A POST-CONSTRUCTION EVALUATION OF LONG-TERM SUCCESS IN LEED-CERTIFIED RESIDENTIAL COMMUNITIES

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Planning, Design, and Construction – Doctor of Philosophy

2021

ABSTRACT

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Project success has been the focus of several studies and traditionally, the iron triangle factors (time, cost, and scope) have been the focus in evaluating project success. However recently, the importance of the long-term evaluation of project success has been highlighted, which evaluates the successful performance of the projects at the post-construction stage with a focus on three main aspects of sustainability, satisfaction, and life cycle performance. This study evaluates multiple aspects of long-term project success by setting sustainability as the baseline and finding the relationships between the performance of the built environment and residential satisfaction in sustainable residential communities.

This study was conducted in two phases; in the first phase, the relationship between the actual performance of infrastructure and sustainability of LEED-certified residential communities was evaluated to compare the consistency of sustainability evaluation criteria in theory and practice. In the second phase, the perceived performance of the discussed infrastructure attributes as well as several building and neighborhood attributes were evaluated to understand their relationships with residential satisfaction and test the consistency of sustainability evaluation criteria with people’s perception and judgments in determining the long-term success of these projects. The data for the first phase of the research was collected from www.usgbc.org and walkscore.com and in the second phase, an online survey was conducted to collect data from the residents of

LEED-certified residential communities as the experiment group (n=192) and the residents of conventional residential communities as the control group (n=183).

The first phase of this study used a multiple regression analysis to evaluate the relationship between infrastructure performance and sustainability. In the second phase, a confirmatory factor analysis (CFA) was performed to validate the measurement model. A structural equation modeling (SEM) was then conducted to evaluate the relationships between the perceived performance of the built environment and residential satisfaction. The most influential attributes in determining residential satisfaction were then determined through path analyses and finally, a multiple-group CFA (MGCFA) was carried out to evaluate the effect of sustainability on the perceived performance of the built environment and residential satisfaction.

As one of the important findings of this study, it was indicated that evaluation of factors such as walking infrastructure that is considered as an important criterion in determining sustainability shows discrepancy in theory and practice. Besides, LEED-certified community residents illustrated the very high importance of this factor in determining satisfaction. This finding highlighted the importance of considering the users' perceptions and judgments in developing sustainability standards. This study contributes to the body of knowledge by developing a comprehensive post-construction evaluation model that considers multiple aspects of the long-term project success by including the feedback and judgments of residents regarding their living environment. The findings of this research can be beneficial for the improvement of housing and community sustainability standards by including the users' opinions in decision-making.

ACKNOWLEDGMENTS

This Ph.D. journey has been a life-changing experience for me. With all ups and downs, it would be impossible without the guidance and support of many people.

First and foremost, I would like to express my deepest appreciation to my Ph.D. advisor, Dr. George H. Berghorn, for listening, encouraging, guiding, inspiring, mentoring, and advising me with wisdom, and for his unconditional and unlimited support both during my Ph.D. journey and my job applications. Without his support, these would have not been possible.

I would like to thank my Ph.D. research committee: Dr. Sinem Mollaoglu, for her unlimited support in all steps of my Ph.D. and her support of my job applications, Dr. Mark Wilson, for always being available to help and support me with enthusiasm and kindness, and Dr. Igor Vojnovic for valuable and timely feedback at key stages in the research process. I also want to thank Dr. Matt Syal, for his invaluable support of my job applications.

I am thankful to my friends in the Iranian community, for their support at the critical points of my Ph.D. life, and to my wonderful colleagues and friends in the School of Planning, Design, and Construction.

I would like to acknowledge the School of Planning, Design, and Construction, the Graduate School, and the Environmental Science and Policy Program at Michigan State University for supporting my dissertation financially. I should also acknowledge MSU Center for Statistical Training and Consulting (CSTAT) for providing me with a wonderful support during my data analysis.

I cannot express my thanks to the love of my life, Nafiseh. I am truly grateful for her love, unconditional support, and patience. Without her, I would not have been able to achieve my goals. I should also thank the most precious gift of my life, my daughter Hannah, for bringing happiness to my life.

Finally, I would like to extend my sincere thanks to my parents, my siblings, and my in-laws for their years of continual support, inspiration, and involvement.

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CHAPTER 1 : INTRODUCTION

1.1 Overview

Buildings have significant direct and indirect impacts on the environment through extracting and using materials (Adalberth, 1997), changing the land use (Holmgren et l., 2017), consuming water (Zeng et al., 2007), using about 40% of global energy, and generating large amounts of carbon emissions (GhaffarianHoseini et al., 2013) while producing a variety of other environmental issues. Green building, as the most successful practice toward reducing environmental impacts in the building industry, has provided a basis for all building and infrastructure developments to reduce their negative impacts.

The concept of the green building incorporates different green technologies such as renewable energy systems, rainwater collection systems, and green roofs (Chong et al., 2011) while considering environmental sustainability in design and construction. However, it has been demonstrated that scattered individual green buildings cannot provide remarkable benefits, and to significantly reduce the negative impacts, large-scale and integrated sustainable systems are required (Marique & Reiter, 2014). Hence, sustainability at the community level becomes highlighted, which includes a cluster of sustainable buildings benefiting from an integrated sustainable infrastructure being placed on a sustainable site through a sustainable layout. According to Marique and Reiter (2014), such a sustainable system can collect the benefits of individual green buildings in a more efficient way by considering an integrated system of building energy consumption and renewable production, water resource management, carbon emission reduction, and other environmental benefits.

However, looking at the performance of a sustainable built environment only from the technical point of view may not provide a comprehensive understanding of the extent to which this type of development is successful. Therefore, besides technical aspects, a comprehensive assessment of a sustainable development project must include users' points of view in the evaluation of project success. In other words, a sustainable development project is a success if besides considering environmental aspects as the baseline, it meets the needs of the users (Pinto & Prescott, 1988; Pinto & Shelvin, 1988; Müller & Jugdev, 2012; Ramlee et al., 2016; Adabre & Chan, 2019; Chan & Adabre, 2019).

In this study, therefore, considering the post-construction evaluation, the actual and perceived performance of sustainable LEED-certified residential communities is emphasized to indicate their long-term success both based on their performance from users' points of view using the judgments, evaluations, and feedback of the users.

1.2 Need Statement

Over the past decades, the approach toward the evaluation of project success has evolved considerably (Davis, 2014; Ika, 2009) and it has been recognized that the success of a project must be evaluated from the various stakeholders perspective (Atkinson, 1999; Gemünden, 2015; Turner & Zolin, 2012) and specifically, the most important stakeholder who is the end-user (Williams et al., 2015). However, due to the nature of the complex and long-term interactions between the users and the built environment, measuring project success from users' points of view is complex (de Wit, 1988; Gou et al., 2013) especially when it comes to sustainable projects. Therefore, in order to provide a realistic understanding of the long-term success of a sustainable project, there is a need for a comprehensive evaluation model that assesses the performance of the project from the users' points of view at the post-construction stage.

The need to have a comprehensive evaluation model that considers multiple aspects of sustainability and long-term project success from users' points of view leads to the following premises that highlight the need for this study.

1.2.1 Premise #1- Sustainability standards lack a comprehensive evaluation of the projects.

Sustainable built environment assessment tools intend to provide a balance among all aspects of sustainability but only a few have been successful in achieving this goal (Yigitcanlar & Dur, 2010). As one of the most populous and comprehensive tools of sustainability assessment, LEED (Leadership in Energy and Environmental Design) has a comprehensive emphasis on the technical and environmental aspects of sustainability. However, as it is clear, both from a sustainability standpoint and from a project success point of view, technical aspects are not the only important aspects that determine successful performance, and the role of users in evaluating any project should be highlighted.

In order to provide the opportunity for such an evaluation, a comprehensive model should be designed to enable the integration of users' feedback from multiple aspects, consider the performance in different metrics and various criteria, and provide an index that allows multiple decision-makers to analyze the performance of a sustainable built environment in development projects.

1.2.2 Premise # 2- Users' feedback is the basis for the evaluation of long-term success.

Despite the importance of users' evaluations and feedback, this aspect has not been considered in the LEED rating system with the same weight as the technical aspect (Atanda, 2019). One important aspect of sustainability is related to the interactions between humans and the built environment and more specifically the role of the human in shaping their immediate built environment. Here, the role of users in judging, providing feedback, and participation in building the environment and satisfaction with the performance of their built environment become highlighted.

Besides, the cost performance of a project from users' points of view is an important aspect that could not be ignored in evaluating the success of the project. If a built project performs well environmentally but the cost of operation and maintenance is too high, it cannot be considered a successful project (Chan, Scott, & Lam, 2002; Ramlee et al., 2016; Sebestyen, 2017). This is particularly important in residential development projects (Adabre & Chan, 2019). Therefore, successful sustainable residential development needs to be economically sound as well. As such, the assessment of the performance of the sustainable built environment should consider both physical and cost performance from users' points of view.

1.2.3 Premise #3-The perceived performance of the built environment attributes determine satisfaction.

Studies have shown that the perceived performance of the residential environment compared to the expected performance is an important factor indicating the satisfaction of the users (de Wit, 1988; Toor & Ogunlana, 2010). One factor that is of high importance in determining the performance of the built environment is its accordance with human needs and expectations, which refers to the level that the given built environment meets the needs and expectations of people who live or occupy it. In sum, it is crucial to consider the interactions between people and the built environment to find out whether it performs well. This highlights the role of understating the users' feedbacks and judgments in determining the success of sustainability practices.

Considering the inhabitants' judgments and perceptions can provide essential ideas and feedback for the successful development of the built environment and improvement of design and construction practices (Aliyu & Muhammad, 2016). This can be important both by providing lessons for architects and contractors and by providing a benchmark and a pool of research on the building industry to indicate how the end product meets the expectations and needs of its end users (Enright, 2002) thus providing satisfaction for them. By ensuring that users' feedback is considered throughout the building design and construction processes, the quality of the built environment is protected both during the construction process and the operation of the facility (Preiser & Vischer, 2006).

1.2.4 Premise # 4- Physical environment attributes are the most influential factors in determining satisfaction.

Although numerous studies have delved into residential satisfaction (e.g. Cloutier et al., 2018, 2014; Hur & Morrow-jones, 2008; Hur et al., 2010; Mccrea, Stimson, & Western, 2005), less research has been found to focus specifically on the physical environment attributes (Buys & Miller, 2012; Gifford, 2007). Furthermore, the studies that are concerned about the satisfaction of residents with their physical environment either focus on one attribute (e.g., green space, density, physical appearance, etc.) or consider a combination of the natural and built features as determinants of residential satisfaction. This combination is misleading as natural features' entities are different than the built features and these two groups cannot be measured with the same scale. Such a combination may deviate the attention of the researchers from some of the most important physical features that create the main structure of each community namely buildings and infrastructures.

Among all factors, the physical attributes are very important factors influencing the satisfaction of residents (Herting & Guest, 1985). Several researchers have demonstrated that housing and neighborhood physical elements such as building and neighborhood infrastructure elements are more influential on residential satisfaction compared to socio-demographic factors (e.g., Parkes et al., 2002; Hur & Nasar, 2014; Lee et al., 2017). According to Sirgy and Cornwell (2002), satisfaction with the physical features of the entire neighborhood contributes significantly to one's satisfaction with the home.

1.3 Research Goal and Objectives

This research aims to develop a robust model for the assessment of the long-term success of sustainable housing development projects from users' points of view to find the relationships among sustainability, residential satisfaction, and the performance of those projects. The research is premised on physical changes that achieve sustainability while affecting the satisfaction of residents.

Setting sustainability, performance, and residential satisfaction as simultaneous objectives for housing development may result in solutions to the issues with sustainable development descriptions and approaches. This research considers these relationships through the following specific objectives and their corresponding tasks (Figure 1.1).

Objective 1: Developing a multi-phase framework that evaluates the relationships between sustainability, satisfaction, and performance of the built environment in residential communities. This objective is accomplished via doing the following tasks.

- Review the literature about long-term project success and housing satisfaction theories, evaluation models, and measures.
- Investigate the LEED-ND certification system and identify the important components that should be evaluated objectively.
- Extract the key components of sustainable buildings and communities to be evaluated from users' points of view.

Objective 2: Investigating the associations between sustainability and actual performance of LEED-certified residential communities. This objective is accomplished via doing the following tasks.

- Identify all the LEED-ND certified built projects in the US that are certified before April 1, 2021.
- Find the scores that reflect the actual performance of the identified neighborhood components from publicly available sources.

- Conduct a multiple regression analysis to understand the relationship between the actual performance of the built environment in LEED-certified residential communities and their level of sustainability.

Objective 3: Developing and validating a model to evaluate the associations between the perceived performance and satisfaction of sustainable LEED-certified residential communities and identifying the key determinants of residential satisfaction in sustainable communities. This objective is accomplished via doing the following tasks.

- Develop a model to evaluate satisfaction in sustainable residential projects.
- Design and conduct a survey to collect the data for evaluation of residential satisfaction in sustainable residential projects.
- Conduct a confirmatory factor analysis (CFA) to assess the fit of the model to the data and validate the model.
- Conduct a structural equation modeling (SEM) to evaluate the relationships between the perceived performance of the built environment and residential satisfaction.
- Conduct a path analysis to determine the most influential attributes of the built environment in determining residential satisfaction.

Objective 4: Developing a multigroup comparison analysis to examine the effects of sustainability on providing residential satisfaction and the perceived performance of the built environment in residential communities. This objective is accomplished via doing the following tasks.

- Conduct an overall CFA for all the samples including residents of both LEED and non-LEED residential communities.
- Compare the means of perceived performance and residential satisfaction between the experiment and control group (if measurement invariance was found).

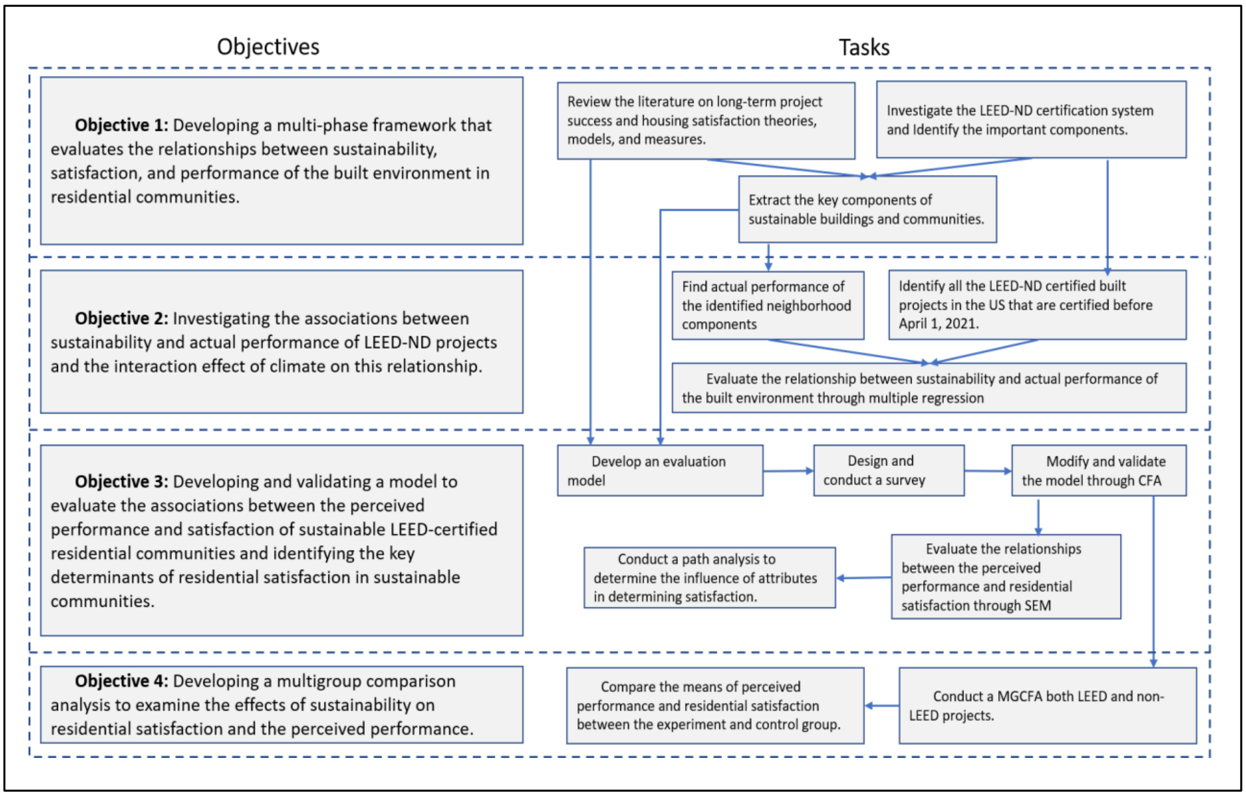

Figure 1.1 Summary of research objectives and their corresponding tasks

1.4 Research Questions

This research is an attempt to answer an overarching question regarding the relations between sustainability, satisfaction, and perceived performance as key indicators of long-term project success. The main question is supported by more specific and detailed research questions. The gap in the literature, as enumerated in premises #1 to #4 coupled with the importance of the subject motivated the consideration of these research questions. The main and supporting questions are as follow:

Overarching research question: How do the three factors of long-term project success including community sustainability, perceived and actual performance of the physical environment, and the satisfaction of residents in LEED-certified residential communities impact one another?

To answer this overarching question, the following questions need to be addressed:

- RQ-1: How is the level of sustainability associated with the performance of infrastructure and physical elements of LEED-certified residential communities?
- RQ-2: Do the perceived building performance, perceived infrastructure performance, perceived neighborhood design, and perceived cost performance predict residential satisfaction in LEED-certified residential communities?
- RQ-3: In LEED-certified residential communities, what are the most important determinants of long-term success through influencing residential satisfaction?
- RQ-4: Does sustainability impact residential satisfaction and the perceived performance of the built environment in residential communities?

1.5 Research Scope and Limitations

The scope of this research is sustainable residential project developers and stakeholders. These groups include key parties that are involved in and affected by this type of development. Therefore, these are important parties to be considered in such a development. The generalizability of the study findings and the conclusion is considered while the research project is moving forward.

There are some limitations to this research that may require more research in the future. The first limitation is that due to the limited access to the data, few factors were evaluated objectively in the first phase of the study. Although the study evaluated important aspects, it might have left some important factors out of the study. The second limitation is that the second phase of the study did not evaluate the actual performance of the built environment to be compared with the perceived performance and provide a more realistic understanding of the relationships between the performance and satisfaction. Furthermore, although the sample was collected randomly and the users of several projects participated in the survey, the sample size for CFA and SEM could be larger in order to prevent the issue of generalizability. Finally, the second phase of the study did not consider the effect of location and climate to distinguish between the projects based on their regional characteristics. Therefore, the findings of the study may or may not apply to projects that are located in extreme climates and special geographical areas. Moreover, the study did not distinguish between urban and suburban projects and between the projects located in big and small cities while these aspects might introduce the perceived performance of the built environment and residential satisfaction.

1.6 Project Outputs/Research Contribution

In this study, a post-construction evaluation is adopted to answer the research questions, as a platform for the systematic study of buildings once constructed and occupied. Through this research, lessons can be learned by scholars, developers, residents, and other stakeholders that will improve the housing conditions and direct the design and construction of future communities. Different aspects of perceived performance and functioning are evaluated in this study as well as more interactional aspects such as satisfaction, preferences, behavioral intentions, etc. This type of research is a necessary and axiomatic part of any development project and is essential for researchers who have a concern about the development of sustainable communities. The findings of this research offer the potential to bring the integration between a range of fragmented facets of the design and construction process and the relationship between the built environment and users by engaging users in decision making and creating development standards.

The outputs of this research can be beneficial in the short-term, medium-term, and long-term: short-term advantages include obtaining the feedback and judgments of residents regarding their living environment and including their opinions in decision making; medium-term benefits include learning lessons and providing criteria to be considered for the future sustainable development practices; and long-term benefits could be the potential for creating a database, which could be updated, as well as the potential for creating planning, design, and construction protocols and paradigms.

CHAPTER 2 : LITERATURE REVIEW

This chapter first offers an overview of housing and neighborhood sustainability and investigates the LEED-ND certification system as one of the most popular sustainability standards related to residential communities. The chapter then focuses on residential satisfaction in sustainable communities as the most important determinant of long-term project success. Next, the theories and models for the evaluation of residential satisfaction are discussed. Finally, key aspects to be considered in the evaluation of residential satisfaction are discussed and the variables that are of concern in this study are highlighted. Figure 2.1 shows the mental model of the topics discussed in this chapter.

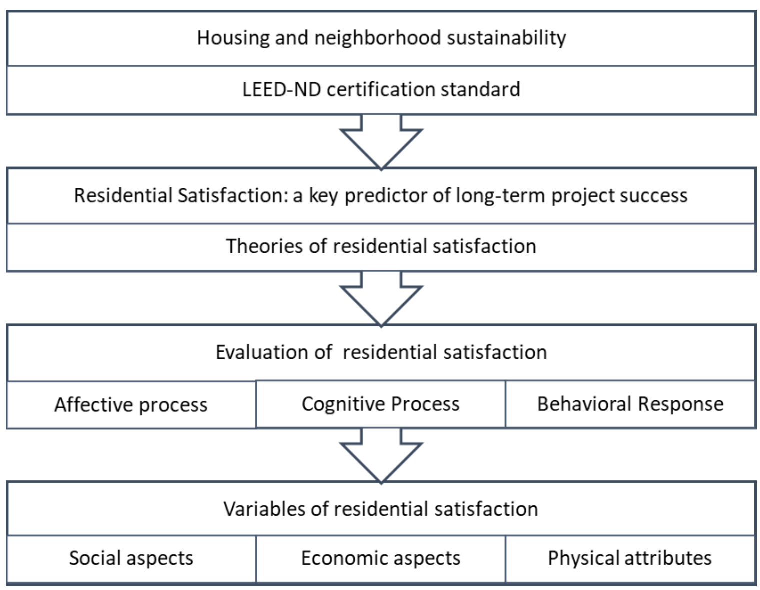

Figure 2.1 Literature review topics

2.1 Housing and Neighborhood Sustainability

Sustainability has been considered as one of the key factors of project success (Chan & Chan, 2004; Chovichien & Nguyen, 2013; Heravi & Ilbeigi, 2012; Khosravi & Afshari, 2011; Wai, Yusof, & Ismail, 2012). According to Adabre & Chan (2019); Chan & Adabre (2019); and Ibem & Azuh, (2011), in housing and residential projects, in particular, sustainability is the main measure of success. One of the concrete applications of sustainability in building design and construction is the concept of “green building” by providing opportunities for buildings and communities to be environmentally responsive, high performance, and healthy for occupants (Wedding & Crawford-Brown, 2007).

Numerous positive impacts are associated with green buildings such as reduced resource consumption, lowered operating costs, reduced waste, healthier living, and working environments, and so forth. With improvements in systems and methods of green building, the number of benefits is increasing and consequently and the interest in this concept is growing significantly. However, it has been demonstrated that scattered individual green buildings cannot provide all the expected benefits. In order to significantly reduce the negative impacts of building construction and operation, integrated sustainable systems are necessary, which include a cluster of sustainable buildings benefiting from an integrated sustainable infrastructure being placed on a sustainable site through a sustainable layout. Such a sustainable building system can collect the benefits of individual green buildings in a more efficient way by considering an integrated system of building energy consumption and renewable production, water resource management, and other environmental and economic features (Marique & Reiter, 2014).

The importance of sustainability and green development as key indicators of project success comes from the significance of environmental damages such as extracting and using materials (Adalberth, 1997), changing the land use (Holmgren et l., 2017), consuming water (Zeng et al., 2007), using about 40% of global energy, and generating large amounts of carbon emissions (GhaffarianHoseini et al., 2013), caused by over 138 million residential units (U.S. Census Bureau, 2016) and more than 5.6 million commercial buildings (EIA, 2015) in the US. The US Green Building Council (USGBC) has played an important role in addressing the impacts associated with the building development industry by offering Leadership in Energy and Environmental Design (LEED) guidelines.

2.2 LEED-ND

Several projects have adopted LEED-ND as a framework for developing residential communities and mixed-use projects around the world. The criteria for the assessment of sustainability in the LEED-ND system are classified into five groups of “smart growth and linkages”, “neighborhood pattern and design”, “green infrastructure and buildings”, “innovation and design process”, and “regional priority credit”. Each group consists of multiple individual criteria providing a scale for assessment of residential/mixed-use projects from different aspects (Sharifi & Murayama, 2014).

Even though LEED is providing valuable opportunities for improving sustainability practices in the building construction sector, it does not include all important facets of sustainability. In this sustainability standard, the main focus is on technical environmental sustainability and only a few aspects of human-environment interactions have been considered as evaluation criteria. In a study by Komeily and Srinivasan (2015), the LEED-ND standard was investigated and it was found that only a few aspects of sociocultural quality including safety, well-being, quality of life, sound emission, affordable housing, inclusive communities, social networks, and infrastructure, and heritage are considered. More specifically, in the LEED-ND system, the participation of local stakeholders in the design and evaluation process under the category "Democracy, Empowerment, and Equity" is the only factor related to stakeholder participation in creating the built environment (Wangel et al., 2016).

As it is clear, despite the importance of sustainability and the efforts toward achieving it, uncertainty arises when trying to measure the long-term successful performance of these types of projects comprehensively. Although the LEED guidelines have provided a great opportunity to step in the right direction, the focus is mainly on the technical aspects associated with building methods and materials with little or no credits given to user preferences and satisfaction concerns. Therefore, it is necessary to consider those aspects to provide a good insight into the success of these practices.

2.3 Improving the Assessment of Sustainable Development Projects

Despite the importance of the technical environmental impacts in evaluating the overall sustainability performance of projects, it is crucial to equitably consider all aspects of sustainability. In fact, sustainable communities should boost healthy social life and relationships (Dempsey et l., 2011) while providing potentials for local economic improvement (Sirgy & Cornwell, 2002; Capon & Blakely, 2007), food production (Capon & Blakely, 2007), and improve the interactions between humans and the built environment. Although some social and economic aspects have been considered in sustainability assessment tools such as LEED-ND, these tools do not include a wide range of stakeholders in the tool development and as a result, some important aspects are missing. The unbalanced focus on different criteria comes from a lack of equal knowledge on the ways to measure social and economic sustainability in comparison with environmental sustainability (Pope et l., 2004). The results of investigations illustrate that sustainability assessment tools such as LEED-ND are expert-led and having a top-down approach in developing the criteria has failed to include different stakeholders both in criteria selection and weights. This prevents bringing different priorities and concerns into consideration. Therefore, a more balanced approach is necessary for tool development to consider all aspects of sustainability and involve a comprehensive array of stakeholders.

Involving stakeholders and parties that are impacted by the development can be very helpful in addressing the downsides and improving human relationships within the community while simplifying the intertwining subjective and objective factors (Scerri & James, 2010). The most important stakeholder of any development project is the end-user who disregarding their feedbacks provides many issues that could not be addressed easily. It is important specifically for the residents to be involved in evaluating and developing standards and assessment tools as Berardi (2013) demonstrated that end user-based systems show more success in measuring and evaluating the performance of the built environment (Hardi & Zdan, 1997; Morse & Fraser, 2005).

Considering sustainability as a baseline for measuring the long-term success of development projects highlights the important role of this factor. Therefore, the sustainability performance of a project should be evaluated to find out the level of success. This evaluation should not only be objective, based on the existing criteria but also it should be from users' points of view as is highlighted in the previous sections.

2.4 Satisfaction: A Key Predictor of Long-Term Project Success

One factor that is of high importance in determining the successful performance of the built environment is its accordance with human needs and expectations. It is crucial to investigate the feedback of users about their living environment to find if it performs well. Perceived project performance compared to the expected performance is an important factor indicating the success of a project (de Wit, 1988; Toor & Ogunlana, 2010). This highlights the role of users' judgments and satisfaction in determining the success of sustainability practices as several experts have suggested that customer satisfaction is a critical dimension of project success (Al-Tmeemy, Abdul-Rahman, & Harun, 2011; Davis, 2014; Dvir, Raz, & Shenhar, 2003; Heravi & Ilbeigi, 2012; Ireland, 1992; Khosravi & Afshari, 2011; Pinto & Shelvin, 1988; Serrador & Rodney Turner, 2014; Wai et al., 2012).

Considering the inhabitants' judgments and perceptions can provide essential ideas for successful housing development and the improvement of design and construction practices (Aliyu & Muhammad, 2016). This can be important both by providing lessons for architects and contractors and by providing a benchmark and a pool of research on the building industry to indicate how the end product meets the expectations and needs of its end users (Enright, 2002). By ensuring that the feedback of users is considered throughout the building design and construction processes, the quality of the built project is protected both during the construction process and later in the operation phase (Preiser & Vischer, 2006).

The approach of including satisfaction and perception into success indicators of a project was suggested by Verma (1995). However, this idea was initiated approximately a decade earlier when Baker, Murphy, and Fisher (1983) included the perception of project performance into project success factors (Sebestyen, 2017). In their words, "instead of using time, cost, and performance as measures for project success, perceived performance should be the measure" (Baker, Murphy, & Fisher, 1983). Ireland, (1992) also highlighted the importance of customer satisfaction as an important project success criterion. Later, Ika (2009) suggested that customer satisfaction must be added to the "iron triangle" criteria to achieve a "virtuous square" which reinforces the role of the user perspective in evaluating the success of a project. Liu & Walker (1998) also considered users' satisfaction an important attribute of project success. Moreover, Torbica and Stroh (2001) suggested that a project can be regarded as successful in the long run only if end users are satisfied. According to Dvir et al. (2003), "there are many cases where projects are executed as planned, on time and budget, and achieved the planned performance goals, but turned out to be complete failures because they failed to produce actual benefits to the customer..." (p89). They also found all the success factors including end-user benefits and satisfaction to be highly inter-correlated and concluded that "projects perceived to be successful are successful for all their stakeholders." (p94). In the "Project Management Body of Knowledge" (PMBOK), published by Project Management Institute, customer satisfaction is suggested to be one of the key determinants of success for projects (Serrador & Rodney Turner, 2014). Therefore, it is clear that a project must be assessed from the most important stakeholders' perspective who is the end-user (Williams, Ashill, Naumann, & Jackson, 2015) to have a clear understanding of its success.

2.5 Bridging The Gap: A Comprehensive Evaluation of Successful Performance

From the literature, it can be implied that a sustainable project is successful if the long-term performance of the project satisfies the needs and expectations of the users. Therefore, it is crucial to evaluate the success of construction projects from this standpoint. Reviewing the existing literature regarding project success of sustainable projects as well as digging into the most comprehensive sustainability standard in building design and construction, it was illustrated that the role of users' judgments, expectations, and preferences has been underestimated in defining the criteria for development and evaluation of sustainable residential development projects. To bridge this gap, in this research, the role of users' perception, evaluation, and satisfaction is highlighted to come up with a true understanding of the long-term successful performance of sustainable residential projects.

Therefore, the work included in this research is an attempt to understand the relations between sustainability, perceived performance, and residential satisfaction as the key determinant of the long-term success of residential projects. In other words, this research serves as a call to action to refocus our research, efforts, resources, and innovation to intentionally develop communities for three outcomes: (1) sustainability, (2) perceived performance, and (3) residential satisfaction.

In this research, the performance of the physical features from users' points of view is evaluated mainly by investigating the perception of the users from the functionality of these features. Similarly, cost performance is evaluated from the residents' points of view. This evaluation investigates their perceived cost-benefit and the relations between the price and costs associated with moving to and living in sustainable residential communities compared to conventional ones. Satisfaction, on the other hand, is evaluated both by asking questions about overall satisfaction with home and community and from the residents' behavioral intentions. All the measurements of this research are conducted under a comprehensive model developed from the existing theories, methods, and models to provide reliable and generalizable outcomes that help identify the most important attributes in determining sustainability, perceived performance, and residential satisfaction.

2.6 Developing A Model for Users' Evaluation of Sustainable Residential Projects

In the following sections, components, measurement methods, and the theories of evaluating residential satisfaction will be discussed. As discussed previously, the evaluation of performance should be both objective and subjective. In order to evaluate the performance of LEED-ND communities objectively, the relevant physical and environmental characteristics of these projects should be identified and classified, and the data regarding the actual performance of their buildings and infrastructures should be collected. A comparison of the level of sustainability (based on LEED-ND credit score) and the scores available for some infrastructures (such and Walk score, bike score, transit score, etc.) can provide an insight into the associations between level of sustainability and the performance of the project.

With regard to the subjective evaluation, to provide a simple and manageable model, the perceived cost performance, perceived physical performance, and the level of residential satisfaction are investigated. The focus of this section is on residential satisfaction. The data regarding perceived physical and cost performance is collected as a part of this evaluation method. The perceived performance data collected from this part are considered to be analyzed as the predictors of residential satisfaction.

2.6.1 Residential Satisfaction

As pointed out, the key indicator of long-term success for each development project is user satisfaction. Thus, it is important to consider this key factor in the planning, design, and construction of the built environments. This is even more important in housing and residential development projects. As individuals' satisfaction can be used as a surrogate for quality of life from a policy standpoint (Myers, 1988), it is widely regarded as an important variable in residential development studies. Research has shown that residential satisfaction is a predictor of mental health (Cho et al., 2005; Leslie & Cerin, 2008) and quality of life (Fried, 1984) as it is demonstrated that a variety of features influence inhabitants' quality of life through residential satisfaction (Sirgy & Cornwell, 2002).

Satisfaction is a variable that encompasses residential priorities held by different people. Due to its association with overall life satisfaction, Parkes et al. (2002) recommended using satisfaction as a dependent variable in residential studies. However, although it is a variable that can be readily collected in surveys, the analysis of residential satisfaction could be challenging (Parkes et al., 2002). According to Galster (1985), there are four different ways to utilize the concept of residential satisfaction: 1) as an important predictor of "quality of life", 2) as a measure to evaluate the success of a development project, 3) as an indicator of residents' behavioral responses to the environment, and 4) as a measure for the assessment of residents' perceptions of their residential environment for quality improvement. Other than the first one, all the approaches are closely related to the development practices and play important role in evaluating the success of a project. As residential satisfaction is dependent on the place, time, assessment purpose, and the evaluation system of the assessors, it is considered as a complex construct that involves a broad range of stakeholders including contractors, architects, planners, psychologists, and sociologists (Mohit & Raja, 2014). Therefore, to successfully measure the level of satisfaction with a residential project, the first step is to understand the theoretical and empirical aspects of residential satisfaction.

2.6.2 Theories of Residential Satisfaction

According to Galster & Hesser (1981), all theories of residential satisfaction are based on measuring the differences between occupants' actual and desired housing conditions. In this regard, three main theories provide the basis for all the empirical studies including "housing needs theory", "housing deficit theory", and "psychological construct theory".

Housing Needs Theory

Rossi (1955) introduced the notion of "housing needs" suggesting that changes in housing needs and aspirations of residents during the time, bring up "lack of fit" between their present and desired housing needs thus creating a low level of satisfaction with their current residential areas. The potential response to this dissatisfaction could be migration to a new community in order to bring their housing condition into adjustment with their needs. The different space requirements resulted from life cycle changes of residents are believed to be the key aspect of the needs (Mohit & Raja, 2014).

Housing Adjustment Theory

This theory was introduced by Morris & Winter (1975) to conceptualize residential satisfaction/dissatisfaction and model residential mobility. They noted that individuals' judgments of their housing situations are based on the norms including both personal/family norms and cultural norms. The inconsistency between the actual housing condition and the personal and/or cultural housing norms could result in a housing deficit, which ends up with residential dissatisfaction. Households with housing dissatisfaction are prone to consider some housing adjustment forms. This can be an attempt to decrease the level of dissatisfaction by modifying their needs and expectations or through the improvement of their housing conditions. Moving to another place could also be another response to dissatisfaction in order to bring their residential area into consistency with their needs. This could act as a driver to move to a neighborhood that is recognized to have a higher quality and provides a higher standard of housing conditions, for instance, sustainable communities.

Psychological Construct Theory

The theory of the "psychological construct" of residential satisfaction was introduced by Galster (1985) suggesting that individuals may cognitively create a "reference" condition for each feature of their residential area based on their self-evaluated needs and expectations. If the perception of the current state is consistent or superior to the reference condition, satisfaction will be manifested. If not, two alternatives are possible. One response could be "adaptation" through redefining needs, reducing expectations, and/or making changes in the assessment of the current situation. If the individuals cannot adapt to the current situation, "dissatisfaction" may happen, which could result in either attempts to moderate their level of dissatisfaction by modifying the situation of the residential area or by moving to another place that is more in conformity with the reference condition. However, these alternatives may not be available due to a lack of purchasing power for lower-income people or other factors such as discrimination against minority households and the effects of cognitive bias on the comparisons between expectations and reality.

2.7 Measurement of Residential Satisfaction

In most of the empirical studies on residential satisfaction, either one or a combination of the discussed theories has been utilized (Mohit & Raja, 2014). Satisfaction should be adequately measured in order to understand it properly (Gifford, 2007a). Acceptable measurements of residential satisfaction are dependent on studying the variables related to three different processes of "cognitive", "affective" and "behavioral" that exist in the dynamic interactions between the individuals and their residential environments and affect the overall satisfaction with the residential environment (Weidemann & Anderson, 1985).

2.8 Variables of Residential Satisfaction

Generally, a variety of factors have been investigated separately in residential satisfaction studies both regarding residential units and their surrounding neighborhoods. Physical attributes of the neighborhood have been explored as the main focus by many researchers (e.g. Hur & Nasar, 2014; Hur, Nasar, & Chun, 2010; Kaplan, 2001; Kweon et al., 2010; Lee, Ellis, Kweon, & Hong, 2008; Sirgy & Cornwell, 2002). Visual quality and appearance of neighborhoods have also been studied as factors of interest as predictors of residential satisfaction (e.g. Kaplan, 1985; Sirgy & Cornwell, 2002; Gruber & Shelton, 1987; Parkes et al., 2002).

In some research projects, factors related to the socio-demographic aspects and resident characteristics are the main focus (e.g. Kweon et al., 2010; Sallis et al., 2009). Other factors that have been studied in residential satisfaction research are safety (Burby & Rohe, 1989; Cook, 1988; Lovejoy, Handy, & Mokhtarian, 2010), and housing-related factors (Basolo & Strong, 2002; Tighe, Mueller, & Mueller, 2013). Variables such as housing and neighborhood condition and residents' characteristics have been evaluated in several studies as the main components affecting satisfaction (Lu, 1999; Parkes et al., 2002). Availability and access to neighborhood amenities have also been found to be significant factors affecting residential satisfaction (Salleh, 2012). Howley et al. (2009b) found residential satisfaction to be associated with features such as the absence of litter in the neighborhood, perceived safety, neighbors looking out for each other, and employment opportunities.

