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Assessing the usability and design of official integrated smart city apps: The case of Vancouver

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Résumé

Les applications de ville intelligente intégrées combinent de nombreuses fonctionnalités d'application de ville intelligente en une seule, offrant aux citoyens une plateforme intégrée pour accéder à divers services (Zhang et al., 2021). Cependant, des problèmes d'utilisabilité sont apparus en raison d'un manque d'études et de conseils de conception, ce qui a conduit à de l'insatisfaction de la part des utilisateurs. Dans le but de concevoir des applications de ville intelligente mieux intégrées que les citoyens continueront d'utiliser, cette étude a été développée pour étudier les éléments de conception et les facteurs d'utilisabilité qui pourraient conduire à des intentions d'utilisation continue dans le contexte des applications de ville intelligente intégrées.

Grâce à une revue de la littérature, nous avons observé un manque d'études explorant l'interaction entre les éléments de conception, l'utilisabilité et l'intention d'utilisation continue. Pour combler cette lacune, un modèle conceptuel a été développé sur la base du modèle Technology Acceptance Model (TAM) (Davis, 1986) et adapté en fonction de recherches récentes sur l'utilisabilité et l'expérience utilisateur (Hong et al., 2002 ; Grange et Barki, 2020 ; Coursaris et Kim, 2011 ; Watters et al., 2003 ; Amin et al., 2014 ; Hsu et Chiu, 2004 ; Kwahk et Han, 2002). L'objectif était d'identifier et de conceptualiser les relations entre les éléments de conception des applications intégrées de ville intelligente, les différentes dimensions de l'utilisabilité (ISO, 1998), ainsi que l'intention d'utilisation continue. Quatorze hypothèses ont été proposées. Cinq éléments de conception, à savoir la conception de l'information, la conception de la mise en page, la conception de la navigation, la conception visuelle et la conception de l'interaction (Garrett, 2003 ; Cyr, 2014 ; Grange et Barki, 2020) ont été identifiés, avec douze autres sous-catégories identifiées (Garrett, 2003 ; Fling, 2009 ; Hoober et Berkman, 2011 ; Choi, 2012) pour générer des items plus spécifiques dans le cadre des applications mobiles. Un questionnaire a été conçu et 51 observations valides ont été recueillies. Grâce à la modélisation par équation structurelle, nous avons validé que tous les items générés étaient valides et significatifs et que cinq des quatorze hypothèses étaient soutenues.

Nos résultats indiquent que la conception de la navigation et la conception visuelle ont un effet positif significatif sur l'efficacité, tandis que la conception de l'information et la conception visuelle ont un effet positif significatif sur l'efficacité. L'efficacité ne démontre pas d'effet significatif sur la satisfaction, tandis que l'efficience démontre un effet significatif sur la satisfaction. Il a également été constaté que la satisfaction était le facteur le plus important influençant l'intention d'utilisation continue, alors que l'efficacité n'a pas démontré d'effet significatif sur cette dernière.

Cette étude fournit des informations précieuses sur la création d'un cadre pour les éléments de conception d'applications mobiles et des conseils sur les aspects de la conception à prioriser lors de la conception d'applications intégrées de ville intelligente. De plus, nous avons constaté que l'intention d'utilisation continue des utilisateurs pour les applications intégrées de ville intelligente est principalement affectée par la satisfaction, qui, à son tour, est principalement affectée par l'efficacité. Se concentrer sur l'offre de services nécessaires et clés de manière claire et pratique, au lieu d'inclure davantage de services et de fonctions, devrait être l'objectif principal des développeurs d'applications intégrées pour les villes intelligentes.

Mots clés : Ville intelligente, application mobile, éléments de conception, application de ville intelligente, application de ville intelligente intégrée, utilisabilité, utilisation continue, intention, modèle d'acceptation de la technologie

Méthodes de recherche: Tri de cartes, Questionnaire, Analyse quantitative, Modélisation d'équations structurelles

Abstract

Integrated smart city apps combine many smart city app features in one, providing citizens with an integrated platform to access various services (Zhang et al., 2021). However, usability issues have arisen due to a lack of studies and design guidance, leading to user dissatisfaction. To design better integrated smart city apps that citizens will continue to use, this study was developed to investigate the design elements and usability factors that could lead to continuous usage intentions in the context of integrated smart city apps.

Through a literature review, we observed a lack of studies exploring the interplay between design elements, usability, and continuous usage intention. To address this gap, a conceptual model was developed based on the Technology Acceptance Model (TAM) model (Davis, 1986) and adapted according to recent research on usability and user experience (Hong et al., 2002; Grange and Barki, 2020; Coursaris and Kim, 2011; Watters et al., 2003; Amin et al., 2014; Hsu and Chiu, 2004; Kwahk and Han, 2002). The goal was to identify and conceptualize relationships between design elements of integrated smart city apps, the different dimensions of usability (ISO, 1998), as well as continuous usage intention. Fourteen hypotheses were proposed. Five design elements, namely information design, page layout design, navigation design, visual design and interaction design (Garrett, 2003; Cyr, 2014; Grange and Barki, 2020) were identified, with twelve further subcategories identified (Garrett, 2003; Fling, 2009; Hoober and Berkman, 2011; Choi, 2012) to generate more specific items in the context of mobile applications. A questionnaire was designed, and 51 valid observations were gathered. Through structural equation modelling, we validated that all generated items were valid and significant and that five out of fourteen hypotheses were supported.

Our findings indicate that both navigation design and visual design have a significant positive effect on effectiveness, while information design and visual design have a significant positive effect on efficiency. Effectiveness does not show a significant effect on satisfaction, while efficiency demonstrates a significant effect on satisfaction. It was also found that satisfaction was the most significant factor influencing continuous usage intention, whereas effectiveness did not show a significant effect on the latter.

This study provides valuable insights into building a framework for mobile app design elements and guidance on what aspects of design should be prioritized when designing integrated smart city apps. Additionally, we found that users' continuous usage intention for integrated smart city apps is mainly affected by satisfaction, which, in turn, is mainly affected by efficiency. Focusing on providing necessary and key services in a clear and convenient way, as opposed to including more services and functions, should be the main objective of integrated smart city app developers.

Keywords: Smart city, Mobile application, Design elements, Smart city app, Integrated smart city app, Usability, Continuous usage, Intention, Technology Acceptance Model

Research methods: Card sorting, Questionnaire, Quantitative analysis, Structural equation modelling

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Abbreviations list

NUP: National New-type Urbanization Plan

IDC: International Data Corporation

ICT: Information and Communications Technology

IoT: Internet of Things

IOS: International Organization for Standardization

SUS: System Usability Scale

MPUQ: Mobile Phone Usability Questionnaire

HCI: Human-Computer Interaction

TAM: Technology Acceptance Model

TRA: Theory of Reasoned Action

BIU: Behavioural Intention to Use

PU: Perceived Usefulness

PEOU: Perceived Ease of Use

PLS: Partial Least Squares

SEM: Structural Equation Modelling

AVE: Average Variable Extracted

CR: Composite Reliability

HTMT: Heterotrait-Monotrait

VIF: Variance Inflation Factor

Preface

An authorization to write the following dissertation has been granted by the administrative direction of the MSc User Experience in a Business Context specialization. This dissertation is written in the form of a classic dissertation.

The HEC Montréal Research Ethics Board (REB) approved the research project in April 2022 (Certificate #2023-4871).

This research identifies mobile applications design elements and investigates the ways in which these elements can influence an integrated smart city app's usability and how the latter further influences users' continuous usage intention. The final objective is to determine what aspects should be emphasized when designing integrated smart city apps to create a better user experience through this approach.

Acknowledgements

Completing this research and writing my thesis has been a long journey for me, filled with numerous obstacles and difficulties. Nevertheless, it has also proven to be an invaluable learning experience. I would like to express my gratitude to all those who have supported me throughout this process.

First and foremost, I would like to extend my heartfelt thanks to the staff and teachers who have taught me throughout my studies at HEC Montréal. I am especially grateful to my thesis director, Ryad Titah, who not only acknowledged my achievement but also supported the project I chose. He had faith in my ability to contribute something valuable to society and offered guidance and assistance at every stage of my research and thesis writing. Whenever I encountered problems, he was always there to lend a helping hand. Despite a significant change in the middle of the data collection process, he provided me with the confidence to continue with the study, even though the original plan and scope had to be altered. Furthermore, his strict requirements ensured the high quality of the work and motivated me to work harder.

I would also like to express my appreciation to all my friends and family members who provided me with assistance during the pretest and data collection process. I am grateful to Mariane and Ying for sharing their ideas and experiences. I am especially thankful to my husband for his unwavering support throughout this journey. I truly appreciate the time, patience, energy, and assistance he provided not only in my studies but also in my work and life. Without him, I would not have come this far.

Chapter 1
Introduction

1.1 Context of study

In recent years, urbanization has accelerated rapidly, leading to a significant increase in urban populations. As a result, the demand for services, facilities, and natural resources from citizens is also growing. This presents a challenge for urban areas to find more intelligent ways to manage and cope with these demands. Concurrently, advancements in information technology have progressed at an incredible pace. As a result, many cities are aiming to leverage these technological advancements to become smarter in their management and operations, often with the goal of achieving sustainable urban development.

The "Smart City" term was first popularized by IBM in 2008. In a white paper published that year, IBM introduced and defined the term as "an urban environment that uses technology to improve the quality of life, increase environmental sustainability, and reduce costs.'' (IBM, 2008). However, it was not the first to discuss the concepts and ideas of what a 'Smart city' could be. Hall (2000) wrote that a crucial aspect of a city being classified as 'smart' is its ability to oversee and incorporate the state of all vital infrastructure components. This concept of a 'smart city' envisions a future with safe and secure urban centers that are highly efficient and, as a by-product of such efficiency, environmentally sustainable. A smart city, according to Goldsmith (2021), is a modern urban area that uses technology to collect and use data to improve the quality of life for citizens, increase efficiency, and reduce costs. The data is collected using various electronic methods and sensors that are then used to improve operations across the city. Whether it is for simple conveniences such as intelligent parking networks or city-wide air quality and energy consumption monitoring, smart cities promise to use data and IoT to continuously process information from a multitude of sources in order to increase the efficiency of everyday city life.

After all, over the last few years, governments have increasingly incorporated information and communication technologies into their operations, with the aim of enhancing public service provision and improving the efficiency of public administration (Vassilakis and Lepouras, 2006).

The European Union launched the “Smart Cities and Communities Initiative” in 2011 as a way to help “design and adapt cities into smart, intelligent and sustainable environments’’. Since around 75% of Europeans live in cities, smart cities presented themselves as a way to tackle major issues in energy, transport and ICT (European Union, 2012). In 2015, the United States Department of Transportation (USDOT) launched the Smart City Challenge, an initiative aimed at creating an integrated city that leverages data, technology, and creativity to transform how people and goods move in urban environments. The winner, Columbus, Ohio, was awarded a $50 million grant to facilitate the integration of technology into its transportation infrastructure, including the development of an autonomous shuttle service, as well as the installation of connected traffic signals (USDOT, 2017). The Indian government launched the Smart City Mission in 2015 with the aim of transforming 100 cities in India into smart cities by 2022, with a focus on various urban services, such as water supply, waste management, mobility, energy and public safety (Ministry of Housing and Urban Affairs, 2023). The Chinese government, which has made smart city initiatives a priority in its recent developments, is now overseeing over 700 projects as part of smart city development for over 500 cities (Zhang et al., 2021). Overall, the International Data Corporation (IDC) found that cities in the Asia/Pacific region generally had higher smart city technology investments, with over 40% of worldwide spending and adoption rates, than cities in Europe and North America (International Data Corporation, 2018).

The scale at which different cities have incorporated IoT in their public services varies from region to region and could be attributed to population size and willingness to adopt new technologies in their everyday life. Coe et al. (2001) mentioned that a smart city’s inception would be based on a community that has learned to learn, adapt and innovate. As an example, Los Angeles in the United States has converted over 98% of its streetlight to LEDs, a network of nearly 4,500 miles, and has connected these streetlight LEDs to a system that automatically reports malfunctions to speed up the replacement process (Los Angeles Bureau of Street Lighting, n.d.). Toronto in Canada has also been researching different IoT solutions to some challenging issues, such as Automated Snow Clearing and Parking Sensors and Curbside Vehicle Detection (City of Toronto, n.d.).

Cities around the world have implemented the concept of smart cities in various ways. To interact with the conveniences of smart cities, an interactive interface is required for users to engage properly with these services. Among the available options, smartphone apps have emerged as the most efficient interface since they do not require users or providers to purchase or provide additional equipment, and the data can be distributed instantly for real-time action (Farias et al., 2019). Typically, smartphone users only need to download an app to access a smart city interface. As a result, offering smart city apps to provide various city services to citizens has become a popular trend (Peng et al., 2017).

Many cities offer multiple apps to help citizens solve various issues. Singapore, for example, offers many different apps to its citizens, such as SingPass, that allows citizens to access services such as tax filing, healthcare appointments as well as applying for public housing, and MyTransport.SG, an app to receive notifications on the traffic situation to better plan trips (Government of Singapore, n.d.). In North America, Montréal has offered apps that aim to solve everyday problems through user feedback, such as the Montreal – Resident Services app, BIXI to use the bike sharing system, Mon RésoVélo to plan bike trips and record trips, as well as P$ Mobile Service, an app to pay for on-street parking (Tourisme Montréal, n.d.).

These types of smart city apps are usually responsible for one aspect of civic services. Zanella et al. (2014) have discussed the importance of standardization in Urban IoTs, which are designed to support smart city app design. They have recommended an emphasis on interoperability and scalability as a way to reduce development costs, increase innovation, offer better services, and improve data management. The Chinese government, in collaboration with Tencent, has developed a similar approach by consolidating multiple services into a single unified platform that can be used nationwide. For example, through the use of various mini apps within WeChat, a popular instant messaging, social media, and mobile payment app used by over a billion people, cities are able to offer a variety of services accessible through one single integrated app that combines private and public stakeholders. These services include but are not limited to Utilities, Share Bike, Parking, Paying Traffic fines, Taxes, and obtaining Medical appointments. This type of smart city app is an integrated platform combining various services in one unified app.

An integrated smart city app is a type of smart city app. However, it is not solely available in China. The United Arab Emirates offers an integrated smart city called DubaiNow, which allows users to access government and non-government services throughout the city of Dubai, including paying bills, settling traffic fines, renewing car registrations, as well as applying for residency

(Smart Dubai, 2020). New York in the United States offers an app called NYC311, which allows users to check for information regarding parking and meters, receive timely information on the city, and report issues. Vancouver, Canada, launched the VanConnect app in 2015. This app offered users multiple functions, such as the possibility to find different locations in the city, dispute parking tickets, apply for development permits and report issues. However, overall, integrated smart city apps appear more in Asia/Pacific Area.

1.2 Problems

The most glaring challenge when trying to assess the current state of smart city apps around the world is the lack of relevant research. This is especially true when trying to assess the usability and design of specific smart city apps in a particular city or country. Zhang et al. (2021) explain that in recent years, there has been a noticeable increase in the number of scholarly articles focusing on the importance and interconnectivity of information, technology, organization, and citizens in the context of smart cities. However, despite this trend, there remains a dearth of research that comprehensively examines the current development patterns, challenges, and utilization of smart city applications in specific cities or countries.

At the same time, the existing literature on smart city apps mainly focuses on analyzing factors that influence user attitude and behaviour toward using such smart city apps (Zhang et al. 2021; Salim et al.2021), evaluating smart city apps and services (Bellone et al., 2021; Jiang et al., 2021; Zhou et al., 2022), or discussing the development or design of a smart city app (Simononfski et al., 2021). However, there is a lack of research bridging these aspects into a single study. Therefore, conducting research that combines the assessment of smart city app design, the evaluation of its usability and exploration of the relation of those aspects with users' intention to continuously use the app in a specific city can fill this gap and generate valuable insights.

Currently, integrated smart city apps, which are mobile applications that combine various functionalities and features to offer a range of services and solutions to residents, businesses, and visitors, are not widely available in most regions. Consequently, studies on this specific type of smart city app are scarce. Furthermore, even among the few integrated smart city apps that do exist, usage is often limited, and user satisfaction is not very high. This is especially true for North American cities. For instance, in Canada, as of March 2023, the 311 Toronto app received an average score of 3.7 out of 5 on the Apple AppStore, while Van311, the updated version of the VanConnect app, received a score of 2.2. In comparison, integrated smart city apps in other regions, such as Asia, usually fare much better with user scores. DubaiNow received an average user score of 4.7 on the Apple AppStore, while Singapore's Singpass received an average score of 4.8 out of 5.

Therefore, the question of how to design integrated smart city apps that are more appealing to users and can help governments provide their services effectively, especially in regions like North America, remains unanswered.

This study aims to bridge the literature gap and fulfill the requirements for an integrated smart city app study by investigating the critical elements to emphasize in the app's design and development. The primary objective is to design better apps to enhance perceived usability and increase user enjoyment, thereby motivating a broader population to use it. This study could facilitate government mandates for the development of integrated smart city apps that offer more services and enable better and more accurate feedback from users.

1.3 Study city choice

This research wants to put focus on Canadian smart city development. Canada has a variety of programs that pertain to smart cities, such as the Smart Cities Challenge (https://www.infrastructure.gc.ca/cities-villes/index-eng.html), an initiative by the government of Canada aimed at encouraging the development of innovative solutions to urban issues through the use of data and connected technologies, as well as strong municipal policies aiming at developing smart cities, such as Toronto's smart city framework, a comprehensive strategy aimed at leveraging technology and data to improve the quality of life for residents, enhance sustainability, and drive economic growth (https://www.toronto.ca/city-government/accountability-operations-customer-service/long-term-vision-plans-and-strategies/smart-cityto/).

Out of the many cities that are adopting smart city development, Vancouver offers one of the most popular integrated smart city apps. Until late 2022, the city of Vancouver provided a mobile app called VanConnect that offered services such as reporting disturbances, making service requests, and searching for nearby road conditions. The app aimed to provide people who prefer accessing

City information digitally with more accessibility. Its format was similar to most integrated apps that offer comprehensive access to city services and information. Although its functionality was limited compared to similar Chinese apps, as mentioned earlier, it offered more functions than similar apps from other large Canadian cities, such as Montreal's Resident Services and Toronto311, the latter referring to the special telephone number used in many municipalities of North America to provide access to non-emergency municipal services.

Despite offering a wide range of functions and services, the user population remained limited. According to the last accessible records (August 13th, 2022, through Internet Archive Wayback Machine at web.archive.org), the total downloads of VanConnect since the app launch were 51,432. Additionally, as mentioned above, the feedback received from the public about this app so far has been unsatisfactory. The integrated nature of the app and the lack of research on this particular type of app in North America are the reasons why the city of Vancouver was chosen as the case to be assessed for this study.

1.4 Objectives

As mentioned above, the primary objective is to design better apps to enhance perceived usability, thereby motivating a broader population to use them. The general research question is:

How can the design and usability of integrated smart city apps help improve their use by citizens?

To answer this question, we have to answer the following questions:

1. ***What are the design elements that should be considered in an integrated smart city app, and how do they relate to the app's perceived usability?***

2. ***What constitutes the perceived usability of an integrated smart city app, and how are they related to each other?***

3. ***How does the perceived usability of an integrated smart city app relate to users' willingness to continuously use the app?***

In order to answer these questions, a conceptual model was built based on Davis's (1989) Technology Acceptance Model (TAM) and adapted according to recent research on usability and user experience (Hong et al., 2002; Grange and Barki, 2020; Coursaris and Kim, 2011; Watters et al., 2003; Amin et al., 2014; Hsu and Chiu, 2004; Kwahk and Han, 2002) to explore and investigate the proposed relationships between various elements of smart city app and perceived usability and users' continuous usage intention. The objective of this research is to evaluate an existing integrated smart city app and assess users' perception regarding different aspects of its design, usability and continuous usage intention, with the purpose of identifying the ways in which different design elements can influence an integrated smart city app's usability and how the latter further influences users' continuous usage intention. Ultimately, the aim is to determine what aspects should be emphasized when designing such apps to create a better user experience for users and how better municipal services can be delivered through this approach.

1.5 Structure of study

This thesis comprises seven chapters, each with a distinct purpose. The first chapter serves as an introduction, where the context of smart city development is outlined, the research problem is identified, the study's objectives are determined, and the reasons for selecting Vancouver as the study case are explained. The second chapter provides a summary of the relevant literature, highlighting its strengths and identifying areas for further research. It also explains why the chosen direction and method were selected.

Chapter 3 details the construction of the research model and the hypotheses related to different variables in the model. In Chapter 4, the data collection methodology, survey development process, sample information, and data analysis methodology are shared.

