventionnaires, il est de votre responsabilité de déposer au CÉR un rapport annuel ou un rapport final avant l'expiration de la présente approbation éthique afin de l'informer de l'avancement de vos travaux. Le formulaire à remplir est disponible à l'adresse suivante : (http://www.polymtl.ca/recherche/formulaires-et-guides).

De plus, il est de votre responsabilité d'informer le CER de toute modification importante qui pourrait être apportée au protocole expérimental avant sa mise en œuvre, de même que de tout élément ou évènement imprévu pouvant avoir une incidence sur le bien-être ou l'intégrité des participant(e)s impliqué(e)s dans le projet de recherche. Nous vous invitons aussi à nous signaler tout problème susceptible d'avoir une incidence sur les membres de l'équipe de recherche.

Je vous souhaite bonne chance dans la poursuite de vos travaux.

Nous vous prions d'agréer, Madame, l'expression de nos sentiments les meilleurs,

Farida Cheriet, présidente
Comité d'éthique de la recherche
Polytechnique Montréal

c.c. Direction de la formation et de la recherche; Service des Finances
Fabiano Armellini, professeur agrégé, Département de mathématiques et de génie industriel
Daniel Imbeau, professeur titulaire, Département de mathématiques et de génie industriel
p.j. Certificat # CER-2122-13-D

Comité d'éthique de la recherche
avec des êtres humains
Tél.: 514 340-4711 poste : 3755
Fax : 514 340-4992
Courriel : ethique@polymtl.ca

Adresse postale
C.P. 6079, succ. Centre-Ville
Montréal (Québec) Canada H3C 3A7

Campus de l'Université de Montréal
2900, boul. Édouard-Montpetit
2500, chemin de Polytechnique
Montréal (Québec) Canada H3T1J4

POLYTECHNIQUE MONTRÉAL
UNIVERSITÉ D'INGÉNIERIE

**CER-2122-13-M**

CERTIFICAT D'APPROBATION ÉTHIQUE

*Le Comité d'éthique de la recherche de Polytechnique Montréal, selon les procédures en vigueur, en vertu des documents qui lui ont été fournis, a examiné le projet de recherche suivant et conclu qu'il respecte les règles d'éthique énoncées dans sa* Politique en matière d'éthique de la recherche avec des êtres humains.

| Projet | |
|---|---|
| **Titre du projet** | **Design and development of a need analysis method based on cognitive mapping techniques**<br>**CER-2122-13-D** |
| **Étudiante requérante** | **Mitra Taraghi**, Candidate au PhD, Département de mathématiques et de génie industriel |
| **Sous la direction de:** | **Fabiano Armellini, professeur agrégé**, Département de mathématiques et de génie industriel, Polytechnique Montréal & **Daniel Imbeau, professeur titulaire**, Département de mathématiques et de génie industriel, Polytechnique Montréal. |

| Financement | |
|---|---|
| Organisme | MITACS |
| No de UBR | |
| | |
| Programme | |
| No d'octroi: | |
| Titre original de l'octroi: | |
| Chercheur principal: | |

MODALITÉS D'APPLICATION

Toute modification importante qui pourrait être apportée au protocole expérimental doit être transmise au Comité avant sa mise en œuvre.

L'équipe de recherche doit informer le Comité de tout élément ou évènement imprévu pouvant avoir une incidence sur le bien-être ou l'intégrité des participant(e)s impliqué(e)s dans le projet de recherche ainsi que tout problème susceptible d'avoir une incidence sur les membres de l'équipe de recherche.

Selon les règles universitaires en vigueur, un suivi annuel est minimalement exigé pour maintenir la validité de la présente approbation éthique, et ce, jusqu'à la fin du projet. Le questionnaire de suivi est disponible sur la page web du Comité.