Some studies have considered the economic aspects of the neighborhood as the predictor of residential satisfaction (Yaman et al., 2018; Sirgy and Cornwell, 2002; Salleh, 2012). Finally, in many studies, only the overall satisfaction has been evaluated as the main factor of evaluation (e.g., de Jong, Albin, Skärbäck, Grahn, & Björk, 2012; Galster & Hesser, 1981; Hur et al., 2010).

Considering the discussed variables and measures, residential satisfaction appears to be a multifaceted and complex subject, and more research is required to gain a better understanding of the correlations between the effective factors. According to the literature, attributes that could potentially affect the level of satisfaction with the built environment can be categorized into three main groups including 1) physical environment attributes, 2) social aspects, and 3) economic aspects (Figure 2.2). Physical environment attributes can be classified into two categories of 1) built attributes and 2) natural attributes. Social attributes can be categorized into two groups including 1) demographic-household situation and 2) social capital. The third group of attributes is economic aspects, which include economic aspects of the development project from the developer perspective (construction cost performance), client standpoint (if different from end-user), and from the user's perspective (e.g., house value, utilities, and maintenance costs). In the following sections, each of the categories will be discussed briefly.

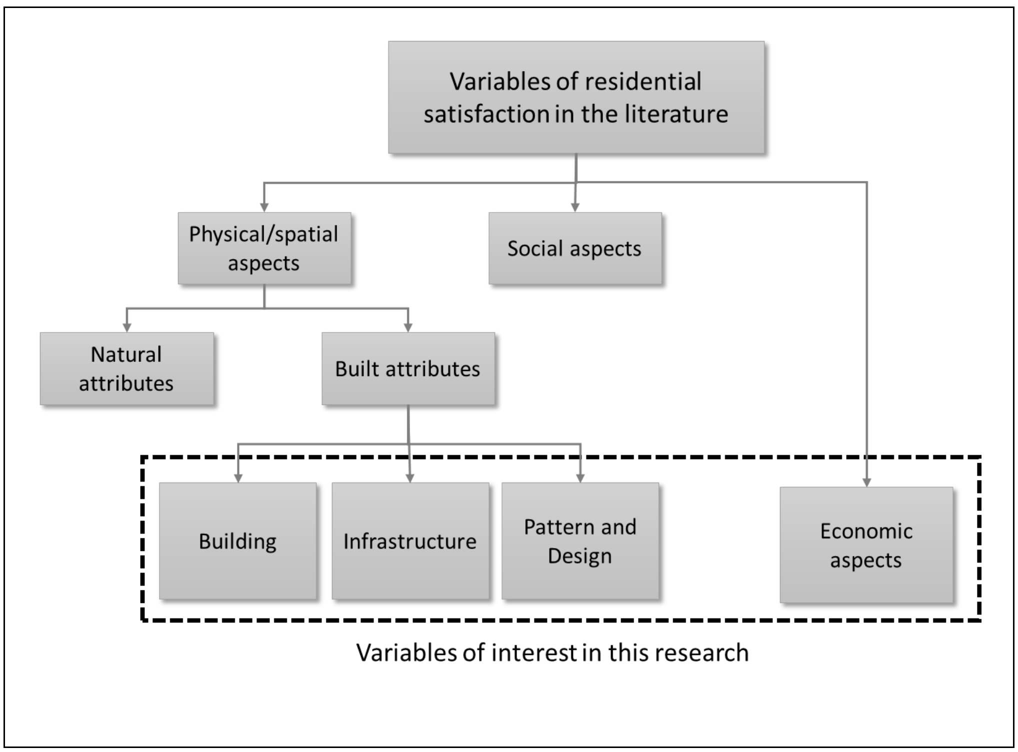

Figure 2.2 Residential satisfaction variables and the focus of this research

2.8.1 Social Aspects

Although social aspects are not the focus of this research, the effects of these aspects cannot be ignored in affecting residential satisfaction, as research has found a variety of social aspects as important determinants of residential satisfaction (Teck-Hong, 2012; Vemuri et al., 2011). Several ways have been suggested to evaluate the social aspect of sustainability among which social capital is highlighted. Social capital defines the value of social networks and the norms of interactions arising within those networks (Rogers et al., 2013).

Social capital consists of two components. The term “social” implies the relationships and interactions that exist in the network, which is impacted by the environment. The term “capital” can be considered as different forms of output from the benefits of collective actions among society members (Yoo & Lee, 2016). Social capital is sometimes considered equal to “social sustainability” as it is found to be a key theme or contributing factor of social sustainability (Siner et al., 2004 as cited in Yoo & Lee, 2016). However, it should be noted that these two concepts are not the same. The idea of considering social capital as an important indicator of sustainability is more reasonable and will be discussed in the following section.

2.8.1.1 Social Capital: A Key Indicator of Social Sustainability and Satisfaction

Scholarly research has illustrated a strong linkage between the desired sustainability outcomes and social capital (Airriess, Li, Leong, Chen, & Keith, 2008). Researchers have found many situations that social capital can be useful in achieving sustainability. These situations include, but are not limited to, collective action regarding environmental issues (Pretty & Smith, 2004), bringing more resiliency to organizations and communities (Airriess et al., 2008), environmental education engagement strategies (Miller & Buys, 2008), and protecting ecosystems. Such actions show that many important issues can be addressed as the consequence of social capital and therefore it can be a desirable goal in and of itself.

As noted above, a variety of desirable environmental and sustainability outcomes are associated with social capital (Rogers et al., 2013). However, a mutual interaction exists between the physical environment and social capital, which is formed through the connections and lives in networks among people. Therefore, there is a need for a space for interaction in the development of social capital. This emphasizes the importance of the residential environment in developing social capital. Studies by Leyden (2003) and Kamruzzaman et al. (2014) have demonstrated that macro-scale factors, such as neighborhood type, walkability, density, and land use have relationships with social capital and social sustainability. Cloutier and Pfeiffer (2015) state that social relationships and consequently social capital are directly affected by neighborhood characteristics or conditions of the built environment, such as street connectivity, housing design, and density, the availability of public spaces, and land use mix. Moreover, several researchers have demonstrated relationships among social cohesion and urban form and density (Brueckner & Largey, 2008; Freeman, 2001; Leyden, Goldberg, & Michelbach, 2011; Mason, 2010). However, they believe that the direction of these relationships is controversial.

The awareness about the role that social relationships play in residential satisfaction is growing (Leyden et al., 2011; R. Lucas & Dyrenforth, 2006). Preventing isolation is the outcome of having relationships with others, which may be reflected as a key to long-term happiness and wellbeing (Hawton et al., 2011). When we can rely on our relationships to get things done, social relationships will lead to social capital (Coleman, 1988; De Souza Briggs, 1997). In fact, social capital forms and grows when we can trust and mutually interact with one another and share common social norms (Coleman, 1988).

Some researchers believe that people living in communities with rich social capital are not willing to move away from their neighborhoods (Kan, 2007) and this shows the importance of social capital in satisfaction with the living environment. Moreover, considering the high importance of long-term residents in providing social sustainability (Nicola Dempsey et al., 2011), social capital directly contributes to the sustainability of residential communities (Kan, 2007). This has been demonstrated by empirical studies showing the positive impact of social capital on social sustainability (Yoo & Lee, 2015).

2.8.2 Economic Aspects

With the growth of environmental challenges as a result of human behaviors, recent approaches toward creating a sustainable built environment have focused mostly on regulating human behaviors toward the environment. In order to provide a comprehensive understanding of the extent to which a sustainable development project is successful, the economic aspects of these projects should also be considered. If the economic aspects of a project are not considered, it can hardly be considered a successful project (Chan et al., 2002; Ramlee et al., 2016; Sebestyen, 2017). Therefore, it is important to approach project success from a cost-performance perspective (Toth & Sebestyen, 2018). The simplest way to evaluate the cost performance of a project is to find the relationship between budgeted cost and actual cost. However, this does not provide a real insight into the cost performance of a project but provides only an idea about the cost performance in the construction stage. To accurately picture the cost performance of a project, it is necessary to consider the economic aspects after construction is completed as the long-term cost performance. It is a very crucial determinant that should be considered in evaluating the economic success of a project (Ramlee et al., 2016).

Therefore, both from a sustainability point of view and from the perspective of project success, the cost performance of a project at the time of operation should be evaluated.

To achieve a real understanding of the cost performance of a project, it is important to evaluate it from a long-term and comprehensive point of view. According to Ramlee et al. (2016), one of the most important dimensions of project success is the financial performance for end-users as they are the only stakeholder that is encountered with both short-term and long-term costs of the building. Furthermore, since a variety of geographical, social, and administrative factors affect the costs of operating a building or residential community, each community has unique characteristics that provide the costs of building operation. Therefore, the cost performance of different communities cannot be easily evaluated and compared based on fixed and predefined criteria. Finally, as the same amount of money can mean different for people with regard to cost-benefit evaluation, it is important to find out the perception of people toward the costs and cost performance of the project rather than only calculate the costs and values. This highlights the role of users' evaluation in providing an accurate cost performance of their community.

The economic evaluation from the end user's point of view is affected directly by the unit value and associated costs of the building. It is discussed that energy conservation, carbon reduction, and water preservation approaches, especially in the commercial and residential sectors, have higher preliminary costs in comparison with conventional ones. However, it has been demonstrated that such developments not only compensate for the preliminary cost differences but also provide many financial benefits throughout the project's lifecycle (Chang et al., 2011). Here, it should be considered that other than utility costs, there are many costs associated with a living environment that potentially affect the cost performance of these projects including purchase/rent costs, taxes and fees, maintenance costs, and other associated costs such as transportation, fuel, cost of access and use of amenities, and other community-specific charges. In this regard, the concept of affordability becomes highlighted to be coupled with sustainability in determining the successful performance of the residential projects (Adabre & Chan, 2019).

The integration of affordability and sustainability into housing and residential development defines sustainable affordable housing as “housing that meets the needs and demands of the present generation without compromising the ability of future generations to meet their housing needs and demands” (Pullen et al., 2009, as cited in Adabre & Chan, 2019). A list of success criteria is provided by Pullen et al. (2009), regarding the three sustainability factors in which some considerations are suggested for economic sustainability focusing on the rent or mortgage payment of a housing facility, the location of the facility, the size and quality, and stress reduction potentials of residential buildings. Chan et al. (2002) define the appropriate cost performance of a building as the state of certainty both for paying and paid parties to the financial results and profitability considering the costs and benefits. Therefore, in this research, the economic and affordability from the end-users points of view are considered to evaluate the cost performance of sustainable residential projects.

As discussed previously, the economic aspects of a development project should be considered in the evaluation to get a realistic understanding of the success of the project. The cost performance of a development project can be evaluated both objectively and subjectively. Objective measures can easily be evaluated based on the data gathered from the project's financial performance including construction cost, the unit value in the market, maintenance fees, and operation fees while subjective measures are very critical and sometimes difficult to achieve since they need to be evaluated from the users' points of view.

Several factors exist in the construction and operation stages of a project that influence the costs and values of buildings. One such factor, which is impossible to control for is the building's geographical location. This generates uncertainty in the objective evaluation of cost performance. For instance, we cannot compare the cost performance of two very similar buildings that are located in different cities and even different neighborhoods in the same city. Therefore, it is important to understand also the cost performance of the projects from users' points of view to get a clear picture of this factor. Furthermore, as the same amount of money can have different meanings for people with regard to cost-benefit evaluation considering all the affective factors, thus it is important to evaluate the perception of residents toward the costs and cost performance of the project rather than only calculate the costs and values. Therefore, in this research, subjective economic attributes of residential projects collected from the existing literature have been considered for evaluation to provide a realistic view of the cost performance as a potential predictor of residential satisfaction and project success. The potential cost performance attributes are shown in Table 2.1.

Table 2-1 Economic attributes

Variable	Attribute	Reference
Cost performance	Home value/rent	Sirgy and Cornwell, 2002; Galster, 1987; Lansing et al., 1970; Lu, 1999; Russ-Eft, 1979
	Costs of living in the community	Sirgy and Cornwell, 2002; Galster, 1987; Lansing et al., 1970; Lu, 1999; Russ-Eft, 1979
	Community improvement rate	Sirgy and Cornwell, 2002; Miller et al., 1980

2.8.3 Physical Attributes

Among the discussed attributes, the physical attributes are very important factors influencing the satisfaction of residents (Herting & Guest, 1985). Several researchers have demonstrated that housing and neighborhood physical elements are more influential on residential satisfaction compared to socio-demographic factors (e.g. Parkes et al., 2002; Hur & Nasar, 2014; Lee et al., 2017). According to Sirgy and Cornwell (2002), satisfaction with the physical features of the entire neighborhood contributes significantly to one's satisfaction with the home. Therefore, it is crucial to evaluate the physical attributes that define housing conditions and neighborhood environments from the residents' points of view in order to understand the levels of residential satisfaction and identify and rate each attribute's weight of contribution to the satisfaction of the residents.

Several attributes have been evaluated individually or in combination with others as the physical predictors of housing satisfaction. Yaman et al. (2018) considered "sufficient street lighting", "sufficient designated green area", "reduced or recycled water practices", "generation or the use of renewable energy", "infrastructure services efficiency", and "bio-diversity reserved availability" as physical determinants of residential satisfaction. Lee et al.

(2017) evaluated “land use mix–access”, “land use mix–diversity”, “residential density”, “walking/cycling”, “street connectivity”, “facilities”, “aesthetics”, “safety from crime”, “pedestrian/traffic safety”, and “park access” as physical determinants of residential satisfaction. Bonaiuto and Fornara (2017) investigated factors such as “building aesthetics”, ‘building density”, “building volume”, “external connections (with the city)”, “internal practicability”, and “green areas (presence and care)” as spatial predictors of residential satisfaction.

Among all physical factors, density (Owen, Humpel, Leslie, Bauman, & Sallis, 2004; Saelens, Sallis, Black, & Chen, 2003; Sallis et al., 2009a; McCulloch, 2012; Van Dyck, Cardon, Deforche, & De Bourdeaudhuij, 2011), access to the park and open spaces (e.g. Bjork et al., 2008; Pfeiffer and Cloutier, 2016; Miller et al., 1980; Russ-Eft, 1979; Kweon et al., 2010; Lee et al., 2008), physical upkeep and efficiency of maintenance (e.g. Hur & Nasar, 2014; Kruger, Reischl, & Gee, 2007) and land use mix (Ellis et al., 2006; Kweon et al., 2010; Yang and Stockard, 2013) have been focused on more than others. Sirgy & Cornwell (2002), and Salleh (2012) listed the physical features of the neighborhood that have been mostly evaluated through residential satisfaction research as: “homes and yards”, “neighborhood landscape and street greenery”, “street lighting”, “proximity to neighborhood facilities and amenities”, “noise level and crowding”, and “environmental quality in the neighborhood”.

CHAPTER 3 : METHODOLOGY

3.1 Summary of Goals and Objectives

This research aims to develop a robust model for the assessment of the long-term success of sustainable housing development projects from users' points of view to find the relationships among sustainability, residential satisfaction, and the performance of those projects. The research is premised on physical changes that achieve sustainability while affecting the satisfaction of residents. The objectives of the study are as follows:

Objective 1: Develop a multi-phase framework that evaluates the relationships between sustainability, satisfaction, and performance of the built environment in residential communities.

Objective 2: Investigate the associations between sustainability and actual performance of LEED-certified residential communities and the interaction effect of climate on this relationship.

Objective 3: Develop and validate a model to evaluate the associations between the perceived performance and satisfaction of sustainable LEED-certified residential communities and Identifying the key determinants of residential satisfaction in sustainable communities.

Objective 4: Develop a multigroup comparison analysis to examine the effects of sustainability on providing residential satisfaction and the perceived performance of the built environment in residential communities.

3.2 Research Framework and Study Phases

In this study, a post-construction evaluation is conducted to evaluate the long-term success of LEED-certified residential communities both objectively and from users' points of view. Considering LEED-certified residential communities as the context of this research, the users' evaluation of the neighborhood, building, and infrastructure performance is investigated to provide an understanding of the long-term success in the post-construction stage of these projects. This study consists of two phases:

Phase I: This phase evaluates the actual performance of infrastructure and the physical form of LEED-certified residential communities and their success in meeting sustainability standards. The relationships between sustainability (based on LEED scores obtained from the US Green Building Council) and infrastructure performance, and the physical form of these projects are analyzed to understand the extent to which the performance of selected infrastructures are in accordance with the level of sustainability of the projects. This phase does not include the perception and satisfaction of the residents and objectively evaluates the relationships between the influence of the infrastructure and physical form on predicting the level of sustainability.

Phase II: In this phase, after validating the measurement instrument, a model is developed and validated to provide a post-occupancy evaluation of the long-term success of LEED-certified residential communities to understand the relationships between the perceived performance of infrastructure, building, and neighborhood features, cost performance, and user satisfaction in LEED-certified residential communities and identify and rate the key determinants of residential satisfaction in sustainable LEED-certified residential communities. A multigroup comparison analysis is also conducted in this phase to assess the possibility of conducting a cross-sectional evaluation and compare the level of satisfaction and perceived physical and cost performance of the built environment between sustainable and conventional projects. As noted previously, the developed conceptual model in the literature review is used to form the relationships between performance and satisfaction in sustainable communities. The framework of the research method is shown in Figure 3.1.

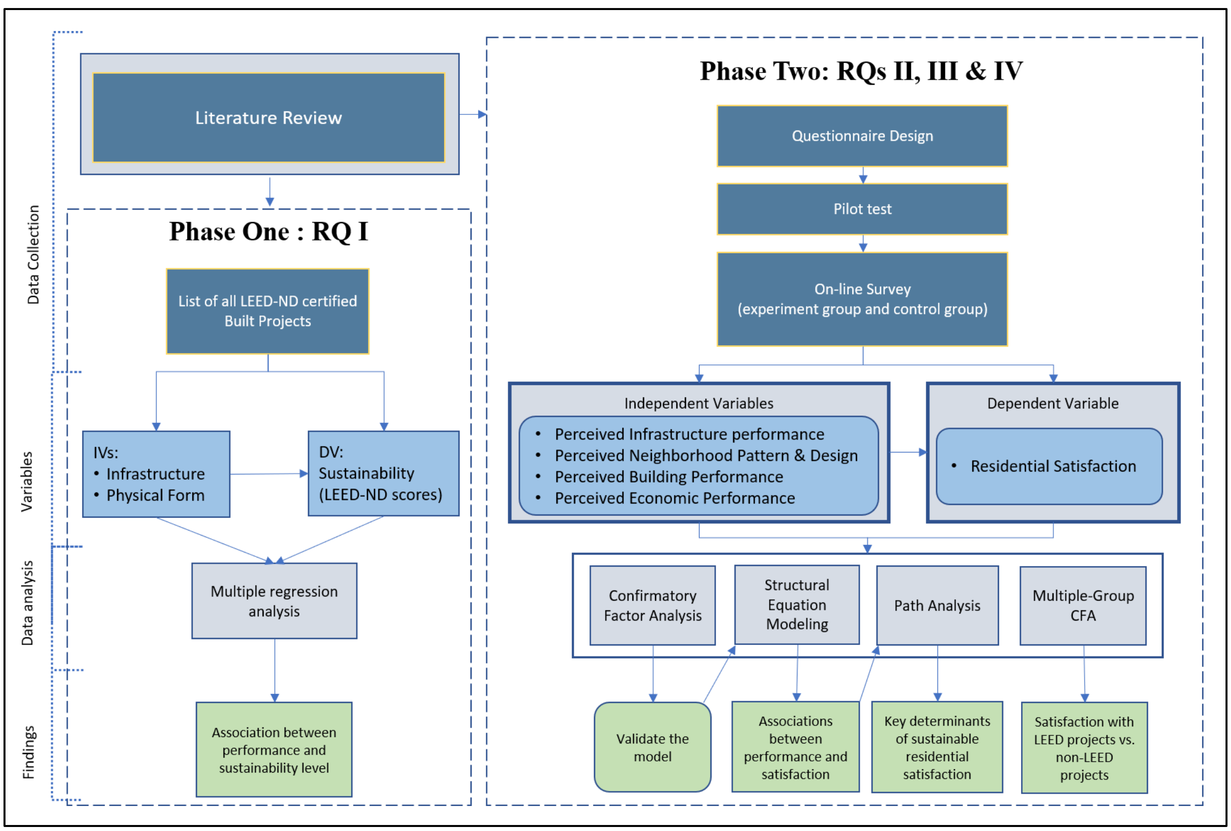

Figure 3.1 Research framework

3.3 A Conceptual Model For Evaluating The Relationships Between Long-Term Success Factors

The development of a model for evaluation of the long-term success of sustainable communities from users' points of view needs the evaluation of a variety of physical features and economic aspects. Thus, a review was conducted to find the main physical and economic attributes of sustainable communities that have potential associations with the perceived performance and satisfaction of the residents. The model for evaluating the project effectiveness of sustainable communities combines indicators and methods from different research findings and sustainability indices to achieve the ultimate goal of this research. Based on the review of the theories, conceptual models, and processes regarding residential satisfaction and users' assessments of the built environment performance, a multi-dimensional evaluation model is developed to help this study find the relationships between sustainability, physical performance, cost performance, and satisfaction as the long-term success factors of sustainable projects. The model is a combination of several components each of which is measured through one or a few variables or indicators (Figure 3.2).

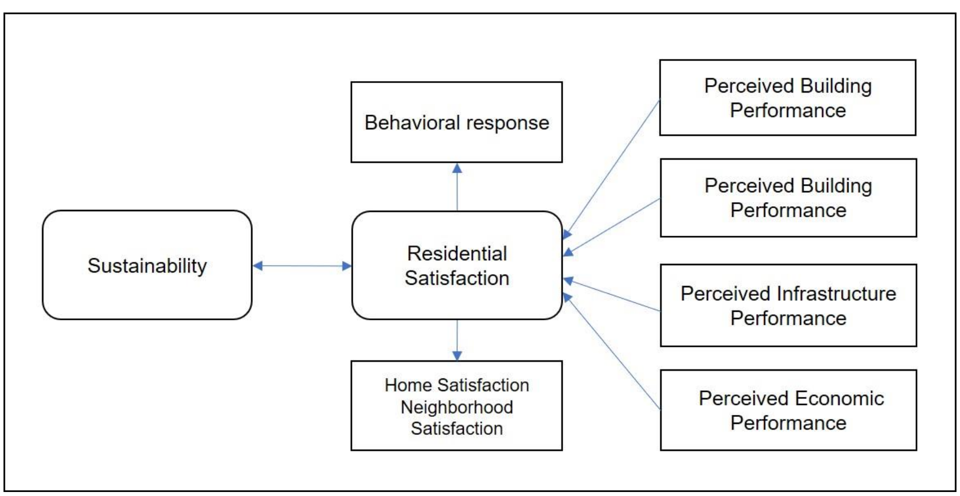

Figure 3.2 Conceptual model of long-term success factor interactions

3.4 Phase I

3.4.1 Data Collection

The data for the first phase of the study was collected from publicly available sources. More specifically, the data about the level of sustainability was obtained from the US. Green Building Council (UGBC) website providing a LEED-ND score for each project that is certified under the LEED certification system. This number varies between 40- 110 with 40-49 being LEED-Certified, 50-59 being LEED-Silver, 60-79 being LEED-Gold, and above 80 is considered as LEED-Platinum. The data about the actual performance of walking infrastructure, cycling infrastructure, and transportation infrastructure was obtained from “walkscore.com”, which provides a number between 0 to 100 for each project based on specific pre-defined criteria. The data about the physical form of each project focused on the residential density, which was calculated from the number of dwelling units per project divided by the constructible acreage of the project.

Study Areas: The first phase of the research is an extensive evaluation of the relationships between the sustainability level of LEED-ND projects (based on their LEED-ND scores) and their actual performance of infrastructure attributes such as walk score, bike score, and transit scores. The residential density of each project is also calculated to provide a picture of the relationships between physical arrangements as the baseline for sustainable community development. In order to provide valid and generalizable results, a long list of all LEED-ND certified built projects were provided and their sustainability characteristics such as credit scores, location, etc., were collected from the US. Green Building Council (USGBC) website (www.usgbc.org). To find the list of LEED-ND certified built projects, “LEED-ND: Built Projects” was selected under the “rating system” tab and a filter was applied for “the United States” from the “country/region” tab. In order to create only the list of projects that have already been certified, another filter was applied by putting the “certification date” before April 01, 2021. As a result, 102 projects were found that included all LEED-ND certified built projects in the US by the date. The list of LEED-ND projects and some of their important information is shown in Appendix A.

3.4.2 Research Variables and Analysis Method

The first phase analyzed the objective data collected about the physical environment and the infrastructure performance of the studied projects and provides an analysis of the relationships between actual performance, physical characteristics, and level of sustainability. This phase answers the first research question, which will be discussed in the following section.

RQ1: How is the level of sustainability associated with the performance of infrastructure and physical elements of LEED-certified residential communities? This research question meant to test hypothesis H1:

H1: The actual performance of walking infrastructure, public transit infrastructure, biking infrastructure, and neighborhood density have positive and significant relationships with sustainability.

Variables: The dependent variable for this question is the level of sustainability, which is measured by the overall LEED-ND score of each project. The data for the sustainability score is achieved from the USGBC website (discussed previously). The independent variables that have been considered for this research question are demonstrated in the literature to be the most important factors in evaluating community sustainability and are either publicly available or can be calculated based on public data. The independent variables for this question are “walk score”, “bike score”, and “transit score”, as well as “residential density”. The first three factors represent, in part, the performance of sustainable infrastructure while the fourth factor represents the number of dwelling units per acre of the total area of a project. Climate has been considered as the moderator in this research question in order to understand its interaction effect on the relationships between the actual performance of the infrastructure and the neighborhood sustainability score.

Analysis method: After finding the data for the dependent and independent variables, a multiple regression analysis was conducted to find the associations between sustainability and the performance of infrastructure and residential density. Furthermore, in order to understand if the relationship between any of the independent variables and the dependent variable is affected by climate, the interaction effect of climate was analyzed through an Analysis of Covariance, which is usually used to test the interaction effect of a categorical variable (climate) on a continuous variable (LEED score).

3.5 Phase II

3.5.1 Data Collection Method

The data collection method for the second phase was an online survey of the residents of LEED-certified residential communities as the experiment group and similar non-LEED residential communities as the control group. The reason for choosing an online survey was the convenience of this method both for surveyors and participants as the case studies are projects located in geographically different locations. Furthermore, due to the COVID-19 world pandemic, it was assumed that people prefer to do online survey rather than opening letters that are mailed to their address. The data collection was conducted using a structured questionnaire. The survey took eight months to complete (August 2020-March 2021). More details about the survey and the data collected for this phase are discussed in the following sections.

The target population for the second phase of the research was residents of sustainable communities. Due to the environmental and economic advantages as well as the social desirability of sustainable communities, there is a growing tendency toward developing such residential areas. Therefore, in the near future, the number of residents of sustainable communities will be significant, and considering this population as the main focus of the research seems crucial.

3.5.2 Recruitment Strategy and Criteria

As conducting a random sampling among all residents of sustainable residential communities was not possible at the time, the method of multistage sampling (cluster sampling) was followed in the first place. In this regard, 6 LEED-certified residential communities were selected initially as the experimental group and 6 conventional residential communities were considered as the control group to be surveyed. In order to enhance the generalizability of the research, projects were selected to represent the three types of climates including cold climate, moderate climate, and hot climate.

To be more specific about the study areas, some additional criteria were considered in selecting projects. In order to select the experimental group, the list of 102 LEED-ND projects provided for the first phase was categorized based on the US. Department of Energy (DOE) climate zones and International Energy Conservation Code (IECC). To make sure that all the selected projects are occupied for at least one year from the time of the survey, only projects that were completed before 2017 were considered for surveying. Also, individual buildings in each project were investigated and only the projects whose buildings were "LEED-BD+C Homes" or "Multifamily Midrise" certified were considered in order to provide a more accurate evaluation of sustainability both in the community scale and in the building scale. Furthermore, a combination of housing types such as apartments, townhomes, and condominiums with different sizes was considered to represent the opinions of people with different tastes, preferences, and expectations.

In summary, the following criteria were considered for selecting sustainable projects:

- The entire project must be LEED-certified
- The project must be completed earlier than 2017.
- Individual residential buildings must be certified as LEED BD+C Homes or Multifamily Midrise

A control group was also considered for participant surveys in order to provide responses from non-LEED community residents to be compared to the experiment group in terms of perceived performance and satisfaction. The control group included conventional communities or the communities that were not recognized as sustainable projects. To be able to provide a reasonable and reliable comparison, a set of criteria for choosing conventional projects was considered to make sure that the responses were coming from a group comparable to the experiment group. Therefore, the residents of multifamily residential projects and master-planned communities that were built after 2005 were considered as the control group.

3.5.3 A-priori Sample Size Estimation

As the data analysis plan is the first prerequisite in estimating sample size (Fowler, 2012), it was important to plan a clear analysis method before sampling. This research is a multi-phase study and consists of multiple analysis methods. Therefore, the required sample size for each analysis was estimated to assure that the findings of the research are reliable. G*Power version 3.0.10 was used to calculate the “a-priori” sample size for this study. This program calculates sample sizes specifically for each data analysis method using expected statistical power (1-β), significance or alpha level, and the effect size. The statistical power is the probability of not making a Type II error; in other words, the power is “the probability that a statistical test will produce a difference between the groups tested at a given level of significance” (Bowling, 2005). The level of significance (alpha level) is “the level of acceptable risk the researcher is willing to accept that the true margin of error exceeds the acceptable margin of error” (Bartlett, Kotrlik, & Higgins, 2001). The effect size indicates the strength of the relationships (Hibberts, Johnson, & Hudson, 2012), which consists of three levels: small, medium, and large (Cohen J., 1988). The numeric amount for each level varies based on the analysis plan.

As shown in the research flow, in this study, multiple regression analysis groups and structural equation modeling (SEM) are the main analysis methods. Therefore, I calculated the ideal sample size for these two analyses to consider as the target sample size. In the calculation of sample size, the medium effect size (Cohen J., 1988) is considered to be appropriate (Balkin & Sheperis, 2011; Bosco, Aguinis, Singh, Field, & Pierce, 2015; Trafimow & Myüz, 2019), the minimum power is established at 0.8, and an alpha level of 0.05 is considered for estimating the required sample size (Gideon, 2012; Hibberts et al., 2012; Lipsey, 1990). Calculating the sample size as a function of these variables; a sample size of 84 was estimated to be appropriate for multiple regression analysis with four predictors, which is conducted in the first phase of the research. For SEM, a sample size of 150 was calculated as the recommended minimum sample size to detect the effect for 5 latent factors and 26 indicators. Therefore, a goal of a minimum sample size of 150 participants was established in order to increase the generalizability of the research.

3.5.4 Sampling

When the population of interest is large, sampling is a strategy to obtain enough sample, which represents the population. The likelihood that a sample reflects the entire population increases when a large random sample is considered. The sample should include individuals with similar characteristics to the entire population in order to be able to draw accurate conclusions about the population. Therefore, it is vital to identify the population accurately. One important point in the representativeness and adequacy of the sample is the participant recruitment strategy used in the research. Using different strategies for participant recruitment help ensure adequate coverage of the population and improve the sample size.

The sampling method in this research initially was a multi-stage sampling in which within each project selected for sampling, individuals were eligible to participate if they were residents of the community for at least six months and were older than 18 years. In order to reach out to target samples, phone contact was made to the property management/leasing office of the listed LEED-ND projects and after describing the research and its procedure, they were asked to share the link of the online survey with their community residents via emails. In order to motivate residents to spend time on the survey, a $5 Starbucks gift card was considered for the first 30 legitimate respondents that completed the survey from each community.

Among over 70 projects that were contacted only 9 agreed to distribute the questionnaire through sharing the online survey link. This first round of data collection took over 5 months from September 2020 to February 2021. However, even among the few LEED-certified community residents that supposedly received the questionnaire in this round, few residents participated in the survey (N=39). Some potential reasons for this lack of response could be the lack of interest in participation due to the COVID-19 pandemic and presidential elections that possibly could negatively affect the willingness of people to participate in online surveys as they were all intruded with multiple opinion surveys throughout the campaign season. After several follow-ups, the number of collected responses reached 59 for LEED-certified residential communities. Therefore, the data collection strategy was revised to include the use of social media for recruiting participants.

In order to make sure that only legitimate individuals participated in the survey shared on social media (LinkedIn and Facebook), prequalification conditions were defined for the individuals to meet in order to be able to participate. The conditions were listed in the survey invitation letter, which made only the individuals eligible to participate if they were living for more than six months in multi-family residential buildings or master-planned communities that were built after 2005. Two additional questions were also added, one asking if the participants were living in a LEED-certified community and the second was an attention check question designed to filter out robots and the individuals that did not pay attention to the questions. In order to motivate the participants to participate in the survey, they were a $5 Starbucks gift card to complete the survey. In this round of the survey, which took 4 weeks, 132 responses from non-LEED communities and 27 responses from LEED-certified community residents were collected. This made the total of LEED responses reach 86, which still did not satisfy the minimum sample size recommended by the a-priori power calculations for structural equation modeling.

Therefore, another round of data collection was conducted with the help of Centiment Research Services, which provides different services regarding all the stages of research including data collection. In this round of the survey, 107 additional responses were collected from LEED-certified community residents in 3 weeks. Each response cost $9.75 in this round of the survey and brought the total valid responses for LEED-certified residential communities up to 192.

3.5.5 Survey Instrument

A structured questionnaire was developed as a survey instrument for this research (Appendix C). After running a pilot study to test the questionnaire and coding the questions, the seven-part questionnaire contained:

Part 1: Introductory questions regarding the understanding of participants about the sustainable built environment.

Part 2: Questions regarding the perceived performance of infrastructure, building, and neighborhood as the measurements for independent variables.

Part 3: Questions regarding satisfaction with the neighborhood and building features, and behavioral intentions, as measures to identify the dependent variable.

Part 4: Questions regarding the preference of different attributes at the time they searched for a home, as the measurements for implicit importance analysis.

Part 5: Questions to evaluate the explicit evaluation of overall satisfaction, perceived overall performances against expectations, and questions to determine explicit contributors to residential satisfaction from the users' points of view as control variables.

Part 6: Socio-demographic questions.

3.6 Research Variables and Analysis Method

This phase of the research is concerned with the subjective data that are collected through a survey to answer the other three questions of this research. This phase uses a structural equation model (SEM) to address research questions 2, 3, and 4. A confirmatory factor analysis (CFA) is used to validate the latent constructs that are used in the context of SEM. Path analysis is conducted to find the relationships between the single observed indicators and the dependent variables, and multiple-group factor analysis is performed to compare the latent factors between the experiment and control groups. In the following sub-sections, the variables and the analysis method for addressing the research questions are discussed.

As noted previously, although numerous studies have delved into residential satisfaction (e.g. Cloutier et al., 2018, 2014; Hur & Morrow-jones, 2008; Hur et al., 2010; Mccrea, Stimson, & Western, 2005), less research has been found to focus specifically on the physical environment attributes (Buys & Miller, 2012; Gifford, 2007). Furthermore, the studies that are concerned about the satisfaction of residents with their physical environment either focus on one attribute (e.g., green space, density, physical appearance, etc.) or consider a combination of the natural and built features as determinants of residential satisfaction. This combination is misleading as natural features' entities are different than the built features and these two groups cannot be measured with the same scale. Such a combination may deviate the attention of the researchers from some of the most important physical features that create the main structure of each community namely buildings and infrastructures.

It is important to distinguish the natural and built physical features and focus merely on one category of attributes in order to provide a more accurate outcome. In the case of this research, the focus is on the built physical attributes. Furthermore, whilst it is well-understood that certain physical environment attributes are correlated with environmental sustainability considerations, it is less clear whether those are also positively associated with residential satisfaction. It is also important to understand which elements among all physical attributes are more important in providing residential satisfaction. Therefore, in this research, there is a focus on the built physical attributes that are associated with sustainability and their importance and performance from the residents' points of view as well as their impacts on the level of satisfaction.

Built attributes of the physical environment that are the concern of this research, can be classified into three main groups of buildings, infrastructures, and neighborhood features. Due to the focus of this research, we focus on these attributes as the main variables creating the structure of the built environment in the housing development projects. Furthermore, since the concern in this research is evaluating the long-term success of sustainable residential projects from the users' point of view, it is important to consider features that are specific to sustainable communities.

The focus of this research is the evaluation of the built attributes of the physical environment in the LEED-certified residential communities to determine the success of these projects from the users' points of view. Therefore, the variables that are the indicators of sustainability will be considered for evaluation. As such, the physical attributes provided in the LEED-ND standard will be adopted as variables to evaluate the performance and satisfaction of these projects from the users' points of view. However, since in the LEED-ND standard, a combination of buildings, infrastructure, and the neighborhood is highlighted and there is an emphasis on compact development through the development of multifamily residential buildings, the variables from LEED BD+C Multifamily Midrise are also playing role in determining the performance of these projects. Therefore, along with LEED-ND, LEED BD+C Multifamily Midrise will also be considered for defining the research variables. As being LEED-ND certified overlaps with several factors in LEED Multifamily Midrise criteria, only the relevant items that exist in the latter and do not exist in the former will be added to the list of evaluation attributes.

In order to define the attributes based on LEED-ND and LEED Multifamily Midrise, it is necessary to first discuss the relevant attributes provided in these two systems. In the following sections, these criteria are discussed and tabulated to provide a poll for selecting the variables of concern for this research.

3.6.1 Green Infrastructure Attributes

Infrastructure can impact human lives tremendously. Adequate and efficient infrastructures and services serve as a foundation for building the environment and are essential for community health, safety, and quality of life (Humboldt County General Plan for the Areas Outside the Coastal Zone, 2017). The benefits of good infrastructure for a community can be summarized as improved health and aesthetics, enhanced quality of life, improved safety of residents, enhanced community vitality, reduced household costs, and providing employment and job opportunities. The construction of effective infrastructure has long been a motivation for advancing and supporting economic development. Developers, businesspersons, and inhabitants are attracted by adequate "on the ground" infrastructure. This implies ample water, sanitary sewer, electricity, transportation, communication resources, and other supporting civil infrastructure. Another broad category of infrastructure is "inbuilt infrastructure", which is a part of housing development, such as waste management, utility lines, etc. (Colorado Aerotropolis Visioning Study, 2016). Table 3.1 shows the sustainable infrastructure variables as the potential measures of perceived performance.