Chapter 5 presents and explains the results of the analysis conducted. Chapter 6 offers a discussion of the results, while Chapter 7 presents the conclusions of the study and discusses the theoretical and practical contributions the study makes, the limitations of the study, as well as the implications for future research.

Chapter 2
Literature Review

The purpose of this literature review is to provide a comprehensive overview of the current literature relevant to the research question of this study.

Specifically, this literature review covers the key aspects of the research question, including smart city, apps, usability, design, and continuous usage. To achieve this, the review will begin by defining the concepts of smart city and smart city apps. This will be followed by a discussion of existing user experience studies on smart city apps, as well as definitions of usability and mobile usability, including evaluating methods and metrics. The review will then identify mobile app design elements and explore the relationship between design and usability, as well as the literature related to continuous usage intention and its relationship with usability. Finally, the literature review will conclude with a summary of the literature and an explanation of how it contributes to the topic and objectives of this research.

The literature review covers a time range from 2000 to 2022 and was conducted using several databases, including ABI/INFORM (ProQuest), The Digital Government Reference Library, ScienceDirect, and IEEE Xplore. To ensure a comprehensive search, keywords such as 'Smart City Application', 'Mobile Usability', 'Application Design', and 'Continuous Usage' were used. Only articles written in English were considered. Due to the potentially large number of articles found, the search criteria were supplemented with limiting factors to ensure relevance to the field of User Experience. For example, the search results for 'Smart city applications' were further focused by requiring the literature to have 'User experience' as a subject, and the search results for 'Application design' and 'Continuous usage' were more specifically focused by requiring the literature to have 'Usability' as a subject. Furthermore, to ensure the literature reviewed was relevant to the research question and accessible to a broad academic audience, content deemed too technical or irrelevant, such as articles in fields like engineering and medicine, was excluded from consideration. Only articles published in reputable academic sources such as theses, journals, and books were considered for this literature review.

Title and abstract assessments were conducted to further narrow down the relevant articles. To ensure the scope of the research was not limited, relevant articles found in the reference list of previously found articles were also included. This included articles that were published outside of the original time frame and sources used.

A total number of 83 articles were selected for the literature review, and the screening steps are illustrated in Figure 1.

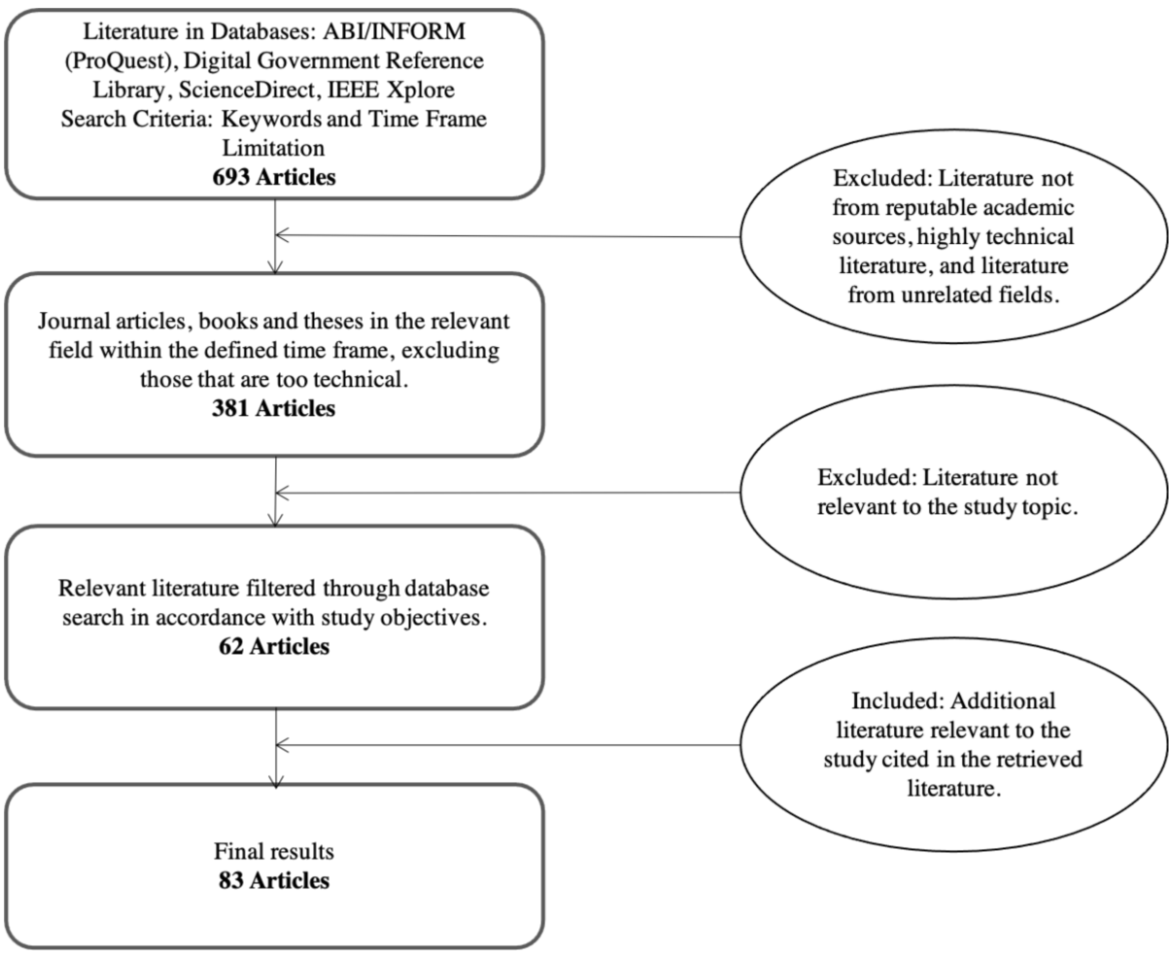

Figure 1. Literature Selection Process

2.1 Smart city and smart city apps

2.1.1 Smart city definition

The concept of a smart city is multifaceted, as noted by various scholars (Nam and Pardo, 2011; Gil-Garcia et al., 2016; Zhang et al., 2021). Albino et al. (2015) provide a comprehensive list of smart city definitions, highlighting the concept's inclusion of information and communication technologies (ICT), as well as community and people-centred elements. Nam and Pardo (2011) note the varying emphasis of smart city definitions, with some highlighting technological aspects while others prioritize social and human elements. They propose that the fundamental components of a smart city include technology, institutional, and human factors. Additionally, Giffinger and Gudrun (2010) argue that the concept of a smart city encompasses six dimensions: the economy, mobility, environment, people, living, and government.

There is a pervasive ambiguity and debate surrounding the precise definition of a smart city within the relevant literature, with multiple definitions being proposed.

Washburn et al. (2010) define a smart city as one that heavily relies on advanced computing technologies. They argue that the current urban issues, namely dwindling resources, subpar infrastructure, energy shortages and fluctuating costs, as well as the environment and public health challenges, necessitate the implementation of smart city strategies. Harrison et al. (2010) define a smart city as an "instrumented, interconnected, and intelligent city." Nam and Pardo (2011) argued that in the context of smart cities, the term 'smart' is often associated with the term 'intelligent'. They further explained that the reason behind this is that something can only be considered smart if it is enabled by an intelligent system that can be adapted to the needs and preferences of its users. In the context of this research, Ballas (2013) presents smartness as an umbrella term that covers any government or public agency policies and programs that cover sustainable development, economic growth, improved quality of life and happiness creation. Gartner (2011) explains that intelligent exchanges of information flowing between different subsystems used for citizen and commercial services are the basis of a smart city. Eger (2009) talks about smart communities that consciously deploy technology as a means to reinvent cities to solve social and business needs for the community. Finally, Townsend (2013) defines a smart city as a place "where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems". This is the definition of a smart city adopted in this research.

2.1.2 Smart city apps definition, features and types

The widespread adoption of mobile devices in developed countries has led to their increased value for consumers through many facets (Coursaris and Kim, 2011). Smart mobile devices are now an essential part of the smart city networked infrastructure, with the ability to instantly distribute data for purposes of real-time data analysis, feedback, and control (Balakrishna, 2012; Farias et al., 2019). As the use of smart mobile devices has increased, the use of apps to deliver products and services has become a common trend. Among these apps, smart city apps are particularly unique, as they are an essential component of smart city solutions and play a vital role in connecting smart service providers with citizens (Peng et al., 2017).

According to Walravens (2015), city apps play a crucial role in connecting citizens and smart cities with their virtual and social environment. Smart city apps can provide various innovative functions and real-time services by making use of the latest technologies and facilities embedded in smart city ecosystems (Zhang, 2021). Smart city apps can be defined as digital platforms that can support a variety of services, including smart transportation, smart government, smart economy, smart safety and emergency management, smart health, smart tourism, smart education, smart buildings, smart waste management, smart energy, and smart water management (Anthopolous, 2017). Zhu and Alamsyah (2021) adapted the seven properties originally identified by Yoo (2010) for experiential computing to the smart city app context, namely programmability, addressability, sensibility, communicability, memorability, traceability and associability, and further classified those seven properties into two groups, internal and external.

Many cities develop apps that only focus on one specific area of service or function (Zhu and Alamsyah, 2021). However, in everyday life, assessing different city services may require downloading various smart apps without a guarantee of convenience (Zhang et al.,2021). In addition to this, running multiple individual applications is costly and requires lengthy information syncing between applications (Litan, 2011), and since completely different IT infrastructures and independent datasets are required to run these apps, there are limits to our understanding of their potential value (Zhang et al.,2021). Some cities chose to bundle various functions together in one single app (Zhu and Alamsyah, 2021). This trend of integrating isolated smart city apps into a single uniform platform is becoming more and more popular (Zhang et al.,2021). Cities such as

Dubai and Vancouver are examples of cities that use integrated smart city apps to provide citizens with comprehensive access to city information and services (Anthopoulos, 2017). Integrated smart city apps aggregate a city's resources, both online and offline, into a single network that offers citizens an integrated platform to access information and services whenever they require to do so (Zhang et al., 2021). This definition of integrated smart city apps will be adopted in this research and the key features of integrated smart city apps are listed below (Table 1).

Table 1. Features of Integrated Smart City Apps (Zhang et al., 2021)

Category	**Feature**
Organizer	Organized or mandated by government.
Stakeholders	Includes different stakeholders and departments: citizens, governments, service providers, etc.
Functions	Connects citizens to city-wide networks of IoT facilities, city services, and information.
System	Combines a variety of online and offline information and services into one platform.
Data	Data is integrated and stored through cloud technology to allow for real-time access.

2.2 Smart city apps and user experience

Smart city research is a heated field, and user-centric studies on smart cities are essential since citizens are the primary stakeholders of smart cities. Among these studies, citizen participation in the development of smart cities is a central focus (Lim et al., 2021). Smart city apps and services play a significant role in involving citizens in the development of smart cities, and evaluating users' experiences when interacting with them is essential for assessing their success and receiving feedback from users (Chatterjee and Kar, 2018).

Existing studies on smart city apps and user experience have explored various aspects of the topic. Factors influencing users' satisfaction and intention to continue using smart city apps have been examined by researchers such as Zhang et al. (2021) and Salim et al. (2021), while Chen et al. (2021) focused on the factors that influence user experience and trust in government during interactions with the apps. Chatterjee and Kar (2018) studied the effects of the successful adoption of information technology-enabled services in smart cities, while Zhu and Alamsyah (2021) investigated the key features of apps that impact users' satisfaction and empowerment of citizens. In summary, factors affecting users' attitudes and behaviours are the key areas of study for related studies.

In addition, many studies also focus on evaluating smart city apps or services. Jiang et al. (2021) evaluated the performance of a Chinese government official WeChat account through clickstream analysis, a card sorting study, stakeholder interviews, and a focus group. Zhou et al. (2022) proposed a framework to evaluate user experience-oriented smart service requirements. Bellone et al. (2021) evaluated and compared the user experience of public autonomous transportation services across different countries. Kumar et al. (2017) evaluated users' experience with smart government services and their impact on users' behaviour.

The development or design of a smart city app is another area of study. Simononfski et al. (2021) identified the characteristics that a smart city participation platform should have to meet the requirements of citizens and public servants. Nurnawati and Ermawati (2018) discussed the design of an integrated database that can be used by various applications, using the Yogyakarta smart city app as a case study. Maulana et al. (2020) presented a Smart Parking System development process based on the IoT using the Object-Oriented Analysis and Design method.

Despite the different approaches, it is clear that research on user experience and smart city apps or services can be categorized into three main areas: analyzing factors that influence user attitude and behaviour of using such smart city apps, evaluating smart city apps and services, and discussing the development or design of a smart city app. However, there is a lack of research that bridges these areas with the objective of smart city apps.

2.3 Usability and mobile usability

Usability is a complex and multidimensional concept that has been defined differently in various relevant literature. Shackel (1991) defined usability as "the capability in human functional terms to use easily and effectively". The common denominator among these definitions is the centrality of users in the usability assessment process. Nielsen (1994) explained that usability places convenience and practicability for users as the main priority and concern when designing software. He defines usability as a qualitative attribute used in the assessment of an interface's ease of use.

This is done through five separate dimensions: learnability, efficiency, memorability, error avoidance, and satisfaction. His definition is one of many provided in the relevant literature. Sherman and Quesenbery (2005) explained that usability could refer to the outcome of the creation of usable systems, a process for design and development that revolves around users, as well as a philosophy that prioritizes the needs of users. Rosson and Carroll (2002) mentioned that usability covers three dimensions: learnability, user Satisfaction, and ease of use. Quesenbery (2003) provided five dimensions to assess usability, namely efficiency, effectiveness, engagement, error tolerance, and ease of learning, whereas Hertzum (2010) provided six perspectives of usability, namely universal, situational, perceived, hedonic, organizational, and cultural usability.

The International Organization for Standardization (1998) defined 'Usability' as ''the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use''. To be more specific, in this definition, 'Effectiveness' refers to "accuracy and completeness with which users achieve specified goals", 'Efficiency' means "resources used in relation to the results achieved", while 'Satisfaction' represents "the extent to which the user's physical, cognitive and emotional responses that result from the use of a system, product or service meet the user's needs and expectations".

This definition mentioned three dimensions of usability and emphasized the importance of context. The definition of usability in the context of mobile devices and applications is crucial, as the success of a mobile website or application is greatly dependent on its usability (Groth and Haslwanter, 2016; Hsu and Chiu, 2004). Zhang and Adipat (2005) highlighted the differences between mobile use and website use contexts, including connectivity, screen size, display resolution, data entry methods, and limited processing capabilities.

Hoehle and Venkatesh (2015) proposed a definition of mobile app usability based on the ISO Standard as "the extent to which a mobile application can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". Harrison et al. (2013) proposed the PACMAD model to represent the usability of mobile applications and mentioned four dimensions besides those acknowledged by the IOS standard definition, namely Learnability, Memorability, Errors and Cognitive. In addition, Baek and Yoo (2018) proposed user-friendliness, personalization, speed, fun, and omnipresence as five components of usability for branded apps. However, there is still a lack of a universally accepted usability framework in the context of mobile devices and applications (Coursaris and Kim, 2011; Groth and Haslwanter, 2016).

Coursaris and Kim (2011) proposed a mobile usability framework that identified four contextual factors impacting usability, which are User, Technology, Task/Activity, and Environment, based on the four contextual variables for usability evaluation proposed by Kwahk and Han (2002) and its dimensions. By analyzing hundreds of empirical mobile usability papers, 31 dimensions were used by different researchers to measure usability, and by further grouping them, the three core dimensions that got the most research were identified as Efficiency, Effectiveness, and Satisfaction, which is consistent with the ISO Standard. Frøkjær et al. (2000) studied the correlation of these three dimensions and concluded that all the dimensions should be included and considered as independent aspects unless suggested otherwise by studies specific to particular domains. Therefore, for this research, the three dimensions of 'Efficiency', 'Effectiveness', and 'Satisfaction' will be used to measure mobile usability.

2.4 Usability evaluation

To determine the quality of a system's usability, we must employ usability evaluation, a method for measuring usability using specific methodologies (Nielsen, 1994).

Several methods exist for conducting usability evaluation. Jeffries et al. (1991) identified four main usability evaluation methods: heuristic evaluation, software guidelines, cognitive walkthroughs, and usability testing. Nielsen (1994) categorized usability evaluation methods into two groups: expert-based evaluations and user-centred evaluations, with the latter primarily encompassing user testing.

Usability testing is a user-centric method that can gather both quantitative and qualitative data on usability issues, device performance, and the mental/physical demands placed on users when using a device (Duh and Chen, 2006). It is user-centric and can provide direct feedback from users and is thus considered to be the most fundamental usability evaluation method (Nielsen, 1994).

Most usability tests are conducted in a laboratory setting (Rubin,1994), which may result in overlooking problems that occur in the real-world context, especially for mobile devices due to their mobility (Duh and Chen, 2006; Gorlenko and Merrick, 2003). And in the case of mobile services, usability evaluations are still conducted in laboratory settings as well (Kjeldskov and Graham, 2003; Duh and Chen, 2006; Hoehle and Venkatesh, 2015). While some researchers have recognized the importance of conducting usability testing in the field for mobile systems (Duh and Chen, 2006; Kjeldskov and Stage J, 2004), these studies are still largely based on task testing, which requires more effort, time, and cost. Additionally, conducting field studies may face numerous unpredictable variables affecting data collection and control methods when users interact with the real world (Kjeldskov and Stage, 2003), making usability testing in the field more challenging (Brewster, 2002). There are also several emerging methods for evaluating mobile usability. For example, Ji et al. (2006) developed a usability checklist for mobile interfaces based on heuristic evaluations, with the aim to efficiently guide design and test it to be valid in identifying usability problems compared to user testing. Hub and Zatloukal (2009) used fuzzy theory and fuzzy inference processes to build a fuzzy usability evaluator which would provide a usability score for any interface. However, user testing in a lab generally remains the most widely used and accurate way to measure mobile usability.

In terms of the metrics to measure usability, there are two approaches. The first approach measures usability as a whole, while the second approach measures each dimension of usability separately. The most widely used tool for the former is the System Usability Scale (SUS), which was proposed by Brooke in 1996. Numerous studies have shown its validity. For instance, Tullis and Stetson (2004) concluded that SUS offered the highest reliability across a wide range of sample sizes by conducting usability measurements comparison using five different surveys. Additionally, Bangor et al. (2008) found SUS to be highly reliable and useful across various interface types. Orfanou et al. (2015) have also used SUS to assess the usability of learning management systems, while Kortum and Miller (2009) added an adjective rating scale after the SUS to help explain and understand the SUS score. Questionnaires used specifically for mobile applications have also been developed. For example, Brown and Kim (2020) used the Mobile Phone Usability Questionnaire (MPUQ) to test the usability of a mobile application prototype.

The second approach, measuring each dimension separately, offers the benefit of assessing the performance of each individual dimension. In this context, efficiency and effectiveness can be measured differently depending on whether the research is task-based or questionnaire-based, whereas satisfaction is invariably assessed in a consistent manner. In the case of task-based research, their measurements can be done through behaviour measurement. Research has demonstrated that efficiency is always measured by time on task (Frøkjær et al., 2000; Groth and Haslwanter, 2016; Sauro and Lewis, 2010) and that another important metric is pages views (Groth and Haslwanter, 2016). In the case of effectiveness, it is usually measured through task success level (Groth and Haslwante, 2016) or through the quality of the solution (Frøkjær et al., 2000). In the context of questionnaires, Coursaris et al. (2007) studied the impact of distraction on usability, with efficiency measured by factors such as “easy to learn”, “easy to use”, “user friendly” and “fast to use”. Coursaris (2016) also measured effectiveness with aspects such as "all information obtained” and “all tasks completed”, and satisfaction through aspects like “Terrible/Delighted,” “Frustrated/Contented,” “Unhappy/Gratified,” as well as “Sad/Joyful”.

In this study, an assessment of each dimension of usability is needed and will be done through a questionnaire.

2.5 Application design and usability

There is a considerable body of research on interface design elements. Kwahk and Han (2002) divided interface design elements into two categories: hardware and software. They described software elements as being made up of programmed or programmable interface elements that are usually seen on a display panel, that can be grouped into displayed items, menu, form, feedback, message, and help. Al-Qeisi et al. (2014) divided web design quality into technical quality, general content quality, special content quality and appearance quality, while Cyr (2014) identified three main elements of website design: information design, navigation design, and visual design. To be more specific, information design represents “elements of the site that convey accurate or inaccurate information to a user”, visual design concerns the “balance, emotional appeal, esthetics, and uniformity” of the system, including colors, icons, photographs, topography, and font, while navigation design refers to “the navigational scheme used to help or hinder users as they access different sections” of the system.