Farida Cheriet, présidente
Comité d'éthique de la recherche
Polytechnique Montréal

Date de délivrance : **8 avril 2022**

Date de fin de validité : **1er mai 2023**

Date du prochain suivi : **1er mai 2023**

Comité d'éthique de la recherche avec des êtres humains
Tél.: 514 340-4711 poste : 3755
Fax : 514 340-4992
Courriel : ethique@polymtl.ca

Adresse postale
C.P. 6079, succ. Centre-Ville
Montréal (Québec) Canada H3C 3A7

Campus de l'Université de Montréal
2900, boul. Édouard-Montpetit
2500, chemin de Polytechnique
Montréal (Québec) Canada H3T1J4

# APPENDIX B  SEARCH QUERY (ARTICLE 1)

(user* OR stakeholder*) AND (need* OR requirement* OR value*) AND (Analy* OR Understand*) AND (map* OR visual*) WN KY

| |
|---|
| (user AND need AND (analysis/understand) OR |
| ($user NEAR/1 $need) AND ($need NEAR/2 $Analysis) AND ($user NEAR/2 $Analysis) OR |
| ($user NEAR/1 $need) AND ($need NEAR/2 $Analyzing) AND ($user NEAR/2 $Analyzing) OR |
| ($user NEAR/1 $need) AND ($need NEAR/2 $Analysing) AND ($user NEAR/2 $Analysing) OR |
| ($user NEAR/1 $need) AND ($need NEAR/2 $understand) AND ($user NEAR/2 $understand) OR |
| user AND requirement AND (analysis/understand) OR |
| ($user NEAR/1 $requirement) AND ($requirement NEAR/2 $Analysis) AND ($user NEAR/2 $Analysis) OR |
| ($user NEAR/1 $requirement) AND ($requirement NEAR/2 $Analyzing) AND ($user NEAR/2 $Analyzing) OR |
| ($user NEAR/1 $requirement) AND ($requirement NEAR/2 $Analysing) AND ($user NEAR/2 $Analysing) OR |
| ($user NEAR/1 $requirement) AND ($requirement NEAR/2 $understand) AND ($user NEAR/2 $understand) OR |
| user AND value AND (analysis/understand) OR |
| ($user NEAR/1 $value) AND ($value NEAR/2 $Analysis) AND ($user NEAR/2 $Analysis) OR |
| ($user NEAR/1 $value) AND ($value NEAR/2 $Analyzing) AND ($user NEAR/2 $Analyzing) OR |
| ($user NEAR/1 $value) AND ($value NEAR/2 $Analysing) AND ($user NEAR/2 $Analysing) OR |
| ($user NEAR/1 $value) AND ($value NEAR/2 $understand) AND ($user NEAR/2 $understand) OR |
| stakeholder AND need AND (analysis/understand) OR |
| ($stakeholder NEAR/1 $need) AND ($need NEAR/2 $Analysis) AND ($stakeholder NEAR/2 $Analysis) OR |
| ($stakeholder NEAR/1 $need) AND ($need NEAR/2 $Analyzing) AND ($stakeholder NEAR/2 $Analyzing) OR |
| ($stakeholder NEAR/1 $need) AND ($need NEAR/2 $Analysing) AND ($stakeholder NEAR/2 $Analysing) OR |
| ($stakeholder NEAR/1 $need) AND ($need NEAR/2 $understand) AND ($stakeholder NEAR/2 $understand) OR |
| stakeholder AND requirement AND (analysis/understand) OR |
| ($stakeholder NEAR/1 $requirement) AND ($requirement NEAR/2 $Analysis) AND ($stakeholder NEAR/2 $Analysis) OR |
| ($stakeholder NEAR/1 $requirement) AND ($requirement NEAR/2 $Analyzing) AND ($stakeholder NEAR/2 $Analyzing) OR |
| ($stakeholder NEAR/1 $requirement) AND ($requirement NEAR/2 $Analysing) AND ($stakeholder NEAR/2 $Analysing) OR |
| ($stakeholder NEAR/1 $requirement) AND ($requirement NEAR/2 $understand) AND ($stakeholder NEAR/2 $understand) OR |
| stakeholder AND value AND (analysis/understand)) |
| ($stakeholder NEAR/1 $value) AND ($value NEAR/2 $Analysis) AND ($stakeholder NEAR/2 $Analysis) OR |
| ($stakeholder NEAR/1 $value) AND ($value NEAR/2 $Analyzing) AND ($stakeholder NEAR/2 $Analyzing) OR |
| ($stakeholder NEAR/1 $value) AND ($value NEAR/2 $Analysing) AND ($stakeholder NEAR/2 $Analysing) OR |
| ($stakeholder NEAR/1 $value) AND ($value NEAR/2 $understand) AND ($stakeholder NEAR/2 $understand) |
| AND (map* OR visual*) WN KY |