Table 3-1 Sustainable Infrastructure variables

Variable	Attribute	Reference
Infrastructure	On-site renewable energy sources	LEED-ND
	District heating and cooling	LEED-ND
	Infrastructure energy efficiency	LEED-ND
	Wastewater management	LEED-ND
	Recycled content in infrastructure	LEED-ND
	Solid waste management infrastructure	LEED-ND
	Light pollution reduction	LEED-ND
	Stormwater management	LEED-ND
	Water-efficient landscaping	LEED-ND

3.6.2 Green Building Attributes

Buildings, as the main physical component of the built environment, need to be considered in any research concerning residential development projects. As pointed out, a review of the most popular building and community sustainability standards and systems (e.g., LEED-ND and LEED BD+C) and the existing literature regarding sustainable housing and community development assisted this study in defining key building attributes that can be considered for sustainable residential development evaluations. In the case of building evaluation, the criteria for evaluation of satisfaction with the indoor environmental quality have been adopted from the Center for the Built Environment (CBE), as one of the most populous criteria for this evaluation. This provides the opportunity to compare the satisfaction with the indoor environmental quality of green buildings with the benchmark established based on the evaluation of a large number of buildings. In this part, the perceived performance of buildings in the study areas is expected as the determinants of residential satisfaction. Table 3.2 shows the building sustainability evaluation variables as the potential measures of perceived performance.

However, in this research, due to the limited scope, we may not consider all features in determining the level of satisfaction with sustainable projects.

Table 3-2 Sustainable building variables

Variable	Attribute	Reference
Buildings	Building energy efficiency	LEED-ND
	Building water efficiency	LEED-ND
	Solar Orientation	LEED-ND
	Utility Tracking	LEED-BD+C
	Building Materials Used	LEED-BD+C
	Indoor Environmental quality	LEED-BD+C; CBE

3.6.3 Neighborhood Pattern and Design

As a neighborhood is a combination of buildings, infrastructure, and social factors, one important aspect determining the function of this combination is the design and layout of components. A system with the same components can function either extraordinary or poor dependent on the design and patterns that determine the interactions among components. Therefore, it is important to consider design factors in evaluating the performance of the built environment.

As discussed previously, taking advantage of the defined design variables in LEED-ND, the design and pattern of the LEED-ND projects will also be evaluated from the user's point of view. These variables are indicated in Table 3.3. However, due to the specific focus of this research, not all the listed variables will be used and only the most relevant ones will be selected to be evaluated from users' points of view.

Table 3-3 Neighborhood Pattern and Design variables

Variable	Attribute	References
Neighborhood Pattern and Design	Walkable streets	LEED-ND
	Access to recreation facilities	LEED-ND
	Visitability and universal design	LEED-ND
	Community outreach and involvement	LEED-ND
	Local food production	LEED-ND
	Tree-lined and shaded streets	LEED-ND
	Compact development	LEED-ND
	Access to schools	LEED-ND
	Mixed-use neighborhood centers	LEED-ND
	Mixed-income diverse communities	LEED-ND
	Reduced parking footprint	LEED-ND
	Street network	LEED-ND
	Transit facilities	LEED-ND
	Access to civic and public space	LEED-ND
	Bicycle network and storage	LEED-ND
	Housing and job proximity	LEED-ND

3.6.4 Research Variables

The independent variables in this phase of the study are measured via the “cognitive process”. To collect the data for this purpose, the participants were asked to rate the specific attributes of their living built environment based on their perceived performances. More specifically, the residents were asked to rate the perceived performance of each attribute on a seven-point Likert scale with 1 being “very poor” and 7 being “very well”. The key attributes that were considered as variables included only the sustainability-specific attributes, obtained from LEED-ND and LEED-BD+C Multifamily Midrise and Homes standards, including infrastructure attributes, building attributes, and neighborhood pattern and design attributes to measure the physical performance of sustainable communities. Furthermore, a set of self-developed economic attributes are considered that are obtained from the literature to evaluate the cost performance of the communities. Each attribute is measured through a number of questions about the specific features under its category.

The dependent variable is “overall satisfaction” with the neighborhood built environment and home. The overall satisfaction is evaluated from the two sets of processes. First is the “affective process”, which consists of questions asking the level of satisfaction with home and neighborhood from the residents’ points of view (Weidemann & Anderson, 1985). The second set of variables is achieved from the “behavioral process” including a set of questions asking about the residents’ intentions to behave in response to the current attributes and general condition of their residential community (Weidemann & Anderson, 1985).

In the “affective process”, the level of satisfaction with their home and community is asked to be rated from (1) being very dissatisfied, to (7) being very satisfied. In the behavioral process, questions are asked to find the residents' intention to behave from pre-defined behavior responses toward their homes and communities. Each question evaluates the level of agreement of the participants with a pre-defined response from (1) being very disagreed to (7) being totally agreed. The analysis of affective and behavioral processes provides the dependent variable of “overall satisfaction” with each community, which will be considered for further analysis. Tables 3.4, 3.5, and 3.6 summarize the variables used in this study and the measures that are considered for assessing the constructs.

Table 3.4 Measures for analysis of performance

Variable	Attribute	Measure
Infrastructure Performance (Modified from LEED-ND)	On-site renewable energy sources	• Renewable energy sources such as solar panels, wind turbines, solar thermal, etc.
	District heating and cooling	• Central heating and/or cooling system in the neighborhood/complex
	Waste management infrastructure	• Recycling facilities
	Outdoor lighting	• The appropriateness of street lighting and building exteriors during the night
	Rainwater management	• Rain gardens Bioswales, drainage system, and rainwater collection system
	Outdoor water efficiency	• Water-efficient landscaping
	School proximity	• Access to high-quality schools
	Transit facilities	• Accessibility of public transport
	Bicycle network and storage	• Connected biking paths in the neighborhood • Availability of biking racks and storage
	Road quality	• Road cover quality
Building Performance (Adopted from LEED-BD+C, CBE Survey)	Building energy efficiency	• The efficiency of the hot water distribution system • The energy efficiency of the heating/cooling system (based on your utility bills)
	Building water efficiency	• The water efficiency of fixtures and appliance (based on your bill)
	Solar Orientation	• Availability of sunlight in your home during the day
	Building Material Used	• Use of appropriate materials for façade • Use on appropriate materials indoor
	Indoor Environmental Quality	• Home layout • Thermal comfort at home • Quality Views • Indoor air quality • Thermal comfort • Sound privacy
Neighborhood Pattern and Design (Adopted from LEED-ND)	Walkable streets	• Suitability of neighborhood for walking
	Visitability and universal design	• Ease of use of the facilities for disabled people
	Tree-lined and shaded streets	• Tree-lined streets and neighborhood greenness
	Local food production	• Opportunities for growing produce in the garden, yard, greenhouse, balcony, etc.
	Compact development	• Appropriateness of the building density
	Mixed-use neighborhood centers	• Ease of access to daily needs by foot
	Mixed-income diverse communities	• Diversity of housing styles in the neighborhood
	Access to civic and public space	• Access to public spaces

Table 3.5 Measures for analysis of cost performance

Variable	Attribute	Measure
Cost performance (Sirgy and Cornwell, 2002; Galster, 1987; Lansing et al., 1970; Lu, 1999; Russ-Eft, 1979; Kasl and Harberg, 1972; Lee and Guest, 1983; Miller et al., 1980)	Home value/rent	• The value/rent of home considering the home quality and neighborhood amenities
	Utility bills	• Utility bills compared to the usage
	Transportation fees	• Travel and transportation costs of living in this community
	Other fees	• Other charges associated with living in this community (HOA fee, condo fee, etc.)

Table 3.6 Satisfaction variables

Variable	Attribute	Measure
Satisfaction	Behavioral responses (Droettboom Jr et al., 1979)	• Intention to stay in this community/complex for a long time • I Recommend this community/complex to others • If I went back, I would move to this community again • I believe regulations in this community help improve the quality of life
	Affective process (Expressed satisfaction with community features)	• Feeling happy living in this neighborhood • Overall satisfaction with the building (home)

3.6.5 Data Analysis Method

This section describes the statistical method used to analyze the data to answer the research questions 2, 3, and 4. In the following, each research question is reviewed and the analysis method for the research question is discussed.

RQ2: Do the perceived building performance, perceived infrastructure performance, perceived neighborhood design, and perceived cost performance predict residential satisfaction in LEED-certified residential communities? This research question tests the following hypotheses:

H2.1: In LEED-certified residential communities, the perceived infrastructure performance, perceived neighborhood pattern and design, perceived building performance, and perceived cost performance have positive and significant relationships with residential satisfaction.

Analysis method: In order to answer these two research questions, first, a confirmatory factor analysis (CFA) was conducted to find the fittest model that represents the variables and to make sure that the developed questionnaire is providing a valid picture of what is expected to be evaluated. CFA also helps account for multicollinearity among the indicators and provides opportunities for defining the most appropriate latent variables resulted from the indicators.

CFA is a particular form of factor analysis, which is used to assess the extent to which measures of a construct are consistent with what the researcher intends to measure by the construct (or factor). Therefore, the goal of CFA is to test whether the collected data fit a hypothesized model that is developed to measure the constructs. The hypothesized model that is tested by CFA should be developed based on the models from previous research or an existing theory about the topic (Preedy & Watson, 2010). Jöreskog (1969) first developed confirmatory factor analysis. This method was built upon and used as an alternative method to older analysis methods for testing construct validity such as the MTMM Matrix (Campbell & Fiske, 1959).

CFA is the appropriate method for confirming or disconfirming the fit of the empirical data to theoretical structure when there is empirical and theoretical evidence for a construct that has multiple dimensions (Long & Perkins, 2003). As in this study, a model was developed based on housing satisfaction theories and existing satisfaction measurement models, there it is necessary to test whether the data fit the developed model that aims to evaluate residential satisfaction in LEED-certified residential communities.

After conducting the CFA, a structural equation modeling (SEM) was performed to provide an understanding of the relationships between independent variables and the dependent variable.

Structural equation modeling is a combination of confirmatory factor models (measurement relationships) and path models (structural relationships) (Hesari et al., 2019). In path models, the phenomena are expressed through a set of one-directional and two-directional relationships between the latent (underlying) variables that are measured by observed variable types. SEM is a comprehensive statistical method to test hypotheses on the relationships among a set of hidden or observed variables.

Despite being similar in terms of evaluating the regression coefficients among a set of variables, structural equation models have three main differences from linear regression models. First, unlike linear regression that only models observed variables, SEM provides opportunities for modeling latent variables that are manifested through multiple indicators in the observed data. Second, SEM models the complex relations among several variables rather than just modeling the simple relationships between predictors and outcomes. Third, structural equation models allow relationships to show the “downstream” effects (Chapman & Feit, 2019). For example, a stated variable on a survey might have a relationship with a latent construct expressed in different survey items, which then relates to another latent construct that is related to an observed behavior (Chapman & Feit, 2019) that indicates the level of residential satisfaction. As in this study, the relationships between the latent variables are of concern, SEM seems to be the most appropriate method to achieve reliable and valid findings.

RQ3: In LEED-certified residential communities, what are the most important determinants of long-term success through influencing residential satisfaction? This research question meant to test the following hypotheses:

H3.1: The perceived performance of each Green Infrastructure attribute has positive and significant relationships with residential satisfaction.

H3.2: The perceived performance of each Neighborhood Pattern and Design attribute has positive and significant relationships with residential satisfaction.

H3.3: The perceived performance of each Building Performance attribute has positive and significant relationships with residential satisfaction.

H3.4: The perceived performance of all Cost Performance attributes has positive and significant relationships with residential satisfaction.

Analysis method: Path analysis describes the directed dependencies and the relationships among a group of variables. Besides being considered as a form of multiple regression that focuses on causality, path analysis is being thought of as a particular type of SEM in which only single indicators (rather than a group of indicators that manifest a latent construct) are applied for each of the variables in the regression model. In other words, path analysis can be described as a structural equation model, which includes a structural model (path model), but does not include a measurement model (Land, 1969; Stage et al., 2004). As in this research question, the relationships between the single indicators and overall satisfaction is of concern, this method is the most appropriate method that can provide reliable and accurate results.

RQ4: Does sustainability impact residential satisfaction and the perceived performance of the built environment in residential communities? This research question is meant to test the following hypotheses:

H4.1: There is a measurement invariance between the LEED and non-LEED residents in terms of their perceptions about building, neighborhood, and economic performance and their satisfaction with their communities.

H4.2: Residents of LEED-certified communities have higher satisfaction with their communities and have better perceptions about the performance of their housing and neighborhood attributes compared to the residents of non-LEED residential communities.

Analysis method: To answer this research question, a comparison between the perceived performance and satisfaction of LEED-certified residential communities, as the experiment group, and conventional residential development projects, as the control group, is conducted. Therefore, variables for this question are the perceived performance variables discussed for research question 2 as well as satisfaction variables. However, here these measures are used to ask the residents of conventional communities to provide a set of comparative variables for the analysis.

In order to compare multiple groups in terms of latent factors, it is necessary to first make sure that all groups (in this study the two groups) have the same understanding of the constructs that are compared between the groups. Therefore, in order to address this research question, first, it is necessary to understand if there is a measurement invariance between the latent factors in the experiment group and the control group.

Measurement invariance tests the equivalence of constructs across groups and assesses whether the construct has the same meaning to those groups. Measurement invariance is a prerequisite to comparing group means between experiment versus control groups or for comparing different cultural, age, gender, or educational groups (Chen, 2007a). If there is no measurement equivalence (invariance), it means that the instrument does not measure the same construct. As a result, the interface problem occurs and the study conclusion may be biased or invalid because the measures that are relied on do not have the same meaning for the different groups (Chen, 2007a).

One of the most common ways to test measurement invariance is testing in a structural equation modeling framework (Putnick & Bornstein, 2016). Therefore, in this research, the measurement invariance is tested in an SEM framework using multiple-group confirmatory factor analysis (MGCFA) as SEM is the main method used in this study. In a CFA, items that generate a construct (e.g., questionnaire items/measures/indicators) load on a latent factor that represents the construct. According to Widaman and Reiss (1997), for testing measurement invariance, four main steps of testing should be conducted. These four measurement invariance steps are (1) configural, which shows the equivalence of model form; (2) metric, which concerns about the equivalence of factor loadings; (3) scalar, which tests the equivalence of item intercepts or thresholds; and (4) residual (strict), which tests equivalence of items' residuals or unique variances across the groups (Putnick & Bornstein, 2016).

If there is measurement invariance between the two groups in configural, metric, and scalar levels, then the means of latent variables can be compared across the groups. Otherwise, the comparison is problematic and cannot be interpreted (Davidov, 2009) because the differences between the coefficients and the means could be due to systematic biases of responses across the groups or because of the different understanding of the measurement items and not because of the actual differences across the different groups (Horn & McArdle, 1992; Steenkamp & Baumgartner, 1998; Vandenberg & Lance, 2000).

“Configural” invariance is the lowest level of invariance (Horn, McArdle, and Mason 1983), which requires that the measures in the instrument show the same configuration of loadings in each of the groups (Horn and McArdle 1992). In other words, the CFA should confirm that each construct is being measured by the same items in both groups. Some conditions should exist so that configural invariance could be supported. First, a single model that specifies the measures of each construct should fit well to the data. Second, all item loadings of the model should be reasonably large and significant. Third, the correlations among the model factors should be less than one to guarantee discriminant validity between the model factors (Steenkamp and Baumgartner 1998).

However, confirming Configural invariance does not mean that the respondents in different groups understand the questions exactly in the same way, and the differences might still exist between the factor loadings across the groups (Davidov, 2009). Therefore, a “metric” invariance should be tested as a higher level of invariance, which requires the invariance of factor loadings between measures and constructs across groups (Rock, Werts, and Flaugher 1978). This level of invariances usually tested by comparing the factor loading for the same item between the groups. According to the relevant literature, if there are two equal factor loadings per construct across groups, it is allowed to compare the effects, which is called partial metric invariance (Byrne, Shavelson, and Muthe´n 1989; Steenkamp and Baumgartner 1998).

In order to do the comparison of the mean of latent factors (underlying constructs) between the groups, which is the concern of this research question, the third level of invariance is required that is the ‘‘scalar’’ invariance of the items (Meredith 1993; Steenkamp and Baumgartner 1998). Scalar invariance ensures that differences in the mean of the measures across the groups are due to mean differences of their corresponding constructs. Scalar invariance is supported if there is a good model fit to the data after the intercepts of the underlying items are constrained to be equal across the groups. The model should not be improved after relaxing some of the equality constraints.

Therefore, in order to compare the means of the items across the two groups of this study, the first three levels of invariance are necessary to be supported. In other words, only if configural, metric, and scalar invariance are supported, it can be presumed that scores are not biased, and this allows us to make a comparison of means between the groups. However, in order to compare the effect of independent variables on dependent variables across the groups, which is not of concern in this research question, only the first two levels of invariance are sufficient.

If the measurement invariance is identified in all three levels, then the “Mean Structure” should be included in the analysis in order to provide a comparison of means between the latent variables of the two groups of LEED and non-LEED projects. Otherwise, the comparison between the two groups cannot provide an accurate understanding of the differences between the two groups in terms of satisfaction and perceived performance of the built environment attributes. Therefore, the comparison will be conducted only if it is confirmed by the statistical analysis.

3.7 Research Quality

In good research, validity and reliability are two fundamental indices in the assessment of research quality (Mohajan, 2017). Reliability is referred to the faith that one can have in the data attained from using an instrument, the extent to which measuring tools control random biases, and stability of findings, while validity refers to what an instrument measures and how well it does so (Mohajan, 2017).

Reliability and validity are two important tools to prevent research from being biased and are important concepts in contemporary research, as they are used for improving the accuracy of the evaluation and assessment of research (Tavakol & Dennick, 2011). Without determining the validity and reliability of the research, it is difficult to explain the effects of measurement errors on theoretical relationships that are being measured. A researcher can increase the reliability and validity of the collected data, by using several types of methods to gather data for finding true information (Forza, 2002).

3.7.1 Reliability

To estimate reliability coefficients, internal consistency methods have been developed to evaluate the internal unity of a scale with no duplicating or dividing of items. One of the best-known measurements is Cronbach's Alpha (Cronbach 1951, as cited in Mohajan 2017). Cronbach's Alpha is a coefficient dealing with the internal consistency of a scale that has been created from a group of items. The alpha is varied from 0 to 1 in which 1 shows the strong internal consistency of the scale (that is, its reliability), but values greater than or equal to 0.7 are generally acceptable. However, some studies have demonstrated that the interpretation of the alpha coefficient is more sensitive than it may seem. There are some effective factors in how to interpret alpha such as “the number of items”, “the degree of correlation between the items, and “the number of dimensions of the concept that are studied” (Tavakol and Dennick 2011). Cronbach's Alpha method is “most often used to determine the degree of reliability of a measuring scale, owing to the limitations of the test-retest and the split halves methods” (Carmines & Zeller, 1979).

In order to ensure the reliability of the survey instrument (questionnaire) and procedure, a pilot test was conducted with 55 neighborhood occupants that met eligibility requirements. The reliability of the questions was tested using the internal reliability method of Cronbach’s Alpha. Modifications are made on a questionnaire based on the responses and three experts’ ideas.

3.7.2 Validity

To show the validity of the questionnaire, according to Creswell (2003), three types of validity should be described including 1) content validity, which tests whether different parts of the test measure the same thing; 2) criterion validity (predictive or concurrent validity), which assesses the predictability of the results; and 3) construct validity, which means whether the measuring device or procedure assesses the research hypothesis. It is also necessary to evaluate external validity, which addresses the generalizability of research findings (Groat & Wang, 2013).

External validity: In order to have generalizable results, the sample was selected in a way that represents the population of the sustainable neighborhoods by using different methods of sampling including multi-stage sampling and random sampling. In the multi-stage sampling, target neighborhoods were identified, and through contacting community management, the survey was distributed randomly among the individuals who were eligible to participate in the survey (age over 18 and living more than 6 months in the neighborhood). The population was then randomly sampled using social media and the Centiment survey support organization.

Content validity: In order to ascertain content validity, the survey was reviewed by two different groups of experts. One group of experts[1,2] whose field of expertise was related to the research topic reviewed the questionnaire multiple times to help improve the appropriateness of the questions to achieve the research objectives. Another expert who had expertise in survey design[3] reviewed the questionnaire from a technical standpoint. Furthermore, five non-experts read the survey in order to assure the face validity of the survey instrument, which focuses on readability, layout and style, feasibility, and clarity of wording. A pilot test was also conducted to evaluate the questionnaire from the participants' points of view and find out if the questions are appropriate and if they can understand the questions. The results of the pilot test were also used for further reliability tests.

Construct and Criterion Validity: To ascertain the construct and criterion validity, a CFA was conducted to test the fit of the model to the data and perform any modification to the model that was necessary in order to improve the fit of the model to the data. In other words, CFA was conducted to quantitatively test the validity of the indicators of the survey (Gerbing & Hunter, 1982). As discussed in section 3.6, CFA tests the validity of the construct by evaluating

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the extent to which measures of a construct are consistent with what the researcher intends to measure by the construct. Therefore, the goal of CFA is to test whether the collected data fit a hypothesized model that is developed to measure the constructs. If the CFA model does not fit the data, modifications should be made to the model in order to improve the fit of the model and validate the model.

CHAPTER 4 : RESULTS FOR PHASE I

4.1 Introduction

This chapter describes the results for phase I of the study. The chapter starts with the sample characteristics and the descriptive statistics about the sample followed by the data analysis results for the first research question. This phase focuses on investigating the relationships between the actual performance of infrastructure in LEED-certified residential communities and the level of sustainability. Research question 1 is reviewed below:

RQ1: How is the level of sustainability associated with the performance of infrastructure and physical elements of LEED-certified residential communities?

As noted in the previous chapter, the dependent variable for this question is the level of sustainability, which is measured by the overall LEED-ND score of each project. The independent variables for this question are "walk score", "bike score", and "transit score", as well as "residential density".

4.2 Preparing Data and Removing Outliers

As a result of the data collection procedure discussed in the previous chapter, 102 projects were identified; this list included all LEED-ND certified built projects in the US by April 1, 2021. Three projects were removed because information about the projects was not found from public data. A primary multiple regression analysis was conducted to check the standard residuals on the remaining 99 cases to identify outliers and influential cases. The analysis of residuals indicated that observations 24, 91, and 94 needed to be removed. After removing the outliers (the observations with standardized residuals higher than 3 or lower than -3), the remaining 96 projects were checked for influential data points using Cook's distance (Cook's D). In this test, the data points that have Cook's distance of higher than 0.049 are considered as influential cases, which need to be removed from the data set in order not to affect the analysis results. This test resulted in removing observations 31, 42, 43, 44, 59, 64, and 80 from the data.

After removing all the influential cases, the remaining 89 projects (N= 89) were considered for the final multiple regression analysis. The data preparation and analysis for the first phase of this dissertation was conducted using XLSTAT, an Excel data analysis add-in, which provides numerous data analysis packages to analyze, customize and share results within Microsoft Excel. Due to a large number of remaining observations, the list of all LEED-ND projects and their characteristics are shown in Appendix A.

4.3 Multiple Regression Analysis Assumptions

There are some assumptions for multiple regression analysis that should be met before conducting and interpreting the analysis in order to make sure that the results of the analysis provide an accurate understanding of the relationships between independent variables and dependent variables. These assumptions include the existence of linear relationships between independent variables and the dependent variable, multivariate normality (normality of residuals), independence of errors, homoscedasticity, and absence of multicollinearity between the independent variables (Osborne & Waters, 2002; Uyanık & Güler, 2013; Williams Carlos Alberto Gomez, Grajales Dason Kurkiewicz & Alberto Gomez, 2013). In the following sections, multiple linear regression assumptions are tested for the research data.

Linear relationships between the dependent variable and independent variables can be tested with the correlation matrix. The rule of thumb is that if there is a correlation of 0.2 or higher between the dependent variable and each of the independent variables, the relationship can be considered linear. However, a preferable method is examining residual plots (Osborne & Waters, 2002). Therefore, in this research, both the correlation matrix (Table 4.1) and residual plot (Figure 4.1) are examined.

Homoscedasticity is another assumption that can be checked through the scatterplot of residuals versus predicted values (Figure 4.1), which means that the variance of errors should be the same across all levels of the independent variables. Tabachnick and Fidell (2019) suggest that heteroscedasticity (lack of homoscedasticity) can lead to serious distortion of findings and may lead to weakening the analysis and consequently increases the possibility of a Type I error.

Table 4-1 Correlation matrix

	Walk Score	Transit Score	Bike Score	DUA	LEED-ND Score (sustainability)
Walk Score	**1**	0.718	0.658	0.350	0.395
Transit Score	0.718	**1**	0.578	0.402	0.551
Bike Score	0.658	0.578	**1**	0.414	0.504
DUA	0.350	0.402	0.414	**1**	0.572
LEED-ND Score sustainability	0.395	0.551	0.504	0.572	**1**

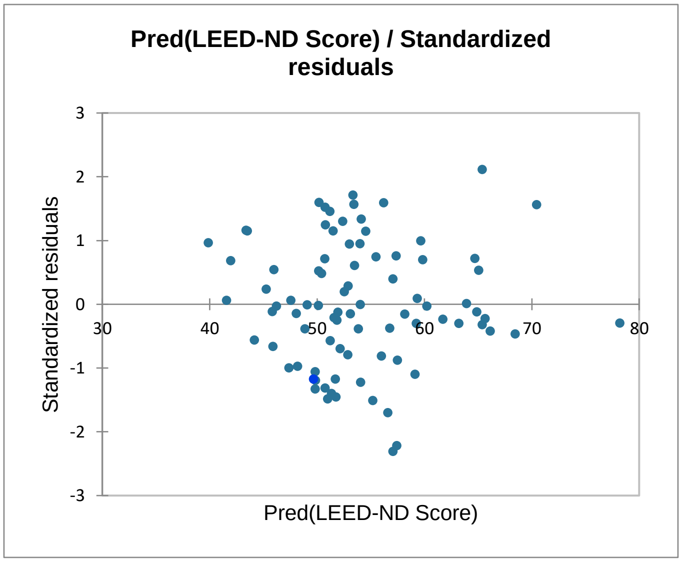

Figure 4.1 Residual plot

As shown in table 4.1, the dependent variable (sustainability) has a correlation of higher than 0.2 with all the independent variables. Furthermore, the scatterplot of standardized predicted values (standardized residuals) indicates a linear relationship between the residuals. Therefore, it could be inferred that the relationship between the dependent variable and independent variables is linear. Furthermore, as there is no clear pattern in the distribution of residuals (bell shape, cone shape, funnel shape, etc.) the data meets the assumptions of homoscedasticity.

Multivariate normality is another important assumption of multiple linear regression that requires the residuals to be normally distributed. This assumption can be examined in multiple ways. In this study, the Shapiro-Wilk test is used to examine multivariate normality assumptions. The results for this test are shown in table 4.2.

Table 4-2 Shapiro-Wilk test on the normality of residuals

W	0.985
p-value (Two-tailed)	0.411
alpha	0.050

In this test, the null hypothesis is that the residuals follow a normal distribution and the alternative hypothesis is that the residuals do not follow a normal distribution. As shown in Table 4.2, the computed p-value is greater than the significance level alpha=0.05. Therefore, one cannot reject the null hypothesis and it is inferred that the residuals are normally distributed.

Independence of errors in the next assumption of multiple linear regression that is examined in this research. Violation of this assumption provides biased estimates of standard errors and the significance of the relationships (Chatterjee & Hadi, 2012). In this research, the Durbin-Watson test is considered to examine the independence of errors. The Durbin-Watson test provides values from 0 to 4, where the value 2 is considered as no autocorrelation between the residuals. The rule of thumb is that values between 1.5 and2.5 meet the assumption of independent errors. Looking at the Durbin-Watson value from the goodness of fit statistics (Table 4.3), it can be inferred that the errors are independent and the data met the assumption of independent residuals (Durbin-Watson value = 1.926).

Table 4-3 Durbin-Watson Statistics

Durbin-Watson		
Autocorrelation	**Statistic**	**p**
0.256	1.461	0.009
0.034	1.926	0.708

Multicollinearity or highly autocorrelated independent variables can lead to inaccurate estimates of the coefficients for independent variables, which inflates the confidence intervals and standard errors (Cohen, 2013). Multicollinearity can be checked by looking at the correlation matrix. If there is no correlation higher than 0.8 between independent variables, it could be inferred that there is no multicollinearity in the data. As shown in Table 4.1, there is no correlation above 0.8 between variables thus the data meets the assumption of multicollinearity. However, in order to ensure that there is no multicollinearity among the IVs, an analysis of Variance Inflation Factor (VIF) and Tolerance was also conducted. Based on this analysis, if the Tolerance is less than 0.1 or the VIF is greater than 10, then there is a multicollinearity problem with the independent variables. Table 4.4 shows the results of multicollinearity analysis. As shown in this table, the results indicate that multicollinearity is not a concern among the independent variables with all the Tolerances being greater than 0.1 and VIFs being smaller than 10.

Table 4-4 Multicollinearity statistics

	Walk Score	Transit Score	Bike Score	DUA
Tolerance	0.396	0.448	0.516	0.789
VIF	2.524	2.230	1.936	1.268

4.4 Multiple Regression Analysis

After the data met all assumptions, the multiple linear regression analysis was conducted for 89 projects (N=89) to understand the relationship between independent variables and the dependent variable. As noted, independent variables for this analysis are the walk score, transit score, bike score, and residential density expressed as Dwelling Units per Acre (DUA). The descriptive statistics of the analysis are provided in table 4.5.

Table 4-5 Descriptive statistics

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
LEED-ND Score (sustainability	89	0	89	40.000	82.000	54.146	9.899
Walk Score	89	0	89	0.000	100.000	67.854	24.794
Transit Score	89	0	89	0.000	100.000	52.157	27.122
Bike Score	89	0	89	19.000	100.000	69.258	18.898
DUA	89	0	89	0.587	195.000	36.986	33.966

First, it is important to review the goodness of fit statistics (Table 4.6) in order to find out how much of the variance in the dependent variable is explained by the independent variables.

Table 4-6 Goodness of fit statistics

Observations	89
Sum of weights	89
DF	84
R^2	**0.474**
Adjusted R^2	0.449
MSE	53.965
RMSE	7.346
MAPE	11.235
DW	1.925
Cp	5.000
AIC	359.815

According to Table 4.6, given that R^2= 0.47, it is determined that 47% of the variability of the dependent variable, sustainability is explained by the 4 explanatory variables. In order to see if the results of the analysis are statistically significant, it is necessary to look at the ANOVA test results (Table 4.7)

Table 4-7 Analysis of Variance

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	4	4095.097	1023.774	18.695	**<0.0001**
Error	81	4435.798	54.763		
Corrected Total	85	8530.895			

Computed against model Y=Mean(Y)

There was a statistically significant difference between the sustainability and the model mean as determined by one-way ANOVA (DF=4; F= 18.695, p<.0001).

Next, in order to find out whether the independent variables are contributing to the results, we need to look at the Type III sum of square tables (Table 4.8) and standardized coefficient table (Table 4.9).

Table 4-8 Type III sum of square table

Source	DF	Sum of squares	Mean squares	F	Pr > F
Walk Score	1.000	92.143	92.143	1.707	0.195
Transit Score	1.000	532.222	532.222	9.862	0.002
Bike Score	1.000	266.307	266.307	4.935	0.029
DUA	1.000	971.526	971.526	18.003	0.000

Table 4-9 Standardized coefficients

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Walk Score	-0.161	0.113	-1.415	0.161	-0.386	0.065
Transit Score	0.371	0.110	3.376	**0.001**	0.153	0.590
Bike Score	0.238	0.099	2.412	**0.018**	0.042	0.434
DUA	0.378	0.067	5.620	**<0.0001**	0.244	0.511

**Dependent variable: LEED-ND score (sustainability)*

As shown in table 4.8, based on the Type III sum of squares, transit score, bike score, and DUA bring significant information to explain the variability of sustainability. In other words, these three independent variables have positive and significant effects on sustainability. According to the coefficient table (Table 4.9), among the explanatory variables, the variable DUA is the most influential (Coefficient=0.378, P-value<0001) followed by transit score (Coefficient= 0.371, P-value=0.001), which has the highest positive significant relationship with sustainability. The bike score (Coefficient = 0.238, P-value=0.018) has the lowest positive influence on sustainability, but the relationship is still significant.

On the other hand, the walk score does not bring significant information to explain the variability of sustainability meaning this independent variable does not show any significant relationship with sustainability and could be removed from the model. Although walkability has been highlighted as one of the most important criteria in the Neighborhood Pattern and Design category of LEED-ND certification by accounting for 9 points out of the 18 available points under the Neighborhood Pattern and Design category this result suggests more in-depth research on the criteria for evaluating walkability to find the reason for this discrepancy. One possible reason for this lack of relationship between walkability and sustainability could be due to the lack of consistency between measures for evaluation of walkability based on walkscore.com and the LEED certification system. This highlighted the importance of looking at this criterion from another point of view and motivated further evaluations of walkability in sustainable neighborhoods from users' points of view, which is discussed in chapters 5 and 6 of this dissertation.

CHAPTER 5 : RESULTS FOR PHASE II

5.1 Introduction

This chapter focuses on the second phase of the research. This phase focuses on investigating the relationships between the perceived performance of infrastructure, perceived building performance, perceived neighborhood pattern, and design, and the cost performance of LEED-certified residential communities as predictive variables, and residential satisfaction as the response variable.

In this phase, after evaluating the measurement instrument through a pilot test and improving the quality of the survey, an online survey was conducted. A Confirmatory Factor Analysis (CFA) was conducted to test the validity of the survey. A Structural Equation Model (SEM) was then developed to provide a post-occupancy evaluation of the long-term success of LEED-certified residential communities to understand the relationships between the perceived performance of infrastructure, building, and neighborhood features, cost performance, and user satisfaction in LEED-certified residential communities and to identify and rate the key determinants of residential satisfaction in sustainable LEED-certified residential communities a path analysis was conducted. A Multigroup Confirmatory Factor Analysis (MCFA) was then conducted in this phase to assess the possibility of conducting a cross-sectional evaluation and compare the level of satisfaction and perceived performance of the built environment between sustainable communities and non-sustainable communities. This phase investigated research questions 2, 3, and 4. In the following sections, after discussing the pilot test results and modifications, the results of the data analysis for research questions 2, 3, and 4 will be discussed and the findings will be discussed accordingly.

5.2 Pilot Test Results

As discussed in chapter 3, to ensure the reliability and validity of the survey, a pilot test was conducted with 55 individuals who met eligibility requirements for participating in the survey (n=55). The reliability of the questionnaire was evaluated using the internal consistency method of Cronbach's alpha (Table 5.1).

Table 5-1 Cronbach's alpha

Cronbach's alpha	Standardized Cronbach's Alpha
0.965	0.965

An alpha coefficient of 0.965 was obtained for the survey instrument, which indicates a high internal consistency of the survey instrument and the reliability of the measure in evaluating the perceived performance of the built environment and the level of satisfaction. Moreover, based on comments and suggestions made by the respondents, modifications were made to the questionnaire and the questionnaire was cross-checked with a group of experts including two faculty members of the School of Planning, Design, and Construction at Michigan State University and one survey expert from Michigan State University Office for Survey Research. All the suggested changes were about terminology used in the survey to make it more understandable for non-expert respondents. Furthermore, three questions were found repetitive by the respondents that were removed from the questionnaire after consulting with the experts.

Institutional Review Board (IRB) approval: The study was subjected to IRB approval due to using human subjects. The survey instrument was submitted for approval before the data collection and the IRB approval was obtained after the review was completed (Appendix B).

5.3 Sample Characteristics and Data Demographics

After minor modifications were made to the questionnaire, an online survey was conducted to collect data from individuals who live in LEED-certified residential communities, as the experiment group, and from individuals who live in non-LEED projects, as the control group. The procedure of the data collection was explained in Chapter 3. The summary of respondents' characteristics is presented in Table 5.2. The location of the LEED-certified residential communities and the distribution of the respondents are shown in Figure 5.1.

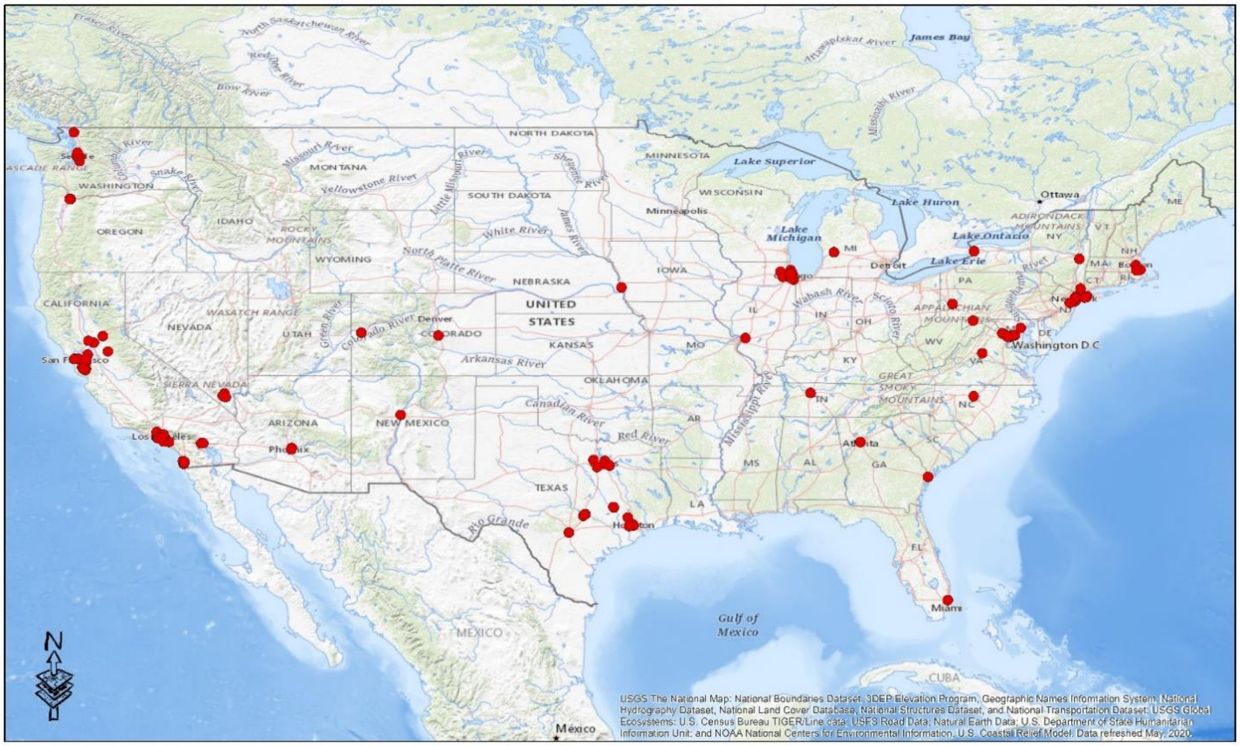

Figure 5.1 The distribution of the surveyed LEED-certified residential communities

Table 5-2 Summary of sample characteristics

Variable	LEED-certified communities (n=192)		Non-LEED communities (n= 183)	
	Number	Percentage	Number	Percentage
Gender				
Female	94	49.0	92	50.3
Male	95	49.5	83	45.4
Other	3	1.6	8	4.4
Age				
18-34	75	39.1	68	37.2
35-54	104	54.2	108	59.0
55 or above	11	5.7	4	2.2
Undefined	2	1.0	3	1.6
Education level				
High school graduate or less	8	4.2	5	2.7
Some College	23	12.0	33	18.0
Two-year degree	13	6.8	16	8.7
Four-year degree	59	30.7	41	22.4
Graduate degree	89	46.4	84	45.9
Undefined	0	0.0	4	2.2
Income				
Less than $30,000	9	4.7	20	10.9
$30,000-$59,990	21	10.9	37	20.2
$60,000 - $89,999	55	28.6	52	28.4
$90,000 - $119,999	46	24.0	26	14.2
$120,000 - $149,999	42	21.9	22	12.0
$150,000 or more	18	9.4	20	10.9
Undefined	1	0.5	6	3.3
Housing tenure				
Owner	139	72.4	109	59.6
Renter	53	27.6	70	38.3
Undefined	0	0.0	4	2.2

The number of respondents who live in LEED-certified residential communities (experiment group) is 192 (N=192), and the number of respondents who live in non-LEED communities (control group for research question 3) is 183 (N=183). In the following sections, the results of the data analysis for phase 2 will be presented.