On top of Cyr's three identified main elements, Grange and Barki (2020) added Page layout design as an additional element in website design systems, whose function is to "capture design elements that facilitate sense-making within web pages". Garrett (2003) proposed a conceptual framework consisting of five planes for user experience design: strategy, scope, structure, skeleton, and surface. Within this framework, interface design, which closely resembles Grange and Barki's Page layout design definition, is one of the five main elements. The other four elements are navigation design, information design, sensory design, which is mainly about visual design, as well as interaction design, which is "concerned with describing possible user behaviour and defining how the system will accommodate and respond to that behaviour". These design elements are applicable not only to website design but also to other types of interface design.

However, while website designs differ from mobile application design, there is no widely accepted standard framework for mobile application design elements (Punchoojit and Hongwarittorrn, 2017). Fling (2009) proposed layout, color, graphics and typography as the main mobile design elements. Hoober and Berkman (2011) defined major design patterns for mobile interfaces, such as Page composition, Display of information, Control and feedback, Navigation, Information control, Input and output. Choi (2012) listed 13 elements for mobile application design, which include typography, visual hierarchy, grid-based layout, alignment, colors, legibility, buttons, intuitiveness, simplicity, navigation, contents, attractiveness and consistency.

These elements can be categorized into five design categories: information design, visual design, layout design, navigation design, and interaction design, demonstrating that the five design categories can also be applied in the context of mobile applications. This study will adopt these five categories of design elements.

It is worth noting that there are application design frameworks focused on some specific types of applications. One such framework is for e-commerce mobile application design, which has become a heated field of research. For example, Magrath and McCormick (2013) proposed 18 marketing design elements for mobile fashion retail apps, and those elements can be further grouped into multimedia product viewing, informative content, product promotions, and consumer-led interactions. Martinez and McAndrews (2020) then adopted three of the four groups and examined the influence of multimedia product viewing, product promotions and consumer-led interactions on users' stickiness intention.

Some researchers have used software user experience guidelines as a basis for application design, with modifications made as needed. For example, Venkatesh and Ramesh (2006) examined the generalizability of Microsoft usability guidelines and applied them in web and wireless site usability evaluation comparisons. However, these guidelines did not take into account contextual factors. Hoehle and Venkatesh (2015) adapted Apple's user experience guidelines, especially in the context of mobile applications, and developed an instrument for assessing mobile application usability and guiding mobile application design. The framework consisted of 19 subconstructs highly connected with design, which were further grouped into six constructs: application design, utility, user interface graphics, user interface input and output, and interface structure. Hoehle et al. (2015) analyzed Microsoft's mobile usability guidelines and defined ten constructs: Aesthetic graphics, Color, Control obviousness, Entry point, Fingertip-size controls, Font, Gestalt Hierarchy, Subtle animation, and Transition. These constructs represent mobile application usability in a manner that is more detailed and connected with application design elements. However, the relationship between design and usability is not explained clearly. Hornbæk and Stage (2004) conducted a literature review of the Human-Computer Interaction (HCI) industry and concluded that the HCI field features a wide range of usability evaluation and interface design techniques. However, they also noted a lack of methodological guidelines that discuss the interplay between these activities.

2.6 Continuous usage intention and usability

The aim of smart city apps is to assist a particular city's citizens with their daily service needs. A smart city app's success should be evaluated on its user's intention to continuously use it after trying it (Abu-Salim et al., 2020).

Susanto et al. (2015) found that user satisfaction and self-efficacy were the critical antecedents of usage continuance. Abu-Salim et al. (2017) concluded that the intention of customers to continue using a service is directly associated with said service provider's ability to attain, but also retain the loyalty of customers by ensuring customer satisfaction. Bhullar and Gill (2019) studied the impact of mobile usability on continued usage intention for mobile shopping applications on smartphones and concluded that factors such as aesthetic graphics and subtle animations have a substantial impact on continued usage intention.

Abu-Salim et al. (2020) concluded that the delivery-channel characteristics of smart city services as well as the personal characteristics of users, influence their satisfaction with these services as well as their continued usage intention for SCS-delivery channels. Zhang et al. (2021) explored the factors that affected the continuous usage of one-stop smart city apps and confirmed the importance of satisfaction on continuance usage intention for smart city apps. And it can be seen that continuous usage intention is often linked with satisfaction.

Despite the significance of satisfaction in determining continuous usage intention, the link between usability, of which satisfaction is a component, and continuous usage intention has not been extensively investigated.

2.7 Summary of literature review

In summary, the field of smart city research has gained significant attention, but the research on integrated smart city apps, which are frequently proposed by governments as service platforms, is still limited. Existing research on user experience and smart city apps can be broadly categorized into three areas: analyzing factors that influence user attitude and behaviour toward using such smart city apps, evaluating smart city apps and services, and discussing the development or design of a smart city app. While all of these areas are closely connected to usability, there is a lack of combined studies of these aspects.

Context plays a significant role in usability, particularly in the case of mobile usability, as mobile devices and applications possess unique features that differentiate them from traditional websites. Although several studies have attempted to propose new models or frameworks to measure mobile usability, there is no universally agreed-upon method for assessing mobile usability. However, ISO's definition of usability, which contains the dimensions of effectiveness, efficiency and satisfaction, has been validated in mobile contexts as well. There is credible research on usability evaluation, user testing being the most user-centric method, but it is often limited by lab and location, particularly for mobile usability testing. While the importance of evaluating usability in the field has been recognized by researchers, it remains challenging to implement and obtain accurate results. Usability metrics used for evaluation have two primary directions: measuring overall usability and assessing each dimension of usability, with the latter providing greater opportunities to identify the relationship between each dimension and evaluating them through a questionnaire, thereby breaking through the constraints imposed by lab settings.

As interface design is a critical factor influencing usability, several studies have focused on it. However, the field of web design research is more mature than that of mobile application design, and there are no standard design elements or guidelines for application design. When assessing usability, some researchers try to take design elements into consideration to build a usability evaluation framework. However, the link between usability and design remains unclear and relevant research on their interplay remains scarce.

Continuous usage intention towards applications is a critical indicator in evaluating the success of smart city apps, and satisfaction, one dimension of usability, significantly influences continuous usage intention. However, there is limited research on the relationship between usability and continuous usage intention.

The above summary of the literature review explains why integrated smart city apps were chosen as a study object, along with the objective of exploring the relationship between application design elements, usability, and continuous usage intention with users' feedback in the field. The goal is to determine the extent to which different design elements influence various dimensions of usability and provide guidance for better design and development of smart city apps that can better serve citizens.

The definitions of this study's key terms are summarized below (Table 2).

Table 2. Definitions of Key Terms

Term	Definition	Source
Smart city	"Places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems."	Townsend, 2013

Smart city apps	Digital platforms that can support a variety of services, including smart transportation, smart government, smart economy, smart safety and emergency management, smart health, smart tourism, smart education, smart buildings, smart waste management, smart energy, and smart water management.	Anthopoulos, 2017
Integrated smart city apps	A smart city app which can facilitate the aggregation of a city's resources, both online and offline, into a comprehensive local network that can offer citizens an integrated platform to access information and services of the city whenever they require to do so.	Zhang et al., 2021
Usability	"The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."	International Organization for Standardization, 1998
Effectiveness	"Accuracy and completeness with which users achieve specified goals."	
Efficiency	"Resources used in relation to the results achieved."	
Satisfaction	"The extent to which the user's physical, cognitive and emotional responses that result from the use of a system, product or service meet the user's needs and expectations."	
Mobile Usability	"The extent to which a mobile application can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use."	Hoehle and Venkatesh, 2015
Information design	"Elements of the site that convey accurate or inaccurate information to a user."	Cyr, 2014
Page layout design	"Capture design elements that facilitate sense-making within web pages."	Grange and Barki, 2020
Navigation design	"The navigational scheme used to help or hinder users as they access different sections."	Cyr, 2014
Visual design	"The balance, emotional appeal, esthetics, and uniformity of the system."	Cyr, 2014
Interaction design	"Concerned with describing possible user behavior and defining how the system will accommodate and respond to that behavior".	Garrett, 2003

Chapter 3
Conceptual Framework and Hypotheses

3.1 Conceptual framework

This research will investigate the relationships between application design elements, usability and continuous usage intention. Design elements are a series of variables, while usefulness, ease of use and satisfaction, the latter being users' attitude towards the interface, are the main aspects of usability (Coursaris and Kim, 2011). Finally, continuous use is an actual behaviour, and continuous use intention is the behavioural intention. The relationships between external variables, usefulness, ease of use, attitude, behavioural intention and actual use, are discussed in the Technology Acceptance Model (TAM) (Figure 2) proposed by Davis et al. (1989), validating the choice of this model for this study. TAM was derived from the 'Theory of Reasoned Action' (TRA) (Fishbein and Ajzen, 1975), which posits that "behaviour is determined by his/her behavioural intention, and behavioural intention is determined by both the person's attitude and subjective norm concerning the behaviour in question". It was first introduced by Davis in 1986 and modified again in 1989 (Davis et al.). Compared to TRA, TAM is an extremely good fit for information system usage study (Ofori et al., 2016). TAM explains that genuine utilization is influenced by user behavioural intention to use (BIU). BIU is influenced by the user's attitude and the conviction of perceived usefulness (PU). The user's attitude, reflecting positive or negative emotions towards utilizing the Information System framework, is resolved mutually by PU and PEOU (perceived ease of use), while PU is influenced by PEOU and external variables. According to Davis (1989), the external variables can be system design features, training, documentation, and client support.

Building on TAM theory, Hong et al. (2002) tested the effect of system characteristics, such as relevance, terminology, and screen design, on perceived usefulness and ease of use, and the effect of these two variables on behaviour intention. Meanwhile, Grange and Barki (2020) claimed that visual quality, navigation quality and page layout quality have an influence on information quality and system quality, which are the antecedents of perceived usefulness and ease of use. They also studied the influence of these two variables on attitude. Their research gives support to the model of studying the influence of design elements on perceived usefulness and ease of use, and the further influence of those two variables on attitude (e.g. satisfaction) and then on behaviour intention (e.g. continuous usage intention). As mentioned in the previous literature review section, this study will use five main design elements: information design, layout design, navigation design, visual design, and interaction design as the external variables.

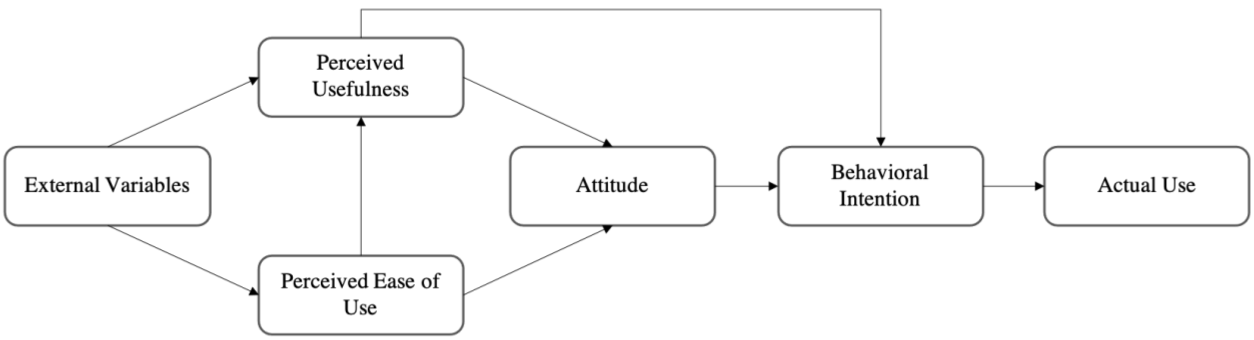

Figure 2. TAM Model (Davis et al. 1989)

According to Coursaris and Kim (2011), PU is a component of effectiveness, while PEOU is a component of efficiency. Watters (et al. 2003) indicated that efficiency and effectiveness fall under the conceptual umbrella of performance, which then affects user satisfaction, while in the TAM model, perceived ease of use and usefulness affect attitude (e.g. satisfaction). Amin et al. (2014) also found a positive correlation between PEOU, PU and mobile users' satisfaction. These findings suggest that the perceived usefulness and ease of use in the above model can be expanded into effectiveness and efficiency. Hsu and Chiu (2004) noted that usability might impact users' attitudes (e.g. satisfaction) towards using mobile devices, while Kwahk and Han (2002) proposed a new usability study model that includes the interface features of a product as design variables, the context impacting usability as a contextual variable, and the usability measures as dependent variables. This model provides further rationale for using effectiveness and efficiency, which are two dimensions of usability, instead of usefulness and ease of use.

Users and the environment are factors that will influence usability (Coursaris and Kim, 2011). Therefore, we will control their main elements, such as age, gender, experience using mobile apps, income level, and usage environment, as control variables to test the proposed research model (Figure 3). Control variables are mainly used in the recruitment process to ensure sample variety but are not used for data analysis.

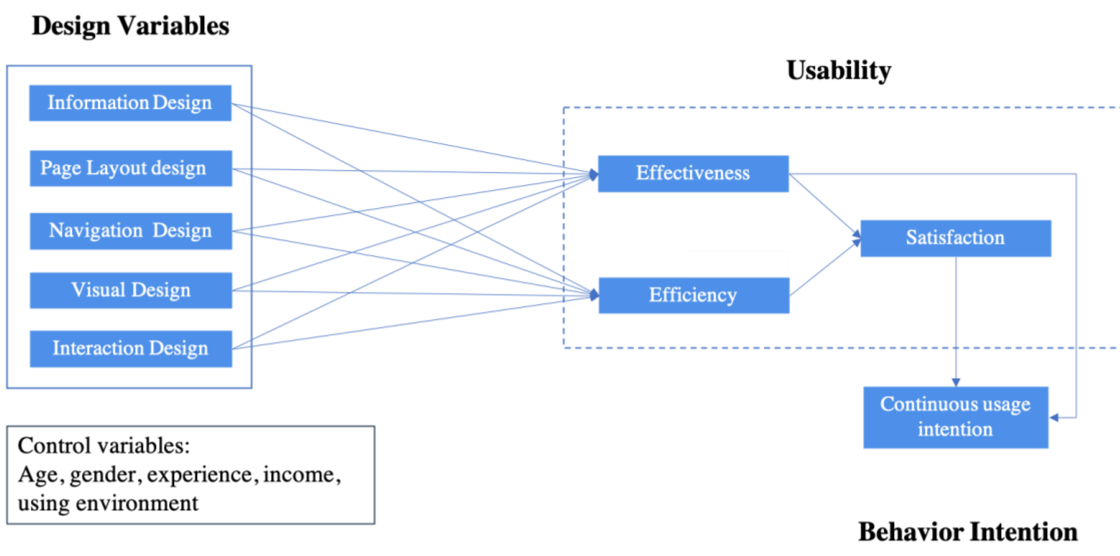

Figure 3. Proposed Conceptual Model

3.2 Hypotheses development

3.2.1 The relationship between design variables and usability

As previously indicated, this study will incorporate five primary design variables, namely information design, page layout design, navigation design, visual design, and interaction design. The objective of the relationship analysis is to investigate the correlation between each of these design variables and the components of usability, namely effectiveness and efficiency. The focus will be on examining the relationship between each design element and its influence on effectiveness and efficiency.

Information design

Information design is defined as "elements of the site that convey accurate or inaccurate information to a user" (Cyr, 2014). The Society for Experiential Graphic Design further adds that it is the presentation of information "in a way that makes it most accessible and easily understood by users".

Quality information design is highly related to product design (Xu and Tong, 2007), and user-centred information design has been verified to improve usability (Henry, 1998). This indicates that a stronger focus on quality information design could result in tangible improvements in efficiency and effectiveness, two important dimensions of usability.

To support this argument, Lipton (2007) similarly concludes that the quality of information design will directly affect the delivery of information, ultimately determining whether users can finish a task, solve a problem, or meet specific needs, all of which are highly connected to the definition of effectiveness. Keshab (2016) claimed that a stronger awareness and good adoption of information design principles could lead to increased effectiveness and efficiency of information transmission. Additionally, Frascara (2015) explained that good information design could reduce cognitive load and errors when users process information, which is highly connected with effectiveness, and can also help users speed up tasks, which is highly connected with efficiency. These studies further support the positive relationship between quality information design and effectiveness and efficiency. This is also the relationship that this study aims to test and clarify.

Thus, based on the above-mentioned literature, we propose the following hypotheses:

H1a: The information design of integrated smart city apps has a positive influence on users' perceived effectiveness of integrated smart city apps.

H1b: The information design of integrated smart city apps has a positive influence on users' perceived efficiency of integrated smart city apps.

<u>Page Layout Design</u>

Page layout design refers to representing and arranging various items on a page in a suitable manner. This includes characteristics related to information presentation, organization, grouping, and finding (Grange and Barki, 2020).

Bernard (2003) conducted a study in which users were asked to place various elements of an e-commerce website on an empty canvas, and the results showed that users have clear and definable expectations regarding the placements of various elements, demonstrating the importance of page layout design in creating user-centric products and experience. Additionally, Sonnenberg (2013) argues that the naturally smaller screen sizes of mobile devices create multiple potential usability concerns, thus implying that the layout of items on the screen can directly affect users' perceived usability. Choi (2012) discovered that an appropriate layout could help users locate the content and information they need easily and effectively on mobile applications. This helps clarify the influence of page layout design on usability, suggesting that good page layout design is very likely to positively influence the efficiency and effectiveness of users' interaction with the application.

Thus, based on the above-mentioned literature, we can propose the following hypotheses:

H2a: The page layout design of integrated smart city apps has a positive influence on users' perceived effectiveness of integrated smart city apps.

H2b: The page layout design of integrated smart city apps has a positive influence on users' perceived efficiency of integrated smart city apps.

Navigation Design

Navigation design is defined as "the navigational scheme used to help or hinder users as they access different sections" (Cyr, 2014). Ochoa (2020) assessed and compared the usability of a library website based on different navigation designs, which demonstrated that navigation design has a significant impact on usability, indicating a potential influence on efficiency and effectiveness, two important dimensions of usability. Gehrke (1999) also noted that in the absence of good navigation design, users tend to get lost and even abandon an interface, which highlights the importance of navigation design quality for efficiency and usefulness of users' interaction with the interface, further supporting the influence of navigation design on both efficiency and effectiveness.

To be more specific, navigation can affect user flow and task completeness, which are key features of effectiveness, and good navigation can result in higher usability, leading to greater satisfaction (Bladders et al., 1999; Moon et al., 2015). Regarding the relationship between navigation design and efficiency, Harridge-March (2006) found that good navigation design schemes can help users save time, leading to greater efficiency. Additionally, Tsiodoulos (2016) compared the usability of two navigation standards and found that compared to the hamburger menu, the bottom bar menu is more efficient, showing that different navigation designs affect perceived efficiency differently. These studies all demonstrate that navigation design can influence perceived effectiveness and efficiency, and that good navigation design can result in better performance of effectiveness and efficiency. Thus, based on the literature, we can propose the following hypotheses:

H3a: The navigation design of integrated smart city apps has a positive influence on users' perceived effectiveness of integrated smart city apps.

H3b: The navigation design of integrated smart city apps has a positive influence on users' perceived efficiency of integrated smart city apps.

Visual Design

Visual design refers to "the balance, emotional appeal, esthetics, and uniformity of the system" (Cyr, 2014). The realm of visual design is commonly regarded as an aspect of aesthetic design, encompassing various elements such as colors, graphics, and typography (Choi, 2012).

Tractinsky (1997) conducted three experiments that explored the correlation between aesthetics and usability across distinct cultural contexts. His findings indicate that aesthetics have a direct bearing on people's perception of apparent usability, which, in turn, can influence their long-term attitudes toward a given system. Similarly, Norman (2002) argued that aesthetics has the power to elicit emotions and affection in users while affecting the cognitive process. Consequently, aesthetics can significantly influence how users perceive usability. Both studies clarified that aesthetics do have an effect on usability.

To dive deeper into their relationships, Cyr et al. (2006) conducted research and discovered that the visual design aesthetics of mobile devices have a significant impact on factors influencing user loyalty towards mobile services, namely perceived usefulness, ease of use, and enjoyment. Similarly, Li and Yeh (2010) explored the relationship between design aesthetics and perceived ease of use, usefulness and customization. They found that design aesthetics have an impact on all three variables, as well as further affecting user trust. Aesthetics are composed of multiple elements, including visual design, indicating that visual design may have an influence on perceived usefulness and perceived ease of use as well. Additionally, since perceived usefulness is a component of effectiveness, while perceived ease of use is a component of efficiency (Coursaris and Kim, 2011), we can deduce that visual design may have an influence on both perceived effectiveness and efficiency.