# APPENDIX C LIST OF SAMPLE PUBLICATIONS (ARTICLE 1)

| No. | Year | Author | Title |
|---|---|---|---|
| 1 | 2021 | Deng et al. | Research on Innovative Design Strategy of Intelligent Infusion Set Based on User Needs |
| 2 | 2021 | Ogeya et al. | Integrating user experiences into mini-grid business model design in rural Tanzania |
| 3 | 2020 | Liu and Wang | Design and Evaluation of Electric Scooter Innovative Service |
| 4 | 2020 | Johnson et al. | Building health-promoting sports clubs: a participative concept mapping approach |
| 5 | 2019 | Fico et al. | What do healthcare professionals need to turn risk models for type 2 diabetes into usable computerized clinical decision support systems? Lessons learned from the MOSAIC project |
| 6 | 2019 | Quispe Vilchez and Pow-Sang Portillo | Mind maps in requirements Engineering - A systematic mapping |
| 7 | 2019 | Xie and Han | Future Personalized Autonomous Shared Car Design Based on User Experience |
| 8 | 2019 | Grenha Teixeira et al. | Bringing service design to the development of health information systems: The case of the Portuguese national electronic health record |
| 9 | 2018 | Castellano and Del Gobbo | Strategic mapping: relationships that count |
| 10 | 2018 | Sambandan et al. | HVAC System Bench Test Analysis for TXV Tuning |
| 11 | 2018 | Sperano et al. | Exploring new usages of Journey Maps: Introducing the pedagogical and the project planning journey maps |
| 12 | 2017 | Wulandari et al. | User requirements analysis for digital library application Using Quality Function Deployment |
| 13 | 2017 | Pahk and Baek Joon | Need network analysis: A process to understand the stakeholder need structure in multi-actor service systems |
| 14 | 2017 | Rosenbaum et al. | How to create a realistic customer journey map |
| 15 | 2017 | Pelicioni et al. | Including the voice of the client in the creative process: a case study of the integration of Quality Function Deployment (QFD) to the Value Proposition Design (VPD) in the service sector |
| 16 | 2016 | Endmann and Keßner | User journey mapping - A method in User Experience Design |
| 17 | 2016 | Ferreira et al. | PATHY: Using empathy with personas to design applications that meet the users' needs |
| 18 | 2015 | Bergaus | The EMPLIT (EMPirical and LITerature-based) Research Framework |
| 19 | 2014 | Stenmark and Lilja | Designing for the satisfaction of high-level needs - Introducing the Ideation need mapping (INM) methodology |
| 20 | 2013 | Villafranca and Loureiro | Stakeholder analysis process using cognitive mapping |
| 21 | 2010 | Cho et al. | Economical, ecological and experience values for Product-Service Systems |
| 22 | 2010 | Yang et al. | Adaptive requirement-driven architecture for integrated healthcare systems |
| 23 | 2010 | Driss et al. | A Requirement-Centric Approach to Web Service Modeling, Discovery, and Selection |
| 24 | 2008 | Song and Lee | Mapping user accessibility needs systematically to universal design principles |
| 25 | 2007 | Rao | Entrepreneurial digital photography - A case study for design research method in the emerging Indian market |
| 26 | 2006 | Siau and Tan | Using cognitive mapping techniques to supplement UML and UP in information requirements determination |
| 27 | 1995 | Swan | Exploring knowledge and cognition in decisions about technological innovation: mapping managerial cognitions |
| 28 | 1986 | Montazemi and Conrath | The use of cognitive mapping for information requirements analysis |