5.4 Relationship Between Perceived Performance and Satisfaction

This section presents the results for the data analysis to address research question 2. This research question concerns the relationship between the perceived performance of the built environment in the LEED-certified residential communities and the satisfaction of the residents. Research question 2 is reviewed below:

RQ2: Do the perceived building performance, perceived infrastructure performance, perceived neighborhood design, and perceived cost performance predict residential satisfaction in LEED-certified residential communities?

The independent variables for this research question are perceived infrastructure performance, perceived neighborhood pattern and design, perceived building performance, and perceived cost performance. Each independent variable is a latent factor that results from several indicators (measures/items). The dependent variable for this research question is residential satisfaction, which is a latent variable that resulted from several indicators querying satisfaction directly and indirectly.

This section begins with the results of the reliability test of the sampled data. Also, the normality of the data is checked as it is an important assumption for conducting CFA and SEM. Next, the results of the CFA are presented examining the construct validity of the data. Finally, the results of the Structural Equation Modeling are presented to address research question 2.

5.4.1 Reliability

One of the best-known reliability measurements is Cronbach's alpha, which is a coefficient dealing with the internal consistency of a scale that has been created from a group of items (Mohajan 2017). The value of alpha varies from 0 to 1, with 1 showing a strong internal consistency of the scale (reliability), but values equal and more than 0.7 are generally acceptable. This method is preferred when there is a questionnaire with multiple Likert scale questions. To test the reliability of the scale, first, a test was conducted for the indicators of each latent variable and then an overall test was performed to examine the internal consistency of the entire survey data. The alpha values for all the latent variables and the entire survey data are above 0.7 indicating that the internal consistency of the measures is high and the data is reliable, thus it can be used for further analysis (Table 5.3).

Table 5-3 Cronbach's Alpha values for latent variables and the survey

Latent factor	No. of indicators	Cronbach's alpha	Standardized Cronbach's alpha
Green infrastructure	9	0.809	0.815
Neighborhood pattern and design	6	0.773	0.775
Building Performance	8	0.834	0.844
Cost performance	4	0.768	0.769
Residential Satisfaction	4	0.840	0.863
All factors	27	0.940	0.943

5.4.2 CFA Assumption Test

In order to perform CFA, some assumptions must be met first. The assumptions for conducting CFA are sufficient sample size ($n \approx 200$), data must come from a random sample, a correct a-priori model should be specified, and the data should meet multivariate normality (Solutions, 2009). The sample size for this research question is 192 (n=192), which approaches the minimum sample size of 200 and the data was collected based on the random sampling method. The procedure for developing the a-priori model and the model constructs were discussed in Chapter 3. The model and the variables were supported by the existing literature and theoretical background thus providing an appropriate a-priori model to be examined through a Confirmatory Factor Analysis. Therefore, the only assumption among the CFA assumptions that still needs to be tested is the normality of the data.

5.4.3 Normality of Data

When conducting CFA or using an SEM, it is recommended to test for multivariate normality. In CFA and SEMs, the method that is commonly used is the maximum likelihood (ML), which assumes multivariate normality of the data; if the data is not approximately normal, the results will be biased (Fuller & Hemmerle, 1966).

There are different ways to test multivariate normality. The univariate normality can also provide some insights into multivariate normality. If there is univariate non-normality, it becomes obvious that the multivariate distribution is non-normal. However, if the univariate distributions are normal across all the items, multivariate non-normality is still possible, although it might not be very severe (Bera & John, 1983). So, in this study, the normality test starts with a univariate normality test.

Among the several methods of evaluation of normality, this study uses skewness and Kurtosis measures along with the Shapiro-Wilk test, which is recognized as the most reliable method of evaluating univariate normality (Srivastava & Hui, 1987). First, A z-test is employed to test the normality using skewness and kurtosis. The z-score was calculated by dividing the excess kurtosis or the skew values by their standard errors. According to Kim (2013), for the medium sample size, between 50 and 300, the data is normal if it has a z value between 3.29 and -3.29. The Shapiro Wilk test was also conducted to evaluate the normality with more accuracy. All the univariate normality tests were conducted using XLSTAT, which is a statistics add-in for MS Excel. Mardia's test for multivariate normality was conducted using the WebPower Statistical power analysis online tool. The results of all the normality tests are presented in tables 5.4 and 5.5.

Table 5-4 Normality tests

Variable/Indicator	Skewness	Standard error	Z-score Skewness	Kurtosis	Standard error	Z-score kurtosis	Shapiro-Wilk
Independent Variable: Perceived Infrastructure Performance							
GI1-Otdoor Water Efficiency	-0.272	0.175	-1.55	-0.812	0.349	-2.33	<0.0001
GI2-Central Heating and Cooling	-0.113	0.175	-0.64	-1.258	0.349	**-3.6**	<0.0001
GI3-Outdoor Lighting	0.063	0.175	0.36	-0.757	0.349	-2.17	<0.0001
GI4-Rcycling Facilities	-0.298	0.175	-1.7	-0.927	0.349	-2.66	<0.0001
GI5-Rainwater Collection System	-0.367	0.175	-2.09	-0.757	0.349	-2.17	<0.0001
GI6-Public Transit Infrastructure	-0.237	0.175	-1.35	-1.084	0.349	-3.11	<0.0001
GI7-Biking Infrastructure	-0.203	0.175	-1.16	-0.781	0.349	-2.24	<0.0001
GI8-Proximity to School	-0.095	0.175	-0.54	-0.888	0.349	-2.55	<0.0001
GI9-Road Quality	-0.103	0.175	-0.59	-0.613	0.349	-1.76	<0.0001
Independent Variable: Perceived Neighborhood Pattern and Design							
ND1-Walking Infrastructure	-0.148	0.175	-0.84	-0.69	0.349	-1.98	<0.0001
ND2-Neighborhood Density	-0.185	0.175	-1.05	-0.091	0.349	-0.26	<0.0001
ND3-Mixed Use Neighborhood	-0.691	0.175	**-3.94**	0.248	0.349	0.71	<0.0001
ND4-Housing Diversity	-0.096	0.175	-0.55	-0.694	0.349	-1.99	<0.0001
ND5-Access to Public Space	-0.389	0.175	-2.22	-0.527	0.349	-1.51	<0.0001
ND6-Neighborhood Greenness	-0.241	0.175	-1.37	-0.479	0.349	-1.37	<0.0001
Independent Variable: Perceived Building Performance							
BP1-Hot Water Distribution System	-0.55	0.175	-3.14	-0.849	0.349	-2.43	<0.0001
BP2-Thermal Comfort	0.057	0.175	0.32	-0.5	0.349	-1.43	<0.0001
BP3-Availability of Daylight	-0.414	0.175	-2.36	-0.235	0.349	-0.67	<0.0001
BP4-Indoor Water Efficiency	-0.231	0.175	-1.32	-0.214	0.349	-0.61	<0.0001
BP5-Quality Views from Window	-0.136	0.175	-0.77	-0.607	0.349	-1.74	<0.0001
BP6-Indoor Materials Used	-0.267	0.175	-1.52	-0.399	0.349	-1.14	<0.0001
BP7-Building Energy Efficiency	-0.238	0.175	-1.36	-0.51	0.349	-1.46	<0.0001
BP8-Insulation	-0.202	0.175	-1.15	-0.651	0.349	-1.87	<0.0001
Independent Variable: Perceived Cost Performance							
EP1-Value/Rent	-0.074	0.175	-0.42	-0.47	0.349	-1.35	<0.0001
EP2-Utility Bills	-0.041	0.175	-0.23	-0.281	0.349	-0.81	<0.0001
EP3-Travel and Transportation Costs	-0.16	0.175	-0.91	-0.781	0.349	-2.24	<0.0001
EP4-Other Fees (HOA/Condo fees, etc.,)	0.067	0.175	0.38	-0.63	0.349	-1.81	<0.0001
Dependent Variable: Residential Satisfaction							
S1-Plan to Live permanently	-0.106	0.175	-0.61	-0.667	0.349	-1.91	<0.0001
S2-Recommend to others	-0.151	0.175	-0.86	-0.608	0.349	-1.74	<0.0001
S3-If look back, would move here again	-0.038	0.175	-0.22	-0.418	0.349	-1.2	<0.0001
S4-Regulations and rules	-0.12	0.175	-0.68	-1.498	0.349	**-4.29**	<0.0001
S5-Overall Neighborhood Satisfaction	-0.242	0.175	-1.38	-0.433	0.349	-1.24	<0.0001
S6-Overall Home Satisfaction	-0.363	0.175	-2.07	0.143	0.349	0.41	<0.0001

Table 5-5 Mardia's multivariate skewness and kurtosis

Test	b	z	p-value
Skewness	141.0779	4514.49211	<0.0001
Kurtosis	799.9258	13.05944	<0.0001

As shown in Table 5.4, the results of the z test indicate that only 3 variables (GI2, ND3, and S4) have non-normal distributions. However, the results of the Shapiro-Wilk test shows that all the p-values are lower than 0.0001 (p-value <0.0001) meaning that the data is not normally distributed. Furthermore, the result of Mardia's multivariate normality test (table 5.5) also indicates that the data does not meet multivariate normality.

5.5 Confirmatory Factor Analysis

The purpose of CFA is to assess the model fit to the data and evaluate the strength of the defined model in providing a set of latent factors to be considered for further analysis (usually SEM). In other words, CFA evaluates model fit and factorial invariance of postulated latent factors (Mac Callum, Browne, & Cai, 2012; Zientek, 2008).

In the previous section, it was indicated that the data is not normally distributed thus violates the assumption of ML estimation, which is the most often used method in CFA. As perfectly normal data is rare in practice, for most parametric tests, approximately normal data is acceptable especially if the other assumptions of the test are met (Alhija, 2010). However, even with z score tests showing that the distribution of the data is not severely non-normal, ML may provide an inflated model and there is a need for an alternative method. Among the available solutions for the issue of non-normality, the "robust" ML estimation, which is suggested by Satorra and Bentler (2001) is found to be the most appropriate approach to address the nonnormality issue (Curran, West, & Finch, 1996; Finney & DiStefano, 2013; Hu, Bentler, & Kano, 1992). Robust ML is less affected by the negative impacts of non-normality and is available in many software packages including JASP, which is used for this analysis. Therefore, robust ML was considered as the estimation method under CFA for this research. The data analysis in this phase was carried out using JASP version 14.1, which uses Lavaan syntax for the data analysis.

5.5.1 Testing Fit Measures

In the first place, an initial CFA was conducted for each latent variable (variable hereafter) to see how well the individual indicators are loading in their variables. In other words, each variable of the a-priori model was tested to see how well it is representing the individual indicators. In order to examine the fit of each model, the fit indices that are found to be the most popular measures are considered including Chi-square, CFI (comparative fit index), RMSEA (root mean square error of approximation), and SRMR (standardized root mean square residual) (Beauducel & Wittmann, 2005; Hooper, Coughlan, & Mullen, 2008; Kline, 1998; Schreiber, Stage, King, Nora, & Barlow, 2006). The fit measures that are considered to evaluate the model fits and their cut-offs are presented in Table 5.6. The key results, including indicators' factor loadings and the fit measures of the initial CFA for each variable, are presented in Table 5.7. For the sake of brevity, all the results of the initial CFA are presented in one table although each variable has been analyzed separately. This is important to note because when the CFA is conducted for the entire model, which includes all 5 latent variables, the loading of the indicators might change slightly due to the correlations with the indicators from other variables. Therefore, it is important first to test each individual variable first to ensure that all the indicators are contributing to the latent variable and next evaluate the whole model to make sure that all factors work well in the model.

Table 5-6 Fit indexes and cut-offs for CFA and SEM

Name	Measure	Cut-off
Absolute/predictive fit Chi-square	X^2	pValue > 0.05
Comparative Fit Index	CFI	CFI ≥ 0.95
Root Mean Square Error of Approximation	RMSEA	RMSEA < 0.08
Standardized Root Mean Square Residual	SRMR	SRMR < 0.08

Source: Beauducel & Wittmann, 2005; Hooper et al., 2008; Kline, 1998; Schreiber et al., 2006

Table 5-7 CFA results for each variable

Variable/Indicator	Estimate	p-value	Std. Estimate	Fit Indices			
				Chi-square p-value	CFI	RMSEA	SRMR
Factor 1: Perceived Infrastructure Performance							
GI1-Otdoor Water Efficiency	0.721	< .001	0.420	0.008	0.950	0.063	0.050
GI2-Central Heating and Cooling	0.955	< .001	0.477				
GI3-Outdoor Lighting	1.03	< .001	**0.740**				
GI4-Rcycling Facilities	1.037	< .001	**0.599**				
GI5-Rainwater Collection System	0.891	< .001	**0.532**				
GI6-Public Transit Infrastructure	1.172	< .001	**0.643**				
GI7-Biking Infrastructure	0.917	< .001	**0.560**				
GI8-Proximity to School	0.8	< .001	0.461				
GI9-Road Quality	1.055	< .001	**0.714**				
Factor 2: Perceived Neighborhood Design							
ND1-Walking Infrastructure	0.937	< .001	**0.651**	0.253	0.991	0.037	0.035
ND2-Neighborhood Density	0.721	< .001	**0.584**				
ND3-Mixed Use Neighborhood	1.045	< .001	**0.712**				
ND4-Housing Diversity	0.881	< .001	**0.582**				
ND5-Access to Public Space	0.93	< .001	**0.664**				
ND6-Neighborhood Greenness	0.65	< .001	0.434				
Factor 3: Perceived Building Performance							
BP1-Hot Water Distribution System	0.905	< .001	0.472	0.019	0.969	0.063	0.044
BP2-Thermal Comfort	0.961	< .001	**0.735**				
BP3-Availability of Daylight	1.004	< .001	**0.721**				
BP4-Indoor Water Efficiency	0.865	< .001	**0.645**				
BP5-Quality Views from Window	1.04	< .001	**0.754**				
BP6-Indoor Materials Used	0.922	< .001	**0.676**				
BP7-Building Energy Efficiency	0.92	< .001	**0.678**				
BP8-Insulation	0.601	< .001	0.405				
Factor 4: Perceived Cost Performance							
EP1-Value/Rent	0.954	< .001	**0.717**	0.247	0.996	0.046	0.022
EP2-Utility Bills	0.888	< .001	**0.635**				
EP3-Travel and Transportation Costs	1.102	< .001	**0.735**				
EP4-Other Fees (HOA/Condo fees, etc.,)	0.852	< .001	**0.608**				
Factor 5: Residential Satisfaction							
S1-Plan to Live permanently	1.271	< .001	**0.840**	0.005	0.973	0.091	0.039
S2-Recommend to others	1.202	< .001	**0.840**				
S3-If look back, would move here again	1.034	< .001	**0.755**				
S4-Regulations and rules	0.92	< .001	0.431				
S5-Overall Neighborhood Satisfaction	0.999	< .001	**0.701**				
S6-Overall Home Satisfaction	0.934	< .001	**0.740**				
Overall model fit measures				<0.001	0.908	0.051	0.059

*Retained indicators with loading greater than 0.5 are highlighted; Weak indicators with loading lower than 0.5 are removed.

Factors 2 and 4 (perceived neighborhood design and perceived cost performance, respectively) show insignificant Chi-squares (p-values > 0.05), and the rest of the fit measures are also acceptable illustrating a good fit of the variables. However, Factors 1, 3, and 5 show significant Chi-squares (p-values < 0.05) although the rest of the fit measures show good fits for factors 1 and 3. It is worth mentioning that Chi-square is the most sensitive fit index and is recognized as the absolute fit measure. It almost always is significant especially when it comes to larger sample sizes. On the other hand, for small sample sizes, it lacks differentiating between a good fit and a poor fit (Bentler & Bonett, 1980; Jöreskog & Sörbom, 1993; Kenny & McCoach, 2003). Therefore, although the Chi-squares are significant for some models, they can still fit well if other indices are in a good shape. Therefore, the fit measures of factors 1, 3, (perceived infrastructure performance and perceived building performance respectively) show good fits of the variables. Factor 5 (residential satisfaction) however, does not show a good fit and needs further considerations such as removing the indicators with low factor loadings or deciding to covariate residuals in order to improve the model. However, any model modification should be theoretically supported besides being statistically meaningful.

Even if fit measures show a good fit, it is important to check the factor loadings for each indicator of variables to make sure that all the indicators have enough strength in the variable. Weak indicators with loading <0.5 reduce the unidimensionality of the measurement model and can damage the fit of the model when the factor that represents the poor indicator becomes part of the model with multiple latent variables (Awang, 2012). Therefore, among all the indicators that are presented in Table 5.7, items GI1, GI2, GI8, ND6, BP1, BP8, and S4 were found to be weak indicators and were removed from the model. As a result, 26 indicators were retained in the model to be represented by 4 independent variables and 1 dependent variable.

5.5.2 CFA Model

After removing the weak indicators, the variables' fit indicators were checked again and showed significant improvements. Therefore, after recoding the retained indicators in each variable, overall confirmatory factor analysis was conducted to check the fit of a model that includes all the variables and see if the model is plausible for the data (n=192). The results of the fit indices for the modified CFA model are summarized in Table 5.8 and Figure 5.2.

Table 5-8 Results of overall model Confirmatory Factor Analysis

Variable/Indicator	Estimate	p	Std. Est. (all)
Factor 1: Perceived Infrastructure Performance			
GI1-Outdoor Lighting	1.176	< .001	0.645
GI2-Rcycling Facilities	0.863	< .001	0.522
GI3-Rainwater Collection System	0.851	< .001	0.519
GI4-Public Transit Infrastructure	0.956	< .001	0.571
GI5-Biking Infrastructure	0.897	< .001	0.548
GI6-Road Quality	1.001	< .001	0.578
Factor 2: Perceived Neighborhood Design			
ND1-Walking Infrastructure	1.035	< .001	0.719
ND2-Neighborhood Density	0.712	< .001	0.577
ND3-Mixed Use Neighborhood	1.052	< .001	0.716
ND4-Housing Diversity	0.802	< .001	0.53
ND5-Access to Public Space	0.879	< .001	0.628
Factor3: Perceived Building Performance			
BP1-Thermal Comfort	0.949	< .001	0.726
BP2-Availability of Daylight	0.999	< .001	0.717
BP3-Indoor Water Efficiency	0.90	< .001	0.671
BP4-Quality Views from Window	0.907	< .001	0.601
BP5-Indoor Materials Used	0.96	< .001	0.704
BP6-Building Energy Efficiency	0.901	< .001	0.665
Factor 4: Perceived Cost performance			
EP1-Value/Rent	0.972	< .001	0.73
EP2-Utility Bills	0.918	< .001	0.656
EP3-Travel and Transportation Costs	1.084	< .001	0.723
EP4-Other Fees (HOA/Condo fees, tax, etc.,)	0.811	< .001	0.579
Factor 5: Residential satisfaction			
S1-Plan to Live permanently	1.264	< .001	0.836
S2-Recommend to others	1.18	< .001	0.825
S3-If look back, would move here again	1.02	< .001	0.744
S4-Overall Neighborhood Satisfaction	1.002	< .001	0.702
S5-Overall Home Satisfaction	0.972	< .001	0.77

Fit indices: X2/df= 1.3, p-value= <.001; CFI= 0.956; RMSEA= .040; SRMR= 0.051

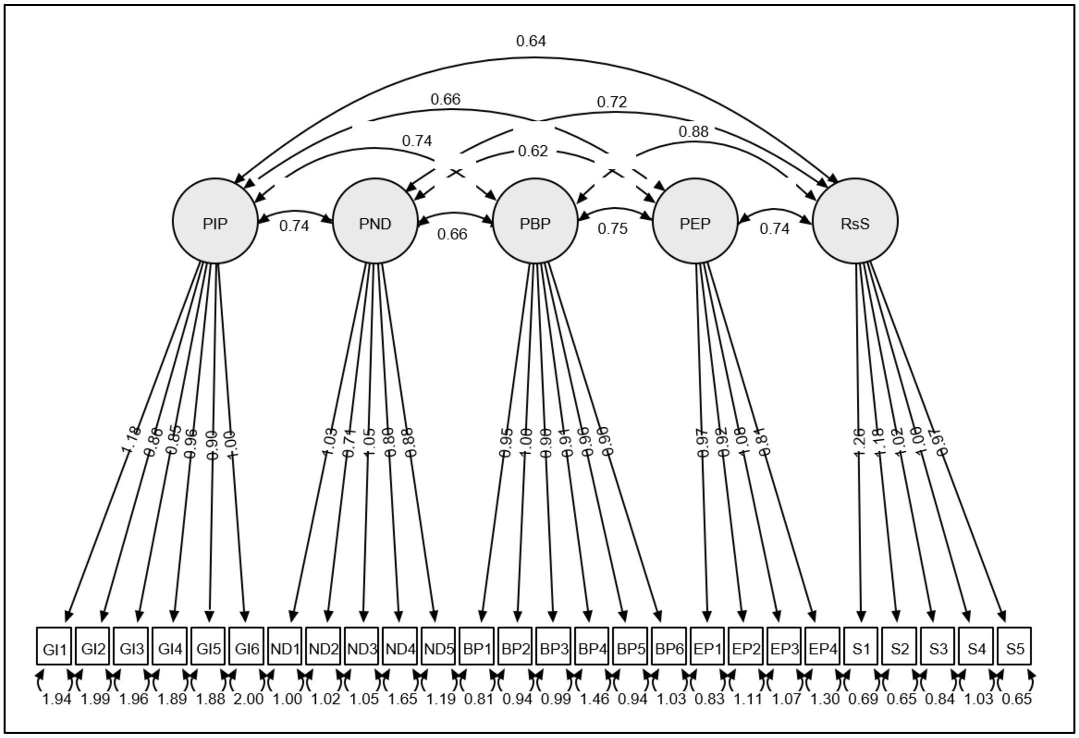

Figure 5.2 Confirmatory Factor Analysis modified model

Fit indices: X2/df= 1.3, p-value= <.001; CFI= 0.956; RMSEA= .040; SRMR= 0.051

As shown in Table 5.8 and Figure 5.2, overall fit indices show that the overall model fits the data and can provide a valid and reliable structural equation model to evaluate the relationships between the latent independent and dependent variables.

5.6 Structural Equation Modeling

This section presents the results of the SEM that is conducted to address research question 2 concerning the relationships between the perceived performance of the built environment and the residential satisfaction in LEED-certified residential communities. The results of the SEM are presented graphically in Figure 5.3 and the key findings are summarized in Table 5.9.

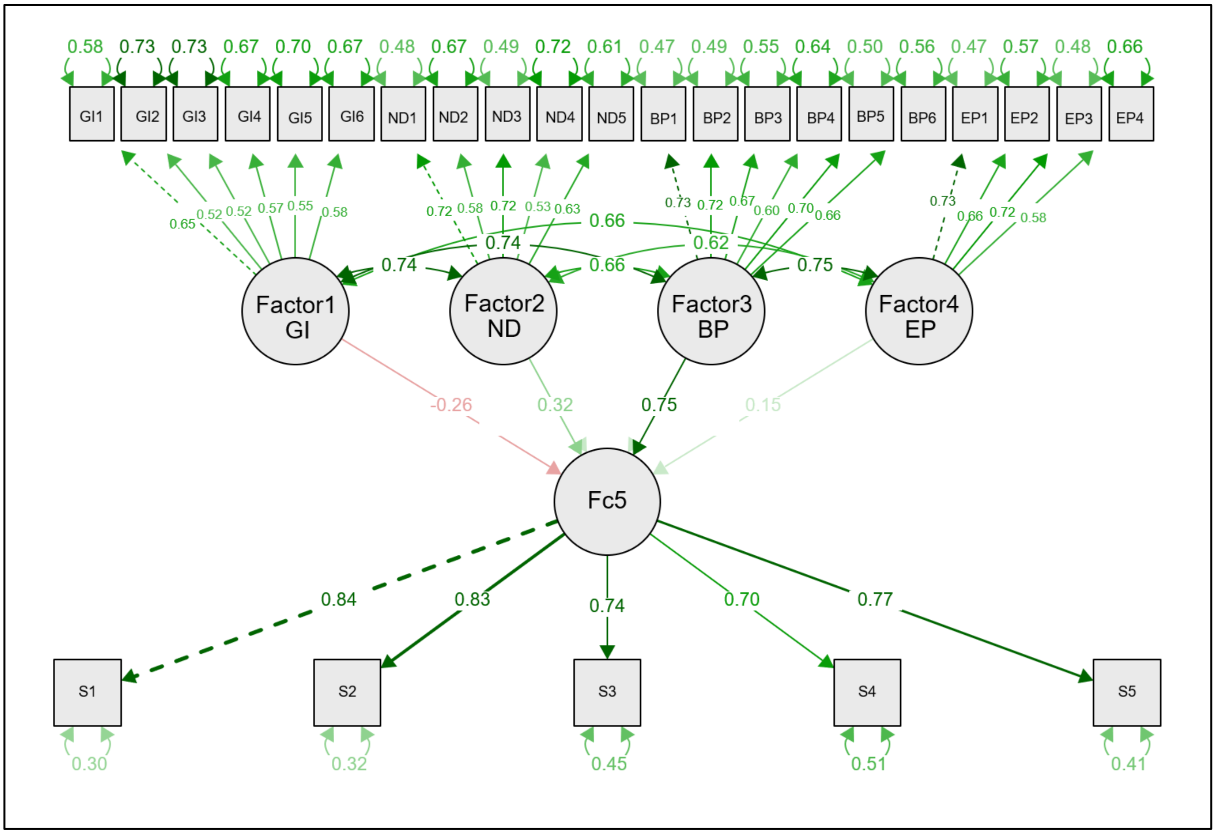

Figure 5.3 Modeling the effects of the perceived performance on satisfaction

Fit indices: X2/df= 1.30, p-value < .001: CFI= 0.956; RMSEA= 0.040; SRMR= 0.51

Table 5-9 Summary of SEM key results: the relationships between IVs and the DV

Latent variables (IVs)	estimate	Std. error	z	p	std (all)
Perceived Infrastructure Performance	-0.281	0.149	-1.883	0.06	-0.261
Perceived Neighborhood Design	0.394	0.157	2.512	**0.012**	0.322
Perceived Building Performance	1	0.203	4.918	**< .001**	0.751
Perceived Cost performance	0.199	0.176	1.132	0.258	0.153

*Dependent Variable: Residential Satisfaction

Perceived building performance and perceived neighborhood design have significant relationships with residential satisfaction. Among the two independent variables, perceived building performance is the most influential (coefficient=0.0.751, p<.001) followed by perceived neighborhood design (coefficient= 0.322, p=0.012). Other independent variables including perceived infrastructure performance (p=0.06) and perceived cost performance (p= 0.15) do not bring significant information to explain the influence on satisfaction score meaning these independent variables do not show a statistically significant relationship with residential satisfaction.

As Hypothesis H2-1 was rejected about the relationships between Perceived GI and RS as well as the relationship between the perceived EP and RS, it seemed necessary to dig into the relationships by adding some control variables to the analysis to account for their effects.

5.7 Adding Control Variables to The Model

In social research, control variables should be added to the regression model to account for their effects on the relationships between independent and dependent variables (Hünermund & Louw, 2020). If the socio-demographic characteristics of the respondents are not the main variables of interest in a study, they should be controlled in order to evaluate the effect of the main factors of interest on one another (Abass & Tucker, 2018). Therefore, socio-economic factors of gender, age, education, and income were considered as the control variables for the model in this study. The results are presented in Figure 5.4 and Table 5.10.

Table 5-10 Summary of SEM key results after accounting for socio-economic factors

Latent variables (IVs)	estimate	Std. error	z	p	std (all)
Gender	0.034	0.125	0.27	0.787	0.014
Age	0.063	0.062	1.016	0.309	0.045
Education	0.032	0.049	0.658	0.511	0.031
Income	0.046	0.046	0.985	0.325	0.048
Perceived Infrastructure Performance	-0.068	0.065	-1.870	0.06	-0.062
Perceived Neighborhood Design	0.249	0.060	2.45	**< .001**	0.233
Perceived Building Performance	0.533	0.063	4.712	**< .001**	0.538
Perceived Cost Performance	0.206	0.061	1.130	**< .001**	0.192

*Dependent Variable: Residential Satisfaction

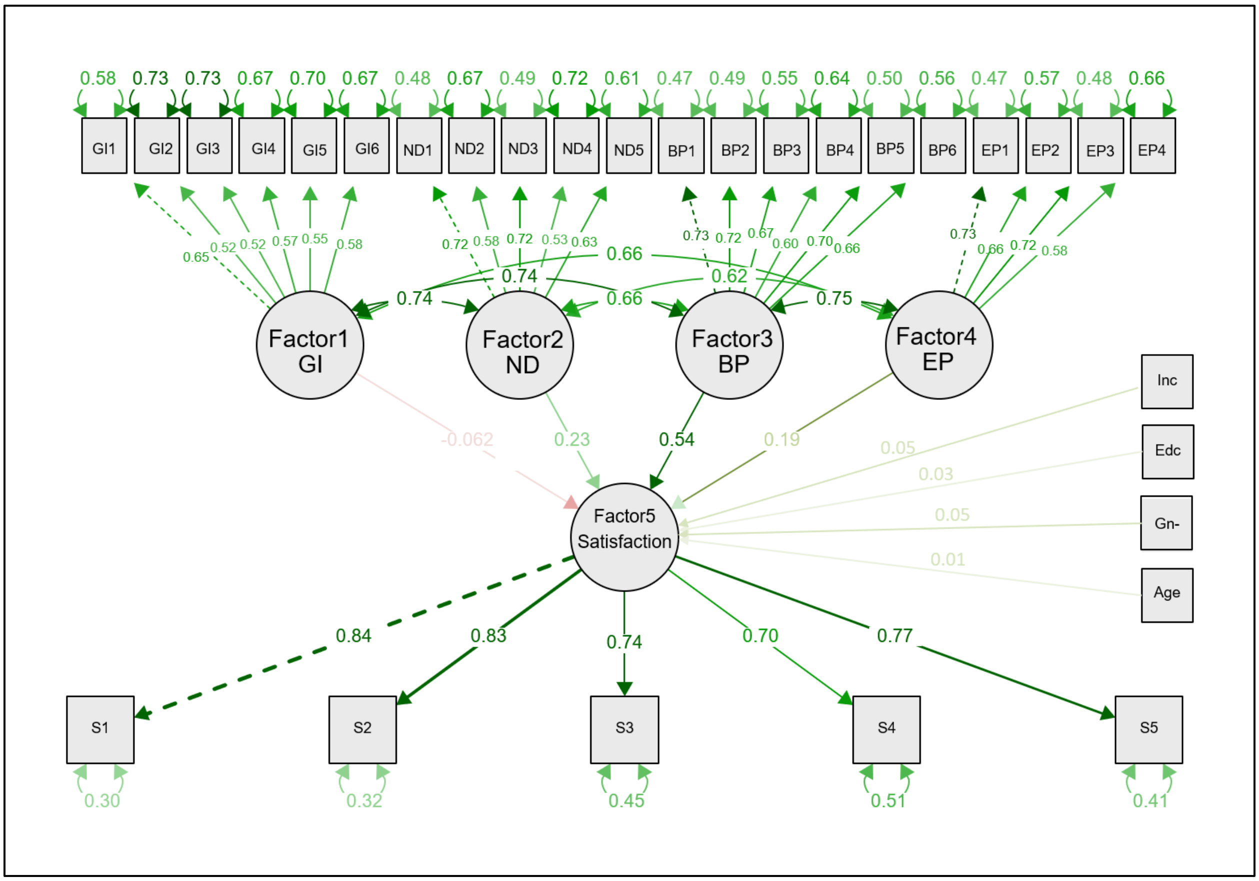

Figure 5.4 The effects of the perceived performance of the built environment on satisfaction after adding control variables

Fit indices: $X^2/df = 1.33$, p-value < .001: CFI= 0.951; RMSEA= 0.042; SRMR= 0.61

Adding control variables to the model, the relationship between perceived cost performance and residential satisfaction turned into a significant relationship (coefficient = 0.206, $p<0.001$) while the other relationships did not show any significant changes.

5.8 Evaluating The Effect of Moderators

Change in the relationship between cost performance and satisfaction motivated the evaluation of the interaction effect of affordability on the relationship between cost performance and overall satisfaction. Therefore, the data on median housing costs per year and median monthly income per household for each county in the US was obtained from Harvard Joint Center for Housing Studies (JCHS). Although within a county there can be variation in income and housing cost, these factors can provide a picture of the affordability of each project location compared to the others. The affordability index for each project (based on the county that the project is located) was then calculated by dividing median yearly income by the housing costs per year. Next, the affordability index was entered into the model as a moderator to interact with cost performance. The results of the moderation analysis are presented in Table 5.11. The results indicate that affordability does not moderate the relationship between cost performance and residential satisfaction ($p= 0.879$).

Table 5-11 Interaction effect of affordability and cost performance

Variable	Unstandardized	Standard Error	Standardized	t	p
Gender	0.041	0.09	0.022	0.455	0.65
Age	0.048	0.048	0.046	1.013	0.312
Education	0.02	0.038	0.025	0.539	0.59
Income	0.028	0.037	0.038	0.754	0.452
GI	-0.067	0.066	-0.061	-1.002	0.318
ND	0.257	0.061	0.241	4.243	< .001
BP	0.539	0.065	0.525	8.336	< .001
CP	0.149	0.445	0.139	0.335	0.738
Affordability	1.961	1.546	0.057	1.269	0.206
CP ＊ Affordability	0.291	1.913	0.063	0.152	0.879

Another factor that was considered as a potential moderator of the relationship between perceived cost performance and residential satisfaction was the housing tenure of the respondents (renter vs. owner). Therefore, tenure was dummy coded (0= renter and 1= owner) to be entered into the model as the moderator. The results (Table 5.12) indicate that the interaction between tenure and cost performance does not have any significant relationship with residential satisfaction. In other words, tenure does not moderate the relationship between perceived cost performance and residential satisfaction (p=0.959).

Table 5-12 Interaction effect of tenure and cost performance

Variable	Unstandardized	Standard Error	Standardized	t	p
Gender	0.049	0.091	0.026	0.539	0.591
Age	0.043	0.049	0.041	0.888	0.376
Education	0.019	0.038	0.024	0.506	0.613
Income	0.043	0.038	0.059	1.116	0.266
GI	-0.053	0.066	-0.049	-0.8	0.425
ND	0.253	0.06	0.238	4.223	< .001
BP	0.547	0.064	0.533	8.596	< .001
CP	0.213	0.091	0.199	2.334	0.021
Tenure-dummy	-0.124	0.095	-0.064	-1.299	0.196
CP ✻ Tenure	-0.006	0.108	-0.004	-0.052	0.959

Another factor that was considered as a potential moderator of the relationship between perceived cost performance and residential satisfaction was the income of the respondents. The results (Table 5.13) indicate that the interaction between income and cost performance does not have any significant relationship with residential satisfaction. In other words, income does not moderate the relationship between perceived cost performance and residential satisfaction (p=0.818).

Table 5-13 Interaction effect of income and cost performance

Variable	Unstandardized	Standard Error	Standardized	t	p
Age	0.051	0.047	0.048	1.074	0.284
Education	0.024	0.038	0.031	0.647	0.518
Income	0.031	0.037	0.042	0.828	0.409
Gender-dummy	0.036	0.09	0.019	0.403	0.687
GI-Factor Score	-0.07	0.066	-0.064	-1.07	0.286
ND-Factor Score	0.249	0.06	0.233	4.148	< .001
BP-Factor Score	0.553	0.064	0.538	8.682	< .001
EP-Factor Score	0.174	0.152	0.162	1.14	0.256
CP ✻ Income	0.008	0.037	0.032	0.231	0.818

Looking back to the relationships between the perceived performance of the infrastructure and residential satisfaction, it was illustrated that this relationship did not change even after adding the control variables to the model. This lack of significant relationship motivated the evaluation of the moderation effect of two important location-related factors on the relationship between perceived infrastructure performance and residential satisfaction. Therefore, reviewing the literature illustrated two important factors that can potentially have a moderation effect on this relationship. Rainfall and temperature are the main factors that define the climate of an area together and climate is found to be an important aspect in determining priorities for the development of infrastructure thus affecting residential satisfaction (Daniel et al., 2014; Maddison & Rehdanz, 2011; Schweikert et al., 2014; Shakou et al., 2019).

First, the moderation effect of rainfall on the relationship between perceived infrastructure performance and residential satisfaction was evaluated. The rainfall data were collected from NOAA (National Oceanic and Atmospheric Administration) and reported based on mean annual climatology for the past 30 years. The results of this test (Table 5.14) indicated no moderation effect of rainfall on the relationship between infrastructure performance and residential satisfaction ($p=0.812$).