After studying the relationship between aesthetics, specifically white space, usability and attractiveness, Coursaris et al. (2012) concluded that a website's usability is likely to progressively deteriorate as visual elements are made smaller, indicating the importance of carefully considering visual design elements to improve the effectiveness and efficiency of a system. This supports the idea that quality visual design positively influences both perceived effectiveness and efficiency. Therefore, based on these studies, we can propose the following hypotheses:

H4a: The visual design of integrated smart city apps has a positive influence on users' perceived effectiveness of integrated smart city apps.

H4b: The visual design of integrated smart city apps has a positive influence on users' perceived efficiency of integrated smart city apps.

Interaction Design

Interaction design can be defined as "describing possible user behavior and defining how the system will accommodate and respond to that behavior" (Garrett, 2003). In the realm of interaction design, several studies have been conducted to assess its effect on various elements of usability, thus highlighting the importance of carefully considering the design of interactive elements in the overall design process to enhance users' engagement and satisfaction with a system.

Rano and Sungkur (2019) explored the use of interactive design and human-computer interaction principles to improve the performance of e-commerce websites. They concluded that good interactive design could enhance user experience, as well as positively impact overall performance, which includes both effectiveness and efficiency. Furthermore, Rogers et al. (2011) argued in their book 'Interaction Design: Beyond Human-Computer Interaction' that interaction design can directly impact users' perceived ease of use, effectiveness, as well as enjoyment of a product. As mentioned previously, perceived ease of use is a component of efficiency (Coursaris and Kim, 2011), thus, interaction design can directly influence both perceived efficiency and effectiveness.

Qin et al. (2011) assessed the usability of interaction design for different mobile input methods and found that different elements of interactive design have varying effects on task effectiveness. Khawaja et al. (2014) claimed that intelligent interaction design could deploy output strategies and adjust the way systems respond, present and interact with users to reduce users' cognitive load and improve task completion, all key metrics of efficiency. These studies further clarify the relationship between effectiveness or efficiency and interaction design, and serve as a basis for the following hypotheses:

H5a: The interaction design of integrated smart city apps has a positive influence on users' perceived effectiveness of integrated smart city apps.

H5b: The interaction design of integrated smart city apps has a positive influence on users' perceived efficiency of integrated smart city apps.

3.2.2 The relationship between effectiveness, efficiency and satisfaction

As mentioned in the previous literature review section, effectiveness, efficiency, and satisfaction are different dimensions of usability (ISO, 1998) and all of them should be included when assessing usability (Frøkjær et al., 2000).

Regarding the relationship that exists between these dimensions, Amin et al. (2014) identified a positive correlation between perceived ease of use, perceived usefulness and mobile users' satisfaction. Bhattacherjee (2001) also concluded that perceived usefulness has a positive influence on users' satisfaction with a system. Since perceived usefulness has been established as a component of effectiveness, while perceived ease of use is also a component of efficiency (Coursaris and Kim, 2011), it can be argued that perceived effectiveness and efficiency both have a positive influence on users' satisfaction.

This is supported by Watters et al. (2003) in their research on the performance of users on small screens viewing large tables that found that efficiency and effectiveness affect user satisfaction. Additionally, Coursaris et al. (2007, 2012) have further supported this relationship by claiming that the perceived efficiency and effectiveness of a mobile device can significantly impact user satisfaction with the device's overall efficiency and effectiveness. The current literature consistently supports the idea that satisfaction is positively influenced by both perceived effectiveness and efficiency. Thus, we propose the following hypotheses:

H6: Users' perceived effectiveness of integrated smart city apps has a positive influence on users' satisfaction with integrated smart city apps.

H7: Users' perceived efficiency of integrated smart city apps has a positive influence on users' satisfaction with integrated smart city apps.

3.2.3 The relationship between usability and continuous usage intention

The conceptual model built for this research focuses on the influence of satisfaction and effectiveness, two dimensions of usability, on continuous usage intention.

In the case of satisfaction, previous research listed in the literature review section has justified and supported the interplay between satisfaction and continuous usage intention and demonstrated that satisfaction has a critical influence on users' continuous usage intention (Susanto et al., 2015; Abu-Salim et al., 2017; Zhang et al. 2021).

To understand this relationship in the context of mobile apps, Tam et al. (2018) studied the factors influencing users' continuous usage intention for mobile apps and found that satisfaction is one of the most important drivers, with the others being habit, performance expectancy, and effort expectancy. Similar results were obtained by Malik et al. (2017) in the discovery of influencing factors of continuous usage intention in a mobile context. In the case of Zhang et al. (2021), a study was done in the context of smart city apps and resulted in the validation of a clear positive correlation between satisfaction and continuous usage intention in this specific context.

Based on the current literature, we can propose the following hypothesis:

H8: Users' satisfaction with integrated smart city apps has a positive influence on users' continuous usage intention of integrated smart city apps.

In addition to satisfaction, usefulness is also mentioned as a critical factor that influences users' behaviour intention in the TAM model. Davis (1989) mentioned that "people form intentions toward behaviors they believe will increase their job performance, over and above whatever positive or negative feelings may be evoked toward the behavior". Job performance is closely associated with usefulness, indicating the importance of positive perceived usefulness in driving behaviour intention. Furthermore, Bhattacherjee (2001), through studying online bank users, found that users' continuance usage intention is determined by their satisfaction with the use of an information system, as well as the perceived usefulness of the system. Yan et al. (2021) found that perceived usefulness is one of the predictors of users' continuous usage intention for health apps, which supports the validity of this relationship in the context of mobile applications.

According to the relevant literature, users' continuous usage intention is influenced by perceived usefulness. Meanwhile, as perceived usefulness is a component of effectiveness (Coursaris and Kim, 2011), perceived effectiveness may have an influence on continuous usage intention as well. Therefore, we can propose the following hypothesis:

H9: Users' perceived effectiveness of integrated smart city apps has a positive influence on users' continuous usage intention of integrated smart city apps.

All the hypotheses associated with the research model are shown below (Figure 4).

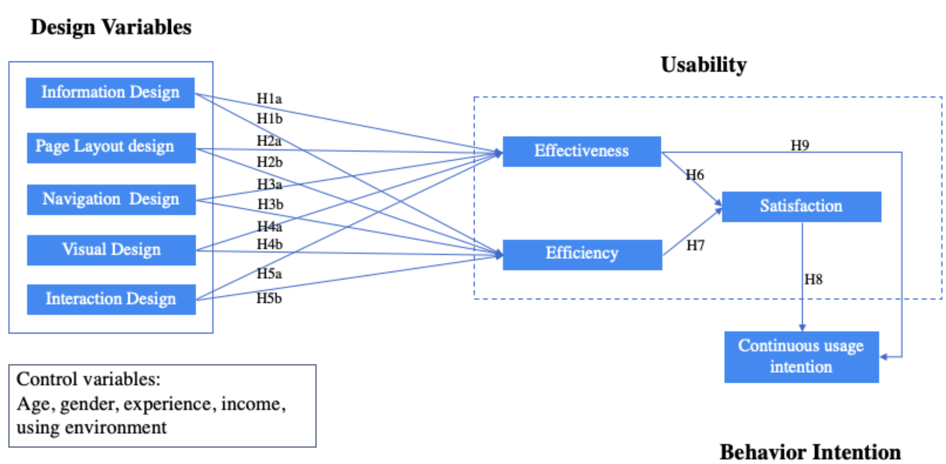

Figure 4. Proposed Conceptual Model with Hypotheses

Chapter 4
Methodology

4.1 The methodological approach

In this study, we had originally intended to collect both quantitative and qualitative data. The plan was to gather quantitative data in the first round through the use of questionnaires. The data collected would then be analyzed to explore the relationships between different dependent and independent variables. The purpose of this analysis was to test our hypotheses and provide guidance on the design of an integrated smart city app. Additionally, we had planned to collect qualitative data in the second round through user testing. This would have allowed us to obtain more detailed feedback from users while they performed their most frequently used functions in the app.

Unfortunately, during the first round of data collection, the VanConnect app was unexpectedly replaced with a new smart city app that did not meet our criteria for an integrated smart city app. As a result, we were forced to stop data collection and could not conduct the second-round user testing with the original interfaces. The app was no longer available and did not work on devices that had previously downloaded it. Therefore, our study will focus solely on quantitative data.

To collect this data, we conducted an online survey through online communities and social media networks. The survey covered various aspects of users' experiences with the VanConnect app, including their usage habits, the environment in which they used the app, their perceptions of the app's design, perceived usability and their intentions to continue using the app. Additionally, we collected demographic information from participants. The survey results will provide quantitative information on the variables being measured and will give indications of which functions are used most frequently by users.

4.2 Questionnaire development

4.2.1 Questionnaire content

The questionnaire is comprised of five distinct sections, namely the usage habit section (Table 3), the design perception section (Table 4), the perceived usability section (Table 5), the continuous usage intention section (Table 6) and the demographic section (Table 7).

Usage habit section

This section (Table 3) comprises four multiple-choice questions designed to gather information from users regarding their usage habits, their experiences using the app, and the environment in which they use it. These factors will all serve as control variables in the research model. In addition to the multiple-choice questions, there is also an open-ended question that asks users about the functions they frequently use. This question will help us understand which functions are commonly used by users in the context of an integrated smart city app.

Table 3. Usage Habit Section Questionnaire

Categories	Questions	Scale
Usage habit, Experience and Environment	How often do you use mobile devices?	Everyday, A few times per week, A few times per month
	How long have you used the VanConnect app?	Less than 1 month, 1-6 months, 6months-1 year, 1-3 years, More than 3 years
	How often do you use this app?	Daily, Weekly, Monthly, Yearly
	What do you use this app for?	Please list the main functions you use this app for
	In what setting do you usually use this app?	At home, At work, Outside, Other

Design perception section

The design perception section is a crucial component of the questionnaire as it aims to gather users' opinions on different elements of the mobile app design of VanConnect. As discussed in the previous chapter, we identified five design elements for mobile apps, namely information design, visual design, layout design, navigation design, and interaction design. The questions in this section were developed based on these five categories.

To establish a connection between these design element variables and a mobile app-specific context, we developed a series of sub-categories that help define items. These eleven sub-categories were combined and grouped from the design elements for mobile applications mentioned in the literature review section. They include content, display of information, page composition, layout, navigation, system navigation, typography, colors, graphics, information control, input and output, control, and feedback (Fling, 2009; Hoober and Berkman, 2011; Choi, 2012). Navigation is further divided into page-level navigation and system navigation (Garrett, 2003) to distinguish it from the main category, resulting in a total of twelve sub-categories.

To appropriately assign the sub-categories under their respective main categories, a closed card sorting exercise was conducted among five participants working in various industries. The card sorting was done through Optimal Workshop, a website used to conduct card sorting. Information design, Page layout design, Navigation design, Visual design and Interaction design were created as ‘Categories’ while the subcategories were created as ‘Cards’. Participants were asked to put each card under the category which made the most sense to them. The results of the card sorting exercises were surprisingly similar. All participants grouped content and display of information under information design, page composition and layout under page layout design, page-level navigation and system navigation under navigation design, typography, colors, and graphics under visual design, while information control, input and output, control, and feedback were categorized under interaction design. This result revealed a clear pattern for assigning all subcategories under their respective main categories.

For each sub-category, a list of items was compiled to assess users' opinions on different aspects related to that sub-category. These items were either directly taken from the literature mentioned earlier or developed based on the definitions of the sub-categories. The table below (Table 4) presents the final constructs, items used, and their sources. Users will be asked to rate each item on a Likert scale ranging from 1 to 7, where 1 represents "strongly disagree" and 7 represents "strongly agree".

Table 4. Design Perception Section Questionnaire

Categories	Sub-categories	Items (I believe…)	Scale	Source

Information Design	Content	The content of this app is understandable and complete enough.	Strongly Disagree (1) ..... Strongly Agree (7)	Choi,2012
		The content of this app is well organized for users.	Strongly Disagree (1) ..... Strongly Agree (7)	
	Display of information	The information of this app is categorized in the right way.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober,2011
		The information of this app is displayed following logical patterns.	Strongly Disagree (1) ..... Strongly Agree (7)	
Page Layout Design	Page composition	The components and content forming the pages of this app are designed appropriately.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober,2011
		The components and content included in the pages of this app are consistent.	Strongly Disagree (1) ..... Strongly Agree (7)	
	Layout	The positions of the components and content of this app are appropriate.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Fling,2009
		The layout of the screen of this app is well adapted to the device and conditions.	Strongly Disagree (1) ..... Strongly Agree (7)	
Navigation Design	Page-Level Navigation	Navigation on the page between different sections of this app is available.	Strongly Disagree (1) ..... Strongly Agree (7)	Garrett,2003
		The navigation on the page between different sections of this app is appropriate.	Strongly Disagree (1) ..... Strongly Agree (7)	
	System Navigation	The number of categories and levels of navigation of this app are appropriate.	Strongly Disagree (1) ..... Strongly Agree (7)	Choi,2012
		Categories of this app are well arranged based on priority, with the most important categories being the most prominent.	Strongly Disagree (1) ..... Strongly Agree (7)	
		There are clear, concise and consistent labels for navigation throughout this app.	Strongly Disagree (1) ..... Strongly Agree (7)	

Visual Design	Typography	The number of different fonts of this app is appropriate and logical.	Strongly Disagree (1) ..... Strongly Agree (7)	Choi,2012
		The spacing between characters, words, and lines, as well as type sizes of this app are appropriate in regards to the function of the text.	Strongly Disagree (1) ..... Strongly Agree (7)	
		Each color used for each text function of this app appears similarly on every page.	Strongly Disagree (1) ..... Strongly Agree (7)	
		The number of colors used for fonts is appropriate	Strongly Disagree (1) ..... Strongly Agree (7)	
	Colors	Colors are used appropriately in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	Choi,2012
		There is a good color palette and a good color relationship in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	
		The color palette of this app appeals to users.	Strongly Disagree (1) ..... Strongly Agree (7)	
	Graphics	The meaning of each icon used in this app is visually clear.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Fling, 2009
		The photos and images found in this app add meaning to the content.	Strongly Disagree (1) ..... Strongly Agree (7)	
Interaction Design	Information Control	Several ways of controlling information (e.g. sort by/filter, search, location jump, zoom. etc.) are provided for users in order to control the information shown in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober, 2011
		The ways to control information (e.g. sort by/filter, search, location jump, zoom. etc.) in this app perform as expected.	Strongly Disagree (1) ..... Strongly Agree (7)	

	Input and Output	The ways to input information in this app and the ways the system responds are appropriate.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober, 2011
		Input can be assisted in this app to predict content or adapt to previous usage.	Strongly Disagree (1) ..... Strongly Agree (7)	
		Input can be guided in this app to avoid errors.	Strongly Disagree (1) ..... Strongly Agree (7)	
		When important notifications occur in this app, users can be alerted.	Strongly Disagree (1) ..... Strongly Agree (7)	
	Control and feedback	The system can be controlled at any step in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober, 2011
		Confirmation is required for specific actions in this app to prevent errors.	Strongly Disagree (1) ..... Strongly Agree (7)	
		Feedback from the system about the processes happening can always be provided immediately in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	

<u>Perceived usability section</u>

Based on the definition of usability discussed in the Literature Review chapter, usability is comprised of effectiveness, efficiency, and satisfaction (Coursaris and Kim, 2011; Frøkjær et al., 2000), a definition that applies in the context of mobile devices as well. Therefore, the perceived usability section was also divided into these three categories. To measure these categories, items from the research conducted by Coursaris et al. (2007, 2016) were adopted (Table 5). Users were asked to rate each item on a scale ranging from 1 to 7. For effectiveness and efficiency measurement, a score of 1 indicated strong disagreement, while a score of 7 indicated strong agreement. On the other hand, for satisfaction measurement, a score of 1 indicated negative emotions, while a score of 7 indicated more positive emotions.

Table 5. Perceived Usability Section Questionnaire

Categories	Items	Scale	Source

Effectiveness	I am able to complete all of my tasks successfully in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	Coursaris et al. 2016
	I am able to accurately obtain the needed information in this app to complete my tasks.	Strongly Disagree (1) ..... Strongly Agree (7)	
Efficiency	Learning how to use this app was easy.	Strongly Disagree (1) ..... Strongly Agree (7)	Coursaris et al. 2007
	Using this app is easy.	Strongly Disagree (1) ..... Strongly Agree (7)	
	This app is user friendly.	Strongly Disagree (1) ..... Strongly Agree (7)	
	Using this app is fast.	Strongly Disagree (1) ..... Strongly Agree (7)	
Satisfaction	Thinking about my experience with this app, I feel Terrible/ Delighted	Terrible (1) ..... Delighted (7)	Coursaris et al. 2007
	Thinking about my experience with this app, I feel Very displeased/ Very pleased	Very displeased (1) .... Very pleased (7)	
	Thinking about my experience with this app, I feel Very dissatisfied/ Very satisfied	Very dissatisfied (1) .... Very satisfied (7)	
	Thinking about my experience with this app, I feel Frustrated/ Contented	Frustrated (1) .... Contented (7)	

Continuous usage intention section

This section aims to measure users' intention to use the app continuously in the future. To do so, the measurements were developed based on the research conducted by Zhang et al. (2021) (Table 6), which studied citizens' continuous usage intention of smart city apps. Users evaluated each item on a scale from 1 to 7, with 1 indicating strong disagreement and 7 indicating strong agreement.

Table 6. Continuons Usage Intention Section Questionnaire

Categories	Items	Scale	Source

Continuous Usage Intention	I am willing to continue the usage of this app on a regular basis.	Strongly Disagree (1) ..... Strongly Agree (7)	Zhang et al. 2021
	I intend to use this app continuously in my daily life	Strongly Disagree (1) ..... Strongly Agree (7)	

Demographic section

In order to control for user-related variables and gain a better understanding of the survey participants, demographic information such as gender, age, income, and education level was collected at the end of the survey (Table 7). This was done to prevent potential bias in participants' responses to other survey questions.

Table 7. Demographic Section Questionnaire

Categories	Questions	Scale
Demographics	What is your age range?	Under 20, 20-30, 30-40, 40-50, Above 50
	What is your gender?	Male/ Female/ Non-binary or third gender/ Prefer not to say
	What is your income range?	Under 30K, 30-50K, 50-70K, 70-100K, Above 100K
	What is the highest level of education that you have completed?	High School, Undergraduate, Graduate, Postgraduate, Other

4.2.2 Realization of the questionnaire

Once the questions and measurements were finalized, the questionnaire was constructed in Qualtrics, a cloud-based platform that enables users to create customized surveys and store data. After activation, the survey link was generated and shared to collect participants' feedback. Once the data collection was completed, the data was exported for further analysis.

4.2.3 Questionnaire pretest and modification

To ensure the validity and accuracy of the data collected, the first version of the questionnaire was tested by three students from different majors at HEC Montréal. Despite having been modified multiple times by the researcher and thesis director, it was still possible that there were flaws or terms that were difficult for users to comprehend. If the wording or content was unclear, it could affect the quality of the data. The pretest was conducted to determine whether the questions were concise and understandable to most users. The questionnaire received positive feedback from the testers, who were able to complete it within 15 minutes. However, they also pointed out some issues. Based on the pre-test results, a few questions were revised, such as the question about color design, which asked about both the color of text and the number of colors for fonts in one question. This was split into two separate questions in the final version. Technical terms like "Information control pattern" were replaced with simpler terms like "the ways to control information," which were more straightforward and easier to understand for participants with limited knowledge of information technology. Additionally, unclear expressions were rephrased, and more details were provided. The demographic section was also expanded to cover a broader range of situations. The questions presented in the previous section are from the final version of the questionnaire.

4.3 Recruitment procedure

Participant recruitment was mainly conducted through online social media platforms, with the questionnaire shared via posts on various local community groups on social media such as Reddit and Facebook. In addition, a small portion of the recruitment was done through personal networking. The recruitment process aimed to strike a balance between finding regular users of the VanConnect app in Vancouver and ensuring that a sufficient number of participants were found. The main criterion for identifying participants was that they had already used the app and either lived in Vancouver or had used the app while visiting the city.

For Reddit, messages were sent to subreddits, which are specific online communities that included Vancouver, to ensure participation from users who lived in Vancouver.

As for Facebook, messages were sent to various Facebook groups, including groups of people living in Vancouver, including international students, as well as student survey participation groups where students can help each other fill out surveys if they meet the requirements.

To recruit participants who had used the VanConnect app, the following post was made in both French and English:

“Hello! Do any of you use the VanConnect app? I am a master's student at HEC Montreal, and I am preparing my thesis on this app and would like to collect the opinions of users. If you have some time to complete a survey, it would be greatly appreciated and may contribute to the better development of 'smart city' apps like VanConnect. Thank you!”