Table 5-14 Interaction effect of rainfall and infrastructure performance

	Unstandardized	Standard Error	Standardized	t	p
Gender	0.014	0.09	0.008	0.161	0.873
Age	0.063	0.047	0.06	1.322	0.188
Education	0.024	0.037	0.029	0.63	0.529
Income	0.032	0.037	0.044	0.877	0.382
GI	-0.055	0.126	-0.05	-0.432	0.666
ND	0.238	0.06	0.223	3.988	< .001
BP	0.56	0.063	0.545	8.837	< .001
CP	0.197	0.061	0.184	3.223	0.002
Rainfall	0.005	0.003	0.087	1.929	0.055
GI ✻ Rainfall	-7.980e -4	0.003	-0.025	-0.239	0.812

Another location-related factor that was considered as a potential moderator of the relationship between perceived infrastructure performance and residential satisfaction was the temperature. The temperature data were collected from NOAA (National Oceanic and Atmospheric Administration) and reported based on mean annual climatology for the past 30 years. The results of this test (Table 5.15) indicated no moderation effect of temperature on the relationship between infrastructure performance and residential satisfaction (p=0.874).

Table 5-15 Interaction effect of temperature and infrastructure performance

	Unstandardized	Standard Error	Standardized	t	p
Gender	0.032	0.09	0.017	0.361	0.719
Age	0.052	0.047	0.049	1.091	0.277
Education	0.024	0.038	0.03	0.628	0.531
Income	0.032	0.037	0.045	0.871	0.385
GI	0.005	0.449	0.005	0.012	0.991
ND	0.251	0.06	0.235	4.167	< .001
BP	0.547	0.064	0.532	8.503	< .001
CP	0.215	0.063	0.2	3.426	< .001
Temperature	0.004	0.006	0.032	0.697	0.487
GI ✻ Temperature	-0.001	0.008	-0.065	-0.159	0.874

In summary, evaluating the moderation effects of three important socio-economic aspects on the relationship between cost performance and residential satisfaction indicated that housing tenure (p Value= 0.956), affordability (p Value= 0.879), and Income (p Value= 0.818) do not moderate this relationship. Moreover, evaluating the moderation effects of the most important determinants of climate on the relationship between infrastructure performance and residential satisfaction showed that mean annual rainfall (p Value= 0.812) and mean annual temperature (p Value= 0.874) do not have any impact on this relationship.

5.9 Identifying The Most Important Determinants of Residential Satisfaction

This section presents the results of the data analysis that was conducted to address research question 3. This research question concerns determining the most influential features of LEED-certified residential communities in predicting residential satisfaction.

RQ3: In LEED-certified residential communities, what are the most important determinants of long-term success through influencing residential satisfaction?

The results for research question 2 indicated the influence of each latent factor on residential satisfaction. However, the role that each attribute of the built environment plays in determining residential satisfaction is still unclear. Therefore, this section moves into more detail and discusses the relationships at the indicator (attribute) level.

With regards to independent variables, after conducting CFA for each factor and modifying them, it became clear that each retained indicator has a meaningful contribution in explaining its corresponding latent factor. However, the importance of each observed indicator in explaining the variance of the latent variable is not still clear. In other words, it is not clear how much each observed indicator (attribute) is effective in predicting residential satisfaction. Understanding the influences of the observed variables (rather than latent variables) on overall satisfaction is possible through conducting a path analysis for the indicators of each factor. The most appropriate analysis method to conduct this path analysis is a multiple linear regression analysis between the indicators of each latent variable and the overall satisfaction.

As the CFA for the dependent variable showed a good fit after modification, it means that factor 5 (satisfaction) is a good representation of all the indicators and therefore, the dependent variable for the multiple regression analysis under the path analysis could be represented by averaging the scores of its indicators. In order to conduct the multiple regression analysis, key method assumptions need to be tested. The importance of meeting regression assumptions and the negative effects of violations of the assumptions were discussed in Chapter 4. Therefore, in this section, only the results of the assumption testing are reported followed by the results of the multiple regression analysis between the indicators of each factor and the dependent variable.

5.9.1 Assumption Test

The scatterplot of standardized predicted values (standardized residuals) (Figure 5.5) clearly shows the linear relationship between dependent and independent variables. Furthermore, as there is no clear pattern in the distribution of residuals (bell shape, funnel shape, cone shape, etc.), the data meet the assumption of homoscedasticity, meaning that the variance of errors is almost the same across all levels of the independent variables.

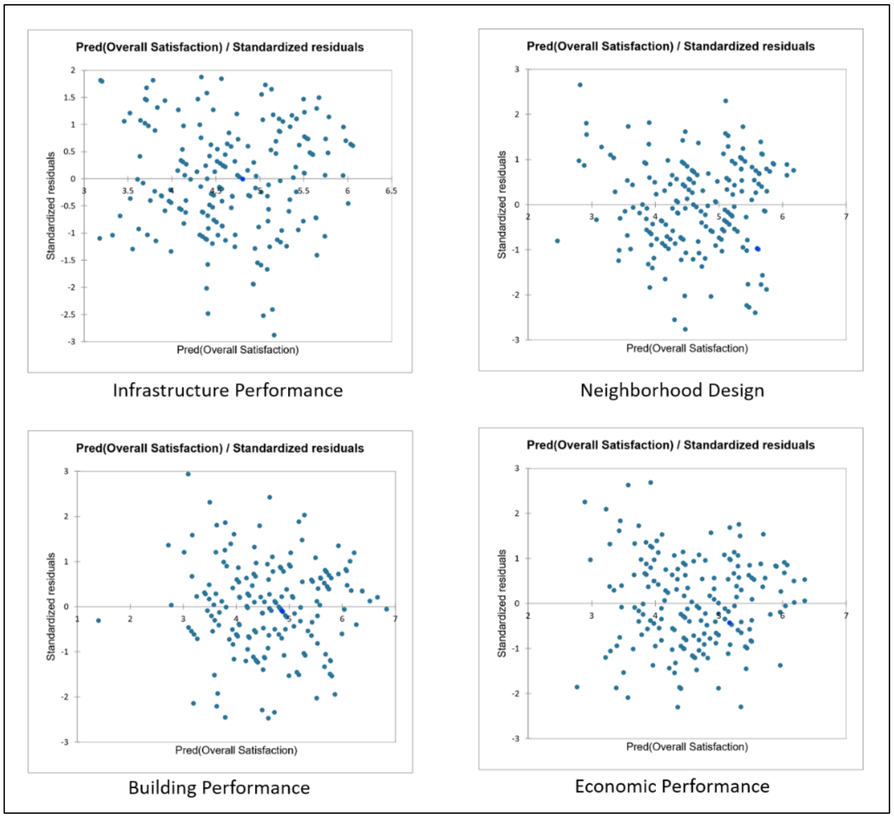

Figure 5.5 residual scatter plot

The results of the Shapiro-Wilk test (Table 5.16) show multivariate normality for all the indicators of each variable (all p-values > 0.05).

Table 5-16 Shapiro-Wilk tests

	GI	ND	BP	EP
Shapiro-Wilk	0.988	0.990	0.992	0.994
p-value (Two-tailed)	0.113	0.247	0.434	0.697

According to the results of the Durbin-Watson tests for examining the autocorrelations among the residuals (Table 5.17), the errors show a random distribution across all the variables (all p-values > 0.05). Therefore, the assumption of independence of errors is met.

Table 5-17 Durbin-Watson test

Variable	Durbin-Watson		
	Autocorrelation	**Statistic**	**p**
Green Infrastructure	0.069	1.857	0.313
Neighborhood Design	0.111	1.643	0.114
Building Performance	0.103	1.793	0.153
Economic Perfromance	0.117	1.573	0.093

Finally, the tests for the assumption of multicollinearity are presented in Table 5.18. As shown in this table, the results indicate that multicollinearity is not a concern among the independent variables with all the tolerances being greater than 0.1 and VIFs (variance inflation factor) being smaller than 10.

Table 5-18 Multicollinearity: Tolerance and VIF tests

Green Infrastructure		GI1	GI2	GI3	GI4	GI5	GI6
	Tolerance	0.662	0.759	0.736	0.780	0.795	0.740
	VIF	1.510	1.318	1.359	1.283	1.258	1.351
Neighborhood Design		ND1	ND2	ND3	ND4	ND5	
	Tolerance	0.697	0.764	0.641	0.768	0.704	
	VIF	1.434	1.309	1.561	1.303	1.420	
Building Performance		BP1	BP2	BP3	BP4	BP	BP6
	Tolerance	0.528	0.573	0.596	0.640	0.616	0.651
	VIF	1.892	1.744	1.677	1.562	1.623	1.535
Cost performance		EP1	EP2	EP3	EP4		
	Tolerance	0.613	0.636	0.575	0.700		
	VIF	1.632	1.573	1.740	1.428		

5.9.2 Multiple Regression Analyses Results

In order to identify and rate the most influential attributes of each latent variable in determining the level of satisfaction, separate multiple regression analyses were conducted between all the indicators of each variable and the overall satisfaction. As such, there was a need for another round of detecting outliers and influential responses based on the new sets of variables. After removing all the outliers, based on residual scatter plot (std. residuals greater than 3.29 and smaller than -3.29) and removing the influential responses based on Cook's distance (Treshhold = 0.049), the retained responses for each category were considered for multiple regression analysis. The sample size for each regression analysis is presented in Table 5.19. The goodness of fit statistics in this table shows a comparison of the percentage of the variability of residential satisfaction that is explained by each set of independent variables (attributes). The results indicate that the building performance attributes explain the variability of the residential satisfaction more than other sets of indicators (R^2 = 0.674).

Table 5-19 Goodness of fit statistics

	GI attributes	ND attributes	BP attributes	EP attributes
Sample size (N)	186	187	184	186
Sum of weights	186	187	184	186
DF	179	181	177	181
R^2	0.392	0.474	0.674	0.481
Adjusted R^2	0.371	0.459	0.663	0.470

*Dependent Variable: Overall Satisfaction

A list of the built environment attributes (independent variables in this research question) that are entered into the regression model is presented in Table 5.20. The dependent variable is overall satisfaction.

Table 5-20 List of the independent variables (indicators) under each factor

Perceived Infrastructure Performance	Perceived Neighborhood Design	Perceived Building Performance	Perceived Cost performance
GI1: Outdoor lighting	ND1: Walkability	BP1: Thermal comfort	EP1: Home value/rent
GI2: Recycling facility	ND2: Density	BP2: Daylight	EP2: Utility bills
GI3: Rainwater collection system	ND3: Mixed-use	BP3: Water efficiency	EP3: Travel costs
GI4: Public transportation	ND4: Housing diversity	BP4: Quality views	EP4: Other fees
GI5: Cycling infrastructure	ND5: Open space access	BP5: Indoor materials	
GI6: Road quality		BP6: Energy efficiency	

In order to find if the results of each analysis are statistically significant, the p-value of the ANOVA test for each analysis is presented in Table 5.21. P-values of <0.0001 were obtained for all tests, indicating that the findings of all the analyses are statistically significant.

Table 5-21 The p-values of ANOVA for each regression model

	GI attributes test	ND attributes test	BP attributes test	EP attributes test
P-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

*Dependent Variable: Overall Satisfaction

Finally, in order to understand the importance of different attributes of the built environment in determining residential satisfaction in LEED-certified residential communities, the regression coefficients for the attributes of each factor are presented in Table 5.22.

Table 5-22 Standardized coefficients for each test

Variable	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Green Infrastructure attributes						
GI1-OutLgth	0.027	0.053	0.508	0.612	-0.078	0.132
GI2-Rcycling	0.226	0.064	3.535	**0.001**	0.100	0.352
GI3-RWCollect	-0.028	0.065	-0.428	0.669	-0.156	0.101
GI4-Transprt	0.276	0.059	4.660	**<0.0001**	0.159	0.392
GI5-Bike	0.184	0.062	2.949	**0.004**	0.061	0.306
GI6-RdQlty	0.237	0.070	3.399	**0.001**	0.099	0.374
Neighborhood Design attributes						
ND1-Walk	0.356	0.064	5.598	**<0.0001**	0.230	0.481
ND2-Dnsty	0.180	0.065	2.775	**0.006**	0.052	0.309
ND3-MixUSe	0.244	0.075	3.235	**0.001**	0.095	0.393
ND4-HsingDiv	0.051	0.060	0.846	0.399	-0.068	0.170
ND5-PbSpce	0.083	0.058	1.447	0.150	-0.030	0.197
Building Performance attributes						
BP1-Thrmal	0.152	0.068	2.244	**0.026**	0.018	0.286
BP2-Dylight	0.199	0.061	3.253	**0.001**	0.078	0.320
BP3-WtrEff	0.256	0.070	3.665	**0.000**	0.118	0.395
BP4-View	0.077	0.050	1.556	0.122	-0.021	0.176
BP5-Mtrial	0.194	0.069	2.812	**0.005**	0.058	0.330
BP6-EnrgyEffic	0.207	0.051	4.086	**<0.0001**	0.107	0.307
Economic Perfromance attributes						
EP1-Vlu/Rnt	0.404	0.081	4.975	**<0.0001**	0.244	0.565
EP2-UtilityBill	0.190	0.067	2.854	**0.005**	0.059	0.322
EP3-TrvlCst	0.192	0.071	2.718	**0.007**	0.053	0.331
EP4-Fees	0.065	0.073	0.895	0.372	-0.078	0.208

*Dependent Variable: Overall Satisfaction

As shown in Table 5.22, among the attributes (indicators) of Green Infrastructure, recycling facility availability (p =.001), public transportation infrastructure (p <.0001), biking infrastructure (p =.004), and road quality (p = .001) provide statistically significant information to explain the variability of residential satisfaction. Among these four attributes, public transportation infrastructure (coefficient=0.276) has the strongest influence on residential satisfaction followed by road quality (coefficient=0.237) and recycling facility availability (coefficient=0.226). Biking infrastructure has the lowest significant contribution in providing residential satisfaction (coefficient=0.184) among Green Infrastructure attributes. Other attributes such as outdoor lighting and rainwater collection system do not have a statistically significant relationship with residential satisfaction.

Among the Neighborhood Design attributes, walkability ($p<.0001$), density ($p=.006$), and mixed-use ($p=.001$) bring statistically significant information to explain the variability of residential satisfaction. Among these three significant attributes, walkability (coefficient=0.356) has the strongest influence on residential satisfaction followed by mixed-use (coefficient=0.244). Density has the lowest significant contribution in providing residential satisfaction (coefficient= 0.180) among Neighborhood Design attributes. Other attributes such as housing diversity and public space access do not have a statistically significant relationship with residential satisfaction.

Among the Building Performance attributes, thermal comfort ($p=.026$), daylight ($p=.001$), water efficiency ($p=.000$), materials ($p=.005$), and energy efficiency ($p<.0001$) provide statistically significant information to explain the variability of residential satisfaction. Among the five significant attributes, water efficiency (coefficient=0.256) has the largest influence on residential satisfaction followed by energy efficiency (coefficient=0.207), daylight (coefficient=0.199), and materials (coefficient=0.194). Thermal comfort has the lowest significant contribution in providing residential satisfaction (coefficient=0.154) among building performance attributes. On the other hand, the quality view does not have a statistically significant relationship with residential satisfaction.

Among the Cost performance attributes, home rent/value (p <.0001), utility bills (p-value =.005), and travel costs (p =.007) have a statistically significant relationship with residential satisfaction. Among these three significant attributes, home value/rent (coefficient=0.404) has the strongest influence on residential satisfaction followed by travel costs (coefficient=0.192) and utility bills (coefficient=0.190). On the other hand, other fees associated with living in these communities do not have a statistically significant relationship with residential satisfaction.

5.9.3 Evaluating The Effect of Moderators on The Relationship Between GI and Residential Satisfaction

As discussed in section 5.5.4, the relationship between perceived infrastructure performance and residential satisfaction remained insignificant after adding control variables to the model. Moreover, average annual rainfall and average annual temperature were not found to function as moderators of the relationships between perceived infrastructure performance and residential satisfaction. Therefore, the effect of moderators at the indicator level became important to be evaluated. More specifically, the two indicators that did not show any significant relationships with satisfaction (outdoor lighting and rainwater collection system) were focused on as the potential reasons for the lack of relationships between infrastructure performance and residential satisfaction.

5.9.4 Interaction Effect of Demographic Factors on The Relationship Between Outdoor Lighting and Satisfaction

Research has shown that outdoor lighting has a strong relationship with the feeling of safety among urban residents (Green et al., 2015; Rahm et al., 2021) and among the residents, women and elderly people are found to have more concern about the street lighting (Boomsma & Steg, 2014; Fotios et al., 2015a; Madge, 1997; Paydar et al., 2017). Therefore, this study evaluated the moderation effect of gender and age on the relationship between lighting and residential satisfaction. Table 5.23 shows the results of testing the interaction effect of gender on the relationship between outdoor lighting and residential satisfaction. The results show that gender does not have any moderation effect on the relationship between outdoor lighting and residential satisfaction (P= 0.319).

Table 5-23 Interaction effect of gender on the relationship between lighting and satisfaction

	Unstandardized	Standard Error	Standardized	t	p
GI1-Outdoor Lighting	-0.037	0.048	-0.072	-0.775	0.439
GI2-Rcycling Infrastructure	0.105	0.04	0.185	2.617	0.01
GI3-RW Collection System	-0.011	0.041	-0.019	-0.272	0.786
GI4-Public Transportation	0.125	0.039	0.222	3.216	0.002
GI5-Biking Infrastructure	0.11	0.04	0.19	2.763	0.006
GI6-Road Quality	0.112	0.039	0.206	2.895	0.004
Gender	-0.098	0.321	-0.052	-0.306	0.76
GI1-Outdoor Lighting ※ Gender	0.066	0.066	0.192	0.999	0.319

Table 5.24 shows the results of testing the interaction effect of age on the relationship between outdoor lighting and residential satisfaction. The results show that age has a moderation effect on the relationship between outdoor lighting and residential satisfaction (P= 0.029).

Table 5-24 Interaction effect of age on the relationship between lighting and satisfaction

	Unstandardized	Standard Error	Standardized	t	p
GI1-OutLgth	-0.222	0.11	-0.43	-2.03	0.044
GI2-Rcycling	0.118	0.041	0.207	2.912	0.004
GI3-RWCollect	-0.03	0.041	-0.051	-0.722	0.471
GI4-Transprt	0.138	0.039	0.245	3.574	< .001
GI5-Bike	0.1	0.039	0.173	2.524	0.012
GI6-RdQlty	0.122	0.038	0.224	3.215	0.002
Age	-0.419	0.179	-0.397	-2.338	0.02
GI1-OutLgth ✻ Age	0.084	0.038	0.594	2.206	0.029

5.9.5 Interaction Effect of Rainfall on The Relationship Between Rainwater Collection System and Satisfaction

The amount of annual rainfall is one of the most important factors in determining the need for rainwater collection systems. Indeed, this factor is expected to be more important in dry areas compared to wet areas. As in this study, the relationship between residential satisfaction and rainwater collection systems in LEED-certified residential communities was not significant, the potential moderation effect of the amount of rainfall on this relationship became important. Therefore, this study evaluated the interaction effect of this factor on the relationship between rainwater collection and residential satisfaction. Although the interaction effect was not significant with a 95% confidence interval, the results (Table 5.25) show a considerable improvement in the significance of the relationship between rainwater collection and residential satisfaction. The relationship between residential satisfaction and rainwater collection system was found to be negatively affected by the average annual rainfall with a 90% confidence interval (Coefficient = 0.179, p=0.065).

Table 5-25 Interaction effect of rainfall on the relationship between RW system and satisfaction

	Unstandardized	Standard Error	Standardized	t	p
GI1-Outdoor Lighting	-0.009	0.038	-0.017	-0.236	0.814
GI2-Rcycling Infrastructure	0.106	0.04	0.186	2.647	0.009
GI3-RW Collection System	0.143	0.095	0.248	1.501	0.135
GI4-Public Transportation	0.116	0.039	0.205	2.966	0.003
GI5-Biking Infrastructure	0.101	0.039	0.176	2.582	0.011
GI6-Road Quality	0.132	0.038	0.242	3.454	< .001
Rainfall	0.027	0.012	0.434	2.317	0.022
GI3-RWCollect ✻ Rainfall	-0.005	0.003	-0.453	-1.854	0.065

5.10 Comparison of Perceived Performance and Residential Satisfaction in LEED and Non-LEED Projects

This section presents the results of the data analysis that was conducted to address research question 4. This research question focuses on a comparison between the perceived performance of the built environment and satisfaction in the LEED projects and non-LEED projects.

RQ4: Does sustainability impact residential satisfaction and the perceived performance of the built environment in residential communities?

To address this research question, a set of comparisons between the perceived performance and satisfaction of LEED projects (as the experiment group) and non-LEED projects (as the control group) should be conducted. Therefore, the variables for this question are the same as the research question 2. However, in this section, the responses from the residents of non-LEED projects are also added to the data, and a two-level categorical variable is also added to the dataset that differentiates between LEED and non-LEED community residents. This variable is called “Type” showing each response’s project type.

There are two strategies to test for invariance among the groups including top-down and bottom-up approaches. In this study, the bottom-up approach was adopted. That is, the test starts with the weakest level of invariance, which is configural invariance (Davidov, 2009). Therefore, in the first place, the single group CFAs are conducted. Next, the invariance tests will be conducted.

The CFA model that was developed for LEED projects was considered again for the experiment group, which showed a good fit (discussed in RQ2). Therefore, confirmatory factor analysis was first conducted for the non-LEED group to check the fit of the model. After few modifications were made (added residual covariances between ND2 and ND4, between GI2 and GI3, between BP3 and BP6, and between ND1 and ND5), the fit measures of the CFA for the control group showed an acceptable fit (X2/df= 1.34, p-value= <.001; CFI= 0.947; RMSEA= .043; SRMR= 0.050). All items had relatively high factor loadings (above 0.5).

5.11 Multiple-Group CFA and Invariance Testing

In order to test for measurement invariance, a CFA was conducted for all the samples (n = 375) without cross-group constraints. This model should show a good fit in order to test further constraints and make a comparison between the two groups. The fit indices for the group containing both LEED and non-LEED residents without grouping showed a very good fit of the model (X2/df= 1.57, p-value= <.001; CFI= 0.955; RMSEA= .039; SRMR= 0.043) thus suggesting that further constraints can be added to begin the comparison between the groups. As pointed out previously, Chi-square (X2) is extremely sensitive to the fit of the model, and only if the model is perfectly fit it will be insignificant (also known as absolute fit measures). Therefore, even when it is significant, the model can be considered a good fit if other fit indices look good.

The next step was to run a Multiple Group CFA to test for configural invariance followed by conducting a test for metric invariance across the two groups, which fixes the loadings across the groups. Next, a scalar invariance test was carried out that fixes both loadings and intercepts across the groups. A comparison was then made between the three models in terms of fit indices. The results of the comparison are presented in table 5-26. According to Chen (2008), if the decrease in CFI for each level of invariance is greater than 0.01, compared with the previous level, the increase in RMSEA is greater than 0.015, and ΔSRMR is greater than +0.030 (for metric invariance) or +0.015 (for scalar invariance), the invariance between the groups is rejected meaning that the two models for the groups cannot be compared as they are not measuring same latent factors. Therefore, although the measures being the same for the two groups, the understanding of the questions and measures could be different between the groups thus resulting in variance in measurement. The results of the fit indices of the metric model and scalar model across the groups are presented in Table 5.26.

Table 5-26 Fit indices of metric and scalar models

	Chi-square			CFI	RMSEA	SRMR
Model	X^2	df	p-value			
Configural	458.95	289	<0.001	0.951	0.042	0.050
Metric	868.97	599	<0.001	0.950	0.042	0.059
Scalar	918.31	620	<0.001	0.943	0.044	0.059

The results show that CFI has decreased more than 0.01 (ΔCFI= 0.07) when moving from the metric level to the scalar level. Therefore, despite RMSEA has increased less than 0.015 (ΔRMSEA = 0.02) and SRMR showed no increase (ΔRMSEA = 0.02), it is concluded that the scalar invariance cannot be met by the data thus comparing the means of latent factors between the two groups will lead to serious misinterpretation of true mean differences (Chen, 2007b, 2008; Davidov, 2009; Horn & McArdle, 1992; Meade, Johnson, & Braddy, 2008; Putnick & Bornstein, 2016; Rutkowski & Svetina, 2014; Steenkamp & Baumgartner, 1998a; Steinmetz, 2013; Vandenberg & Lance, 2000).

Although measurement invariance in the scalar level is desirable to compare two groups, it may happen rarely in practice (Millsap & Meredith, 2012). Therefore, some researchers suggest that partial invariance is enough to make comparisons across groups (Byrne et al., 1989; Steenkamp & Baumgartner, 1998b; French & Finch, 2016). Partial invariance means that some but not all factor parameters should be equal across the groups (Maller & French, 2004). Looking back to the measurement invariance test results (Table 5.26), the groups are invariant in the metric level meaning that complete inequality does not exist in the data. This situation can be considered as partial invariance (Dimitrov, 2006). Therefore, the mean structure was included in the MGCFA model to provide a comparison of the means between the two groups by fixing the intercept (mean) of one group to zero and comparing the mean of the other group with the first group. Table 5.27 indicates the results of the comparison of perceived performance and residential satisfaction between LEED and non-LEED groups. The table indicates that there is no significant difference between LEED and non-LEED projects with regard to factors 1 to 5, meaning that there is no significant difference between perceived performance and residential satisfaction of the two groups.

Table 5-27 The factor intercept for non-LEED projects

Factor	**Estimate**	**Std. Error**	**z-value**	**p**	**95% Confidence Interval**		**Std. Est. (all)**
					Lower	**Upper**	
Factor 1	-0.116	0.12	-0.963	0.336	-0.352	0.12	-0.113
Factor 2	-0.144	0.118	-1.22	0.222	-0.374	0.087	-0.143
Factor 3	-0.132	0.11	-1.208	0.227	-0.347	0.082	-0.143
Factor 4	0.114	0.113	1.013	0.311	-0.107	0.335	0.125
Factor 5	0.122	0.108	1.135	0.256	-0.089	0.333	0.129

*The Estimate for all factors is fixed to zero for LEED projects

5.12 Chapter Summary

This chapter started with validating the evaluation model through a CFA. The model was modified and validated by removing the weak indicators from the model. Next, an SEM was performed in order to test the relationship between the explanatory latent variables representing the perceived performance of the built environment and the outcome latent variable that represented residential satisfaction. The results of this analysis motivated controlling for socio-demographic factors and evaluating the moderation effect of some socioeconomic factors (affordability, housing tenure) on the relationships between cost performance and residential satisfaction. The results also motivated evaluating the moderation effect of some location-related factors (mean annual rainfall and mean annual temperature) on the relationship between infrastructure performance and residential satisfaction in LEED projects.

Determining the most influential indicators in determining residential satisfaction was conducted then via a series of path analyses. These analyses resulted in identifying and rating the influential housing and neighborhood attributes on residential satisfaction. Finally, in order to compare the perceived performance and residential satisfaction between the residents of LEED-certified and non-LEED projects, an MGCFA was conducted to evaluate measurement invariance between the groups and after finding partial invariance, the mean of perceived performance and residential satisfaction were compared between the two groups. The findings of this chapter are discussed in the following chapter.

CHAPTER 6 : DISCUSSION

This chapter discusses the key findings of the research based on the results of each research question. Each key finding is discussed in detail and the overall discussion about the findings of this research is provided at the end of the chapter.

6.1 Actual Performance of The Built Environment and Sustainability

Key finding 1: The results of this study illustrated that residential density is the most influential factor, among the studied factors, in predicting community sustainability.

Density has been highlighted in the LEED-ND standard as an important factor in creating a sustainable community. This factor is a prerequisite for being LEED-certified. The importance of compactness has been even more highlighted in the LEED-ND standard by allocating up to 6 points (33% of available points under the Neighborhood Pattern and Design category) for meeting the density requirements. Looking at the majority of LEED-ND certified built projects in this study, the influence of this factor on the level of sustainability of residential communities is also highlighted demonstrating that this criterion is playing a crucial role in predicting sustainability. However, it is important to look at the other aspects of sustainability that, as pointed out in the literature review, are not considered as important in LEED certification. In other words, it is important to see if higher density, which is associated with a higher level of sustainability from the USGBC standpoint, influences other aspects of sustainability that are not highlighted in this standard.

The findings of the studies focusing on the relationships between density and sustainability indicate mixed and contradicting results. The findings of studies such as Leyden (2003) and

Kamruzzaman et al. (2014) illustrate that the density of residential projects has a positive impact on social sustainability in residential communities. On the other hand, Dempsey et al. (2012) demonstrate that increase in density is associated with negative impacts on some aspects of social sustainability including feeling of safety, less social interaction, and poor access to green space. These findings highlight that sustainability cannot be evaluated only from physical and environmental aspects, but it is important to consider the social and economic aspects in developing sustainability criteria.

Another important factor that was found in this research to significantly influence sustainability and showed a positive relationship with the level of sustainability was access to quality transit (public transit infrastructure). This factor is also highlighted in LEED-ND certification as an important aspect in determining the sustainability of residential communities. This factor provides up to 7 points (50% of available points under the Smart Location and Linkage category). The results of this research show that access to quality public transit considerably influences the level of sustainability in LEED-ND certified built projects. Several studies have highlighted the importance of high-quality public transport in enhancing sustainability in the built environment each of which has focused on a specific aspect of public transit. For example, Schiller et al. (2010) has focused on sustainability benefits that are associated with the energy efficiency of public transit. Schiller et al. (2010) focus on the social benefits and space efficiency of public transit in providing sustainability. Banister (2008) suggests that public transport provides more spaces in the urban areas to be allocated to public spaces thus improving the social and environmental sustainability of the cities. Litman and Burwell (2006) provide a long list of the social, economic, and environmental benefits of efficient public transport that could improve sustainability in the built environment. Looking at the literature, it becomes clear that public transit is a very critical aspect of sustainability, which is also highlighted in LEED certification and includes all aspects of sustainability. Showing the positive influence of public transit in predicting sustainability and discussing the findings of other studies about the importance of public transit in sustainability, this study demonstrates that the application of this criterion in LEED-ND certification is both practical and realistic.

Biking infrastructure was the third factor that was found to be associated with sustainability. Biking infrastructure is also an important factor in the LEED-ND certification system. However, its weight is lower than the two discussed factors with having 2 points (15% of available points under Smart Location and Linkage category). The results of this research showed that in the LEED-ND certified built projects, higher quality of cycling infrastructure is associated with a higher level of sustainability. This association has also been highlighted in the other studies. For example, Kaplan (2015) reported biking infrastructure as an important sustainability infrastructure that could resolve the problem of busy streets and help environmental sustainability. Newell et al. (2013) suggested the improvement of cycling infrastructure as a strategy for developing sustainable urban infrastructure. Therefore, despite having a lower weight in LEED certification, it is still considered an important part of neighborhood sustainability both based on the literature and according to the findings of this study.

Key finding 2: Walkability did not show any significant relationship with sustainability meaning it does not have any measurable influence on the level of sustainability in LEED-ND communities.

This is a very interesting and unexpected finding as walkability has been highlighted as one of the most important criteria in the Neighborhood Pattern and Design category of LEED-ND certification. This criterion is not only a prerequisite for becoming certified, but it is also worth 9 points out of the 18 available points under the Neighborhood Pattern and Design category (50% of total available points under this category). This makes walkability the most important criterion in the Neighborhood Pattern and Design category by accounting for 50% of the total available credits. However, based on the evaluation of the relationship between the built LEED-certified residential communities and their sustainability scores, this factor did not show any association with the level of sustainability.

Walkability is one of the most studied neighborhood sustainability criteria in the literature, thus highlighting the importance of this factor. For example, Hilley and Sim (2020) discuss that walkability is an important aspect of sustainability and Noriza et al. (2013) suggest that walkability is the basis of urban sustainability. Besides, Leyden (2003) and Kamruzzaman et al. (2014) have discussed walkability as an important factor that has a positive relationship with sustainability. Rafiemanzelat et al. (2017) found walkability as the determinant of sustainable urban form and discussed walking as green transportation that has a positive effect on the environment by reducing energy use, noise pollution, and providing other environmental benefits.

Therefore, the findings of this study highlight this important point that although walkability is considered as an important factor in determining sustainability both by LEED-ND standard and according to the literature, the application of this criterion does not seem very practical in the

LEED certification system and the evaluation of this factor in the process of certification should be reconsidered.

Overall, the findings of phase one of this study show some harmony and some contradictions with the existing literature. Moreover, these findings illustrate that LEED-ND certification may need to reconsider the criteria and weight of the factors that determine walkability in the neighborhood scale. Considering all the arguments that were made in this section, it is clear that more in-depth studies focusing on the post-occupancy evaluation of the LEED-certified residential communities are necessary.

6.2 The Perceived Performance of The Built Environment and Residential Satisfaction

Key finding 1: Perceived building performance has the highest influence on overall satisfaction with the residential communities followed by perceived neighborhood pattern and design. On the other hand, cost performance and neighborhood infrastructure did not show any significant relationship with residential satisfaction.

The perceived building performance having the highest influence on residential satisfaction was expected as people spend several hours of their days in their homes, and a positive perception about their immediate living environment will create higher satisfaction. Satisfaction with home can affect the residents' opinions about their neighborhood and provide overall satisfaction as Bonaiuto (2004) suggests that perceived quality of the residential units is a prerequisite of obtaining an environmental and psychological picture of the living environment. Moreover, Ibem et al. (2015) suggested that resident's evaluation of their living environment is mainly influenced by the perceived quality of housing characteristics along with the actual quality of the housing environment.

Furthermore, the influence of perceived neighborhood pattern and design on providing residential satisfaction was also expected as the design factors are tangible factors for people, and they can easily evaluate them visually. The effect of perceived performance of the neighborhood built environment on place attachment and residential satisfaction has been demonstrated by Bonaiuto et al. (1999), Gidlöf-Gunnarsson and Öhrström (2007), and Noriza et al. (2013) highlighting that neighborhood design factors are among the factors that have very important effects on determining residential satisfaction. Factors such as compactness, housing diversity, access to the public spaces, walkability, and land use mix could easily be understood and if the residents are satisfied with these factors, they usually perceive their neighborhood as a satisfactory community.

On the other hand, the relationship between perceived infrastructure performance and residential satisfaction was not found to be significant in this study. This finding was not expected as the infrastructure features that are considered in this study, namely outdoor lighting, rainwater collection systems, recycling facility, public transit, and road quality, are demonstrated to directly affect the quality of life of the people in their living environment. The finding of this research is inconsistent with Bonaiuto (2004) and Cao et al. (2020) indicating that infrastructure features are influential in determining the satisfaction of residents. However, the findings of Amérigo and Aragonés (1990) and Adriaanse (2007) showed that neighborhood infrastructure is not among the most important influential factors in determining residential satisfaction. It is worth mentioning that each of the evaluated infrastructure attributes can potentially be significantly associated with satisfaction but when we look at them as a group, their perceived performances do not have any association with overall satisfaction. This highlights the importance of evaluating the relationship between each infrastructure attribute and the overall satisfaction to understand the influence of each individual infrastructure in predicting residential satisfaction.

This study has another finding that was not expected based on the existing literature. The cost performance of the built environment was found not to have any significant relationship with residential satisfaction while Chan et al. (2002) defined the appropriate cost performance of a building as the predictor of certainty for the residents. Several studies have considered the economic aspects of the neighborhood as an important predictor of residential satisfaction (Yaman et al., 2018; Sirgy and Cornwell, 2002; Salleh, 2012, Sirgy and Cornwell, 2002; Galster, 1987; Lansing et al., 1970; Lu, 1999; Russ-Eft, 1979). As the most tangible criteria by residents, perceived cost performance was expected to be a significant predictor of residential satisfaction in this research. This finding can be due to two reasons: first, it may come from the overall high cost of living in the LEED-certified buildings and communities. If this is the case, one of the most highlighted aspects of living in a sustainable community, which is lower post-construction costs would be in doubt. The other possible reason for this finding could be the lower importance of the cost of living in sustainable communities when it comes to comparison with the quality that it is providing for residents. Even if this is the reason for the insignificant relationship between satisfaction and cost performance, still one of the main aspects that are highlighted in LEED-certification and green buildings is not working well in practice.

However, after controlling for socio-demographic variables, the relationship between perceived cost performance and residential satisfaction became significant while the other relationships did not show considerable changes. This finding highlighted the effect of these control variables in determining satisfaction with cost performance of LEED-ND communities. This finding was expected as perceived cost performance is interconnected with socio-demographic factors. This finding was inconsistent with the findings of Abass and Tucker (2018), which indicated a significant change in the relationship between the physical built environment and satisfaction after accounting for socio-demographic variables.

Following the changes in the relationship between perceived cost performance and residential satisfaction, the interaction effect of affordability and the housing tenure of the respondents were evaluated to understand if this relationship is dependent on the changes in affordability and tenure status. The results showed no moderation effect of these factors meaning that living in communities with a higher level of affordability does not affect the relationship between perceived cost performance and residential satisfaction. This finding was expected as one of the important aspects of housing sustainability is affordability, thus it can be presumed that most of the LEED-certified residential communities are meant to be affordable. The findings of this study demonstrated this presumption by indicating that all the studied projects were located in areas with affordability indices of lower than 30% (percentage of median household income per year to the housing costs per year). However, the lack of moderation effect of housing tenure on the relationship between perceived cost performance and residential satisfaction was not expected. This finding was inconsistent with Boschman (2018) and Huang et al. (2015) that illustrated the significant effect of homeownership on positively evaluating residential satisfaction.

As the relationship between perceived infrastructure performance and residential satisfaction did not change after controlling for socio-demographic variables, two location-related factors (mean annual rainfall and mean annual temperature) were entered into the model to evaluate their moderation effects on this relationship. However, neither of those variables showed a moderation effect on the relationship between perceived infrastructure performance and residential satisfaction. This finding motivated the study to dig into these relationships at the indicator level in order to identify the indicators that can describe this relationship. The findings of this analysis are discussed in the following section.

6.3 The Most Important Determinants of Residential Satisfaction in LEED Projects

As discussed in the previous section, some categories of the attributes showed a significant influence on residential satisfaction, and some did not show any relationship with satisfaction. Therefore, it was discussed that while the overall influence of a group of attributes might not be significantly related, each attribute might show influence on satisfaction if it is evaluated individually. Therefore, the relationship between each attribute and the overall satisfaction was tested and the key findings are discussed in the following sub-sections.

Key finding 1: Among the six perceived Green Infrastructure attributes, public transit infrastructure has the most significant and strongest influence on residential satisfaction followed by road quality, recycling facility, and biking infrastructure, respectively.

The public transit infrastructure being the most influential factor among the infrastructure attributes was an expected outcome as several studies have reported similar results by illustrating the importance of public transit infrastructure in providing neighborhood satisfaction. For instance, Salleh (2008) reported that poor public transportation is one of the main reasons for a low level of satisfaction. Lucas (2012)indicated that neighborhood deprivation was directly related to transportation disadvantage. Kyttä et al. (2016), Mouratidis

(2019), and Ulmer et al. (2016) found that good transport infrastructure is an important factor of residents' happiness and Dawkins et al. (2015) indicated that access to adequate and efficient transportation is an important factor in providing residential satisfaction. Therefore, the findings of this study are consistent with the existing literature. The reason for access to quality public transportation being the highest influential factor among neighborhood infrastructure attributes could be due to its direct effect on the quality of life and the living costs of residents especially in the big cities where driving personal vehicles is difficult.

Road quality is another factor that is related to both transportation quality and the visual quality of the neighborhoods. Therefore, it is one of the first things that residents pay attention to it. Road quality is one of the transportation infrastructure components that are of high importance from urban residents' points of view. Cao et al. (2020) found that transportation infrastructure and its associated features including road quality and connectivity are directly associated with residential satisfaction. It is worth mentioning that road quality is not only important for people who use public transport, it is also important for those who use personal vehicles. This highlights the importance of this factor in determining residential satisfaction.

Recycling facility was found to be the third important infrastructure attribute in determining residential satisfaction. This finding shows the importance of some aspects of sustainability that are emphasized in recent years. Some aspects related to waste management and recycling have been studied in the neighborhoods. For example, in their study, Hur and Nasar (2014) found that physical upkeep and lack of litter in the neighborhood improved residential satisfaction. This might seem not very relevant to recycling but having recycling facilities in the neighborhood encourages residents to take the benefit of these facilities and helps to prevent litter in the neighborhood, thus improving residential satisfaction. Furthermore, people who live in LEED residential buildings or communities might have an understanding of the environmental aspects of recycling besides the indirect economic effects. Therefore, having this attribute in their residential environment can help improve their satisfaction with the neighborhood.

Finally, biking infrastructure was found to be the last factor that influences residential satisfaction. Research has shown the importance of biking in providing residential satisfaction. Bonaiuto et al. (2003) recognize neighborhood suitability for biking as an important factor that has a positive impact on the place attachment thus improving residential satisfaction. Recently, biking has been highlighted in several developed countries as an alternative transportation mode that could provide several environmental and health benefits. Dempsey et al. (2012) discussed biking as the preferred transportation mode among people to access their daily needs when it comes to dense urban areas. The reason for choosing biking as an important determinant of residential satisfaction may go beyond using the bike as alternative transportation means and could be for health reasons as Bopp et al. (2011) indicated that biking to work can reduce the chance of chronic disease and obesity.

Two attributes that did not show any significant influence on residential satisfaction are outdoor lighting and the presence of a rainwater collection system. Outdoor lighting, which is referred to as street lighting in the literature is found to be important in improving safety and visibility (Clarke, 2008; Fotios et al., 2015; Laze, 2019). It is also recognized to enhance biking and walking opportunities after dark (Uttley et al., 2020) thus improving the quality of life and satisfaction. However, the findings of this research are inconsistent with the literature. The reason for this finding could be partially due to the location of the LEED-certified residential communities , which are usually located in urbanized areas and by default benefit from the existing city lighting. This might lead to a lack of attention to the influence of lighting provided specifically by the neighborhood.

The rainwater collection system is another attribute that did not show a significant relationship with residential satisfaction. This result was expected as it is very much related to the climate and if, for example, we ask questions about this attribute from people who live in a dry climate, they might see this infrastructure differently than those who live in a humid climate. Therefore, the responses can be significantly different. This may lead to the discrepancy of the responses and result in the insignificant relationship showing neither a positive nor negative relationship with satisfaction.

Key finding 2: The moderation effect of gender on the relationship between outdoor lighting and residential satisfaction was not significant while age showed a significant moderation effect on this relationship. The first part of this finding is inconsistent with the literature while the second part is in accordance with the findings of other studies demonstrating the importance of gender and age in evaluating residential satisfaction with lighting and consequently the overall satisfaction with the neighborhood (Madge, 1997; Boomsma & Steg, 2014; Fotios et al., 2015a; Paydar et al., 2017). The positive and significant moderation effect of age on the relationship between perceived lighting performance and residential satisfaction might be due to the fact that elderly people are more concerned about the safety and brightness of their living environment, compared to young people, as it provides opportunities for them to walk even after darkness (Rahm et al., 2021). This is also the case for women, although the findings of this study do not support that women are more concerned about outdoor lighting compared to men.

Key finding 3: Rainfall showed a slightly significant moderation effect on the relationship between the perceived performance of rainwater collection systems and residential satisfaction in LEED-ND neighborhoods. However, this moderation effect was negative, meaning that with an increase in the average annual rainfall, the relationship between the perceived performance of the rainwater collection system and residential satisfaction becomes less important in determining residential satisfaction. The reason for this finding can be the fact that people who live in wet areas are less concerned about water shortage and rainwater collection because they are not negatively affected if there is no rainwater collection system. On the other hand, people who live in dry areas are aware of the importance of the rainwater collection system due to the direct effect that it might have on their daily life.

Key finding 4: Among the five attributes of the Neighborhood Pattern and Design factor, walkability was found to have the most significant and strong influence on residential satisfaction followed by mixed-use and density. Among the findings of this section, the high influence of walkability was expected while the lack of relationship between access to open space and satisfaction was an unexpected outcome.

Despite research showing the significant effect of neighborhood walkability on residential satisfaction, there are contradictory findings that show the positive or negative effects of this factor on residential satisfaction. Lee et al. (2017), for instance, illustrated that walkability is an important factor that affects residential satisfaction. Studies by Leyden (2003) and Kamruzzaman et al. (2014) also found walkability as an important aspect that enhances social capital and consequently improves residential quality. Lee et al. (2017b) and Pfeiffer et al. (2020) also found it to positively affect residential satisfaction while Dyck et al. (2011) and Grasser et al. (2016) found a negative relationship between the walkability of neighborhoods and residential satisfaction. Therefore, the results found in this study are in contrast with some findings while being consistent with others. Two aspects of walkability that make it important are the health and sustainability benefits that come with walking. Therefore, from the standpoint of this study, walkability being the most important Neighborhood Design factor in determining residential satisfaction was expected.

The mixture of the uses in the neighborhood was the second most important neighborhood design factor in determining residential satisfaction. This finding is in line with the literature as Lee et al. (2017), Ellis et al. (2006), Kweon et al. (2010), and Yang and Stockard (2013) find land use mix as an important aspect in determining residential satisfaction. Yang (2008) indicated that mixed-use environmental features were found to be desirable in residential communities in Portland, OR while in Charlotte, NC they found a different result, and mixed-use features showed negative relationships with residential satisfaction. The author discussed that this difference may be due to the higher integrity, better transportation system, and higher walkability of compact neighborhoods in Portland, OR compared to Charlotte, NC. The reason for the high importance of mixed land use could be ease of access to daily needs without spending much time driving or taking public transit. This provides a high level of satisfaction for residents by offering them confidence that they can get whatever they need in a very short time. It also provides some opportunities for walking in the neighborhood and improves social interactions (Christian et al., 2011; Duncan et al., 2010; Gehrke & Clifton, 2019). On the other hand, the negative relationship of the mixed land use with satisfaction could be due to safety issues or crowdedness.

Density was the third most important determinant of residential satisfaction among Neighborhood Pattern and Design attributes. Studies by Leyden (2003) and Kamruzzaman et al. (2014) found density as one of the aspects that have relationships with social capital and social sustainability. Cloutier and Pfeiffer (2015) found density as one of the neighborhood aspects that improve social relationships. Lee et al. (2017) suggested that density is one of the predictors of residential satisfaction. On the other hand, Van Dyck et al. (2011) indicated that density has a negative influence on residential satisfaction, which could be the outcome of pollution and lack of safety. Yang (2008), found a higher level of satisfaction associated with higher density in Portland, OR, and a negative relationship in Charlotte, NC. The author suggested that this difference can be due to higher walkability, access to public transport, and neighborhood integrity in Portland, OR compared to Charlotte, NC. These findings having contradictory results show that there is no trend on the relationship between density and residential satisfaction. However, as this factor is highlighted in LEED certification as an important factor in determining sustainability, the findings of this study both about the relationship between density and sustainability and the relationship between density and residential satisfaction become important.

On the other hand, it was surprising that access to open spaces did not show any significant relation with residential satisfaction. Access to open spaces is one of the most studied aspects of neighborhood satisfaction and in most cases, it was found to have a strong relation with satisfaction (e.g. Bjork et al., 2008; Pfeiffer and Cloutier, 2016; Miller et al., 1980; Russ-Eft, 1979; Kweon et al., 2010; Lee et al., 2008). The reason for the insignificant relation in this study could be due to the availability of other amenities in LEED projects for spending time and ease of accessibility to the open spaces, which reduces the importance of this aspect from users' points of view.

Finally, housing diversity was not found to be an important determinant of residential satisfaction. This finding was expected because most of the LEED-certified residential communities are either a combination of apartments and townhouses or master-planned communities. In each case, the diversity of housing is not very high, therefore residents cannot sense a housing mix in their community and the evaluation of the housing mix may not be reasonable to them.

Key finding 5: Among the Building Performance attributes, water efficiency showed the highest significant influence on residential satisfaction followed by energy efficiency, daylight, materials, and thermal comfort, respectively.

The relationship between building water efficiency and residential satisfaction has been studied by Lee and Tansel (2013) and Buys and Miller (2012), showing a high correlation between the water efficiency of the appliance and residential satisfaction. Water efficiency is one of the most noticeable aspects of building performance because it can be easily understood by the users while using water in their homes. Besides, even if during the use it is not clear that whether the appliance is water-efficient, the utility bill can clearly show that how efficient are the appliances. Therefore, as it is expected that LEED-certified buildings will be water-efficient and that users would recognize it as an important building attribute in providing satisfaction, the high influence of this factor in determining satisfaction was expected.

This is also the case for the energy efficiency of the building systems. However, understanding energy efficiency is not as straightforward as water efficiency due to the more complex nature of energy systems in the building. The importance of energy efficiency in residential satisfaction has been highlighted in several studies. Buys and Miller (2012) illustrated in their study, that energy, waste, and water conservation were the key concern of residents of high-density residential areas. Amasyali and El-Gohary (2016) also found energy efficiency to be an important parameter in defining residential satisfaction in several buildings. Therefore, the findings of this study are consistent with the previous studies showing the importance of energy efficiency in determining residential satisfaction. Similar to water efficiency, one of the reasons that energy efficiency is found to be an important predictor of residential satisfaction is the effect of energy use on the energy bill and its direct economic effect on residents. Therefore, people often tend to pay high attention to the energy efficiency of their homes.

Daylighting was found to be the third important Building Performance attribute in determining residential satisfaction. A study by Wang et al. (2020) indicated that satisfaction with daylighting has the most significant effect on residential satisfaction among other factors. In their study about the factors influencing housing satisfaction, Huang et al. (2015) found the daylight to be one of the most important factors in influencing satisfaction. The importance of daylight in improving not only indoor environmental quality but also improving the physical and mental health of the residents (Aries, Veitch, & Newsham, 2010; Haynes, 2008; Hwang & Jeong, 2011; J. H. Lee, Yoon, Baik, & Kim, 2013) could probably clarify the reason for the influence of this factor in determining residential satisfaction.

The materials used in the indoor environment can be important for residents due to their direct and indirect effects. If the quality of the materials is high, there is less need for maintenance in the long term. Lower maintenance means lower costs for owners and lowers issues for renters. Furthermore, high-quality materials used in the building can improve the indoor environmental quality thus improving occupant satisfaction (Astolfi & Pellerey, 2008; Lai, Mui, Wong, & Law, 2009; Sant'Anna, Dos Santos, Vianna, & Romero, 2018; Wong, Mui, & Hui, 2008). Therefore, the direct and indirect effects of material could be the reason why people in LEED-certified residential communities tend to recognize it as an important contributor to residential satisfaction.

Thermal comfort, as one of the most important factors of indoor environmental quality, is another important contributor in predicting residential satisfaction in LEED-certified residential communities . Several studies have shown that thermal comfort is an important indicator of occupant satisfaction (Afacan & Demirkan, 2016; Astolfi & Pellerey, 2008; Lai et al., 2009; Sant'Anna et al., 2018; Wong et al., 2008). Ibem and Aduwo (2013) reported that thermal comfort was one of the three strongest predictors of satisfaction in residential buildings. The reason for the importance of this factor is that thermal comfort connects human perception and sensation with several physical and environmental parameters (Fanger, 1970) thus affecting the feeling of satisfaction.

Although research indicates that quality views from windows have positive psychological effects (Hartig & Mang, 1991; R. Kaplan, 2001; Talbot & Kaplan, 1991), it was the only Building Performance attribute that did not show any significant relationship with residential satisfaction. This could be due to the location of the buildings and the nature of the green buildings and residential communities having high density and being located in compact areas with fewer scenic views and natural elements surrounding them. This might prevent having high-quality views for all the residential units.

Key finding 6: Among the Cost performance attributes, home value/rent has the most significant and strong influence on residential satisfaction followed by travel costs and utility bills.

Home value (for owners) and rent (for renters) are the main costs associated with housing. These costs are always compared to the quality that is offered by the home thus providing an understanding of the cost-benefit of the housing unit. Therefore, the home value is the most influential variable among the four was expected. The second factor that has a significant influence on residential satisfaction is the travel cost associated with living in these communities. As smart location and access to public transportation are among the most important factors of sustainability in buildings and communities, the use of public transport and the daily transportation cost become important. Therefore, a reason why LEED project residents found this attribute influential in determining satisfaction could be their expectations for low commuting and travel costs when they decided to move to a sustainable community.

Another cost that can be recognized very easily by residents is the utility bill compared to their usage. People usually tend to compare this with their previous homes. However, as one of the important aspects of green buildings is understood to be lower utility costs, this can make the residents sensitive to the utility bills and highlights it as an important factor in determining satisfaction.

Finally, other fees and costs such as HOA fee, condo fee, maintenance costs, property tax, and other fees associated with living in green buildings and communities did not show any significant relationship with residential satisfaction. The reason for the lower importance of this aspect could be that LEED-certified residential communities are usually young projects and therefore these projects are not still in a stage that they need significant maintenance. Therefore, some of the costs associated with maintenance can be unimportant at this time. Furthermore, fees like HOA fees, condo fees, and property taxes can be comparable in LEED and non-LEED projects. Therefore, those fees might not catch the attention of residents thus being unimportant in determining residential satisfaction.

6.4 The Differences Between the Perceived Performance and Satisfaction in LEED and Non-LEED Projects

Key finding: The results show that there is no measurement invariance between the two groups thus comparison of means between the LEED and non-LEED groups cannot provide very accurate results and comparing the mean of perceived Infrastructure Performance, Perceived Neighborhood Design, Perceived Building Performance, Perceived Cost performance, and Residential Satisfaction between the two groups will lead to serious misinterpretation of true mean differences (Chen, 2007b, 2008; Davidov, 2009; Horn & McArdle, 1992; Meade et al., 2008; Putnick & Bornstein, 2016; Rutkowski & Svetina, 2014; Steenkamp & Baumgartner, 1998a; Steinmetz, 2013; Vandenberg & Lance, 2000).

This finding could be due to the differences between the importance of some aspects of the living environment for LEED residents and non-LEED. For example, people who tend to live in LEED-certified residential communities usually pay attention to some infrastructure attributes such as recycling facilities, public transit, and some environmental aspects, or they might be willing to live in high-density neighborhoods. Therefore, these aspects become highlighted for them, and they might see the performance of these sustainability features different while people who live in conventional projects might not notice those aspects. Therefore, if the same question about the same feature is asked from the two groups, they might approach the question in very different ways and answer the question from different standpoints. This leads to the variance in the measurement and as a result, the responses of the two groups cannot be compared.

However, as perfect invariance is hardly achievable in practice, some researchers believe that partial invariance can also provide opportunities for comparing some aspects across the groups (Millsap & Meredith, 2012). Therefore, this study found partial invariance between the two groups and included the mean structure to compare the two groups. However, comparing the mean of perceived performance and satisfaction across the groups showed no significant differences meaning that the data did not provide enough confidence to compare the two groups. Therefore, the difference between the approaches of residents in the two groups became highlighted again. This difference in the residents' perspectives was found to be the most likely reason why there was no significant difference between the perceived physical and cost performance as well as residential satisfaction between the two groups.

6.5 Overall Discussion

All the findings of the study were discussed in detail in the previous section. The consistency of the findings with the existing knowledge was also discussed for each finding of the research. Looking at the arguments made, some aspects of this research are highlighted that can bridge the gap in the knowledge of long-term success evaluation in green buildings and communities, with focus and residential satisfaction. In order to discuss this, first, it is worth reviewing the research gap and the purpose of this study.

Reviewing the literature and digging into the LEED-ND certification system, it was illustrated that the role of users' judgments and feedback was underestimated in defining the criteria for the development and evaluation of the long-term success of sustainable residential communities. To bridge this gap, in this study, besides evaluating the actual performance of some of the most important infrastructure and physical elements of sustainable communities, the role of users' perception, evaluation, and satisfaction was investigated to come up with a true understanding of the long-term successful performance of sustainable residential communities. Therefore, this research was an attempt to understand the relations between sustainability, performance, and residential satisfaction as the key determinant of the long-term success of residential projects.

After evaluating the relationship between the actual performance of the infrastructure and physical elements of the built environment in sustainable residential communities, the performance of the physical features and economic aspects were evaluated from users' points of view mainly by investigating the perception of the users from the functionality of their residential environment attributes. Satisfaction, on the other hand, was evaluated both by asking questions about overall satisfaction with home and community and by investigating the residents' behavioral intentions toward living in their current communities. This research developed and validated a model for the evaluation of sustainable buildings and communities from users' points of view and bridged the gap of knowledge about the sustainability-specific post-occupancy evaluation model for residential communities. This research took advantage of the most popular housing theories such as Housing Needs Theory (Rossi, 1955), Housing Adjustment Theory (Morris & Winter, 1975), and Psychological Construct Theory (Galster, 1985) as well as the conceptual model of residential satisfaction developed by Weidemann and Anderson (1985) to develop a model that could be useful in different contexts. All the measures used in developing evaluation constructs were adopted and modified from LEED certification standards and other building-related survey tools such as UC Berkeley Center for the Built Environment Survey tool. This approach was taken to provide reliable, valid, and generalizable outcomes that help identify the most important attributes in determining sustainability, perceived performance, and residential satisfaction.

Putting the findings of the first and second phases of this research together, it was illustrated that among the four important elements that were evaluated, walking infrastructure did not show any significant relationship with the level of sustainability of the communities. This finding was unexpected as walkability accounts for 50% of the total points in the Neighborhood Pattern and Design category of the LEED-ND certification system (9 out of 18) besides showing to be the most important neighborhood pattern and design factor in determining residential satisfaction. On the other hand, residential density was found to be the most influential factor, among the studied factors, in predicting neighborhood sustainability while this factor was the third influential factor, among neighborhood design attributes, in determining residential satisfaction. One reason for this discrepancy could be because of a lack of consistency of LEED-ND guidelines with the needs and expectations of the users.

The other finding of this research indicated the significant relationship between satisfaction and only two factors of building performance and neighborhood design, among four factors. This became interesting when it was compared with the other findings regarding the relationship between the actual performance of the infrastructure and the level of sustainability. Two of the infrastructure elements that showed to be strong predictors of sustainability (transit infrastructure and biking infrastructure) were in the category of perceived infrastructure performance, which did not show any influence on residential satisfaction. This finding resulted in another argument about the inconsistency of LEED guidelines with the users' points of view.

The lack of relationships between cost performance and infrastructure performance with residential satisfaction motivated more in-depth investigation on these relationships by accounting for socio-economic aspects. After accounting for these aspects, cost performance turned to show influence on residential satisfaction. Two control factors that could potentially cause this change were income and education and the reason for their effects could be the variability of cost-benefit calculations among the people with different levels of income and education. Therefore, these two factors and two additional relevant factors (affordability and housing tenure) that could potentially affect the relationship between cost performance and residential satisfaction were added to the model one by one as the moderators. However, the results showed that none of the four factors had moderation effects on the influence of perceived cost performance and residential satisfaction.

The discussed findings motivated the evaluation of the influence of each attribute among building, infrastructure, neighborhood, and cost performance attributes on residential satisfaction. The path analysis conducted to determine these relationships showed that perceived performance of public transit infrastructure, road quality, recycling infrastructure, and biking infrastructure influence residential satisfaction. This highlighted the fact that these elements are appropriately considered and applied in the LEED certification standard and the results of this phase were in accordance with the findings of the first phase of the study showing the influence of public transit infrastructure and biking infrastructure on the level of sustainability. However, as discussed previously, the evaluation of the relationship between neighborhood pattern and design attributes and residential satisfaction showed otherwise. This finding was discussed in the previous paragraphs. Comparing the findings of this analysis with phase one, the shortcoming of the LEED-ND certification standard in evaluating walkability became highlighted. Walkability, as an important determinant of residential satisfaction and as a critical factor in evaluating projects for LEED certification does not show consistency in theory and practice. Therefore, this is very important for the LEED standard to reconsider the criteria for evaluating the walkability of projects that are seeking LEED certification.

The evaluation of the relationship between building attributes and satisfaction showed that water efficiency and energy efficiency were the most influential determinants of residential satisfaction. This finding was very important and resulted in an argument about the understanding of residents about the efficiency of their building features. Water and energy efficiency are easily understandable by residents because they can be estimated by the utility bills. Therefore, these two aspects become very important from users' points of view because they determine how much they should pay monthly.

Lastly, the results of the study showed that comparison of satisfaction and perceived performance of the built environment between the LEED and non-LEED projects was not feasible due to the differences between the understanding of the two groups from the built environment elements. This finding was even more highlighted after including mean structure in the model assuming that there was a partial invariance between the two groups. The results of including mean structure indicated no significant differences between the two groups in terms of perceived performance of the built environment and residential satisfaction.

With green residential buildings and communities becoming more and more popular in the US., it is crucial to identify the key factors that contribute to residential satisfaction in green buildings. This research illustrated that residential satisfaction in sustainable residential projects (defined as both satisfaction with the dwelling unit and satisfaction with the neighborhood) is dependent on a specific set of neighborhood and building attributes. By assessing several specific aspects of residential satisfaction, the study highlighted some neighborhood factors and individual unit design and construction factors that are critical in satisfaction with green residential complexes. Thus, the findings of this research can potentially contribute directly to the design and construction of sustainable residential buildings and communities, especially in the US.

The findings of this research also highlighted how design and construction play a crucial role in residential satisfaction and thus determining the long-term success of the projects. Along with neighborhood design attributes, individual unit considerations – such as water efficiency, energy efficiency, thermal comfort, daylighting, and materials– were found to be the most important factors in predicting residential satisfaction and emphasized the significance of high-quality building construction. Given that there has been relatively little research on the green building-specific design and construction characteristics, these findings provide opportunities for understanding, identifying, and encouraging developments that best meet residents' needs and expectations.

CHAPTER 7 : SUMMARY, CONCLUSION, AND FUTURE RESEARCH

This chapter summarizes the goals and objectives of the study, study methods, and findings, and discusses deliverables and contributions of the research in the body of knowledge. Then it focuses on the limitations of the study and finally provides some recommendations for future research.

7.1 Summary of Research Goal and Objectives

This research aimed to develop a model for the assessment of the long-term success of sustainable housing development projects from users' points of view to evaluate the relationships among sustainability, residential satisfaction, and the performance of those projects. The objectives of the study were as follows:

- **Objective 1:** Develop a multi-phase framework that evaluates the relationships between sustainability, satisfaction, and actual and perceived performance of the built environment in residential communities.
- **Objective 2:** Investigate the associations between sustainability and actual performance of LEED-ND projects and the interaction effect of climate on this relationship.
- **Objective 3:** Develop and validate a model to evaluate the associations between the perceived performance and satisfaction of sustainable LEED-certified residential communities and identify the key determinants of residential satisfaction in sustainable communities.

- **Objective 4**: Develop a multiple group comparison analysis to examine the effects of sustainability on providing residential satisfaction and the perceived performance of the built environment in residential communities.

7.2 Summary of Study Methods

As multi-phase research, this study started with conducting a multiple regression analysis to evaluate the relationship between the actual performance of neighborhood infrastructure and its physical form and the sustainability level of the LEED-ND certified projects. This analysis was followed by an Analysis of Covariance (ANCOVA) to investigate the interaction effect of climate on the relationship between the independent variables and the dependent variable.

In the second phase of the study, the data was collected through an online survey that targeted LEED-certified residential project occupants as the experiment group and similar conventional project residents as the control group. This survey, collected data regarding the perceived performance of infrastructure, building, neighborhood, and economic aspects as well as the level of satisfaction of residents in LEED-certified residential projects. A Confirmatory Factor Analysis was conducted to test, modify, and validate the model for evaluation of the discussed variables followed by Structural Equation Modeling to uncover the relationship between the perceived performance of the built environment and residential satisfaction.

The relationship between the measures of each construct and the residential satisfaction was then evaluated through a path analysis by conducting a separate multiple regression analysis between the measures of each construct and the overall satisfaction. Finally, in order to compare the perceived performance and residential satisfaction between the experiment group and the control group, a Multiple Group CFA was conducted to test measurement invariance between the two groups and potentially compare the mean of the latent variables. However, as the results of the measurement invariance test did not show equivalence in measurement between the two groups, the comparison of means analysis was not conducted.

7.3 Summary of Findings

Several findings resulted from this study both from phase one and phase two of the research, which are listed below.

1- Residential density was found to be the most influential factor, among the studied factors, in predicting neighborhood sustainability while this factor was the third influential factor, among neighborhood design attributes, in determining residential satisfaction. On the other hand, walkability, as another prerequisite for sustainability, showed to be the most important factor in determining residential satisfaction while this factor did not show any significant relationship with the level of sustainability based on LEED score. This discrepancy can be because there is not much variability in the data due to LEED-ND guidelines and prerequisites.

2- Another important factor that showed a positive relationship with the level of sustainability was access to quality transit. Biking infrastructure was the third factor that was found to be associated with neighborhood sustainability.

3- Perceived building performance showed the highest influence on overall satisfaction with the residential community followed by perceived neighborhood pattern and design.

4- The relationship between perceived infrastructure performance and residential satisfaction was not significant. Similarly, the cost performance of the built environment did not show a significant relationship with residential satisfaction.

5- Among the six Green Infrastructure attributes, public transit infrastructure showed the most significant and strong influence on residential satisfaction followed by road quality, recycling facility, and biking infrastructure, respectively.

6- Two aspects that did not show any significant influence on residential satisfaction are outdoor lighting and the rainwater collection system.

7- The moderation effect of gender on the relationship between outdoor lighting and residential satisfaction was not significant while age showed a significant moderation effect on this relationship.

8- Rainfall showed a slightly significant moderation effect on the relationship between the perceived performance of rainwater collection systems and residential satisfaction in LEED-ND neighborhoods.

9- Among the five attributes of the Neighborhood Pattern and Design factor, walkability was found to have the most significant and strong influence on residential satisfaction followed by mixed-use and density.

10- Access to open spaces and housing diversity did not show any significant relation with residential satisfaction.

11- Among the Building Performance attributes, water efficiency showed the most significant and strong influence on residential satisfaction followed by energy efficiency, daylight, materials, and thermal comfort, respectively.

12- Quality view from windows was the only Building Performance attribute that did not show any significant relationship with residential satisfaction.
13- Among the Cost performance attributes, home value/rent showed the most significant and strong influence on residential satisfaction followed by travel costs and utility bills.
14- Other fees such as HOA fee/condo fee, property tax, and maintenance cost did not show any significant relationship with residential satisfaction.
15- The results showed that the comparison between the perceived performance and satisfaction between LEED and non-LEED groups cannot provide accurate results and comparing the mean of perceived Infrastructure Performance, Perceived Neighborhood Design, Perceived Building Performance, Perceived Cost performance, and Residential Satisfaction between the two groups will lead to serious misinterpretation of true mean differences.

7.4 Deliverables and Contribution to the Body of Knowledge

The main contribution of this study is developing a model that is specific to green communities and buildings to investigate the feedback and perspective of end-users living in such communities and evaluate the relationships between the perceived performance of the built environment features and the satisfaction of the residents. This study provided a comprehensive post-occupancy evaluation model that can be used for the long-term success assessment of sustainability practices in the building industry.

As discussed in the literature, most of the previous studies about residential satisfaction focused on either only building factors or only neighborhood-scale factors. However, this study combined both levels to provide a comprehensive framework that provides a holistic understanding of the post-construction performance of the projects. Moreover, most of the previous studies focused only on one aspect of residential satisfaction such as physical, economic, or social. However, this study considered physical and economic aspects in the same study as believes that these aspects are interconnected and should be evaluated together. Third, this research categorized the attributes of the built environment based on their characteristics to develop a practical model and provide understandable outcomes that could be useful for both academia and industry experts.

Overall, considering the three key aspects of long-term success in the same study, the findings of this study provide novel contributions to the body of knowledge through the following:

- Determining priorities for future sustainable building and community developments and providing a holistic model for evaluation of the long-term success of these projects.
- Obtaining the feedback and judgments of occupants regarding their living environment and engaging their opinions in the evaluations, which help promote the performance of buildings and infrastructure, and increase users' satisfaction.
- Providing the potential for creating a database, which could be updated, as well as the potential for creating design and construction protocols and paradigms.
- Providing practical and useful data for the improvement of LEED sustainability standards through introducing users' points of view and preferences to the evaluation criteria.

7.5 Research Limitations

As this research is a novel study that aims to introduce innovative ideas and provides a practical model for studying residential satisfaction in sustainable communities, there are some limitations associated with it, which are mentioned below.

- Due to the limited access to the data, few factors were evaluated objectively in the first phase of the study. Although the study evaluated important aspects, it might have left some important factors out of the study.
- The second phase of the study did not evaluate the actual performance of the built environment to be compared with the perceived performance and provide a more realistic understanding of the relationships between the performance and satisfaction.
- Although the sample was collected randomly and the users of several projects participated in the survey, the sample size for CFA and SEM could be larger in order to prevent the issue of generalizability.
- The second phase of the study did not consider the effect of location and climate to distinguish between the projects based on their regional characteristics. Therefore, the findings of the study may or may not apply to projects that are located in extreme climates and special geographical areas. Moreover, the study did not distinguish between urban and suburban projects and between the projects located in big and small cities while these aspects might introduce the perceived performance of the built environment and residential satisfaction.

7.6 Future Research

The method used in this research including the model developed and validated can be used for future research on evaluating relations between performance and satisfaction. However, the limitations of the study, discussed in the previous section, lead to opportunities for future research. Therefore, some areas of research that could follow this study are discussed below.

7.6. 1 A Comprehensive Evaluation by Combining Objective and Subjective Evaluation

In the current research, the actual performance of four neighborhood attributes was evaluated and this limited the chance of creating a comparison between the actual and perceived performance of the neighborhood features in order to create a holistic evaluation. Therefore, a combination of the actual and perceived performance of the built environment can be considered in future research to add another aspect to the study and provide opportunities to evaluate the relationships between both perceived and actual performance and satisfaction. Adding this aspect of analysis will provide opportunities for measuring residential satisfaction as a function of objectively measured neighborhood features. The objective data can also provide opportunities for controlling some influential aspects that may affect the findings. For instance, In this study, the role of density both in the first and second phases was highlighted as an important factor that affects both sustainability and satisfaction. However, due to a lack of access to the data regarding the density of the projects, the effect of this factor was not controlled when the perceived performance of the built environment and satisfaction were compared. Therefore, it is recommended for future research to compute the density of each community and add the density as a control variable to the model when the comparison is made between LEED-certified and non-LEED residential communities.

7.6. 2 Evaluate The Role of Socio-Demographic Variables in Determining Satisfaction

In this research, socio-economic variables were included in the study as control variables, but the direct and indirect roles of these factors were not measured since it was out of the scope of the research. However, evaluating the relationship between residential satisfaction and socio-economic variable can enrich the findings and improve the accuracy of judgments and evaluations. Some variables such as property value growth, appreciation of land value for LEED projects, and water and energy costs can potentially provide invaluable information and affect the level of satisfaction especially if these values are evaluated from the perspective of owners and renters separately. Therefore, including socio-economic aspects in future research would be recommended.

7.6. 3 Evaluation Life-Cycle Performance of The Projects

In this research, only a post-occupancy evaluation of the projects was conducted, which brought a lack of comprehensiveness into the study. In the future study, the life cycle performance of the projects can be considered and a comparison between the traditional success factors including cost performance at the construction stage, and the long-term success factors, which consider the post-construction stage can be conducted.

7.6. 4 Evaluate Projects Based on Location-related Variables

In this research, some location-related variables such as rainfall and temperature were considered as moderators of the relationships between the perceived neighborhood performance and residential satisfaction. However, there are several other aspects that may, directly or indirectly, affect the relationship between performance and satisfaction. For future research, it is recommended to identify and include critical location-related aspects in the analysis and evaluate the performance of the projects based on their regional, climate, and context (city, suburb, or rural) factors in order to provide more region-specific and applied findings that could be used both for researchers and practitioners. Including those factors provide opportunities for conducting a cross-sectional analysis to compare the performance and satisfaction across the groups and understand the effect of external factors on the relationships.

7.7 Research Contribution to the industry and community

In this study, a post-construction evaluation was adopted to answer the research questions, as a platform for the systematic study of buildings once constructed and occupied. Through this research, lessons can be learned by scholars, developers, residents, and other stakeholders that will improve the housing conditions and direct the design and construction of future communities. Different aspects of perceived performance and functioning are evaluated in this study as well as more interactional aspects such as satisfaction, preferences, behavioral intentions, etc. This type of research is a necessary and axiomatic part of any development project and is essential for researchers who have a concern about the development of sustainable communities. The findings of this research offer the potential to bring the integration between a range of fragmented facets of the design and construction process and the relationship between the built environment and users by engaging users in decision making and creating development standards.

With green residential buildings and communities becoming popular in the US., it is crucial to identify the key factors that contribute to residential satisfaction in green buildings and ultimately result in long-term success of these projects. This research illustrated that residential satisfaction in sustainable residential projects (defined as both satisfaction with the dwelling unit and satisfaction with the neighborhood) is dependent on a specific set of neighborhood and building attributes. By assessing several specific aspects of residential satisfaction, the study highlighted some neighborhood factors and individual unit design and construction factors that are critical in satisfaction with green residential complexes. Thus, the findings of this research can potentially contribute directly to the design and construction of sustainable residential buildings and communities, especially in the US.

Along with neighborhood design attributes, individual unit considerations – such as water efficiency, energy efficiency, thermal comfort, daylighting, and materials– were found to be the most important factors in predicting residential satisfaction and emphasized the significance of high-quality building construction. Given that there has been relatively little research on the green building-specific design and construction characteristics, these findings provide opportunities for understanding, identifying, and encouraging developments that best meet residents' needs and expectations by Providing the potential for creating a database, which could be updated, as well as the potential for creating design and construction protocols and paradigms. Furthermore, providing practical and useful data for the improvement of LEED sustainability standards the findings of this research and similar studies can be translated to sustainability standards in order to be applicable for the developers that focus on developing green buildings and communities.