"Bonjour! Est-ce que certains d’entre vous utilisez l’application VanConnect? Je suis étudiante à la maitrise à HEC Montréal et je prépare mon mémoire sur cette application et aimerait récolter l’opinion des utilisateurs. Si vous avez un peu de temps pour répondre à un sondage, ce serait grandement apprécié et pourrait contribuer au meilleur développement d’applications ‘smart city’ comme VanConnect. Merci! “

Potential participants were informed of the project's purpose and its potential contribution to improving the field of user experience for integrated smart city apps. The participants who were interested and also met the screening criteria were selected to fill out the questionnaire.

4.4 The sample

To ensure that potential participants understood the purpose of the project and the potential impact their participation could have on improving the field of user experience for integrated smart city apps, they were informed of the project's purpose and its potential contributions before being invited to participate. After expressing interest and meeting the screening criteria, participants were selected to fill out the questionnaire.

The data collection phase lasted for a duration of three months. Initially, the anticipated sample size for the questionnaire was around 140-150, and 10 participants for the user testing stage. However, towards the end of August 2022, the VanConnect app, which was the focus of the research, was taken down and replaced by Van123. The latter app mainly specializes in report functions and cannot be considered an integrated smart city app, and consequently could not be used as a substitute for VanConnect. As a result, the data collection had to be halted, and user testing was not feasible without an active interface.

Upon ending the data collection phase, 78 participants responded to the questionnaire. However, twenty of them had skipped all questions, and five had partially answered the questionnaire. These five participants were excluded from the final analysis. Additionally, to ensure the quality of the data, the remaining responses were scrutinized for instances where many identical values were recorded for multiple questions, which could indicate that the participant had carelessly filled the questionnaire without paying attention to the questions. During this process, two responses were excluded since almost all the questions had identical answers, except for the usage habits and demographic sections. Ultimately, 51 valid responses were obtained and analyzed in the subsequent stages (Table 8).

Table 8. Sample Distribution

Responses Number	**Exclusion Criteria**			**Remaining Reponses**
	No Answer	Partially response	Response with too many identical values	
78	20	5	2	51

4.5 Methodology of data analysis

In order to test the hypotheses proposed in Chapter 3, which aim to examine the relationships between various dependent and independent variables, which all have multiple items, structural equation modelling was selected to analyze the data. This model can use different data types and analyze the structural relationship between measured variables and latent constructs. However, determining the appropriate sample size for using structural equation modelling can be challenging, as researchers generally assume that a large sample size is necessary. However, Wolf et al. (2013) found that the required sample size can vary greatly depending on the context of the study and that meaningful results can be obtained with sample sizes ranging from 30 to 460. In fact, some studies have shown that structural equation modelling analyses with small sample sizes have no significant impact on the validity of the results (Kahai and Cooper, 2003; Malhotra et al., 2007; Majchrzak et al., 2005). Additionally, it has been found that the required sample size decreases when a factor has more indicators (Wolf et al., 2013; Marsh et al., 1998). Since most latent variables in this study have more than four indicators, structural equation modelling was still selected for the analysis despite the relatively small sample size. SmartPLS 4 was used to conduct the structural equation modelling in this study.

Anderson and Gerbing (1988) proposed a two-step approach for structural equation modelling. The first step involves conducting a confirmatory factor analysis to evaluate the reliability and validity of the measurement model, followed by testing the structural model. In SmartPLS 4, this process can be completed by implementing the PLS-SEM algorithm and conducting PLS bootstrapping.

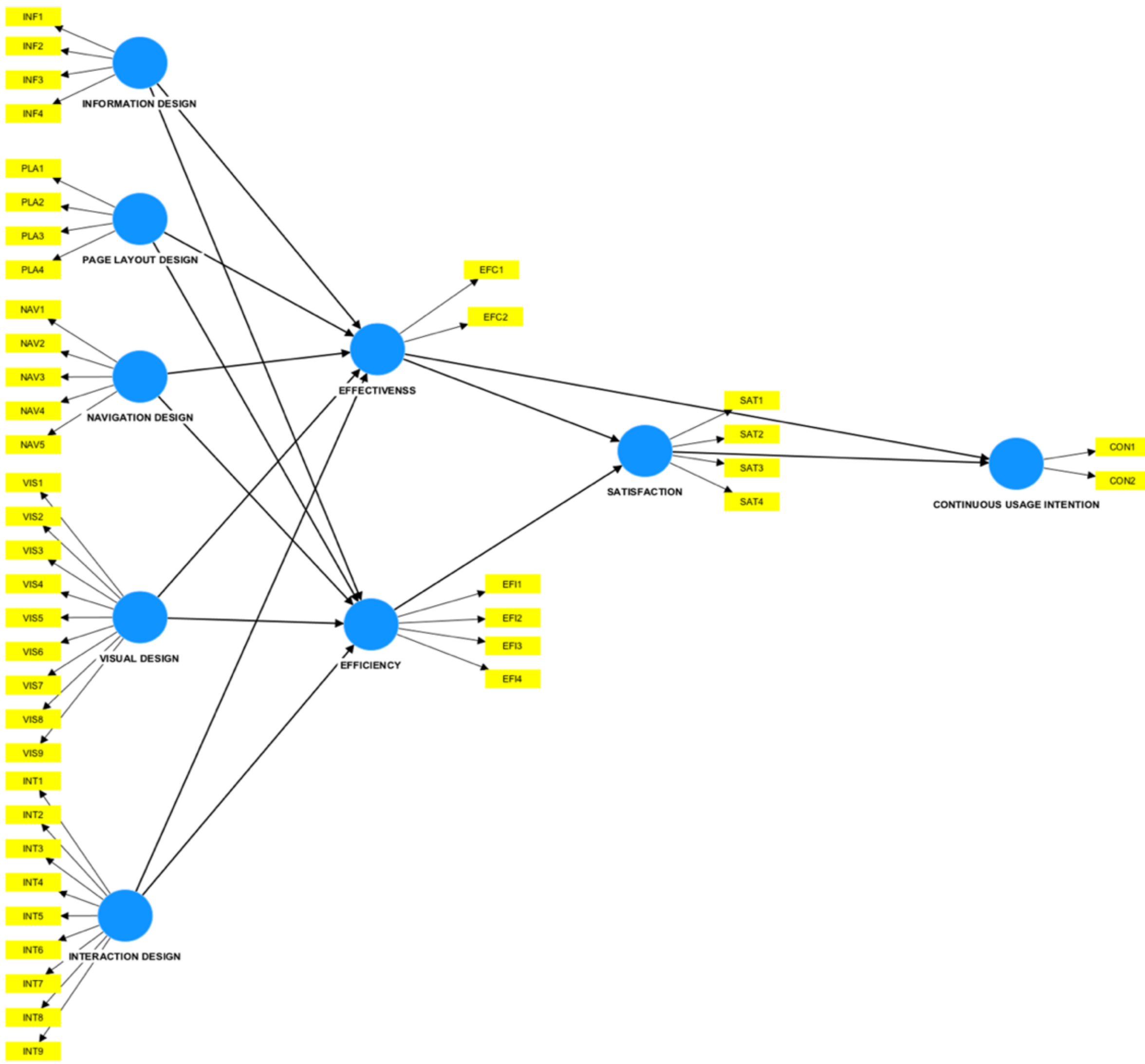

Figure 5. Conceptual Model in SmartPLS 4

In this study, the model presented in Figure 5 is reflective in nature, and therefore, the use of a consistent PLS-SEM Algorithm is deemed to be more suitable. This algorithm is designed to obtain results that are consistent with a factor model by adjusting the correlations of the reflective constructs (Dijkstra 2010; Dijkstra 2014; Dijkstra and Henseler 2015; Dijkstra and Schermelleh-Engel 2014). However, during the implementation of this algorithm, it was observed that T-values and P-values displayed many N/A values, leading to potential bias in the results. Therefore, PLS-SEM Algorithm and PLS Bootstrapping were considered for analysis. As suggested by Hair et al. (2019), PLS-SEM is particularly well-suited for analyzing models with small sample sizes and complex structures, which is the case in this study. Thus, PLS-SEM Algorithm and PLS Bootstrapping were utilized for the analysis.

Chapter 5
Results

This chapter serves to present the outcomes of the data and analysis conducted in the context of the research.

5.1 Demographics

As previously outlined, the data analysis phase comprised 51 participants whose ages spanned a wide range from under 20 to above 50. The majority of participants, exceeding 50%, fell within the 20-30 age range, while 21.6% were aged between 30 and 40. Participants under 20 and above 50 constituted an equal proportion of 9.8%. Regarding gender distribution, with the exception of those who declined to specify, male and female participants were equally represented, with a slightly higher percentage of females at 5.9%. In terms of income, the majority of participants, or 82.3%, earned less than 70K annually, while 15.7% earned between 70-100k annually, and only 2% earned above 100K. Additionally, more than half of the participants possessed an undergraduate degree, 23.5% held a graduate degree, 13.7% had a high school degree, and 7.8% held a postgraduate degree, as summarized in Table 9.

Overall, the participants comprised a diverse group in terms of age, income, educational background, and gender, thereby providing a robust sample for controlling variables in the study.

Table 9. Demographics

	Measurements	**Number**	**Percentage**
Age	Under 20	5	9.8%
	20-30	29	56.9%
	30-40	11	21.6%
	40-50	1	2.0%
	Above 50	5	9.8%
Gender	Male	21	41.2%
	Female	24	47.1%
	Non-binary or third gender	0	0.0%

	Prefer not to say	6	11.8%
Income	Under 30K	15	29.4%
	30-50K	15	29.4%
	50-70K	12	23.5%
	70-100K	8	15.7%
	Above 100K	1	2.0%
Education	High School	7	13.7%
	Undergraduate	28	54.9%
	Graduate	12	23.5%
	Postgraduate	4	7.8%
	Other	0	0.0%

5.2 Usage habits and environment

As illustrated in Table 10, virtually all participants frequently utilize mobile devices and possess a level of familiarity with mobile apps. However, a significant majority of participants, 82.4%, have employed the app for less than one year, with 41.2% utilizing the app for less than one month. Among the participants who used the app, 11.8% used it for one to three years, while a mere 5.9% utilized the app for over three years. Monthly app usage proved to be the most common frequency, with approximately half of the participants using the app in this manner. Roughly 27.5% of participants used the app less frequently, on a yearly basis, while a similar percentage, 19.6%, did so on a weekly basis. Few participants used the app on a daily basis. Nearly half of the users utilized the app at home, while 43.1% used the app primarily outside of the home environment.

Table 10. Usage Habits and Environment Data

Questions	Measurements	Number	Percentage
How often do you use mobile devices?	Everyday	46	90.2%
	A few times per week	4	7.8%
	A few times per month	1	2.0%
How long have you used this app?	Less than 1 month	21	41.2%
	1-6 months	11	21.6%

	6 months-1 year	10	19.6%
	1-3 years	6	11.8%
	More than 3 years	3	5.9%
How often do you use this app?	Daily	3	5.9%
	Weekly	10	19.6%
	Monthly	24	47.1%
	Yearly	14	27.5%
In what setting do you usually use this app?	At home	25	49.0%
	At work	2	3.9%
	Outside	22	43.1%
	Other	2	3.9%

Concerning the primary functions employed by users in the app, Table 11 indicates that various functions were reported by participants. Among the participants who responded to this question, 34.3% indicated that reporting issues in the city, such as potholes and graffiti, was a frequently used function. Obtaining information about public transportation and road conditions was another popular function, mentioned by 14.3% of participants. 11.4% of participants reported using the app to search for city-related information, such as energy usage and waste, or to access tourist travel information. A further 8.6% of participants primarily used the app to check government news, stay abreast of city updates, or request services and changes from the government. Real-time monitoring of public spaces was also mentioned as a function employed in the app.

Table 11. Main Functions Used by Users

Features used	Number	Percentage
Report issues	12	34.3%
Get transportation information	5	14.3%
Search for city related info	4	11.4%
Search for travel information	4	11.4%
Check government news	3	8.6%
Check city updates	3	8.6%

Request service	3	8.6%
Check public space status	1	2.9%

5.3 Descriptive statistics

Upon examination of the design-related variables in this study, including Information Design, Page Layout Design, Navigation Design, Visual Design, and Interaction Design, it is apparent that most indicators share a similarity in their means. Specifically, the majority of indicators have an average mean score falling between 4.5 and 5.5, with a minimum range of 1-3. However, there is one noteworthy exception: Interaction Design. This category exhibits numerous indicators scoring between 2 and 3, with a minimum score of 1 for all indicators. Overall, users' perception of Navigation Design is worse than that of the other variables.

To elaborate further, Information Design comprises two subcategories: content and display of information. The scores for both subcategories are similar, with slightly better feedback for content. The same holds true for Page Layout Design, which has two subcategories: page composition and layout. In the case of Navigation Design, there is a greater difference between its two subcategories, with page-level navigation receiving much better feedback than system-level navigation. With regard to Visual Design, which encompasses typography, colors, and graphics, it is evident that typography performs the best among all categories, whereas the mean score for graphics is relatively low among the three subcategories. Finally, Interaction Design fares the worst in terms of user feedback. All three of its subcategories have an average score below 4, with control and feedback receiving an average score lower than 3, indicating a significant weakness in this aspect of design.

The means of indicators representing Effectiveness and Efficiency are similar and slightly higher than those of Satisfaction, while the means of indicators representing Continuous Usage Intention are the lowest among the four variables.

Further information regarding the descriptive statistics for each variable can be found in Table 12.

Table 12. Descriptive Statistics

Variables	Subcategory	Mean	Indicators	Mean	Min.	Max.	Standard Deviation
Information Design	Content	5.25	INF1	5.4	1	7	1.3
			INF2	5.1	2	7	1.2
	Display of information	4.95	INF3	4.9	2	7	1.4
			INF4	5	2	7	1.3
Page Layout Design	Page Composition	5.2	PLA1	5.2	2	7	1.2
			PLA2	5.2	3	7	1.2
	Layout	4.9	PLA3	5	2	7	1.2
			PLA4	4.8	1	7	1.6
Navigation Design	Page-Level Navigation	5.4	NAV1	5.7	2	7	1.3
			NAV2	5.1	2	7	1.3
	System Navigation	4.5	NAV3	5	2	7	1.2
			NAV4	4.1	1	7	1.6
			NAV5	4.4	2	7	1.3
Visual Design	Typography	5.6	VIS1	5.6	2	7	1.2
			VIS2	5.7	3	7	1.2
			VIS3	5.5	2	7	1.2
			VIS4	5.6	1	7	1.2
	Colors	5.2	VIS5	5.5	2	7	1.3
			VIS6	5.2	2	7	1.4
			VIS7	4.9	2	7	1.4
	Graphics	4.45	VIS8	4.5	1	7	1.4
			VIS9	4.4	2	7	1.3
Interaction Design	Information Control	3.9	INT1	3.3	1	7	1.4
			INT2	4.5	1	7	1.6
	Input and Output	3.95	INT3	4.6	1	7	1.4
			INT4	4.1	1	7	1.6
			INT5	3.7	1	7	1.7
			INT6	3.4	1	7	1.7

	Control and Feedback	2.93	INT7	2.9	1	7	1.6
			INT8	3	1	7	1.5
			INT9	2.9	1	7	1.6
Effectiveness	EFC1			5.5	1	7	1.4
	EFC2			5.2	1	7	1.2
Efficiency	EFI1			5.6	2	7	1.1
	EFI2			5.4	3	7	1.2
	EFI3			5	2	7	1.3
	EFI4			4.8	1	7	1.5
Satisfaction	SAT1			4.8	2	7	1.2
	SAT2			4.6	2	6	1
	SAT3			4.7	2	7	1.2
	SAT4			4.5	1	7	1.4
Continuous Usage Intention	CON1			4.6	1	7	1.4
	CON2			4.1	1	7	1.6

5.4 Measurement model evaluation

Structural equation modelling can be done through two steps: the first step is evaluating the reliability and validity of the measurement model, and the second step is testing the structural model (Anderson and Gerbing, 1988). In this study, the results of the two steps will be presented in sections 5.4 and 5.5.

The reflective measurement model evaluation will follow the steps recommended by Hair et al. (2019). Evaluating the measurement model is the first step in examining the results of PLS-SEM. The internal consistency reliability of the measurement model is then assessed. The next step addresses the convergent validity of each construct measure. Finally, discriminant validity is assessed to determine the extent to which a construct is distinct from other constructs in the structural model. In addition to these steps, a collinearity analysis was also conducted.

5.4.1 Indicator Loadings

A confirmatory factor analysis was conducted by using the PLS-SEM algorithm in SmartPLS4 to assess the reliability and validity of the measurement model. The key parameters of the analysis are presented in Table 13.

The loadings of each indicator, which indicate the relationship between the indicators and the latent construct, are also included in Table 13. The loadings of NAV4, VIS4, VIS8, VIS9, INT1, INT5, INT6, INT8, and INT9 fall below the 0.7 threshold recommended by Barclay et al. (1995). However, some researchers suggest that loadings of 0.5 or higher are still acceptable for the model, especially for exploratory studies (Kline, 2015; Brown, 2015; Hair et al., 2019). In our model, all the indicators' loadings are above 0.55, indicating a strong relationship between the indicators and the latent construct. Furthermore, all indicators' T-values are above 1.96, which is significant at a 0.05 level ($p<0.05$) in SmartPLS software (Garson, 2016). Therefore, all indicators are statistically significant, and there is no need to eliminate any indicators for further analysis.

5.4.2 Reliability Analysis

In order to ensure the reliability of a model, it is common practice to conduct a reliability analysis on the items included. This analysis serves to test the internal consistency of the items, and it is generally agreed upon that both Cronbach's alpha and composite reliability (CR) are necessary to provide accurate and robust results (Gefen et al., 2011; Bagozzi and Yi, 2012; Hair et al., 2019). Cronbach's alpha is a measure that tests the correlation between items in a test (Cronbach, 1951), while CR assesses the shared variance among the observed variables used to indicate a latent construct (Fornell & Larcker, 1981).

Although Cronbach's alpha is a powerful measure of internal consistency, it may overestimate reliability in certain situations (Bagozzi and Yi, 2012). Therefore, in this study, both Cronbach's alpha and CR will be used to assess reliability.

As can be seen in Table 13, all variables have Cronbach's alpha values above 0.7, which is the threshold proposed by Cronbach (1951). With respect to composite reliability, there is no universally accepted threshold, but it is generally considered acceptable when it is at least 0.7 (Fornell and Larcker, 1981; Henseler and Sarstedt, 2015; Hair et al., 2019). In this study, the CR values for variables range from 0.85 to 0.95, which is much higher than the suggested value, indicating strong reliability (Hair et al., 2019). The positive results of both Cronbach's alpha and CR tests confirm the internal consistency of the measures in the model.

5.4.3 Convergent Validity Analysis

Convergent validity analysis is an indispensable process to measure the degree of correlation among diverse measures of the same construct (Campbell and Fiske, 1959). In SEM, several measures are commonly used to assess convergent validity, including factor loadings, Average Variable Extracted (AVE), and Composite Reliability (CR), which have been widely recognized by researchers as reliable measures (Fornell and Larcker, 1981; Kline, 2015; Hair et al., 2019). AVE measures the proportion of variance captured by a latent variable compared to measurement error (Fornell and Larcker, 1981).

In SEM analysis, factor loadings above 0.5 are generally considered indicative of good convergent validity (Gerbing and Anderson, 1988; Hair et al., 2017). An AVE value of 0.5 or higher and a CR value of 0.7 or higher are typically considered acceptable thresholds (Fornell and Larcker, 1981; Hair et al., 2017). The results in Table 13 demonstrate that all factor loadings in this study exceed 0.5, and all CR values exceed 0.7, indicating good convergent validity. In this model, all indicators have AVE values exceeding the acceptable threshold of 0.5, with some considerably higher, providing further evidence of the model's convergent validity.

Table 13. Reliability and Convergent Validity Analysis

Variables	**Indicator**	**Loading** (> 0.7)	**T value** (>1.96)	**Cronbach's alpha** (> 0.7)	**Composite reliability** (> 0.7)	**Average variance extracted** (> 0.5)
Information Design	INF1	0.843	15.947	0.891	0.924	0.753
	INF2	0.935	27.151			
	INF3	0.820	9.467			
	INF4	0.870	15.544			
Page Layout Design	PLA1	0.874	18.651	0.867	0.909	0.716
	PLA2	0.842	15.574			
	PLA3	0.912	22.413			

	PLA4	0.747	8.187			
Navigation Design	NAV1	0.834	14.194	0.821	0.875	0.588
	NAV2	0.814	13.139			
	NAV3	0.824	9.262			
	NAV4	***0.572***	4.074			
	NAV5	0.757	8.088			
Visual Design	VIS1	0.801	11.503	0.898	0.917	0.556
	VIS2	0.780	10.596			
	VIS3	0.781	9.039			
	VIS4	***0.631***	4.592			
	VIS5	0.871	19.218			
	VIS6	0.832	15.675			
	VIS7	0.723	7.897			
	VIS8	***0.657***	6.496			
	VIS9	***0.581***	5.620			
Interaction Design	INT1	***0.666***	2.716	0.91	0.909	0.529
	INT2	0.801	3.236			
	INT3	0.814	2.838			
	INT4	0.905	3.423			
	INT5	***0.667***	2.628			
	INT6	***0.652***	2.665			
	INT7	0.709	2.792			
	INT8	***0.639***	1.983			
	INT9	***0.643***	1.966			
Effectiveness	EFC1	0.944	40.875	0.876	0.942	0.89
	EFC2	0.942	36.028			
Efficiency	EFI1	0.873	19.633	0.898	0.929	0.766

	EFI2	0.847	12.377			
	EFI3	0.932	48.990			
	EFI4	0.845	15.792			
Satisfaction	SAT1	0.949	50.014	0.932	0.952	0.833
	SAT2	0.916	26.244			
	SAT3	0.937	34.130			
	SAT4	0.845	11.510			
Continuous Usage Intention	CON1	0.933	63.936	0.764	0.892	0.805
	CON2	0.860	8.458			

5.4.4 Discriminant Validity Analysis

The aim of discriminant validity analysis is to assess the extent to which a construct differs from others. To achieve more reliable results, researchers recommend using a combination of cross loadings of each indicator, Fornell-Larcker criteria, and Heterotrait-Monotrait ratio (HTMT ratio) in SEM (Kock, 2015; Byrne, 2016; Hair et al., 2019). However, it has been suggested that assessing the HTMT ratio may not be necessary when using multi-item measures (Chen et al., 2006). Therefore, in this study, we will analyze cross loadings and Fornell-Larcker criteria to assess discriminant validity.

Examining Table 14, which presents the cross loading of each indicator, it can be observed that all indicators have higher values under their intended construct than under all other constructs. This finding confirms the discriminant validity of the model from this perspective.

Table 14. Cross Loadings

	INF	PLA	NAV	VIS	INT	EFC	EFI	SAT	CON
INF1	***0.843***	0.559	0.397	0.489	-0.075	0.480	0.604	0.499	0.407
INF2	***0.935***	0.641	0.593	0.475	0.069	0.490	0.588	0.538	0.467
INF3	***0.820***	0.656	0.592	0.413	0.015	0.378	0.308	0.355	0.213
INF4	***0.870***	0.697	0.786	0.471	0.219	0.518	0.509	0.532	0.476

PLA1	0.681	***0.874***	0.528	0.393	-0.048	0.523	0.511	0.434	0.304
PLA2	0.559	***0.842***	0.524	0.295	0.032	0.445	0.373	0.429	0.327
PLA3	0.696	***0.912***	0.545	0.409	0.055	0.429	0.467	0.509	0.371
PLA4	0.504	***0.747***	0.446	0.123	0.192	0.301	0.387	0.494	0.487
NAV1	0.594	0.562	***0.834***	0.495	0.067	0.659	0.429	0.401	0.466
NAV2	0.530	0.424	***0.814***	0.431	-0.027	0.560	0.259	0.246	0.236
NAV3	0.641	0.467	***0.824***	0.415	0.177	0.545	0.359	0.449	0.390
NAV4	0.284	0.320	***0.572***	0.358	0.264	0.349	0.305	0.349	0.273
NAV5	0.480	0.505	***0.757***	0.461	0.323	0.502	0.368	0.457	0.438
VIS1	0.472	0.261	0.406	***0.801***	0.053	0.541	0.480	0.335	0.319
VIS2	0.483	0.298	0.559	***0.780***	0.155	0.666	0.544	0.392	0.449
VIS3	0.377	0.263	0.459	***0.781***	0.224	0.569	0.486	0.303	0.405
VIS4	0.235	0.105	0.333	***0.631***	0.111	0.433	0.193	0.095	0.187
VIS5	0.411	0.152	0.388	***0.871***	0.254	0.547	0.467	0.268	0.283
VIS6	0.422	0.347	0.409	***0.832***	0.260	0.490	0.571	0.409	0.464
VIS7	0.427	0.361	0.318	***0.723***	0.172	0.365	0.477	0.308	0.271
VIS8	0.337	0.389	0.521	***0.657***	0.305	0.488	0.478	0.428	0.382
VIS9	0.391	0.344	0.353	***0.581***	0.239	0.288	0.352	0.331	0.239
INT1	0.206	0.181	0.078	0.072	***0.666***	-0.057	0.206	0.378	0.365
INT2	-0.056	-0.053	0.129	0.204	***0.801***	0.238	0.227	0.349	0.472
INT3	0.135	0.032	0.136	0.228	***0.814***	0.242	0.301	0.356	0.540
INT4	0.075	0.040	0.220	0.237	***0.905***	0.235	0.156	0.324	0.463
INT5	0.042	0.123	0.260	0.304	***0.667***	0.255	0.137	0.213	0.286
INT6	-0.012	0.024	0.160	-0.025	***0.652***	0.020	-0.006	0.334	0.319
INT7	-0.054	0.049	0.061	0.079	***0.709***	0.031	0.150	0.340	0.381
INT8	-0.001	-0.015	-0.079	0.019	***0.639***	-0.113	0.136	0.335	0.295
INT9	0.020	0.011	-0.035	0.043	***0.643***	-0.101	0.160	0.349	0.322
EFC1	0.487	0.483	0.638	0.659	0.223	***0.944***	0.734	0.599	0.637
EFC2	0.542	0.481	0.675	0.606	0.229	***0.942***	0.628	0.630	0.580
EFI1	0.497	0.427	0.435	0.543	0.209	0.679	***0.873***	0.633	0.599
EFI2	0.451	0.411	0.342	0.569	0.182	0.642	***0.847***	0.580	0.558

EFI3	0.598	0.517	0.411	0.579	0.254	0.668	***0.932***	0.803	0.739
EFI4	0.536	0.450	0.397	0.485	0.272	0.547	***0.845***	0.741	0.656
SAT1	0.476	0.470	0.405	0.279	0.370	0.538	0.718	***0.949***	0.767
SAT2	0.560	0.564	0.504	0.404	0.304	0.675	0.777	***0.916***	0.734
SAT3	0.492	0.488	0.471	0.365	0.398	0.578	0.688	***0.937***	0.727
SAT4	0.532	0.465	0.429	0.548	0.460	0.583	0.715	***0.845***	0.742
CON 1	0.525	0.473	0.582	0.602	0.412	0.756	0.790	0.809	***0.933***
CON 2	0.278	0.263	0.223	0.157	0.631	0.339	0.484	0.630	***0.860***

Note: INF= Information Design, PLA= Page Layout Design, NAV= Navigation Design, VIS=Visual Design; INT=Interaction Design, EFC= Effectiveness, EFI= Efficiency, SAT=Satisfaction, CON= Continuous Usage Intention

Additionally, it is important to assess the Fornell-Larcker criterion, which compares the square root of each construct's AVE to the correlation of that construct with other constructs in the model (Fornell and Larcker, 1981). As shown in Table 15, the square root of each construct's AVE is greater than their correlation with other constructs, indicating that the criterion is met for all constructs.

We can conclude that the model exhibits discriminant validity based on the results obtained from the previous two measures.

Table 15. Fornell-Larcker Criterion

	CON	**EFC**	**EFI**	**INF**	**INT**	**NAV**	**PLA**	**SAT**	**VIS**
CON	***0.897***								
EFC	0.646	***0.943***							
EFI	0.735	0.723	***0.875***						
INF	0.468	0.545	0.599	***0.868***					
INT	0.557	0.239	0.265	0.067	***0.727***				
NAV	0.480	0.696	0.453	0.676	0.195	***0.766***			
PLA	0.428	0.511	0.519	0.729	0.054	0.605	***0.846***		

SAT	0.815	0.652	0.795	0.566	0.419	0.496	0.545	***0.913***	
VIS	0.463	0.671	0.621	0.536	0.263	0.567	0.376	0.437	***0.745***

Note:

1. Diagonal elements are AVE's square root, while off-diagonal elements are correlations between constructs.

2. INF= Information Design, PLA= Page Layout Design, NAV= Navigation Design, VIS=Visual Design; INT=Interaction Design, EFC= Effectiveness, EFI= Efficiency, SAT=Satisfaction, CON= Continuous Usage Intention

5.4.5 Collinearity Analysis

Collinearity analysis is an integral aspect of structural equation modelling as it enables the detection of multicollinearity among variables in the model. Variance Inflation Factor (VIF) is commonly used to assess collinearity (Kock, 2015; Hair et al., 2017).

This model comprises an inner model and an outer model. In reflective models, multicollinearity should only be assessed in the inner model (Kline, 2015; Hair et al., 2019). As such, only the VIFs of the inner model are necessary, and they are presented in Table 16.

The commonly used VIF threshold for assessing multicollinearity in SEM is 3.3 (Gefen and Straub, 2011; Kock, 2015). In this study, all VIFs in the inner model are less than 3.3, indicating no significant multicollinearity among the variables.

To summarize, we can conclude that our measurement model is reliable and valid.

Table 16. Inner Model VIFs

	Effectiveness	**Efficiency**	**Satisfaction**	**Continuous Usage Intention**
Information Design	2.858	2.858		
Page Layout Design	2.273	2.273		
Navigation Design	2.232	2.232		
Visual Design	1.671	1.671		
Interaction Design	1.101	1.101		

Effectiveness			2.093	1.739
Efficiency			2.093	
Satisfaction				1.739

5.5 Structural model testing

After the measurement model has been tested, the second part of structural equation modelling involves testing the structural model with hypotheses related to the defined factors (Anderson and Gerbing, 1988). This can be accomplished using bootstrapping in SmartPLS 4, which involves creating subsamples with randomly drawn observations from the original data set to calculate the coefficients and significance of the estimated path analysis (Hair et al., 2017). Through bootstrapping, path coefficients between latent variables, T-values, and P-values can be obtained (Table 17).

In this study, the bootstrapping setup was configured to test 5,000 subsamples with 51 observations at a 5% confidence level.

Garson (2016) pointed out that when T-values reach 1.96, they are significant at a 0.05 level. As shown in the results (Table 5.9), when T-values are greater than 1.96, the P-values are all below 0.05. For the link between information design and efficiency, the T-value is close to 1.96, and the path is not significant at the 95% level, but it is significant at the 90% level, which is also acceptable in this study, however this may require further investigation.

Table 17. Structural Model Path Coefficients and Results Significance

	Path	**Path coefficients**	**T Values**	**P values**
H1a	Information Design > Effectiveness	-0.063	0.318	0.75
H1b	Information Design > Efficiency	0.305*	1.766	0.077
H2a	Page Layout Design > Effectiveness	0.159	1.309	0.191
H2b	Page Layout Design > Efficiency	0.226	1.411	0.158
H3a	Navigation Design > Effectiveness	0.405**	2.788	0.005

H3b	Navigation Design > Efficiency	-0.159	1.012	0.311
H4a	Visual Design > Effectiveness	0.402***	3.335	0.001
H4b	Visual Design > Efficiency	0.423***	3.714	0
H5a	Interaction Design > Effectiveness	0.05	0.337	0.736
H5b	Interaction Design > Efficiency	0.152	1.274	0.203
H6a	Effectiveness > Satisfaction	0.161	1.122	0.262
H7	Efficiency > Satisfaction	0.679***	6.384	0
H8	Satisfaction > Continuous Usage Intention	0.684***	5.491	0
H9	Effectiveness > Continuous Usage Intention	0.200	1.551	0.121

Notes: *p < 0.1; **p<0.01; ***p < 0.001

Design Elements & Usability

Regarding the relationship between the design variables and effectiveness and efficiency, it is worth noting that the design variables explain a substantial amount of the variance in effectiveness, with an R^2 value of 61.1% (Figure 6). This value is above the moderate R^2 value of 0.33 recommended by Chin (1998) and is very close to the substantial value of R^2=0.67.

Additionally, it can be observed that the relationship between navigation design and effectiveness is significant (p<0.01), with a coefficient of 0.405, thus supporting hypothesis H3a. Similarly, visual design has a significant influence on effectiveness (p<0.001), with a coefficient of 0.402, supporting hypothesis H4a. However, all other variables do not have a significant influence on effectiveness.

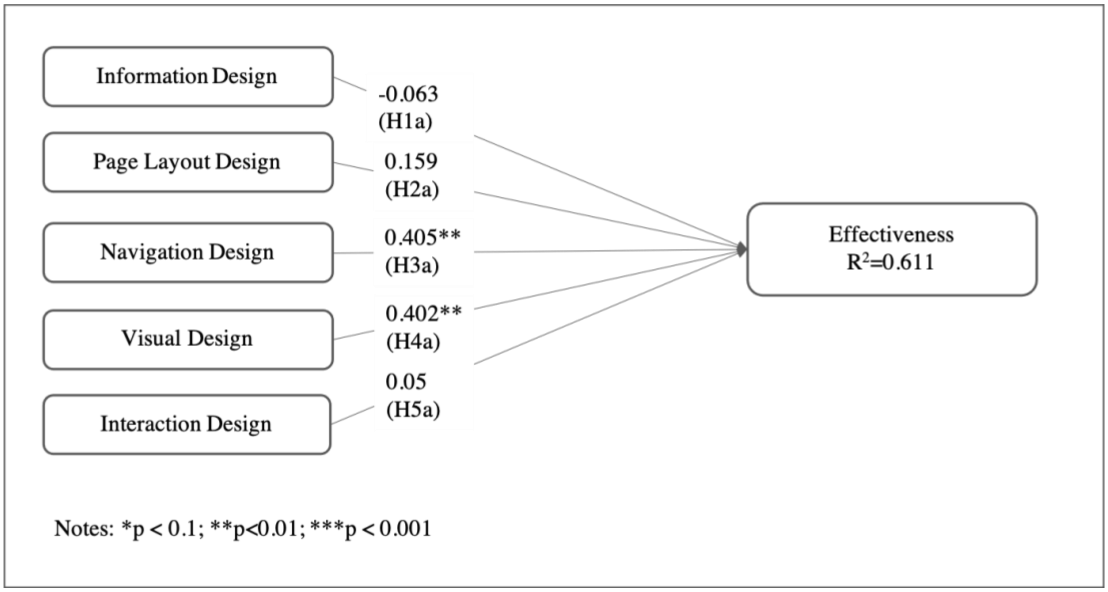

Figure 6. Effectiveness Structural Model

The results indicate that information design has a significant influence on efficiency at a 90% confidence level ($p<0.1$), with a coefficient of 0.305, thus supporting hypothesis H1b, but requiring further investigation in the future. Additionally, visual design has a significant influence on efficiency ($p< 0.001$), with a coefficient of 0.423, supporting hypothesis H4b. However, none of the other design variables were found to have a significant influence on efficiency.

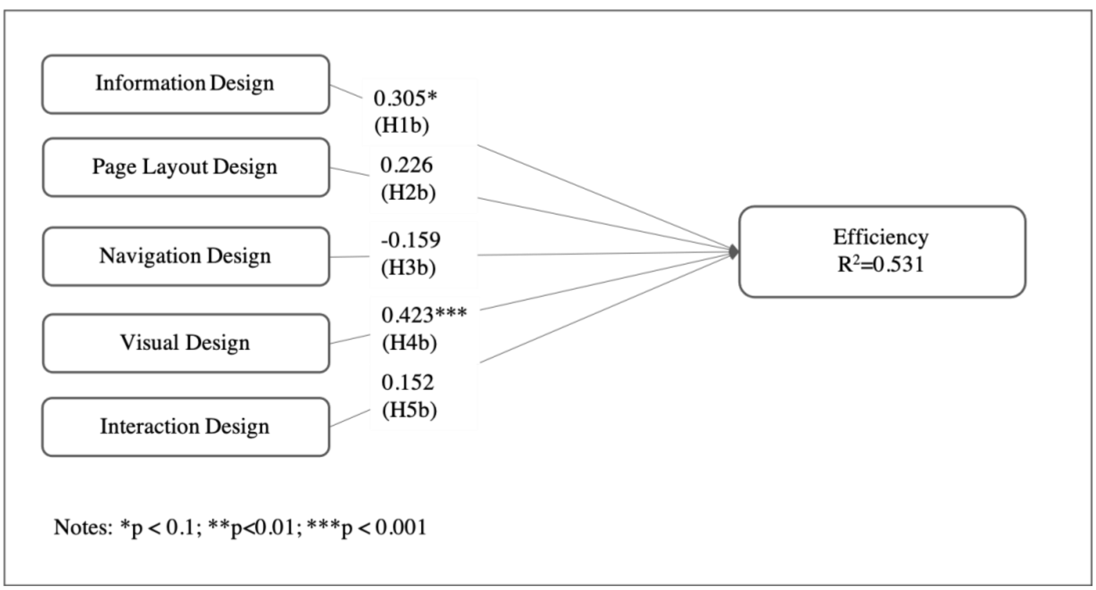

Figure 7. Efficiency Structural Model

Usability

In terms of the relationship between effectiveness, efficiency, and satisfaction, the three aspects of usability, the analysis indicates that the majority of the variance in satisfaction can be explained by effectiveness and efficiency, with a coefficient of determination (R^2) of 64.5% (Figure 8). This R^2 value is above the recommended moderate value of 0.33 by Chin (1998) and is closer to the substantial value of 0.67. However, the results show that only efficiency has a significant influence on satisfaction at a highly significant level of $p<0.001$, with a coefficient of 0.679. Therefore, only hypothesis H7 is supported.

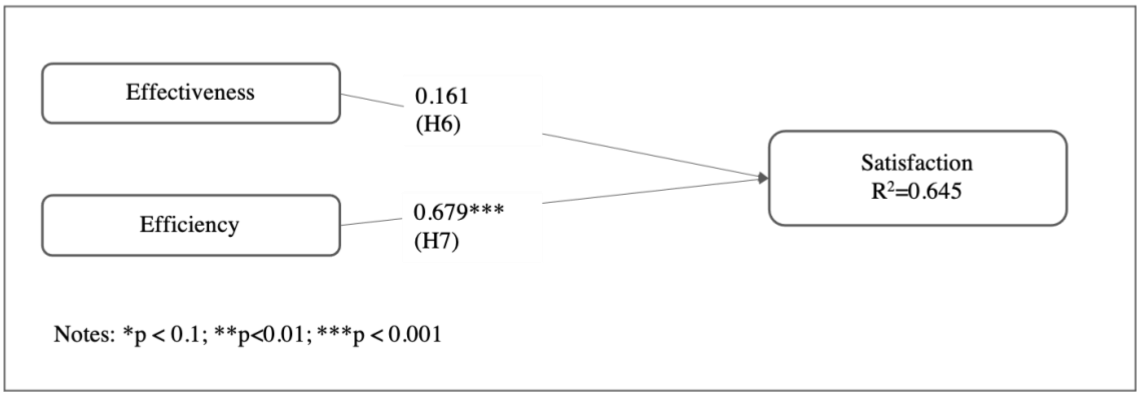

Figure 8. Satisfaction Structural Model

Usability & Continuous usage intention

The relationship between usability and continuous usage intention was examined by considering the effect of satisfaction and effectiveness. Based on the literature and the modified model, it was hypothesized that both satisfaction and effectiveness would have an influence on continuous usage intention. The test results revealed that the variance of continuous usage intention could be explained by the two usability variables with a substantial R^2 value of 68.6% (Figure 9), above the substantial R^2 value recommended by Chin (1998). However, only satisfaction had a significant and positive influence on continuous usage intention ($\beta = 0.684$, $p<0.001$). Therefore, only hypothesis H8 is supported.

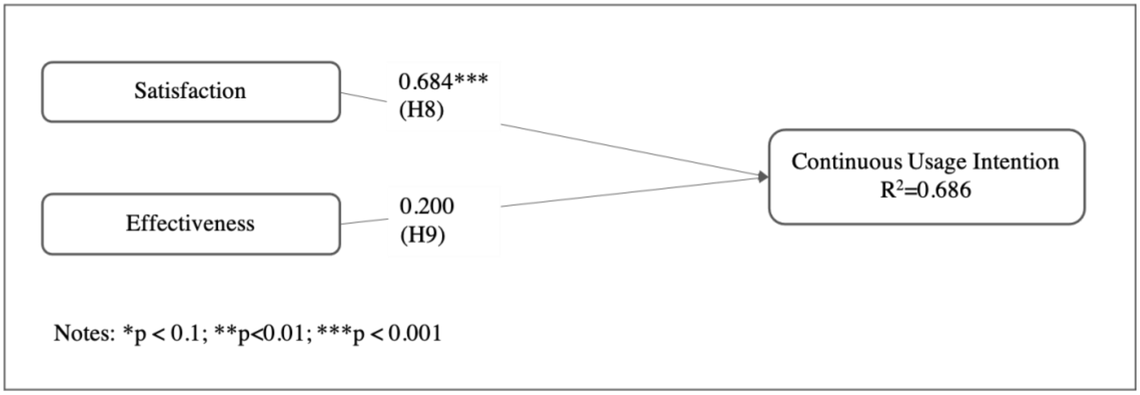

Figure 9. Continuous Usage Intention Structural Model

To summarize, the R^2 values for effectiveness, efficiency, satisfaction, and continuous usage intention are 0.611, 0.531, 0.645, and 0.686, respectively. These values exceed the acceptable R^2 threshold outlined by Chin (1998). Based on the analysis, we were able to validate six of our proposed hypotheses (as outlined in Table 18), while the remaining hypotheses could not be supported. It is possible that the relatively small sample size may have contributed to these unsupported hypotheses. Further discussion of these findings will be presented in the next chapter.