APPENDICES

APPENDIX A: List of studied LEED-ND projects

Table 8.1 : List of LEED-ND projects including outliers and influential cases

	Name	Walk Score	Transit Score	Bike Score	DUA	LEED-ND Score	Cook's D	Std. residual	Reason for removing
1	Hawaii Regiol Housing PPV Increment 2	30	0	52	9	40	0.007	-0.841	
2	Simpson Wisser Fort Shafter	53	62	43	5	41	0.010	-0.916	
3	Northwest Gardens	71	48	59	20	54	0.000	0.124	
4	Brickell City Centre	96	100	85	86	63	0.000	-0.075	
5	Sustaible Fellwood	43	0	50	12	52	0.001	0.339	
6	Mueller	61	51	75	8	51	0.000	-0.290	
7	Global Green USA Holy Cross Project	36	33	60	16	50	0.000	-0.175	
8	City of Tucson and Gadsden Comp.	80	71	100	37	67	0.005	0.661	
9	Alliance Town Center	40	9	36	37	45	0.002	-0.417	
10	The Navy Yard at Noisette	34	29	41	6	46	0.000	-0.239	
11	Legends Park & University Place	56	41	58	9	46	0.001	-0.533	
12	West Town	36	25	42	37	49	0.000	-0.175	
13	The Reissance	21	35	35	9	48	0.000	-0.023	
14	Celadon	48	46	67	18	47	0.002	-0.634	
15	Quarry Falls (Civita)	48	46	59	21	60	0.002	0.722	
16	Westfield UTC Revitalization	79	55	75	4	60	0.002	0.609	
17	Cornfields/Arroyo Seco Specific Plan	93	84	56	37	44	0.018	-1.140	
18	Taylor Yard, Parcel C	67	47	59	24	41	0.004	-1.185	
19	Good	67	39	79	21	43	0.007	-1.161	
20	Township 9	33	40	84	46	51	0.008	-0.629	
21	Depot Walk	75	42	54	18	41	0.008	-1.050	

Table 8.1 (cont'd)

	Name	Walk Score	Transit Score	Bike Score	DUA	LEED-ND Score	Cook's D	Std. residual	Reason for removing
22	Miraflores	53	58	76	14	64	0.007	0.905	
23	Union Park (Symphony Park)	61	64	49	5	62	0.011	1.067	
24	Emeryville Marketplace	85	0	93	45	87	0.377	3.010	Residual (Std. residual > 3)
25	Habitat for Humanity East Bay Edes 'B'	62	41	60	30	40	0.005	-1.309	
26	The Hive	98	74	96	21	44	0.023	-1.449	
27	MacArthur BART Transit Village	91	68	93	107	63	0.000	-0.177	
28	pa Pipe	8	20	47	51	62	0.021	0.968	
29	PHS District Neighborhood-The Presidio	53	55	77	5	47	0.005	-0.699	
30	Hunters View	56	52	60	20	50	0.000	-0.302	
31	Hercules Bayfront	33	0	42	27	63	0.053	1.408	Influential (Cook's Distance > .049)
32	Delaware Addition	76	23	99	20	47	0.020	-0.923	
33	Tassafaronga Village	66	59	69	21	66	0.004	1.123	
34	Mosaic at Merrifield	77	0	61	22	52	0.000	0.130	
35	Founder's Square	94	75	87	94	64	0.000	0.064	
36	1812 N Moore Street	91	74	84	37	63	0.001	0.444	
37	Crystal City Plan	88	73	81	37	40	0.013	-1.781	
38	Reston Heights	42	53	60	48	50	0.002	-0.521	
39	Terrapin Row Development Stage3	63	43	81	70	57	0.000	-0.204	
40	Pike & Rose Neighborhood Development	78	64	72	19	65	0.004	0.975	
41	Decker Walk envirowHOMES	81	55	62	48	51	0.001	-0.457	
42	Twinbrook Station	64	65	42	11	66	0.056	1.499	Influential (Cook's Distance > .049)
43	Solea Condos	98	82	82	172	60	0.057	-0.911	Influential (Cook's Distance > .049)
44	3910 Georgia Commons	97	74	88	186	65	0.059	-0.555	Influential (Cook's Distance > .049)

Table 8.1 (cont'd)

	Name	Walk Score	Transit Score	Bike Score	DUA	LEED-ND Score	Cook's D	Std. residual	Reason for removing
45	The Yards	93	65	92	67	60	0.000	-0.133	
46	Parkside Mixed-Use Development	65	68	65	19	61	0.002	0.647	
47	Old Convention Center	95	100	92	67	69	0.003	0.573	
48	Constitution Square Phase I	96	79	93	92	64	0.000	-0.015	
49	The New Stapleton Waterfront	89	72	68	26	54	0.000	-0.152	
50	West Village Residences LLC Neighborhood	100	100	93	100	65	0.000	-0.088	
51	Willets Point Redevelopment Project	49	92	62	89	64	0.003	0.325	
52	Melrose Commons	95	100	72	37	57	0.000	-0.133	
53	Lincoln Park Coast Cultural District	87	76	52	8	62	0.013	0.950	
54	Teachers Village	92	91	59	9	58	0.003	0.385	
55	The Gateway to shville	91	54	68	133	61	0.001	-0.202	
56	The Culch	85	50	64	26	56	0.000	0.204	
57	Reissance Place at Grand	65	49	56	16	42	0.004	-0.992	
58	East 54	58	42	74	58	68	0.005	1.060	
59	9th and Berks Street TOD	76	84	66	63	82	0.051	2.284	Influential (Cook's Distance > .049)
60	THE ARBORS	32	38	19	9	47	0.000	0.055	
61	Barelas Homes	87	51	73	8	41	0.012	-1.247	
62	South Lake Union Urban Center	94	86	81	27	41	0.021	-1.674	
63	The Waterfront District	94	50	85	27	55	0.000	-0.162	
64	Eliot Tower	99	99	93	172	51	0.119	-2.011	Influential (Cook's Distance > .049)
65	South Waterfront Central District	73	66	98	87	70	0.004	0.620	
66	Hoyt Yards	99	95	97	74	81	0.024	1.672	
67	Ladd Tower	99	100	87	195	76	0.005	0.339	
68	Helensview	54	42	91	21	63	0.006	0.645	
69	Hassalo on Eighth	96	92	99	119	82	0.025	1.408	
70	Eastside III	97	71	87	24	61	0.001	0.325	

Table 8.1 (cont'd)

	Name	Walk Score	Transit Score	Bike Score	DUA	LEED-ND Score	Cook's D	Std. residual	Reason for removing
71	Whistler Crossing	32	0	35	9	47	0.000	0.052	
72	Town of Normal Uptown Renewal Project	71	51	71	25	54	0.000	-0.071	
73	Prairie Crossing - Station Village	11	26	46	1	40	0.013	-0.831	
74	St. Luke's Neighborhood Redevelopment	79	53	41	52	50	0.002	-0.323	
75	Flats East Development	72	69	65	23	45	0.004	-0.964	
76	Syracuse Art, Life, & Tech. (SALT) Dist.	69	43	57	37	62	0.003	0.830	
77	Old Colony Redevelopment	90	68	72	18	60	0.001	0.472	
78	Jackson Square Redevelopment	90	76	93	40	51	0.005	-0.879	
79	Edgewater	78	0	45	7	47	0.000	-0.058	
80	360 State Street	98	72	97	111	83	0.055	1.696	Influential (Cook's Distance > .049)
81	Harbor Point	66	67	82	30	60	0.000	0.265	
82	Metro Green Residential	83	74	89	49	65	0.001	0.489	
83	Midtown Crossing at Turner Park	90	43	75	31	41	0.016	-1.412	
84	Park Avenue Redevelopment-Block 3	91	84	98	27	60	0.000	0.009	
85	Washington Village (fmrly Cedar Commons)	87	51	97	10	52	0.003	-0.476	
86	Horizon Uptown	0	0	25	37	41	0.011	-0.627	
87	City Creek Center	91	68	95	27	54	0.002	-0.467	
88	Meadow Ranch	52	0	45	7	42	0.004	-0.544	
89	Westlawn Revitalization	53	48	60	10	54	0.000	0.188	
90	Excelsior & Grand	84	44	68	37	41	0.011	-1.382	
91	The Brewery	81	63	61	15	81	0.060	3.492	Residual (Std. residual > 3)
92	Uptown at Falls Park	68	33	76	123	60	0.001	-0.212	
93	Sweetwater	13	0	63	22	47	0.003	-0.382	

Table 8.1 (cont'd)

	Name	Walk Score	Transit Score	Bike Score	DUA	LEED-ND Score	Cook's D	Std. residual	Reason for removing
94	Ever Vail	41	0	49	24	82	0.110	3.220	Residual (Std. residual > 3)
95	Newpark Town Center	54	0	55	42	50	0.000	-0.149	
96	Aspen Club Living	26	0	71	42	40	0.035	-1.323	
97	MGM Springfield	91	58	68	42	61	0.001	0.481	
98	Lamirer neighborhood	73	65	74	37	51	0.001	-0.570	
99	UCSB San Joaquin Apartments	35	38	88	37	60	0.002	0.287	

APPENDIX B: Institutional Review Board Approval

MICHIGAN STATE UNIVERSITY

EXEMPT DETERMINATION
Revised Common Rule

July 7, 2020

To: George H Berghorn

Re: **MSU Study ID:** STUDY00004709
Principal Investigator: George H Berghorn
Category: Exempt 2ii
Exempt Determination Date: 7/7/2020
Limited IRB Review: Not Required.

Title: A POST-CONSTRUCTION EVALUATION OF LONG-TERM SUCCESS IN SUSTAINABLE LEED-ND CERTIFIED PROJECTS

This study has been determined to be exempt under 45 CFR 46.104(d) 2ii.

Principal Investigator (PI) Responsibilities: The PI assumes the responsibilities for the protection of human subjects in this study as outlined in Human Research Protection Program (HRPP) Manual Section 8-1, Exemptions.

Temporary institutional restrictions are in place until further notice for human subject research conducted by MSU employees or agents. All MSU human research activities conducted by MSU employees or agents that take place in Michigan and cannot be done at home or place of residence with no inter-personal interaction with participants and others like research staff must stop unless the project is a clinical trial activity, that if discontinued, would negatively impact the patient's care, or is urgently related to the COVID-19 pandemic. Ongoing clinical trial activity, which if discontinued, would negatively impact the patient's care may continue with already enrolled participants. New enrollment in clinical trials conducted in Michigan is not permitted without additional institutional approval.

For MSU human research activities that take place outside of Michigan, unless there is the potential for direct therapeutic benefit to the participant (drug or device), any in-person participant interaction must immediately pause. This applies to both exempt and non-exempt research studies.

For all human research studies, research procedures involving no direct in-person interactions with participants may continue (e.g. data analysis, online surveys, telephone interviews) in otherwise permissible venues, so long as State and local requirements are met.

Office of Regulatory Affairs
Human Research Protection Program

4000 Collins Road
Suite 136
Lansing, MI 48910

517-355-2180
Fax: 517-432-4503
Email: irb@msu.edu
www.hrpp.msu.edu

Please note that the situation is rapidly evolving and may further change. Visit http://hrpp.msu.edu/COVID-19/index.html for the latest information and updates, including the restrictions and their duration as the situation evolves.

Continuing Review: Exempt studies do not need to be renewed.

Modifications: In general, investigators are not required to submit changes to the Michigan State University (MSU) Institutional Review Board (IRB) once a research study is designated as exempt as long as those changes do not affect the exempt category or criteria for exempt determination (changing from exempt status to expedited or full review, changing exempt category) or that may substantially change the focus of the research study such as a change in hypothesis or study design. See HRPP Manual Section 8-1, Exemptions, for examples. If the study is modified to add additional sites for the research, please note that you may not begin the research at those sites until you receive the appropriate approvals/permissions from the sites.

Please contact the HRPP office if you have any questions about whether a change must be submitted for IRB review and approval.

New Funding: If new external funding is obtained for an active study that had been determined exempt, a new initial IRB submission will be required, with limited exceptions. If you are unsure if a new initial IRB submission is required, contact the HRPP office. IRB review of the new submission must be completed before new funds can be spent on human research activities, as the new funding source may have additional or different requirements.

Reportable Events: If issues should arise during the conduct of the research, such as unanticipated problems that may involve risks to subjects or others, or any problem that may increase the risk to the human subjects and change the category of review, notify the IRB office promptly. Any complaints from participants that may change the level of review from exempt to expedited or full review must be reported to the IRB. Please report new information through the study's workspace and contact the IRB office with any urgent events. Please visit the Human Research Protection Program (HRPP) website to obtain more information, including reporting timelines.

Personnel Changes: After determination of the exempt status, the PI is responsible for maintaining records of personnel changes and appropriate training. The PI is not required to notify the IRB of personnel changes on exempt research. However, he or she may wish to submit personnel changes to the IRB for recordkeeping purposes (e.g. communication with the Graduate School) and may submit such requests by submitting a Modification request. If there is a change in PI, the new PI must confirm acceptance of the PI Assurance form and the previous PI must submit the Supplemental Form to Change the Principal Investigator with the Modification request (available at hrpp.msu.edu).

Closure: Investigators are not required to notify the IRB when the research study can be closed. However, the PI can choose to notify the IRB when the study can be closed and is especially recommended when the PI leaves the university. Closure indicates that research activities with human subjects are no longer ongoing, have stopped, and are complete. Human research activities are complete when investigators are no longer obtaining information or biospecimens about a living person through interaction or intervention with the individual, obtaining identifiable private information or identifiable biospecimens about a living person, and/or using, studying, analyzing, or generating identifiable private information or identifiable biospecimens about a living person.

For More Information: See HRPP Manual, including Section 8-1, Exemptions (available at hrpp.msu.edu).

Contact Information: If we can be of further assistance or if you have questions, please contact us at 517-355-2180 or via email at IRB@msu.edu. Please visit hrpp.msu.edu to access the HRPP Manual, templates, etc.

Exemption Category. The full regulatory text from 45 CFR 46.104(d) for the exempt research categories is included below. [1234]

Exempt 1. Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Exempt 2. Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

> (i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
>
> (ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or
>
> (iii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

Exempt 3. (i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met:

> (A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
>
> (B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or
>
> (C) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

(ii) For the purpose of this provision, benign behavioral interventions are brief in duration, harmless, painless, not physically invasive, not likely to have a significant adverse lasting impact on the subjects, and the investigator has no reason to think the subjects will find the interventions offensive or embarrassing. Provided all such criteria are met, examples of such benign behavioral interventions would include having the subjects play an online game, having them solve puzzles under various noise conditions, or having them decide how to allocate a nominal amount of received cash between themselves and someone else.

(iii) If the research involves deceiving the subjects regarding the nature or purposes of the research, this exemption is not applicable unless the subject authorizes the deception through a prospective agreement to participate in research in circumstances in which the subject is informed that he or she will be unaware of or misled regarding the nature or purposes of the research.

Exempt 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

> (i) The identifiable private information or identifiable biospecimens are publicly available;
>
> (ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of ``health care operations'' or ``research'' as those terms are defined at 45 CFR 164.501 or for ``public health activities and purposes'' as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Exempt 5. Research and demonstration projects that are conducted or supported by a Federal department or agency, or otherwise subject to the approval of department or agency heads (or the approval of the heads of bureaus or other subordinate agencies that have been delegated authority to conduct the research and demonstration projects), and that are designed to study, evaluate, improve, or otherwise examine public benefit or service programs, including procedures for obtaining benefits or services under those programs, possible changes in or alternatives to those programs or procedures, or possible changes in methods or levels of payment for benefits or services under those programs. Such projects include, but are not limited to, internal studies by Federal employees, and studies under contracts or consulting arrangements, cooperative agreements, or grants. Exempt projects also include waivers of otherwise mandatory requirements using authorities such as sections 1115 and 1115A of the Social Security Act, as amended. (i) Each Federal department or agency conducting or supporting the research and demonstration projects must establish, on a publicly accessible Federal Web site or in such other manner as the department or agency head may determine, a list of the research and demonstration projects that the Federal department or agency conducts or supports under this provision. The research or demonstration project must be published on this list prior to commencing the research involving human subjects.

Exempt 6. Taste and food quality evaluation and consumer acceptance studies: (i) If wholesome foods without additives are consumed, or (ii) If a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

Exempt 7. Storage or maintenance for secondary research for which broad consent is required: Storage or maintenance of identifiable private information or identifiable biospecimens for potential secondary research use if an IRB conducts a limited IRB review and makes the determinations required by 45 CFR 46.111(a)(8).

Exempt 8. Secondary research for which broad consent is required: Research involving the use of identifiable private information or identifiable biospecimens for secondary research use, if the following criteria are met:

> (i) Broad consent for the storage, maintenance, and secondary research use of the identifiable private information or identifiable biospecimens was obtained in accordance with 45 CFR 46.116(a)(1) through (4), (a)(6), and (d);
>
> (ii) Documentation of informed consent or waiver of documentation of consent was obtained in accordance with 45 CFR 46.117;
>
> (iii) An IRB conducts a limited IRB review and makes the determination required by 45 CFR 46.111(a)(7) and makes the determination that the research to be conducted is within the scope of the broad consent referenced in paragraph (d)(8)(i) of this section; and
>
> (iv) The investigator does not include returning individual research results to subjects as part of the study plan. This provision does not prevent an investigator from abiding by any legal requirements to return individual research results.

[1]Exempt categories (1), (2), (3), (4), (5), (7), and (8) cannot be applied to activities that are FDA-regulated.

[2] Each of the exemptions at this section may be applied to research subject to subpart B (Additional Protections for Pregnant Women, Human Fetuses and Neonates Involved in Research) if the conditions of the exemption are met.

[3] The exemptions at this section do not apply to research subject to subpart C (Additional Protections for Research Involving Prisoners), except for research aimed at involving a broader subject population that only incidentally includes prisoners.

[4] Exemptions (1), (4), (5), (6), (7), and (8) of this section may be applied to research subject to subpart D (Additional Protections for Children Involved as Subjects in Research) if the conditions of the exemption are met. Exempt (2)(i) and (ii) only may apply to research subject to subpart D involving educational tests or the observation of public behavior when the investigator(s) do not participate in the activities being observed. Exempt (2)(iii) may not be applied to research subject to subpart D.

APPENDIX C: Survey Questionnaire

A Post-construction Evaluation of Sustainable LEED-ND certified projects - Experiment Group - ID3038

Introductory Questions:

Introduction This survey aims to evaluate the long-term success of housing development projects from residents' points of view, as part of my Ph.D. dissertation. In this survey, your perception, evaluation, and feedback about different aspects of your home and community will be asked. Please note that all the answers will be anonymous and only the combination of results from the survey of all participants will be analyzed and presented in the report. Your participation will help improve the quality of current and future residential communities.

E1 Are you currently living in a LEED-certified multifamily residential building/community?

○ Yes

○ No

A1 How familiar are you with the concept of Green Building?

○ Not familiar at all

○ Slightly familiar

○ Moderately familiar

○ Very familiar

A2 Please select ONE word that you think of when you hear "Green Building” .

- ○ Environmental
- ○ Comfortable
- ○ Healthy
- ○ Efficient
- ○ Quality
- ○ Ecological
- ○ Water
- ○ Recycle
- ○ Natural resource
- ○ Energy
- ○ Other

P1 On a scale of 1 to 7, how do you perceive the performance of the following infrastructures in your residential complex/community? (1=Performs Very Poor,....7=Performs Excellent)

Not Applicable

	1	2	3	4	5	6	7
The water efficiency of landscape irrigation system							
Use of renewable energy							
Central heating and/or cooling system							
Outside lighting quality							
Recycling facility							
Rainwater collection and drainage system							

P2 On a scale of 1 to 7, how do you perceive the performance of the following factors in your neighborhood?
(1=Performs very poor,....7=Performs Excellent)

Not Applicable

	1	2	3	4	5	6	7
Possibility of walking around for fun/exercise/daily needs							
Neighborhood compactness and building density							
Access to daily needs and local services (store, gym, etc.,)							
Diversity of housing types in the neighborhood							
Access to public transport							
Access to public spaces and recreation facilities (park, movie theater, etc.,)							
Suitability of the community for people with disability							
Opportunities for growing produce in the yard, greenhouse, balcony, community garden, etc.							
Suitability of neighborhood for biking							
Street greenness and landscape quality							
Proximity to schools							
Road quality and connectivity of streets							

AC1 Recent research on decision-making shows that choices are affected by context. Specifically, we are interested in whether you are taking the time to read each question. To show that you are paying attention, please check only the “none of the above” option as your answer.

- ○ Interested
- ○ Distressed
- ○ Excited
- ○ Upset
- ○ Strong
- ○ All of the above
- ○ None of the above

P3 On a scale of 1 to 7, how do you perceive the performance of the following factors in your home? (1=Performs very poor,....7=Performs Excellent)

Not Applicable

	1	2	3	4	5	6	7
Home layout							
Hot water distribution system							
Thermal comfort in your home without using an air conditioner							
Availability of daylight in your home							
Indoor air quality							
Sound privacy in your home							
Quality views from your home							
Materials used in your home (Walls, flooring, cabinet, ...)							
The energy efficiency of heating and cooling systems (based on your utility bills and your usage)							
The water efficiency of your home's appliance (based on your utility bills and your usage)							
Your home's value/rent considering housing and neighborhood quality							
Costs of living in this home (utility bills)							
Travel and transportation costs of living in this neighborhood							
Other community charges (condo fee, HOA fee, property tax, etc.)							

S1 On a scale of 1 to 7, how do you agree/disagree with the following statements?
(1= Strongly disagree,....., 7= Strongly agree)

Not Applicable/ I Don't Know

	1	2	3	4	5	6	7
I plan to stay in my current home/community for a long time (more than 10 years)							
I recommend this neighborhood to others							
If I go back, I would move to this neighborhood again							
There are opportunities to participate in community activities							
I believe that living in a high-density neighborhood contributes to the spread of the Covid-19 virus							
I believe that the rules and regulations of this community help improve the quality of living in this neighborhood.							

S2 On a scale of 1 to 7, how satisfied/dissatisfied are you with the following factors of your home and neighborhood?
(1= Very dissatisfied,....., 7= Very satisfied)

	1	2	3	4	5	6	7
The overall quality of your home							
The overall quality of your neighborhood							

S3 Please select one or more thing(s) you LIKE the most about your neighborhood.

- ☐ Neighbors
- ☐ Upkeep
- ☐ Safety
- ☐ Walkways/trails/biking paths
- ☐ Greenness
- ☐ Appearance
- ☐ Access to amenities and daily needs
- ☐ Access to green space
- ☐ Road quality
- ☐ Access to public transport
- ☐ Other

S4 Please select one or more thing(s) you DISLIKE the most about your home and/or neighborhood

- ☐ Noise
- ☐ Lack of access to public transport
- ☐ Road quality
- ☐ Lack of access to amenities
- ☐ Traffic
- ☐ Neighbors and the social environment
- ☐ Lack of walkability
- ☐ Appearance
- ☐ Litter
- ☐ Lack of safety
- ☐ Other

I1 On a scale of 1 to 7, how important were these factors in choosing your new home? (1=not important at all....., 7=Very important)

	1	2	3	4	5	6	7
The energy efficiency of the building (Heating and cooling systems, etc.)							
The indoor and outdoor water efficiency of your home							
Use of renewable energy							
Central heating and/or cooling system							
Outdoor lighting overnight							
Recycling facility							
Rainwater collection system and drainage							

I2 On a scale of 1 to 7, how important were these factors in choosing your new neighborhood? (1=not important at all....., 7=Very important)

	Not Applicable/ I Don't Know						
	1	2	3	4	5	6	7
Possibility of walking around for fun/exercise							
Neighborhood compactness							
Access to daily needs and local services (store, gym, etc.,)							
Diversity of home types in the neighborhood							
Access to public transport							
Access to public spaces and recreation facilities							
Suitability of the community for people with disability							
Opportunities for growing produce in the yard, greenhouse, balcony, community garden, etc.							
Suitability of neighborhood for biking							
Street greenness and landscape quality							
Proximity to schools							
Road quality and connectivity of streets							

O Please rank the following in order of importance for your satisfaction?

_______ Energy efficiency of building and infrastructure
_______ Economic and financial considerations
_______ Your neighbors and opportunities for social interactions
_______ Experience of living in a sustainable neighborhood
_______ The appearance of neighborhood and homes
_______ Neighborhood Safety
_______ Cleanness and physical upkeep of your neighborhood
_______ Neighborhood location

D1 What is your age?

◯ Under 18

◯ 18 - 24

◯ 25 - 34

◯ 35 - 44

◯ 45 - 54

◯ 55 - 64

◯ 65 or older

◯ Prefer not to answer

D2 What is your education level?

- Less than high school
- High school graduate
- Some college
- 2-year degree
- 4-year degree
- Graduate degree
- Prefer not to answer

D3 How much is your household income per year?

- Less than $30,000
- $30,000 - $59,999
- $60,000 - $89,999
- $90,000 - $119,999
- $120,000 - $149,999
- $150,000 or more
- Prefer not to answer

D4 How do you define your gender?

- Female
- Male
- Prefer to self identify
- Prefer not to answer

D5 How long have you been living in this community?

- Less than 6 months
- 6 months to 2 years
- More than 2 years

D6 What is your property ownership status?

- Renter
- Owner

D7 What type of dwelling unit are you living in?

○ Single family house

○ Site condominium

○ Town house

○ Row house

○ Condominium

○ Apartment

○ Other

Z1 Please Enter your Zip Code here

REFERENCES

REFERENCES

Abass, Z. I., & Tucker, R. (2018). Residential satisfaction in low-density Australian suburbs: The impact of social and physical context on neighbourhood contentment. *Journal of Environmental Psychology*, *56*, 36–45. https://doi.org/10.1016/j.jenvp.2018.02.005

Adabre, M. A., & Chan, A. P. C. (2019). Critical success factors (CSFs) for sustainable affordable housing. *Building and Environment*, *156*(April), 203–214. https://doi.org/10.1016/j.buildenv.2019.04.030

Adalberth, K. (1997). Energy use during the life cycle of single-unit dwellings: Examples. *Building and Environment*, *32*(4), 321–329. https://doi.org/10.1016/S0360-1323(96)00069-8

Adriaanse, C. C. M. (2007). Measuring residential satisfaction: A residential environmental satisfaction scale (RESS). *Journal of Housing and the Built Environment*, *22*(3), 287–304. https://doi.org/10.1007/s10901-007-9082-9

Afacan, Y., & Demirkan, H. (2016). The influence of sustainable design features on indoor environmental quality satisfaction in Turkish dwellings. *Architectural Science Review*, *59*(3), 229–238. https://doi.org/10.1080/00038628.2015.1056768

Airriess, C. A., Li, W., Leong, K. J., Chen, A. C.-C., & Keith, V. M. (2008). Church-based social capital, networks and geographical scale: Katrina evacuation, relocation, and recovery in a New Orleans Vietnamese American community. *Geoforum*, *39*(3), 1333–1346. https://doi.org/10.1016/j.geoforum.2007.11.003

Al-Tmeemy, S. M. H. M., Abdul-Rahman, H., & Harun, Z. (2011). Future criteria for success of building projects in Malaysia. *International Journal of Project Management*, *29*(3), 337–348. https://doi.org/10.1016/J.IJPROMAN.2010.03.003

Alhija, F. A. N. (2010). Factor analysis: An overview and some contemporary advances. In *International Encyclopedia of Education* (pp. 162–170). Elsevier Ltd. https://doi.org/10.1016/B978-0-08-044894-7.01328-2

Aliyu, A. A., & Muhammad, M. S. (2016). a Review of Post-Occupancy Evaluation As a Tool and Criteria for. In *Proceedings of the Academic Conference on Agenda for Sub-Sahara Africa*.

Amasyali, K., & El-Gohary, N. M. (2016). Energy-related values and satisfaction levels of residential and office building occupants. *Building and Environment*, *95*, 251–263. https://doi.org/10.1016/j.buildenv.2015.08.005

Amérigo, M., & Aragonés, J. I. (1990). Residential satisfaction in council housing. *Journal of Environmental Psychology*, *10*(4), 313–325. https://doi.org/10.1016/S0272-4944(05)80031-3

Aries, M. B. C., Veitch, J. A., & Newsham, G. R. (2010). Windows, view, and office characteristics predict physical and psychological discomfort. *Journal of Environmental Psychology*, *30*(4), 533–541. https://doi.org/10.1016/j.jenvp.2009.12.004

Astolfi, A., & Pellerey, F. (2008). Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. *The Journal of the Acoustical Society of America*, *123*(1), 163–173. https://doi.org/10.1121/1.2816563

Awang, Z. (2012). *Research Methodology and Data Analysis Second Edition - Zainudin Awang - Google Books*. Retrieved from https://www.google.com/books/edition/Research_Methodology_and_Data_Analysis_S/9hscEAAAQBAJ?hl=en&gbpv=1&dq=Research+Methodology+and+Data+Analysis+(2nd+ed.).+Universiti+Teknologi+Mara,+UiTM+Press&pg=PR4&printsec=frontcover

Baker, B. N., Murphy, D. C., & Fisher, D. (1983). Factors Affecting Project Success. In *Project Management Handbook* (pp. 902–919). Hoboken, NJ, USA: John Wiley & Sons, Inc. https://doi.org/10.1002/9780470172353.ch35

Balkin, R. S., & Sheperis, C. J. (2011). Evaluating and Reporting Statistical Power in Counseling Research. *Journal of Counseling & Development*, *89*(3), 268–272. https://doi.org/10.1002/j.1556-6678.2011.tb00088.x

Bartlett, J. E., Kotrlik, J. W. K. J. W., & Higgins, C. (2001). Organizational research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, *19*(1), 43.

Basolo, V., & Strong, D. (2002). Understanding the neighborhood: From residents' perceptions and needs to action. *Housing Policy Debate*, *13*(1), 83–105. https://doi.org/10.1080/10511482.2002.9521436

Beauducel, A., & Wittmann, W. W. (2005). Simulation study on fit indexes in CFA based on data with slightly distorted simple structure. *Structural Equation Modeling*, *12*(1), 41–75. https://doi.org/10.1207/s15328007sem1201_3

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588–606. https://doi.org/10.1037/0033-2909.88.3.588

Bera, A., & John, S. (1983). Tests for multivariate normality with pearson alternatives. *Communications in Statistics - Theory and Methods*, *12*(1), 103–117. https://doi.org/10.1080/03610928308828444

Berardi, U. (2013). Sustainability assessment of urban communities through rating systems. *Environment, Development and Sustainability*, *15*(6), 1573–1591. https://doi.org/10.1007/s10668-013-9462-0

Bjork, J., Albin, M., Grahn, P., Jacobsson, H., Ardo, J., Wadbro, J., … Skarback, E. (2008). Recreational values of the natural environment in relation to neighbourhood satisfaction, physical activity, obesity and wellbeing. *Journal of Epidemiology & Community Health*, *62*(4), e2–e2. https://doi.org/10.1136/jech.2007.062414

Bonaiuto, M. (2004). Residential Satisfaction and Perceived Urban Quality. In *Encyclopedia of Applied Psychology, Three-Volume Set* (pp. 267–272). https://doi.org/10.1016/B0-12-657410-3/00698-X

Bonaiuto, M., Aiello, A., Perugini, M., & Bonnes, M. (1999). Multidimensional perception of residential environment quality and neighborhood attachment in the urban environment Migraine vertigo View project Place attachment and risky environments View project. *Article in Journal of Environmental Psychology*. https://doi.org/10.1006/jevp.1999.0138

Bonaiuto, M., Fornara, F., & Bonnes, M. (2003). Indexes of perceived residential environment quality and neighbourhood attachment in urban environments: A confirmation study on the city of Rome. In *Landscape and Urban Planning* (Vol. 65, pp. 41–52). Elsevier. https://doi.org/10.1016/S0169-2046(02)00236-0

Boomsma, C., & Steg, L. (2014). Feeling Safe in the Dark: Examining the Effect of Entrapment, Lighting Levels, and Gender on Feelings of Safety and Lighting Policy Acceptability. *Environment and Behavior*, *46*(2), 193–212. https://doi.org/10.1177/0013916512453838

Bopp, M., Kaczynski, A. T., & Wittman, P. (2011). The relationship of eco-friendly attitudes with walking and biking to work. *Journal of Public Health Management and Practice*, *17*(5). https://doi.org/10.1097/PHH.0b013e31821138de

Boschman, S. (2018). Individual differences in the neighbourhood level determinants of residential satisfaction. *Housing Studies*, *33*(7), 1127–1143. https://doi.org/10.1080/02673037.2018.1424804

Bosco, F. A., Aguinis, H., Singh, K., Field, J. G., & Pierce, C. A. (2015). Correlational effect size benchmarks. *Journal of Applied Psychology*, *100*(2), 431–449. https://doi.org/10.1037/a0038047

Bowling, A. (2005). Quantitative social science: the survey. In *Handbook of health research methods. Investigation, measurement and analysis* (pp. 190–214).

Brueckner, J. K., & Largey, A. G. (2008). Social interaction and urban sprawl. *Journal of Urban Economics*, *64*(1), 18–34. https://doi.org/10.1016/j.jue.2007.08.002

Burby, R. J., & Rohe, W. M. (1989). Deconcentration of Public Housing. *Urban Affairs Quarterly*, *25*(1), 117–141. https://doi.org/10.1177/004208168902500108

Buys, L., & Miller, E. (2012). Residential satisfaction in inner urban higher-density Brisbane, Australia: Role of dwelling design, neighbourhood and neighbours. *Journal of Environmental Planning and Management*, *55*(3), 319–338. https://doi.org/10.1080/09640568.2011.597592

Byrne, B. M., Shavelson, R. J., & Muthén, B. (1989). Testing for the Equivalence of Factor Covariance and Mean Structures: The Issue of Partial Measurement Invariance. *Psychological Bulletin*, *105*(3), 456–466. https://doi.org/10.1037/0033-2909.105.3.456

Campbell, D. T., & Fiske, D. W. (1959). Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological Bulletin*, *56*(2), 81–105. https://doi.org/10.1037/h0046016

Cao, J., Hao, Z., Yang, J., Yin, J., & Huang, X. (2020). Prioritizing neighborhood attributes to enhance neighborhood satisfaction: An impact asymmetry analysis. *Cities*, *105*, 102854. https://doi.org/10.1016/j.cities.2020.102854

Capon, A. G., & Blakely, E. J. (2007). Checklist for healthy and sustainable communities. *New South Wales Public Health Bulletin*, *18*(3–4), 51–54. https://doi.org/10.1071/nb07066

Carmines, E., & Zeller, R. (1979). *Reliability and Validity Assessment*. 2455 Teller Road, Thousand Oaks California 91320 United States of America : SAGE Publications, Inc. https://doi.org/10.4135/9781412985642

Chan, A. P. C., & Adabre, M. A. (2019). Bridging the gap between sustainable housing and affordable housing: The required critical success criteria (CSC). *Building and Environment*, *151*, 112–125. https://doi.org/10.1016/J.BUILDENV.2019.01.029

Chan, A. P. C., & Chan, A. P. L. (2004). Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, *11*(2), 203–221. https://doi.org/10.1108/14635770410532624

Chan, A. P. C., Scott, D., & Lam, E. W. M. (2002). Framework of success criteria for design/build projects. *Journal of Management in Engineering*, *18*(3), 120–128. https://doi.org/10.1061/(ASCE)0742-597X(2002)18:3(120)

Chang, N. Bin, Rivera, B. J., & Wanielista, M. P. (2011). Optimal design for water conservation and energy savings using green roofs in a green building under mixed uncertainties. *Journal of Cleaner Production*, *19*(11), 1180–1188. https://doi.org/10.1016/j.jclepro.2011.02.008

Chapman, C., & Feit, E. M. (2019). Confirmatory Factor Analysis and Structural Equation Modeling (pp. 265–297). Springer, Cham. https://doi.org/10.1007/978-3-030-14316-9_10

Chatterjee, S., & Hadi, A. S. (2012). *Regression Analysis by Example, 5th Edition*. Retrieved from https://www.wiley.com/en-us/Regression+Analysis+by+Example%2C+5th+Edition-p-9781118456248

Chen, F. F. (2007a). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling*, *14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Chen, F. F. (2007b). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling*, *14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Chen, F. F. (2008). What Happens If We Compare Chopsticks With Forks? The Impact of Making Inappropriate Comparisons in Cross-Cultural Research. *Journal of Personality and Social Psychology*, *95*(5), 1005–1018. https://doi.org/10.1037/a0013193

Cho, Y., Park, G. S., & Echevarria-Cruz, S. (2005). Perceived neighborhood characteristics and the health of adult Koreans. *Social Science and Medicine*, *60*(6), 1285–1297. https://doi.org/10.1016/j.socscimed.2004.06.054

Chong, W. T., Naghavi, M. S., Poh, S. C., Mahlia, T. M. I., & Pan, K. C. (2011). Techno-economic analysis of a wind-solar hybrid renewable energy system with rainwater collection feature for urban high-rise application. *Applied Energy*, *88*(11), 4067–4077. https://doi.org/10.1016/j.apenergy.2011.04.042

Chovichien, V., & Nguyen, T. A. (2013). List of Indicators and Criteria For Evaluating Construction Project Success and Their Weight Assignment. In *Proceedings of the 2013 (4th) International Conference on Engineering, Project, and Production Management* (pp. 130–150). Association of Engineering, Project, and Production Management. https://doi.org/10.32738/CEPPM.201310.0011

Christian, H. E., Bull, F. C., Middleton, N. J., Knuiman, M. W., Divitini, M. L., Hooper, P., … Giles-Corti, B. (2011). How important is the land use mix measure in understanding walking behaviour? Results from the RESIDE study. *International Journal of Behavioral Nutrition and Physical Activity*, *8*(1), 1–12. https://doi.org/10.1186/1479-5868-8-55

Clarke, R. V. (2008). *Problem-Oriented Guides for Police Improving Street Lighting to Reduce Crime in Residential Areas*. Retrieved from www.cops.usdoj.gov

Cloutier, S., Berejnoi, E., Russell, S., Ann Morrison, B., & Ross, A. (2018). Toward a holistic sustainable and happy neighborhood development assessment tool: A critical review of relevant literature. *Ecological Indicators*, *89*(February), 139–149. https://doi.org/10.1016/j.ecolind.2018.01.055

Cloutier, S., Larson, L., & Jambeck, J. (2014). Are sustainable cities “happy” cities? Associations between sustainable development and human well-being in urban areas of the United States. *Environment, Development and Sustainability*, *16*(3), 633–647. https://doi.org/10.1007/s10668-013-9499-0

Cloutier, S., & Pfeiffer, D. (2015). Sustainability Through Happiness: A Framework for Sustainable Development. *Sustainable Development*, *23*(5), 317–327. https://doi.org/10.1002/sd.1593

Cohen. (2013). *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. Routledge. https://doi.org/10.4324/9780203774441

Cohen J. (1988). Statistical Power Analysis for the Behavioural Science (2nd Edition). In *Statistical Power*

Anaylsis for the Behavioral Sciences (pp. 110–116).