Table 18. Summary of Hypotheses Validation

Hypotheses	Validation
Design Elements & Usability	
1. Information Design	
H1a. The information design of integrated smart city apps has a positive influence on users' perceived effectiveness of integrated smart city apps.	Not Supported
H1b. The information design of integrated smart city apps has a positive influence on users' perceived efficiency of integrated smart city apps.	Supported
2. Page Layout Design	
H2a. The page layout design of integrated smart city apps has a positive influence on users' perceived effectiveness of integrated smart city apps.	Not Supported
H2b. The page layout design of integrated smart city apps has a positive influence on users' perceived efficiency of integrated smart city apps.	Not Supported
3. Navigation Design	
H3a. The navigation design of integrated smart city apps has a positive influence on users' perceived effectiveness of integrated smart city apps.	Supported

H3b. The navigation design of integrated smart city apps has a positive influence on users’ perceived efficiency of integrated smart city apps.	Not Supported
4. Visual Design	
H4a. The visual design of integrated smart city apps has a positive influence on users’ perceived effectiveness of integrated smart city apps.	Supported
H4b. The visual design of integrated smart city apps has a positive influence on users’ perceived efficiency of integrated smart city apps.	Supported
5. Interaction Design	
H5a. The interaction design of integrated smart city apps has a positive influence on users’ perceived effectiveness of integrated smart city apps.	Not Supported
H5b. The interaction design of integrated smart city apps has a positive influence on users’ perceived efficiency of integrated smart city apps.	Not Supported
Usability	
H6. Users’ perceived effectiveness of integrated smart city apps has a positive influence on users’ satisfaction with integrated smart city apps.	Not Supported
H7. Users’ perceived efficiency of integrated smart city apps has a positive influence on users’ satisfaction with integrated smart city apps.	Supported
Usability & Continuous usage intention	
H8. Users’ satisfaction with integrated smart city apps has a positive influence on users’ continuous usage intention of integrated smart city apps.	Supported
H9. Users’ perceived effectiveness of integrated smart city apps has a positive influence on users’ continuous usage intention of integrated smart city apps.	Not Supported

The complete model with hypotheses result is also shown below (Figure 10).

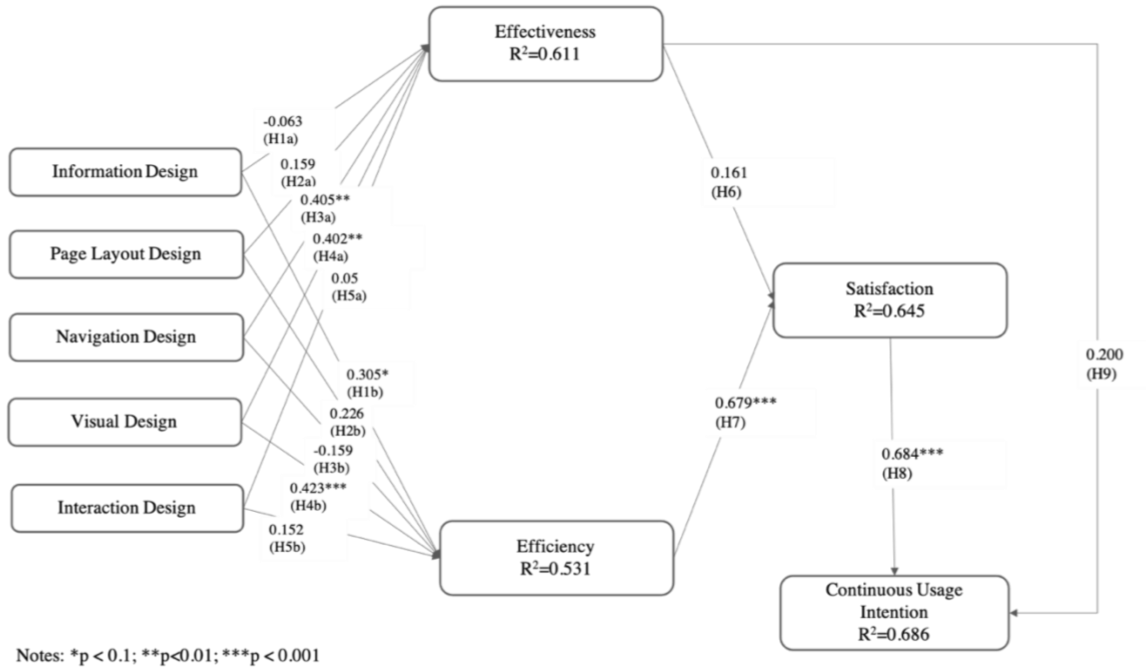

Figure 10. Complete Model with Results

Chapter 6
Discussion

The preceding chapter presented the outcomes obtained from the analysis of descriptive data and structural equation modelling. This chapter aims to provide a comprehensive interpretation and discussion of these results.

The conceptual model developed for this study was based on Davis's (1989) Technology Acceptance Model and adapted according to recent research on usability and user experience (Hong et al., 2002; Grange and Barki, 2020; Coursaris and Kim, 2011; Watters et al., 2003; Amin et al., 2014; Hsu and Chiu, 2004; Kwahk and Han, 2002) and is comprised of three main parts. The first part examined the relationship between design elements of integrated smart city apps and their perceived usability. The second part focused on the correlation between the three dimensions of usability, and the final part explored the connection between perceived usability and users' continuous usage intention. Research questions and hypotheses were proposed and tested for each of these three parts, and the discussion in this chapter will follow the same pattern.

6.1 The relationship between design elements and usability

Based on the conceptual model we developed, the relationship between design elements and usability is actually a direct relationship between design elements and both effectiveness and efficiency.

The literature review led us to categorize applications' design elements into five groups: information design, page layout design, navigation design, visual design, and interaction design. To make them more suitable for the mobile context, we further divided these categories into subcategories. For example, information design includes content and display of information, while page layout design consists of page composition and layout. Navigation design is divided into page-level navigation and system navigation. Visual design encompasses typography, colors, and graphics, while interaction design includes information control, input and output, as well as control and feedback. We generated multiple items based on the subcategories' definitions and literature review to provide a more detailed explanation of the variables. Ultimately, we created four items to reflect information design, four items to explain page layout design, five items for navigation design, and nine items for both visual design and interaction design.

Regarding the measurement model, all items of the design variables have loading values above 0.5 and T-values above 1.96, indicating their significance (Garson, 2016). Therefore, all generated items are valid, reflecting their corresponding design variables and validating the subcategories for each design variable.

In terms of the structural model testing, the design elements were found to account for 61.1% of the variance in effectiveness and 53.1% of the variance in efficiency, with slightly better explanatory power for the former than the latter. A closer examination of the results reveals that interaction design does not demonstrate a significant influence on either effectiveness or efficiency, particularly with regard to interaction design's influence on effectiveness. The coefficient for this variable is very low ($\beta = 0.05$), and the p-value is extremely high ($p = 0.736$). Interaction design, which is a more abstract design element compared to others, may be difficult for users to comprehend or recognize in everyday use. Despite its lack of significant influence on effectiveness and efficiency, the results still suggest that interaction design has a greater influence on efficiency than effectiveness, as indicated by a higher coefficient ($\beta = 0.152$) and a much lower p-value ($p = 0.203$). This can be attributed to the fact that interaction design primarily focuses on accommodating and responding to users' behaviour, influencing their overall experience using the application and potentially influencing their task completion times without directly affecting their ability to perform tasks in the application.

Similarly, page layout design does not have a significant influence on effectiveness or efficiency. However, it does have a positive influence on both variables, with a larger influence on efficiency ($\beta = 0.226$) than effectiveness ($\beta = 0.159$). This suggests that page composition and layout can have a greater influence on how quickly users find information, as opposed to their ability to complete tasks within the application.

Information design is an important part of integrated smart city apps, differentiating them from other smart city apps. This is because it provides a platform which combines various services and information in one (Zhang et al., 2021), necessitating the organization and presentation of a greater volume and variety of information within the application. Information design has a significant positive influence on efficiency (β = 0.305, p=0.077), supporting the hypothesis, as well as findings from previous research, that information design will positively influence users' perceived efficiency (Frascara, 2015; Keshab, 2016). The Society for Experiential Graphic Design emphasizes that information design involves the presentation of information in a clear and understandable manner, and it is, therefore, reasonable to assume that the quality of information presented in the application affects users' ability to obtain information and accomplish tasks efficiently. However, the influence of information design on effectiveness is not significant at all, and the path coefficient displays a negative tendency. Despite studies by Lipton (2007), Frascara (2015), and Keshab (2016) that have shown a positive effect of information design on effectiveness, it is not always the case. In some instances, providing additional features to satisfy user expectations can lead to cognitive overload and cause users to struggle to complete tasks and encounter errors or redundant information. Rust et al. (2006) have also noted that adding device functionality may increase complexity and result in feature fatigue. Given the diverse range of functions offered in integrated smart city applications, this complexity may have a negative influence on effectiveness, even though the effect is not statistically significant. This issue should be considered when designing this specific type of smart city application.

The influence of navigation design on effectiveness has been validated to have a positive and significant influence (β= 0.405, p=0.005), and it is the most influential among all design elements. This finding aligns with prior research, which suggests that effective page-level navigation design and system navigation design prevent users from abandoning the interface or failing to complete tasks (Gehrke,1999; Bladders et al., 1999; Moon et al., 2015), thus increasing users' perceived effectiveness. However, it is surprising that navigation design does not significantly affect efficiency (p=0.311). This contradicts previous studies emphasizing the importance of navigation design in enhancing efficiency (Gehrke,1999; Harridge-March, 2006). One possible reason for this discrepancy is that the application is not excessively complex to interact with, so the quality of navigation design may not significantly affect users' task completion time.

Visual design is the only variable that has been proven to have a positive influence on both effectiveness (β = 0.402, p=0.005) and efficiency (β = 0.423, p<0.001). This finding is consistent with prior research (Tractinsky, 1997; Cyr et al., 2006; Li and Yeh, 2010; Coursaris et al., 2012).

When comparing the path coefficients of all design variables on effectiveness and efficiency, it becomes apparent that visual design has the second strongest influence on effectiveness and the strongest influence on efficiency, highlighting its influence on usability. Specifically, it has a greater influence on efficiency than on effectiveness since visual design includes typography, colors, and graphics, the quality of which affects users' ability to efficiently gather the information conveyed by these elements within the application.

Despite certain invalid hypotheses, our study still confirms the influence of certain design elements on effectiveness and efficiency within the context of an integrated smart city app. Effectiveness is mainly influenced by navigation design and visual design, while efficiency is mainly influenced by information design and visual design. As such, future integrated smart city app designs should focus on improving these specific design elements: information design, navigation design, and visual design.

6.2 The relationship between effectiveness, efficiency and satisfaction

This conceptual model demonstrates that design elements have an influence on the effectiveness and efficiency of an application, which ultimately affects user satisfaction with the application.

After evaluating the measurement model for usability, we found that all items related to effectiveness, efficiency, and satisfaction had loadings above 0.5 and were statistically significant ($T>1.96$), indicating their validity.

Upon testing the structural model, we discovered that both effectiveness and efficiency could explain 64.5% of the variance in user satisfaction. However, only efficiency had a significant and strong positive influence on satisfaction ($\beta = 0.679$, $p<0.001$), which aligns with previous studies (Davis, 1989; Coursaris et al., 2007, 2016). It is noteworthy, however, that effectiveness did not have a significant influence on satisfaction. One possible explanation for this result is that integrated smart city apps provide users with multiple services, enabling them to complete numerous tasks. However, this may lengthen the time required to complete those tasks, which suggests users are more sensitive to efficiency and may be less concerned with whether they require a single app or multiple apps to complete their tasks. Another possible explanation is that effectiveness is influenced by efficiency, previously tested and verified by Coursaris et al. in 2016, and thus the influence of effectiveness on satisfaction may be categorized under the influence of efficiency in certain contexts. We can therefore conclude that to enhance user satisfaction with an integrated smart city app, improving efficiency should be prioritized. However, further research is required to fully explain the relationship between effectiveness, efficiency, and satisfaction.

6.3 The relationship between usability and continuous usage intention

According to our conceptual model, the relationship between continuous usage intention and usability lies in the connection between effectiveness and satisfaction.

Our evaluation of the measurement model confirmed that all items related to satisfaction, effectiveness, and continuous usage intention were valid, with all indicator loadings of this variable above 0.5 and significant ($T>1.96$) as well. Through structural model testing, we found that effectiveness and satisfaction can explain 68.6% of the variance in satisfaction, making it the highest among all the models tested. This suggests that the independent and dependent variables have a good fit. However, only one of the two hypotheses associated with continuous usage intention was validated. Satisfaction was found to have a significant and strong positive influence on continuous usage intention ($\beta = 0.684$, $p<0.001$), which is consistent with previous literature (Susanto et al., 2015; Abu-Salim et al., 2017; Zhang et al., 2021). This validates the connection between these variables in the context of this specific integrated smart city app.

On the other hand, the influence of effectiveness on continuous usage intention, as originally verified by Bhattacherjee (2001), could not be verified ($\beta = 0.2$, $p=0.121$), even though it was very close to being significant at the 90% level, a larger sample size could show a significant relationship between these variables. This result indicates that even if an integrated smart city app is more useful and can complete various tasks at once, users will still not use the app again if they are not satisfied with their experience. This may be because users can complete their tasks using other smart city apps and are more concerned about the overall experience rather than what the integrated app can do. This finding is consistent with the result that users prioritize efficiency over effectiveness when using this type of app.

The validated conceptual model is shown below (Figure 11):

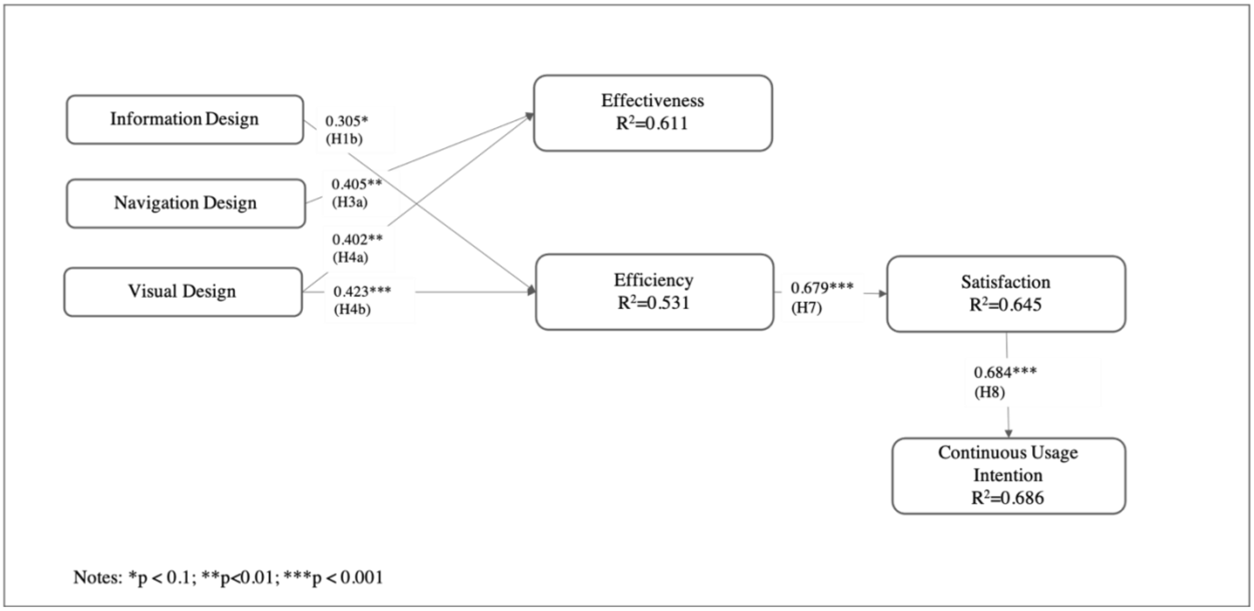

Figure 11. Validated Conceptual Model

Chapter 7
Conclusion

7.1 Summary of the study

With the increasing demands of cities and advancements in technology, the development of smart cities has become a major goal and strategy for many municipalities around the world. Smart city applications have become a critical approach for cities to provide services to their citizens. Although there have been many studies on smart cities, research on smart city apps specific to a particular country or city is limited, and those with integrated smart city apps are even rarer. Many cities opt for integrated smart city apps as a one-stop destination platform for a variety of services. However, the lack of research on these apps has resulted in usability issues and unpleasant user experiences.

To better understand this specific type of smart city app and identify design elements that would lead to its continuous usage, a study focusing on design elements, usability, and continuous usage intention in the context of integrated smart city apps was conducted. Vancouver, one of the few cities in Canada with an integrated smart city app, was selected as a case study (Chapter 1).

To achieve the research goals, a literature review was conducted (Chapter 2), where definitions of smart city, smart city apps, integrated smart city apps, and mobile usability were clarified. Design elements were identified and modified in the context of mobile applications. The literature gap between design, usability, and continuous usage intention was noted. Based on this, a conceptual model was built on the basis of the Technology Acceptance Model (TAM). The model aims to identify and conceptualize the five design elements of integrated smart city apps, namely information design, page layout design, navigation design, visual design, and interaction design, some of which have an influence on usability and how usability further influences continuous usage intention. Fourteen hypotheses were proposed based on prior research (Chapter 3).

To gather user feedback on all variables, a questionnaire was developed and distributed among existing app users, and 51 valid responses were obtained (Chapter 4). The results were analyzed using structural equation modelling and presented. Although the sample size was limited, the results provided valuable insights into the relationship between the different factors investigated (Chapter 5). The findings were discussed in three parts, answering the three research questions (Chapter 6).

This chapter presents the main conclusions of the research. A summary is provided, followed by discussions on the contributions, limitations, and insights for future research.

7.2 Summary of the main results

The use of structural equation modelling has validated the significance and validity of all the items developed through the research and literature review. The fit of the items and the measurement model indicates the validity of creating subcategories under each design variable, including information design (content and display), page layout design (composition and layout), navigation design (page level and system), visual design (typography, colors, graphics), and interaction design (information control, input/output, and control/feedback).

Of the fourteen hypotheses tested, five were supported by the structural model. Effectiveness was found to be influenced positively by navigation design and visual design, with the model explaining 61.1% of its variance. Efficiency was influenced by information design and visual design, with the model explaining 53.1% of its variance. Satisfaction was found to be strongly influenced by efficiency but not by effectiveness, with the model explaining 64.5% of its variance. Finally, continuous usage intention was influenced by satisfaction but not by effectiveness, with the model explaining 68.6% of its variance.

Overall, this study provides valuable insights into the design elements of mobile applications and their relationship to usability and continuous usage intention, particularly in the context of integrated smart city apps.

7.3 Contributions

7.3.1 Theoretical Contributions

Firstly, this study conducted a literature review and identified five interface design elements that fit the context of mobile applications. The current literature has yet to provide a clear framework for the design of mobile applications. This study proposed subcategories under these design elements and generated multiple items for these subcategories. The significance of the items was verified through structural model testing, proving their validity in explaining the five design elements. This study provides a theoretical framework for mobile application design, and future research can utilize the five design elements as well as the subcategories under each design element as more specific variables to interpret mobile application design.

Secondly, previous studies have applied software user experience guidelines to guide application design, but there is a lack of research exploring the relationship between design and usability. This is particularly true for research on the influence of design elements on perceived usability. This study used structural equation modelling to test the relationship between different mobile application design elements and the dimensions of perceived usability. It fills this gap and validates that design elements affect effectiveness and efficiency, which further affect satisfaction. Navigation design and visual design mainly influence effectiveness, while information design and visual design mainly influence efficiency. Efficiency mainly influences satisfaction in the context of an integrated smart city app.

Thirdly, existing studies on how usability affects continuous usage intention mainly focus on satisfaction, while the influence of other dimensions of usability is not explained clearly. This study verified the important influence of satisfaction on users' continuous usage intention in the context of an integrated smart city app. In addition, the study also explored the relationship between effectiveness and continuous usage intention, which was found to have no significant influence. This study fills the gap in research and highlights a direction for further study.

Lastly, prior literature on user experience and smart city apps or services can be divided into three areas: analyzing the factors affecting users' satisfaction and intention of continuous use, evaluating smart city apps or services, and discussing the development or design of smart city apps. However, there is a lack of research attempting to link all these directions. This study built a conceptual model that links smart city design elements with different dimensions of usability and continuous usage intention. By assessing users' opinions on all the variables, the study clarifies the relationship between them.

7.3.2 Practical Contributions

In addition to its theoretical contributions, this research also has practical implications. Specifically, the goal of this research is to understand how to design a more user-friendly integrated smart city app that encourages continuous usage and enables governments to provide municipal services.

One important aspect of this research is its focus on the integrated smart city app, which is a relatively new type of smart city app. Research on this type of app is scarce, and there is no universal guideline for its design. Additionally, many current integrated smart city apps on the market suffer from usability issues, leading to user dissatisfaction. To address this gap in research, this study examines VanConnect, an integrated smart city app, and aims to deepen our understanding of this type of app and draw attention to the study of integrated smart city apps.

It is worth noting that Asian countries have launched more integrated smart city apps than North American countries, and user feedback on these apps is generally more positive in Asia than in North America. Therefore, this study focuses on Vancouver, a smart city in Canada, to assess the design and usability of integrated smart city apps in North America and identify potential areas for improvement in the future.

This study found that user satisfaction is the key factor influencing continuous usage intention, which is consistent with findings from previous research (Susanto et al., 2015; Abu-Salim et al., 2017; Zhang et al., 2021). For smart city apps, efficiency is essential in influencing user satisfaction, and it is crucial to make the app as convenient and time-saving for users as possible. While effectiveness also affects user satisfaction, its influence is less pronounced, suggesting that the application's efficiency is more critical than its functionality. Researchers have observed that some integrated smart city apps include too many functions, making them feel complicated to users (Peng et al., 2019), which reduces the importance of effectiveness. This finding aligns with our results, indicating that the primary goal of integrated smart city app design should not be to include more services and functions but rather to focus on providing necessary and key services in a clear and convenient way. The replacement of VanConnect with Van311, which is an app for reporting issues and requesting services, suggests a focus on key services that are most frequently used. However, there is still potential for further exploration of what features to include rather than completely abandoning the development of an integrated smart city app.

Regarding the design elements that should be emphasized in integrated smart city apps, those highly connected with efficiency include information and visual design. Specifically, content, information display, graphics, colors, and typography should be prioritized, and the content and information display should follow the guidelines mentioned above.

7.4 Limitations

While this study has made both theoretical and practical contributions, it is important to acknowledge some limitations that may affect the generalizability and applicability of the results.

7.4.1 Small sample size

The present study faced a challenge in finding a sufficient number of participants for the survey, resulting in a limited sample size. While the obtained results may be suggestive, the small sample size may affect the testing results' significance and limits the generalizability of the findings.

The process of recruiting participants for a study about integrated smart city apps can be challenging due to several factors. Firstly, the user base of such apps may be smaller compared to more mainstream apps, resulting in a limited pool of potential participants. Generally speaking, only residents or travellers who have been to Vancouver have used the app and not all of them are aware of the app or have the need to use it. For instance, as of the official website's last accessible records (August 13th, 2022, through the Internet Archive Wayback Machine at web.archive.org), VanConnect had only been downloaded 51,432 times since its launch. Hence, it is challenging to reach this already small pool of users.

Additionally, the usage of smart city apps may be irregular, as users may only use the app when they have a specific purpose or need, or they may even forget that the app exists. Among participants that completed the survey, nearly 50% used the app on a monthly basis, and nearly 30% on a yearly basis. Only about 25% of participants used the app on a daily or weekly basis. This usage pattern can further limit the pool of potential participants and make it difficult to reach a sufficient sample size.

Another challenge in recruiting participants for such a study may be a lack of interest in participating in research. Many individuals may not view participating in research as a priority or may not be motivated to participate in a study about integrated smart city apps specifically.

Future studies may consider exploring alternative recruitment methods, such as targeted advertising or incentives for participation or extending the participant recruitment period duration to obtain a larger sample size. Additionally, the use of incentives or collaboration with relevant organizations and schools may increase the likelihood of participant engagement as well as improve access to the relevant participant pool. Researchers may need to identify other ways to clearly communicate the potential benefits and value of participating in the study to motivate individuals to participate.

Nonetheless, it is important to note that the study's contributions and potential implications should not be disregarded due to the small sample size. Rather, it highlights the need for further research with larger samples to confirm and extend the present findings.

7.4.2 Lack of qualitative data

Originally, the study plan involved a second-round data collection for the purpose of gathering qualitative data through user testing, following the completion of quantitative data collection. However, due to circumstances beyond our control, the study object, the VanConnect app, became unavailable as of August 2022 and has been replaced by another app that differs significantly from the original. As a result, it is no longer feasible to conduct user testing with the VanConnect app. The collection of qualitative data through user testing could have added value to the study by providing insights into users' thoughts, behaviours, and emotions during app interaction that may not have been captured through surveys. This could have further contributed to the field by providing a deeper understanding of user experience and identifying areas for improvement that may have been overlooked during survey data collection.

7.4.3 Limitation of case comparison

While the use of only one app as a research object may have limitations, the choice of VanConnect as the sole app evaluated in this study was not arbitrary. The app was selected due to its unique integrated features that are seldom found in other smart city apps in Canada. VanConnect is an integrated smart city app that provides a wide range of services, such as transportation, parking, and public safety. In contrast, other smart city apps typically focus on a specific area, such as transportation or parking, and lack the integration of services that VanConnect provides. It is difficult to find other smart city apps that are integrated in a similar way in Canada for the purpose of conducting comparative research or obtaining more generalized results.

Additionally, integrated smart city apps vary in their focus and services offered across regions and countries, such as Singapore and China. To provide more comprehensive conclusions and recommendations on integrated smart city design, it may be beneficial to evaluate multiple smart city apps across different regions, comparing and contrasting their features and challenges.

7.5 Future research

As noted in the limitations section, future research could be conducted with a larger sample size to validate the conceptualization model, potentially yielding more reliable and insightful results.

Furthermore, while this study identified five design elements and their corresponding subcategories, the subcategories were primarily proposed to generate more specific mobile-context items and were not heavily analyzed in later stages. Thus, future research could delve deeper into how these sub-elements affect usability.

While the current research sheds light on the importance of design elements in shaping perceived usability and satisfaction, there are other factors that can influence the perceived usability of integrated smart city apps. For instance, the control variables in the study are user characteristics such as age, gender, income, education level and individual differences in cognitive abilities and prior experience with technology. Additionally, factors influencing users' continuous usage intention could be investigated through expanded model testing and analysis of additional variables and their relationships.

Furthermore, analyzing integrated city apps in various regions could offer valuable insights into the model's universality and the diverse effects of its constituent elements. This approach could provide a more comprehensive understanding of the unique features and challenges that arise in different contexts, such as varying population density and transit options. Finally, comparing and contrasting smart city apps from different regions can inform the development of best practices and explore the possibility of proposing guidelines for creating effective interactive smart city apps across the globe while allowing flexibility in region-specific apps that are tailored to the specific needs and challenges of different regions.

Overall, while this study provides clear evidence of relationships between design elements, dimensions of usability, and continuous usage intention in the context of integrated smart city apps, more remains to be validated and applied. This remains an up-and-coming field filled with numerous opportunities for research and development.

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Appendix

Appendix 1. REB Ethics Approval Certificate

HEC MONTRÉAL

Comité d'éthique de la recherche

April 21, 2022

To the attention of:
Yuchun Xia

Re: Ethics approval of your research project

Project No.: 2023-4871

Title of research project: Assessing the usability and design of official integrated smart city apps: The case of Vancouver

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Your research project has been evaluated in accordance with ethical conduct for research involving human subjects by the Research Ethics Board (REB) of HEC Montréal.

Committee members authorize the first phase of the project, via questionnaires. The second phase, via interviews, will require a further approbation, via an F8 - project modification form, so that the final scenarios to be presented during the interviews as well as questionnaires to be used during the interviews be presented to the REB an approved before being used for the project.

A Certificate of Ethics Approval attesting that your research complies with HEC Montréal's *Policy on Ethical Conduct for Research Involving Humans* has been issued, effective April 21, 2022. This certificate is **valid until April 01, 2023.**

In the current context of the COVID-19 pandemic, you must ensure that you comply with the directives issued by the Government of Quebec, the Government of Canada and those of HEC Montréal in effect during the state of health emergency.

Please note that you are nonetheless required to renew your ethics approval before your certificate expires using Form *F7 – Annual Renewal*. You will receive an automatic reminder by email a few weeks before your certificate expires.

When your project is completed, you must complete Form *F9 – Termination of Project.* (or *F9a – Termination of Student Project if certification is under the supervisor's name).* **All students must complete an F9 form to obtain the "Attestation d'approbation complétée" that is required to submit their thesis/master's thesis/supervised project.**

If any major changes are made to your project before the certificate expires, you must complete Form *F8 – Project Modification.*

Under the *Policy on Ethical Conduct for Research Involving Humans*, researchers are responsible for ensuring that their research projects maintain ethics approval for the entire duration of the research work, and for informing the REB of its completion. In addition, any significant changes to the project must be submitted to the REB for approval before they are implemented.

You may now begin the data collection for which you obtained this certificate.

We wish you every success in your research work.

REB of HEC Montréal

HEC MONTRĒAL

Comité d'éthique de la recherche

CERTIFICAT D'APPROBATION ÉTHIQUE

La présente atteste que le projet de recherche décrit ci-dessous a fait l'objet d'une évaluation en matière d'éthique de la recherche avec des êtres humains et qu'il satisfait aux exigences de notre politique en cette matière.

Les membres du comité approuvent la première phase du projet. Toutefois, vous devrez déposer via un F8 et obtenir son approbation par le CER pour le scénario final pour l'entrevue lorsqu'il sera prêt, ainsi que le questionnaire à présenter lors de l'entrevue, avant de procéder à ces entrevues.

Projet # : 2023-4871

Titre du projet de recherche : Assessing the usability and design of official integrated smart city apps: The case of Vancouver

Chercheur principal :
Yuchun Xia,

Directeur:
Ryad Titah
Professeur - HEC Montréal

Date d'approbation du projet : April 21, 2022

Date d'entrée en vigueur du certificat : April 21, 2022

Date d'échéance du certificat : April 01, 2023

Maurice Lemelin
Président
CER de HEC Montréal

Signé le 2022-04-25 à 14:13

HEC MONTRĒAL

Comité d'éthique de la recherche

July 15, 2022

To the attention of:
Yuchun Xia

Project No.: 2023-4871

Project title:
Assessing the usability and design of official integrated smart city apps: The case of Vancouver

---

Further to the evaluation of your Form F8 – Project Modification, the Research Ethics Board (REB) of HEC Montréal wishes to inform you of its decision:

The changes have been noted in the file. The current certificate will remain valid until the next renewal.

Thank you.

REB of HEC Montréal

HEC MONTRĒAL

Comité d'éthique de la recherche

February 06, 2023

To the attention of :
Yuchun Xia
HEC Montréal

Project No. 2023-4871

Title:Assessing the usability and design of official integrated smart city apps: The case of Vancouver

---

Further to your request for renewal, the Ethics Approval Certificate for the above project has been renewed as at April 01, 2023. **This certificate is valid until April 01, 2024.**

You must therefore request renewal of your ethics approval before that date using Form *F7 – Annual Renewal.* You will receive an automatic reminder by email a few weeks before your certificate expires.

When your project is completed, you must complete Form *F9 – Termination of Project.* (or *F9a – Termination of Student Project if certification is under the supervisor's name).* **All students must complete an F9 form to obtain the "Attestation d'approbation complétée" that is required to submit their thesis/master's thesis/supervised project.**

If any major changes are made to your project before the certificate expires, you must complete Form *F8 – Project Modification.*

Please note also that any new member of your research team must sign the Confidentiality Agreement, which must be sent to us prior to your request for renewal.

We wish you every success in your research work.

Yours very truly,

REB of HEC Montréal

HEC MONTRĒAL

Comité d'éthique de la recherche

ATTESTATION D'APPROBATION ÉTHIQUE COMPLÉTÉE

La présente atteste que le projet de recherche décrit ci-dessous a fait l'objet des approbations en matière d'éthique de la recherche avec des êtres humains nécessaires selon les exigences de HEC Montréal.

La période de validité du certificat d'approbation éthique émis pour ce projet est maintenant terminée. Si vous devez reprendre contact avec les participants ou reprendre une collecte de données pour ce projet, la certification éthique doit être réactivée préalablement. Vous devez alors prendre contact avec le secrétariat du CER de HEC Montréal.

Projet # : 2023-4871 **-** Master's Thesis

Titre du projet de recherche : Assessing the usability and design of official integrated smart city apps: The case of Vancouver

Chercheur principal :
Yuchun Xia
HEC Montréal

Directeur/codirecteurs :
Ryad Titah
HEC Montréal

Date d'approbation initiale du projet : April 21, 2022

Date de fermeture de l'approbation éthique : April 17, 2023

Maurice Lemelin
Président
CER de HEC Montréal

Signé le 2023-04-17 à 13:34

Retrait d’une ou des pages pouvant contenir des renseignements personnels

Appendix 3. Variable Items Coding

Coding	Items (I believe…)	Scale	Source
Information Design			
INF1	The content of this app is understandable and complete enough.	Strongly Disagree (1) ..... Strongly Agree (7)	Choi,2012
INF2	The content of this app is well organized for users.	Strongly Disagree (1) ..... Strongly Agree (7)	
INF3	The information of this app is categorized in the right way.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober,2011
INF4	The information of this app is displayed following logical patterns.	Strongly Disagree (1) ..... Strongly Agree (7)	
Page Layout Design			
PLA1	The components and content forming the pages of this app are designed appropriately.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober,2011
PLA2	The components and content included in the pages of this app are consistent.	Strongly Disagree (1) ..... Strongly Agree (7)	
PLA3	The positions of the components and content of this app are appropriate.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Fling,2009
PLA4	The layout of the screen of this app is well adapted to the device and conditions.	Strongly Disagree (1) ..... Strongly Agree (7)	
Navigation Design			
NAV1	Navigation on the page between different sections of this app is available.	Strongly Disagree (1) ..... Strongly Agree (7)	Garrett,2003
NAV2	The navigation on the page between different sections of this app is appropriate.	Strongly Disagree (1) ..... Strongly Agree (7)	
NAV3	The number of categories and levels of navigation of this app are appropriate.	Strongly Disagree (1) ..... Strongly Agree (7)	Choi,2012

NAV4	Categories of this app are well arranged based on priority, with the most important categories being the most prominent.	Strongly Disagree (1) ..... Strongly Agree (7)	
NAV5	There are clear, concise and consistent labels for navigation throughout this app.	Strongly Disagree (1) ..... Strongly Agree (7)	
Visual Design			
VIS1	The number of different fonts of this app is appropriate and logical.	Strongly Disagree (1) ..... Strongly Agree (7)	Choi,2012
VIS2	The spacing between characters, words, and lines, as well as type sizes of this app are appropriate in regards to the function of the text.	Strongly Disagree (1) ..... Strongly Agree (7)	
VIS3	Each color used for each text function of this app appears similarly on every page.	Strongly Disagree (1) ..... Strongly Agree (7)	
VIS4	The number of colors used for fonts is appropriate	Strongly Disagree (1) ..... Strongly Agree (7)	
VIS5	Colors are used appropriately in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	Choi,2012
VIS6	There is a good color palette and a good color relationship in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	
VIS7	The color palette of this app appeals to users.	Strongly Disagree (1) ..... Strongly Agree (7)	
VIS8	The meaning of each icon used in this app is visually clear.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Fling, 2009
VIS9	The photos and images found in this app add meaning to the content.	Strongly Disagree (1) ..... Strongly Agree (7)	
Interaction Design			
INT1	Several ways of controlling information (e.g. sort by/filter, search, location jump, zoom. etc.) are provided for users in order to control the information shown in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober, 2011
INT2	The ways to control information (e.g. sort by/filter, search, location jump, zoom. etc.) in this app perform as expected.	Strongly Disagree (1) ..... Strongly Agree (7)	
INT3	The ways to input information in this app and the ways the system responds are appropriate.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition

INT4	Input can be assisted in this app to predict content or adapt to previous usage.	Strongly Disagree (1) ..... Strongly Agree (7)	from Hoober, 2011
INT5	Input can be guided in this app to avoid errors.	Strongly Disagree (1) ..... Strongly Agree (7)	
INT6	When important notifications occur in this app, users can be alerted.	Strongly Disagree (1) ..... Strongly Agree (7)	
INT7	The system can be controlled at any step in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	Developed based on the definition from Hoober, 2011
INT8	Confirmation is required for specific actions in this app to prevent errors.	Strongly Disagree (1) ..... Strongly Agree (7)	
INT9	Feedback from the system about the processes happening can always be provided immediately in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	
Effectiveness			
EFC1	I am able to complete all of my tasks successfully in this app.	Strongly Disagree (1) ..... Strongly Agree (7)	Coursaris et al. 2016
EFC2	I am able to accurately obtain the needed information in this app to complete my tasks.	Strongly Disagree (1) ..... Strongly Agree (7)	
Efficiency			
EFI1	Learning how to use this app was easy.	Strongly Disagree (1) ..... Strongly Agree (7)	Coursaris et al. 2007
EFI2	Using this app is easy.	Strongly Disagree (1) ..... Strongly Agree (7)	
EFI3	This app is user friendly.	Strongly Disagree (1) ..... Strongly Agree (7)	
EFI4	Using this app is fast.	Strongly Disagree (1) ..... Strongly Agree (7)	
Satisfaction			
SAT1	Thinking about my experience with this app, I feel Terrible/ Delighted	Terrible (1) ..... Delighted (7)	Coursaris et al. 2007
SAT2	Thinking about my experience with this app, I feel Very displeased/ Very pleased	Very displeased (1) .... Very pleased (7)	

SAT3	Thinking about my experience with this app, I feel Very dissatisfied/ Very satisfied	Very dissatisfied (1) .... Very satisfied (7)	
SAT4	Thinking about my experience with this app, I feel Frustrated/ Contented	Frustrated (1) .... Contented (7)	
Continuous Usage Intention			
CON1	I am willing to continue the usage of this app on a regular basis.	Strongly Disagree (1) ..... Strongly Agree (7)	Zhang et al. 2021
CON2	I intend to use this app continuously in my daily life	Strongly Disagree (1) ..... Strongly Agree (7)	

Appendix 4. PLS-SEM Settings

	Setting
Initial weights	1
Max. number of iterations	3000
Stop criterion	10^{-7}
Type of results	Standardized
Use Lohmoeller settings?	No
Weighting scheme	Path

Appendix 5. Bootstrapping Settings

	Setting
Complexity	Most important (faster)
Confidence interval method	Percentile bootstrap
Parallel processing	Yes
Samples	5000
Seed	Fixed seed
Significance level	0.05
Test type	Two tailed

Appendix 6. Structural Model Bootstrapping Results

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
EFC -> CON	0.2	0.217	0.129	1.551	0.121
EFC -> SAT	0.161	0.143	0.143	1.122	0.262
EFI -> SAT	0.679	0.691	0.106	6.384	0
INF -> EFC	-0.063	-0.05	0.199	0.318	0.75
INF -> EFI	0.305	0.309	0.173	1.766	0.077
INT -> EFC	0.05	0.025	0.149	0.337	0.736
INT -> EFI	0.152	0.162	0.119	1.274	0.203
NAV -> EFC	0.405	0.376	0.145	2.788	0.005
NAV -> EFI	-0.159	-0.172	0.157	1.012	0.311
PLA -> EFC	0.159	0.154	0.121	1.309	0.191
PLA -> EFI	0.226	0.212	0.16	1.411	0.158
SAT -> CON	0.684	0.676	0.125	5.491	0
VIS -> EFC	0.402	0.405	0.121	3.335	0.001
VIS -> EFI	0.423	0.429	0.114	3.714	0

Note: INF= Information Design, PLA= Page Layout Design, NAV= Navigation Design, VIS=Visual Design; INT=Interaction Design, EFC= Effectiveness, EFI= Efficiency, SAT=Satisfaction, CON= Continuous Usage Intention

Appendix 7. VanConnect App Screenshots