Coleman, J. S. (1988). Social Capital in the Creation of Human Capital. *American Journal of Sociology*. The University of Chicago Press. https://doi.org/10.2307/2780243

Colorado Aerotropolis Visioning Study. (2016). *Infrastructure Development for the Colorado Aerotropolis Study Area*. Retrieved from https://www.codot.gov/library/studies/study-archives/aerotropolis/reports/visioning-study-infrastructure.pdf

Cook, C. C. (1988). Components of Neighborhood Satisfaction. *Environment and Behavior*, *20*(2), 115–149. https://doi.org/10.1177/0013916588202001

Creswell, J. W. (2003). *Research design : qualitative, quantitative, and mixed methods approaches*. Sage Publications. Retrieved from https://books.google.com/books/about/Research_Design.html?id=nSVxmN2KWeYC

Curran, P. J., West, S. G., & Finch, J. F. (1996). The Robustness of Test Statistics to Nonnormality and Specification Error in Confirmatory Factor Analysis. *Psychological Methods*, *1*(1), 16–29. https://doi.org/10.1037/1082-989X.1.1.16

Daniel, J. S., Jacobs, J. M., Douglas, E., Mallick, R. B., & Hayhoe, K. (2014). Impact of Climate Change on Pavement Performance: Preliminary Lessons Learned through the Infrastructure and Climate Network (ICNet). *Climatic Effects on Pavement and Geotechnical Infrastructure - Proceedings of the International Symposium of Climatic Effects on Pavement and Geotechnical Infrastructure 2013*, 1–9. https://doi.org/10.1061/9780784413326.001

Davidov, E. (2009). Measurement Equivalence of Nationalism and Constructive Patriotism in the ISSP: 34 Countries in a Comparative Perspective. *Political Analysis*, *17*, 64–82. https://doi.org/10.1093/pan/mpn014

Davis, K. (2014). Different stakeholder groups and their perceptions of project success. *International Journal of Project Management*, *32*(2), 189–201. https://doi.org/10.1016/J.IJPROMAN.2013.02.006

Dawkins, C., Jeon, J. S., & Pendall, R. (2015). Transportation Access, Rental Vouchers, and Neighborhood Satisfaction: Evidence From the Moving to Opportunity Experiment. *Housing Policy Debate*, *25*(3), 497–530. https://doi.org/10.1080/10511482.2014.986662

de Jong, K., Albin, M., Skärbäck, E., Grahn, P., & Björk, J. (2012). Perceived green qualities were associated with neighborhood satisfaction, physical activity, and general health: Results from a cross-sectional study in suburban and rural Scania, southern Sweden. *Health & Place*, *18*(6), 1374–1380. https://doi.org/10.1016/J.HEALTHPLACE.2012.07.001

De Souza Briggs, X. (1997). Social capital and the cities: Advice to change agents. *National Civic Review*, *86*(2), 111–117. https://doi.org/10.1002/ncr.4100860204 de Wit, A. (1988). Measurement of project success. *International Journal of Project Management*, *6*(3), 164–170. https://doi.org/10.1016/0263-7863(88)90043-9

Dempsey, N., Brown, C., & Bramley, G. (2012). The key to sustainable urban development in UK cities? The influence of density on social sustainability. *Progress in Planning*, *77*(3), 89–141. https://doi.org/10.1016/j.progress.2012.01.001

Dempsey, Nicola, Bramley, G., Power, S., & Brown, C. (2011). The social dimension of sustainable development: Defining urban social sustainability. *Sustainable Development*, *19*(5), 289–300. https://doi.org/10.1002/sd.417

Dimitrov, D. M. (2006). Comparing groups on latent variables: A structural equation modeling approach. *Work*, *26*(4), 429–436. Retrieved from https://www.researchgate.net/publication/6996484_Comparing_groups_on_latent_variables_A_structural_equation_modeling_approach

Duncan, M. J., Winkler, E., Sugiyama, T., Cerin, E., Dutoit, L., Leslie, E., & Owen, N. (2010). Relationships of land use mix with walking for transport: Do land uses and geographical scale matter? *Journal of Urban Health*, *87*(5), 782–795. https://doi.org/10.1007/s11524-010-9488-7

Dvir, D., Raz, T., & Shenhar, A. J. (2003). An empirical analysis of the relationship between project planning and project success. *International Journal of Project Management*, *21*(2), 89–95. https://doi.org/10.1016/S0263-7863(02)00012-1

Dyck, D. Van, Cardon, G., Deforche, B., & De Bourdeaudhuij, I. (2011). Do adults like living in high-walkable neighborhoods? Associations of walkability parameters with neighborhood satisfaction and possible mediators. *Health and Place*, *17*(4), 971–977. https://doi.org/10.1016/j.healthplace.2011.04.001

EIA. (2015). CBECS 2012: Building Stock Results. Retrieved May 12, 2020, from https://www.eia.gov/consumption/commercial/reports/2012/buildstock/

Ellis, C. D., Lee, S.-W., & Kweon, B.-S. (2006). Retail land use, neighborhood satisfaction and the urban forest: an investigation into the moderating and mediating effects of trees and shrubs. *Landscape and Urban Planning*, *74*(1), 70–78. https://doi.org/10.1016/J.LANDURBPLAN.2004.10.004

Enright, S. (2002). Post-Occupancy Evaluation of UK Library Building Projects: Some Examples of Current Activity. *LIBER Quarterly*, *12*(1), 26. https://doi.org/10.18352/lq.7665

Fanger, P. O. (1970). Thermal comfort. Analysis and applications in environmental engineering. *Thermal Comfort. Analysis and Applications in Environmental Engineering.*

Finney, S. J., & DiStefano, C. (2013). Non-normal and categorical data in structural equation modeling. *Structural Equation Modeling: A Second Course*, 269–314. Retrieved from https://psycnet.apa.org/record/2014-01991-011

Forza, C. (2002). Survey research in operations management: a process-based perspective. *International Journal of Operations & Production Management*, *22*(2), 152–194. https://doi.org/10.1108/01443570210414310

Fotios, S., Unwin, J., & Farrall, S. (2015a, June 6). Road lighting and pedestrian reassurance after dark: A review. *Lighting Research and Technology*. SAGE Publications Ltd. https://doi.org/10.1177/1477153514524587

Fotios, S., Unwin, J., & Farrall, S. (2015b, June 6). Road lighting and pedestrian reassurance after dark: A review. *Lighting Research and Technology*. SAGE Publications Ltd. https://doi.org/10.1177/1477153514524587

Fowler, F. (2012). *Survey Research Methods (4th ed.)*. *Survey Research Methods (4th ed.)*. SAGE Publications, Inc. https://doi.org/10.4135/9781452230184

Freeman, L. (2001). The effects of sprawl on neighborhood social ties: An explanatory analysis. *Journal of the American Planning Association*, *67*(1), 69–77. https://doi.org/10.1080/01944360108976356

French, B. F., & Finch, H. (2016). Factorial Invariance Testing under Different Levels of Partial Loading Invariance within a Multiple Group Confirmatory Factor Analysis Model. *Journal of Modern Applied Statistical Methods*, *15*, 5–6. https://doi.org/10.22237/jmasm/1462076700

Fried, M. (1984). The structure and significance of community satisfaction. *Population and Environment*, *7*(2), 61–86. https://doi.org/10.1007/BF01254778

Fuller, E. L., & Hemmerle, W. J. (1966). Robustness of the maximum-likelihood estimation procedure in factor analysis. *Psychometrika*, *31*(2), 255–266. https://doi.org/10.1007/BF02289512

Galster, G. C. (1985). Evaluating indicators for housing policy: Residential satisfaction vs marginal improvement priorities. *Social Indicators Research*, *16*(4), 415–448. https://doi.org/10.1007/BF00333289

Galster, G. C., & Hesser, G. W. (1981a). Residential satisfaction: Compositional and Contextual Correlates. *Environment and Behavior*, *13*(6), 735–758. https://doi.org/10.1177/0013916581136006

Galster, G. C., & Hesser, G. W. (1981b). Residential Satisfaction: Compositional and Contextual Correlates. *Environment and Behavior*, *13*(6), 735–758. https://doi.org/10.1177/0013916581136006

Gehrke, S. R., & Clifton, K. J. (2019). An activity-related land use mix construct and its connection to pedestrian travel. *Environment and Planning B: Urban Analytics and City Science*, *46*(1), 9–26.

https://doi.org/10.1177/2399808317690157

Gerbing, D. W., & Hunter, J. E. (1982). The metric of the latent variables in a lisrel-IV analysis. *Educational and Psychological Measurement*, *42*(2), 423–427. https://doi.org/10.1177/001316448204200204

GhaffarianHoseini, A., GhaffarianHoseini, A., Makaremi, N., & GhaffarianHoseini, M. (2013). The Concept of Zero Energy Intelligent Buildings (ZEIB): A Review of Sustainable Development for Future Cities. *British Journal of Environment and Climate Change*, 339–367. https://doi.org/10.9734/bjecc/2012/2531

Gideon, L. (2012). *Handbook of survey methodology for the social sciences*. *Handbook of Survey Methodology for the Social Sciences*. Springer New York. https://doi.org/10.1007/978-1-4614-3876-2

Gidlöf-Gunnarsson, A., & Öhrström, E. (2007). Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. *Landscape and Urban Planning*, *83*(2–3), 115–126. https://doi.org/10.1016/j.landurbplan.2007.03.003

Gifford, R. (2007a). *Environmental psychology : principles and practice*. Optimal Books.

Gifford, R. (2007b). The Consequences of Living in High-Rise Buildings. *Architectural Science Review*, *50*(1), 2–17. https://doi.org/10.3763/asre.2007.5002

Gou, Z., Prasad, D., & Siu-Yu Lau, S. (2013). Are green buildings more satisfactory and comfortable? *Habitat International*, *39*, 156–161. https://doi.org/10.1016/j.habitatint.2012.12.007

Grasser, G., Titze, S., & Stronegger, W. J. (2016). Are residents of high-walkable areas satisfied with their neighbourhood? *Journal of Public Health (Germany)*, *24*(6), 469–476. https://doi.org/10.1007/s10389-016-0744-5

Green, J., Perkins, C., Steinbach, R., & Edwards, P. (2015). Reduced street lighting at night and health: A rapid appraisal of public views in England and Wales. *Health and Place*, *34*, 171–180. https://doi.org/10.1016/j.healthplace.2015.05.011

Groat, L. N., & Wang, D. (2013). *Architectural Research Methods, 2nd Edition*. Retrieved from https://www.wiley.com/en-us/Architectural+Research+Methods%2C+2nd+Edition-p-9780470908556

Gruber, K. J., & Shelton, G. G. (1987). Assessment of neighborhood satisfaction by residents of three housing types. *Social Indicators Research*, *19*(3), 303–315. https://doi.org/10.1007/BF00300363

Hardi, P., & Zdan, T. (1997). *Assessing Sustainable Development: PRINCIPLES in Practice. In- ternational Institute for Sustainable Development*. Retrieved from https://www.iisd.org/pdf/bellagio.pdf

Hartig, T., & Mang, M. (1991). Restorative effects of natural environment experiences. *Environment and Behavior*, *23*(1), 3–26. https://doi.org/10.1177/0013916591231001

Hawton, A., Green, C., Dickens, A. P., Richards, S. H., Taylor, R. S., Edwards, R., … Campbell, J. L. (2011). The impact of social isolation on the health status and health-related quality of life of older people. *Quality of Life Research*, *20*(1), 57–67. https://doi.org/10.1007/s11136-010-9717-2

Haynes, B. P. (2008). An evaluation of the impact of the office environment on productivity. *Facilities*, *26*(5–6), 178–195. https://doi.org/10.1108/02632770810864970

Heravi, G., & Ilbeigi, M. (2012). Development of a comprehensive model for construction project success evaluation by contractors. *Engineering, Construction and Architectural Management*, *19*(5), 526–542. https://doi.org/10.1108/09699981211259603

Herting, J. R., & Guest, A. M. (1985). COMPONENTS OF SATISFACTION WITH LOCAL AREAS IN THE METROPOLIS. *Sociological Quarterly*, *26*(1), 99–116. https://doi.org/10.1111/j.1533-8525.1985.tb00218.x

Hesari, E., Peysokhan, M., Havashemi, A., Gheibi, D., Ghafourian, M., & Bayat, F. (2019). Analyzing the Dimensionality of Place Attachment and Its Relationship with Residential Satisfaction in New Cities: The Case of Sadra, Iran. *Social Indicators Research*, *142*(3), 1031–1053. https://doi.org/10.1007/s11205-018-1949-5

Hibberts, M., Johnson, R. B., & Hudson, K. (2012). Common survey sampling techniques. In *Handbook of Survey Methodology for the Social Sciences* (pp. 53–74). Springer New York. https://doi.org/10.1007/978-1-4614-3876-2_5

Hilley, J., & Sim, S. (2020). Context-based neighborhood sustainability assessment in birmingham, alabama. *Sustainability (Switzerland)*, *12*(22), 1–18. https://doi.org/10.3390/su12229426

Holmgren, M., Kabanshi, A., & Sörqvist, P. (2017). Occupant perception of “green” buildings: Distinguishing physical and psychological factors. *Building and Environment*, *114*, 140–147. https://doi.org/10.1016/j.buildenv.2016.12.017

Hooper, D., Coughlan, J., & Mullen, M. R. (2008). Structural Equation Modelling: Guidelines for Determining Model Fit. *Electronic Journal of Business Research Methods*, *6*(1), 53–60. Retrieved from www.ejbrm.com

Horn, J. L., & McArdle, J. J. (1992). A practical and theoretical guide to measurement invariance in aging research. *Experimental Aging Research*, *18*(3), 117–144. https://doi.org/10.1080/03610739208253916

Howley, P., Scott, M., & Redmond, D. (2009). Sustainability versus liveability: an investigation of neighbourhood satisfaction. *Journal of Environmental Planning and Management*, *52*(6), 847–864.

https://doi.org/10.1080/09640560903083798

Hu, L. tze, Bentler, P. M., & Kano, Y. (1992). Can Test Statistics in Covariance Structure Analysis Be Trusted? *Psychological Bulletin*, *112*(2), 351–362. https://doi.org/10.1037/0033-2909.112.2.351

Huang, Z., Du, X., & Yu, X. (2015). Home ownership and residential satisfaction: Evidence from Hangzhou, China. *Habitat International*, *49*, 74–83. https://doi.org/10.1016/j.habitatint.2015.05.008

Humboldt County General Plan for the Areas Outside the Coastal Zone. (2017). Retrieved from https://humboldtgov.org/DocumentCenter/View/61984/Humboldt-County-General-Plan-complete-document-PDF

Hünermund, P., & Louw, B. (2020). On the Nuisance of Control Variables in Regression Analysis. Retrieved from http://arxiv.org/abs/2005.10314

Hur, M., & Morrow-jones, H. (2008). Residents ' Satisfaction With. *Environment and Behavior*, *40*(5), 619–635. https://doi.org/10.1177/0013916507307483

Hur, M., & Nasar, J. L. (2014). Physical upkeep, perceived upkeep, fear of crime and neighborhood satisfaction. *Journal of Environmental Psychology*, *38*, 186–194. https://doi.org/10.1016/J.JENVP.2014.02.001

Hur, M., Nasar, J. L., & Chun, B. (2010). Neighborhood satisfaction, physical and perceived naturalness and openness. *Journal of Environmental Psychology*, *30*(1), 52–59. https://doi.org/10.1016/j.jenvp.2009.05.005

Hwang, T., & Jeong, T. K. (2011). Effects of indoor lighting on occupants' visual comfort and eye health in a green building. In *Indoor and Built Environment* (Vol. 20, pp. 75–90). SAGE PublicationsSage UK: London, England. https://doi.org/10.1177/1420326X10392017

Ibem, E. O, & Azuh, D. E. (2011). Framework for Evaluating the Sustainability of Public Housing Programmes in Developing Countries. *Journal of Sustainable Development and Environmental Protection*, *1*(3), 24–39. Retrieved from https://www.academia.edu/1603737/FRAMEWORK_FOR_EVALUATING_THE_SUSTAINABILITY_OF_PUBLIC_HOUSING_PROGRAMMES_IN_DEVELOPING_COUNTRIES

Ibem, E O, Adeboye, A. B., & Alagbe, O. A. (2015). SIMILARITIES AND DIFFERENCES IN RESIDENTS' PERCEPTION OF HOUSING ADEQUACY AND RESIDENTIAL SATISFACTION. *Journal of Building Performance*, *6*(1), 1–14. Retrieved from http://spaj.ukm.my/jsb/index.php/jbp/index

Ibem, Eziyi Offia, & Aduwo, E. B. (2013). Assessment of residential satisfaction in public housing in Ogun State, Nigeria. *Habitat International*, *40*, 163–175. https://doi.org/10.1016/j.habitatint.2013.04.001

Ika, L. A. (2009). Project Success as a Topic in Project Management Journals. *Project Management Journal*, *40*(4), 6–19. https://doi.org/10.1002/pmj.20137

Ireland, L. R. (1992). Customer satisfaction: the project manager's role. *International Journal of Project Management*, *10*(2), 123–127. https://doi.org/10.1016/0263-7863(92)90065-H

Jöreskog, K. G. (1969). A general approach to confirmatory maximum likelihood factor analysis. *Psychometrika*, *34*(2), 183–202. https://doi.org/10.1007/BF02289343

Jöreskog, K. G., & Sörbom, D. (1993). *LISREL 8: Structural equation modeling with the SIMPLIS command language. Scientific Software International. Scientific Software*. Retrieved from https://psycnet.apa.org/record/1993-97878-000

Kamruzzaman, M., Wood, L., Hine, J., Currie, G., Giles-Corti, B., & Turrell, G. (2014). Patterns of social capital associated with transit oriented development. *Journal of Transport Geography*, *35*, 144–155. https://doi.org/10.1016/j.jtrangeo.2014.02.003

Kan, K. (2007). Residential mobility and social capital. *Journal of Urban Economics*, *61*(3), 436–457. https://doi.org/10.1016/j.jue.2006.07.005

Kaplan, D. H. (2015). Transportation sustainability on a university campus. *International Journal of Sustainability in Higher Education*, *16*(2), 173–186. https://doi.org/10.1108/IJSHE-03-2013-0023

Kaplan, R. (2001). The nature of the view from home psychological benefits. *Environment and Behavior*, *33*(4), 507–542. https://doi.org/10.1177/00139160121973115

Kaplan, Rachel. (2001). The Nature of the View from Home. *Environment and Behavior*, *33*(4), 507–542. https://doi.org/10.1177/00139160121973115

Kenny, D. A., & McCoach, D. B. (2003). Effect of the Number of Variables on Measures of Fit in Structural Equation Modeling. *Structural Equation Modeling*, *10*(3), 333–351. https://doi.org/10.1207/S15328007SEM1003_1

Khosravi, S., & Afshari, H. (2011). A Success Measurement Model for Construction Projects. In *International Conference on Financial Management and Economics* (pp. 186–190). Singapore: IACSIT Press. Retrieved from http://www.ipedr.com/vol11/36-W00014.pdf

Kim, H.-Y. (2013). Statistical notes for clinical researchers: assessing normal distribution (2) using skewness and kurtosis. *Restorative Dentistry & Endodontics*, *38*(1), 52. https://doi.org/10.5395/rde.2013.38.1.52

Kline, R. B. (1998). *Principles and Practice of Structural Equation Modeling, Second Edition*. *Methodology in the social sciences*. Retrieved from https://books.google.com/books?id=EkMVZUxZrgIC&newbks=0&hl=en&source=newbks_fb

Komeily, A., & Srinivasan, R. S. (2015). A need for balanced approach to neighborhood sustainability assessments: A critical review and analysis. *Sustainable Cities and Society*, *18*, 32–43. https://doi.org/10.1016/j.scs.2015.05.004

Kruger, D. J., Reischl, T. M., & Gee, G. C. (2007). Neighborhood Social Conditions Mediate the Association Between Physical Deterioration and Mental Health. *American Journal of Community Psychology*, *40*(3–4), 261–271. https://doi.org/10.1007/s10464-007-9139-7

Kweon, B.-S., Ellis, C. D., Leiva, P. I., & Rogers, G. O. (2010). Landscape Components, Land Use, and Neighborhood Satisfaction. *Environment and Planning B: Planning and Design*, *37*(3), 500–517. https://doi.org/10.1068/b35059

Kyttä, M., Broberg, A., Haybatollahi, M., & Schmidt-Thomé, K. (2016). Urban happiness: context-sensitive study of the social sustainability of urban settings. *Environment and Planning B: Planning and Design*, *43*(1), 34–57. https://doi.org/10.1177/0265813515600121

Lai, A. C. K., Mui, K. W., Wong, L. T., & Law, L. Y. (2009). An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings. *Energy and Buildings*, *41*(9), 930–936. https://doi.org/10.1016/j.enbuild.2009.03.016

Land, K. C. (1969). Principles of Path Analysis. *Sociological Methodology*, *1*, 3. https://doi.org/10.2307/270879

Laze, K. (2019). *Assessing Public Perceptions about Road Lighting in five Neighborhoods of Tirana, Albania*. Advance. https://doi.org/10.31124/ADVANCE.7707617.V1

Lee, J. H., Yoon, Y., Baik, Y. K., & Kim, S. (2013). Analyses on human responses to illuminance variations for resident-friendly lighting environment in a small office. *Indoor and Built Environment*, *22*(3), 535–550. https://doi.org/10.1177/1420326X12446208

Lee, M., & Tansel, B. (2013). Water conservation quantities vs customer opinion and satisfaction with water efficient appliances in Miami, Florida. *Journal of Environmental Management*, *128*, 683–689. https://doi.org/10.1016/j.jenvman.2013.05.044

Lee, S.-W., Ellis, C. D., Kweon, B.-S., & Hong, S.-K. (2008). Relationship between landscape structure and neighborhood satisfaction in urbanized areas. *Landscape and Urban Planning*, *85*(1), 60–70. https://doi.org/10.1016/J.LANDURBPLAN.2007.09.013

Lee, S. M., Conway, T. L., Frank, L. D., Saelens, B. E., Cain, K. L., & Sallis, J. F. (2017a). The Relation of Perceived and Objective Environment Attributes to Neighborhood Satisfaction. *Environment and Behavior*, *49*(2), 136–160. https://doi.org/10.1177/0013916515623823

Lee, S. M., Conway, T. L., Frank, L. D., Saelens, B. E., Cain, K. L., & Sallis, J. F. (2017b). The Relation of Perceived and Objective Environment Attributes to Neighborhood Satisfaction. *Environment and*

Behavior, *49*(2), 136–160. https://doi.org/10.1177/0013916515623823

Leslie, E., & Cerin, E. (2008). Are perceptions of the local environment related to neighbourhood satisfaction and mental health in adults? *Preventive Medicine*, *47*(3), 273–278. https://doi.org/10.1016/j.ypmed.2008.01.014

Leyden, K. M. (2003). Social Capital and the Built Environment: The Importance of Walkable Neighborhoods. *American Journal of Public Health*, *93*(9), 1546–1551. https://doi.org/10.2105/AJPH.93.9.1546

Leyden, K. M., Goldberg, A., & Michelbach, P. (2011). Understanding the Pursuit of Happiness in Ten Major Cities. *Urban Affairs Review*, *47*(6), 861–888. https://doi.org/10.1177/1078087411403120

Lipsey, M. W. (1990). *Design sensitivity : statistical power for experimental research*. Sage Publications.

Liu, A. M. M., & Walker, A. (1998). Evaluation of project outcomes. *Construction Management and Economics*, *16*(2), 209–219. https://doi.org/10.1080/014461998372493

Long, D. A., & Perkins, D. D. (2003, May 1). Confirmatory factor analysis of the sense of community index and development of a brief SCI. *Journal of Community Psychology*. John Wiley & Sons, Ltd. https://doi.org/10.1002/jcop.10046

Lovejoy, K., Handy, S., & Mokhtarian, P. (2010). Neighborhood satisfaction in suburban versus traditional environments: An evaluation of contributing characteristics in eight California neighborhoods. *Landscape and Urban Planning*, *97*(1), 37–48. https://doi.org/10.1016/J.LANDURBPLAN.2010.04.010

Lu, M. (1999). Determinants of Residential Satisfaction: Ordered Logit vs. Regression Models. *Growth and Change*, *30*(2), 264–287. https://doi.org/10.1111/0017-4815.00113

Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy*, *20*, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013

Lucas, R., & Dyrenforth, P. (2006). Does the Existence of Social Relationships Matter for Subjective Well-Being? In *Self and Relationships: Connecter Intrapersonal and Interpersonal Processes* (p. 254). Retrieved from https://psycnet.apa.org/record/2006-04109-013

Mac Callum, R. C., Browne, M. W., & Cai, L. (2012). Factor analysis models as approximations. In *Factor Analysis at 100: Historical Developments and Future Directions* (pp. 153–176). https://doi.org/10.4324/9780203936764

Maddison, D., & Rehdanz, K. (2011). The impact of climate on life satisfaction. *Ecological Economics*, *70*(12), 2437–2445. https://doi.org/10.1016/J.ECOLECON.2011.07.027

Madge, C. (1997). Public parks and the geography of fear. *Tijdschrift Voor Economische En Sociale Geografie*, *88*(3), 237–250. https://doi.org/10.1111/j.1467-9663.1997.tb01601.x

Maller, S. J., & French, B. F. (2004). Universal Nonverbal Intelligence Test factor invariance across deaf and standardization samples. *Educational and Psychological Measurement*, *64*(4), 647–660. https://doi.org/10.1177/0013164404263877

Marique, A.-F., & Reiter, S. (2014). A simplified framework to assess the feasibility of zero-energy at the neighbourhood/community scale. *Energy and Buildings*, *82*, 114–122. https://doi.org/10.1016/J.ENBUILD.2014.07.006

Mason, S. G. (2010). Can community design build trust? A comparative study of design factors in Boise, Idaho neighborhoods. *Cities*, *27*(6), 456–465. https://doi.org/10.1016/j.cities.2010.07.003

Mccrea, R., Stimson, R., & Western, J. (2005). Testing a Moderated Model of Satisfaction with Urban Living using Data for Brisbane-South East Queensland, Australia. *Social Indicators Research*, *72*(2), 121–152. https://doi.org/10.1007/s11205-004-2211-x

McCulloch, A. (2012). Housing density as a predictor of neighbourhood satisfaction among families with young children in urban England. *Population, Space and Place*, *18*(1), 85–99. https://doi.org/10.1002/psp.650

Meade, A. W., Johnson, E. C., & Braddy, P. W. (2008). Power and Sensitivity of Alternative Fit Indices in Tests of Measurement Invariance. *Journal of Applied Psychology*, *93*(3), 568–592. https://doi.org/10.1037/0021-9010.93.3.568

Miller, E., & Buys, L. (2008). The role of social capital in predicting and promoting 'feelings of responsibility' for local environmental issues in an Australian community. *Australasian Journal of Environmental Management*, *15*(4), 231–240. https://doi.org/10.1080/14486563.2008.9725207

Millsap, R. E., & Meredith, W. (2012). Factorial invariance: Historical perspectives and new problems. In *Factor Analysis at 100: Historical Developments and Future Directions* (pp. 131–152). https://doi.org/10.4324/9780203936764

Mohajan, H. (2017). Two Criteria for Good Measurements in Research: Validity and Reliability. *Annals of Spiru Haret University*, *17*(4), 56–82. Retrieved from https://mpra.ub.uni-muenchen.de/83458/

Mohit, M. A., & Raja, A. M. M. A. K. (2014). Residential satisfaction-Concept, theories and empirical studies. *Planning Malaysia: Urban Planning and Local Governance*, *12*(July 2014), 47–66. https://doi.org/10.21837/pmjournal.v12.i3.131

Morris, E. W., & Winter, M. (1975). A Theory of Family Housing Adjustment. *Journal of Marriage and the Family*, *37*(1), 79. https://doi.org/10.2307/351032

Morse, S., & Fraser, E. D. G. (2005). Making “dirty” nations look clean? The nation state and the problem of selecting and weighting indices as tools for measuring progress towards sustainability. *Geoforum*, *36*(5), 625–640. https://doi.org/10.1016/j.geoforum.2004.10.005

Mouratidis, K. (2019). Compact city, urban sprawl, and subjective well-being. *Cities*, *92*, 261–272. https://doi.org/10.1016/j.cities.2019.04.013

Müller, R., & Jugdev, K. (2012). Critical success factors in projects. *International Journal of Managing Projects in Business*, *5*(4), 757–775. https://doi.org/10.1108/17538371211269040

Myers, D. (1988). Building Knowledge about Quality of Life for Urban Planning. *Journal of the American Planning Association*, *54*(3), 347–358. https://doi.org/10.1080/01944368808976495

Newell, J. P., Seymour, M., Yee, T., Renteria, J., Longcore, T., Wolch, J. R., & Shishkovsky, A. (2013). Green Alley Programs: Planning for a sustainable urban infrastructure? *Cities*, *31*, 144–155. https://doi.org/10.1016/j.cities.2012.07.004

Noriza, R., Ariffin, R., & Khairi Zahari, R. (2013). Selection and peer-review under responsibility of Centre for Environment-Behaviour Studies (cE-Bs), Faculty of Architecture, Planning & Surveying ScienceDirect Perceptions of the Urban Walking Environments. *Procedia-Social and Behavioral Sciences*, *105*, 589–597. https://doi.org/10.1016/j.sbspro.2013.11.062

Osborne, J. W., & Waters, E. (2002). Four assumptions of multiple regression that researchers should Four assumptions of multiple regression that researchers should always test always test. *Practical Assessment, Research, and Evaluation*, *8*(2), 2. https://doi.org/10.7275/R222-HV23

Owen, N., Humpel, N., Leslie, E., Bauman, A., & Sallis, J. F. (2004). Understanding environmental influences on walking. *American Journal of Preventive Medicine*, *27*(1), 67–76. https://doi.org/10.1016/j.amepre.2004.03.006

Parkes, A., Kearns, A., & Atkinson, R. (2002). What Makes People Dissatisfied with their Neighbourhoods? *Urban Studies*, *39*(13), 2413–2438. https://doi.org/10.1080/0042098022000027031

Paydar, M., Kamani-Fard, A., & Etminani-Ghasrodashti, R. (2017). Perceived security of women in relation to their path choice toward sustainable neighborhood in Santiago, Chile. *Cities*, *60*, 289–300. https://doi.org/10.1016/j.cities.2016.10.002

Pfeiffer, D., Ehlenz, M. M., Andrade, R., Cloutier, S., & Larson, K. L. (2020). Do Neighborhood Walkability, Transit, and Parks Relate to Residents’ Life Satisfaction?: Insights From Phoenix. *Journal of the American Planning Association*, *86*(2), 171–187. https://doi.org/10.1080/01944363.2020.1715824

Pinto, J. K., & Prescott, J. E. (1988). Variations in Critical Success Factors Over the Stages in the Project Life Cycle. *Journal of Management*, *14*(1), 5–18. https://doi.org/10.1177/014920638801400102

Pinto, J. K., & Shelvin, D. P. (1988). Critical Success Factors Across the Project Life Cycle. *Project Management Journal*, *19*(June 1988), 67.

Pope, J., Annandale, D., & Morrison-Saunders, A. (2004). Conceptualising sustainability assessment. *Environmental Impact Assessment Review*, *24*(6), 595–616. https://doi.org/10.1016/j.eiar.2004.03.001

Preedy, V. R., & Watson, R. (2010). *Handbook of Disease Burdens and Quality of Life Measures | Victor R. Preedy | Springer*. Retrieved from https://www.springer.com/gp/book/9780387786643

Preiser, W. F. E., & Vischer, J. C. (2006). The evolution of building performance evaluation: an introduction. In *Assessing Building Performance* (pp. 25–36). Routledge. https://doi.org/10.4324/9780080455228-9

Pretty, J., & Smith, D. (2004). Social Capital in Biodiversity Conservation and Management. *Conservation Biology*, *18*(3), 631–638.

Putnick, D. L., & Bornstein, M. H. (2016, September 1). Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Developmental Review*. Mosby Inc. https://doi.org/10.1016/j.dr.2016.06.004

Rafiemanzelat, R., Emadi, M. I., & Kamali, A. J. (2017). City sustainability: the influence of walkability on built environments. In *Transportation Research Procedia* (Vol. 24, pp. 97–104). https://doi.org/10.1016/j.trpro.2017.05.074

Rahm, J., Sternudd, C., & Johansson, M. (2021). "In the evening, I don't walk in the park": The interplay between street lighting and greenery in perceived safety. *Urban Design International*, *26*(1), 42–52. https://doi.org/10.1057/s41289-020-00134-6

Ramlee, N., Tammy, N. J., Raja Mohd Noor, R. N. H., Ainun Musir, A., Abdul Karim, N., Chan, H. B., & Mohd Nasir, S. R. (2016). Critical success factors for construction project. In *AIP Conference Proceedings* (Vol. 1774, p. 030011). AIP Publishing LLC. https://doi.org/10.1063/1.4965067

Rogers, S. H., Gardner, K. H., & Carlson, C. H. (2013). Social capital and walkability as social aspects of sustainability. *Sustainability (Switzerland)*, *5*(8), 3473–3483. https://doi.org/10.3390/su5083473

Rossi, P. H. (1955). Why Families Move A Study in the Social Psychology of Urban Residential Mobility. *The Free Press, Glencoe*. Retrieved from https://www.scirp.org/(S(lz5mqp453edsnp55rrgjct55))/reference/ReferencesPapers.aspx?ReferenceID=1207629

Rutkowski, L., & Svetina, D. (2014). Assessing the Hypothesis of Measurement Invariance in the Context of Large-Scale International Surveys. *Educational and Psychological Measurement*, *74*(1), 31–57. https://doi.org/10.1177/0013164413498257

Saelens, B. E., Sallis, J. F., Black, J. B., & Chen, D. (2003). Neighborhood-based differences in physical activity: an environment scale evaluation. *American Journal of Public Health*, *93*(9), 1552–1558. https://doi.org/10.2105/ajph.93.9.1552

Salleh, A. G. (2008). Neighbourhood factors in private low-cost housing in Malaysia. *Habitat International*, *32*(4), 485–493. https://doi.org/10.1016/j.habitatint.2008.01.002

Salleh, A. G. (2012). Sustainable Urban Neighbourhoods: The Need to Consider Residents' Satisfaction. *OIDA International Journal of Sustainable Development*, *03*(10), 103–108. Retrieved from http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html

Sallis, J. F., Saelens, B. E., Frank, L. D., Conway, T. L., Slymen, D. J., Cain, K. L., … Kerr, J. (2009a). Neighborhood built environment and income: examining multiple health outcomes. *Social Science & Medicine (1982)*, *68*(7), 1285–1293. https://doi.org/10.1016/j.socscimed.2009.01.017

Sallis, J. F., Saelens, B. E., Frank, L. D., Conway, T. L., Slymen, D. J., Cain, K. L., … Kerr, J. (2009b). Neighborhood built environment and income: Examining multiple health outcomes. *Social Science & Medicine*, *68*(7), 1285–1293. https://doi.org/10.1016/J.SOCSCIMED.2009.01.017

Sant'Anna, D. O., Dos Santos, P. H., Vianna, N. S., & Romero, M. A. (2018). Indoor environmental quality perception and users' satisfaction of conventional and green buildings in Brazil. *Sustainable Cities and Society*, *43*, 95–110. https://doi.org/10.1016/j.scs.2018.08.027

Satorra, A., & Bentler, P. M. (2001). A scaled difference chi-square test statistic for moment structure analysis. *Psychometrika*, *66*(4), 507–514. https://doi.org/10.1007/BF02296192

Scerri, A., & James, P. (2010). Accounting for sustainability: Combining qualitative and quantitative research in developing "indicators" of sustainability. *International Journal of Social Research Methodology*, *13*(1), 41–53. https://doi.org/10.1080/13645570902864145

Schreiber, J. B., Stage, F. K., King, J., Nora, A., & Barlow, E. A. (2006). *Reporting Structural Equation Modeling and Confirmatory Factor Analysis Results: A Review*.

Schweikert, A., Chinowsky, P., Espinet, X., & Tarbert, M. (2014). Climate Change and Infrastructure Impacts: Comparing the Impact on Roads in ten Countries through 2100. *Procedia Engineering*, *78*, 306–316. https://doi.org/10.1016/J.PROENG.2014.07.072

Schweikert, A., Chinowsky, P., Kwiatkowski, K., & Espinet, X. (2014). The infrastructure planning support system: Analyzing the impact of climate change on road infrastructure and development. *Transport Policy*, *35*, 146–153. https://doi.org/10.1016/J.TRANPOL.2014.05.019

Sebestyen, Z. (2017). Further Considerations in Project Success. *Procedia Engineering*, *196*(June), 571–577. https://doi.org/10.1016/j.proeng.2017.08.032

Serrador, P., & Rodney Turner, J. (2014). The Relationship between Project Success and Project Efficiency. *Procedia - Social and Behavioral Sciences*, *119*, 75–84. https://doi.org/10.1016/J.SBSPRO.2014.03.011

Shakou, L. M., Wybo, J. L., Reniers, G., & Boustras, G. (2019). Developing an innovative framework for enhancing the resilience of critical infrastructure to climate change. *Safety Science*, *118*, 364–378. https://doi.org/10.1016/J.SSCI.2019.05.019

Sharifi, A., & Murayama, A. (2014). Neighborhood sustainability assessment in action: Cross-evaluation of three assessment systems and their cases from the US, the UK, and Japan. *Building and Environment*, *72*, 243–258. https://doi.org/10.1016/j.buildenv.2013.11.006

Sirgy, M. J., & Cornwell, T. (2002). How Neighborhood Features Affect Quality of Life. *Social Indicators Research*, *59*(1), 79–114. https://doi.org/10.1023/A:1016021108513

Solutions, S. (2009). Factor Analysis | Statistics Solutions. *Dissertation Consultants*. Retrieved from https://www.statisticssolutions.com/free-resources/directory-of-statistical-analyses/confirmatory-factor-analysis/

Srivastava, M. S., & Hui, T. K. (1987). On assessing multivariate normality based on shapiro-wilk W statistic. *Statistics and Probability Letters*, *5*(1), 15–18. https://doi.org/10.1016/0167-7152(87)90019-8

Stage, F. K., Carter, H. C., & Nora, A. (2004). Path Analysis: An Introduction and Analysis of a Decade of Research. *Journal of Educational Research*, *98*(1), 5–13. https://doi.org/10.3200/JOER.98.1.5-13

Steenkamp, J. B. E. M., & Baumgartner, H. (1998a). Assessing measurement invariance in cross-national consumer research. *Journal of Consumer Research*, *25*(1), 78–90. https://doi.org/10.1086/209528

Steenkamp, J. B. E. M., & Baumgartner, H. (1998b). Assessing measurement invariance in cross-national consumer research. *Journal of Consumer Research*, *25*(1), 78–90. https://doi.org/10.1086/209528

Steinmetz, H. (2013). Analyzing observed composite differences across groups: Is partial measurement invariance enough? *Methodology*, *9*(1), 1–12. https://doi.org/10.1027/1614-2241/a000049

Tabachnick, B. G., & Fidell, L. S. (2019). *Using Multivariate Statistics Title: Using multivariate statistics*. Retrieved from https://lccn.loc.gov/2017040173

Talbot, J. F., & Kaplan, R. (1991). The benefits of nearby nature for elderly apartment residents. *International Journal of Aging and Human Development*, *33*(2), 119–130. https://doi.org/10.2190/XK9Q-3MDL-XYW9-9QL3

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Teck-Hong, T. (2012). Housing satisfaction in medium- and high-cost housing: The case of Greater Kuala Lumpur, Malaysia. *Habitat International*, *36*(1), 108–116. https://doi.org/10.1016/j.habitatint.2011.06.003

Tighe, R., Mueller, E., & Mueller, E. (2013). *The Affordable Housing Reader*. Routledge. https://doi.org/10.4324/9780203722671

Toor, S.-R., & Ogunlana, S. O. (2010). Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. *International Journal of Project Management*, *28*(3), 228–236. https://doi.org/10.1016/J.IJPROMAN.2009.05.005

Torbica, Ž. M., & Stroh, R. C. (2001). Customer Satisfaction in Home Building. *Journal of Construction Engineering and Management*, *127*(1), 82–86. https://doi.org/10.1061/(ASCE)0733-9364(2001)127:1(82)

Toth, T., & Sebestyen, Z. (2018). Project risk management process for professionals: A value-based approach. In *Global Business Expansion: Concepts, Methodologies, Tools, and Appl.* (pp. 725–747). IGI Global. https://doi.org/10.4018/978-1-5225-5481-3.ch033

Trafimow, D., & Myüz, H. A. (2019). The sampling precision of research in five major areas of psychology. *Behavior Research Methods*, *51*(5), 2039–2058. https://doi.org/10.3758/s13428-018-1173-x

U.S. Census Bureau. (2016). U.S. Census Bureau QuickFacts: UNITED STATES. Retrieved May 12, 2020, from https://www.census.gov/quickfacts/fact/table/US/HSG010218#HSG010218

Ulmer, J. M., Wolf, K. L., Backman, D. R., Tretheway, R. L., Blain, C. J., O'Neil-Dunne, J. P., & Frank, L. D. (2016). Multiple health benefits of urban tree canopy: The mounting evidence for a green prescription. *Health and Place*, *42*, 54–62. https://doi.org/10.1016/j.healthplace.2016.08.011

Uttley, J., Fotios, S., & Lovelace, R. (2020). Road lighting density and brightness linked with increased cycling rates after-dark. *PLoS ONE*, *15*(5), e0233105. https://doi.org/10.1371/journal.pone.0233105

Uyanık, G. K., & Güler, N. (2013). A Study on Multiple Linear Regression Analysis. *Procedia - Social and Behavioral Sciences*, *106*, 234–240. https://doi.org/10.1016/j.sbspro.2013.12.027

Van Dyck, D., Cardon, G., Deforche, B., & De Bourdeaudhuij, I. (2011). Do adults like living in high-walkable neighborhoods? Associations of walkability parameters with neighborhood satisfaction and possible mediators. *Health & Place*, *17*(4), 971–977. https://doi.org/10.1016/j.healthplace.2011.04.001

Vandenberg, R. J., & Lance, C. E. (2000). A Review and Synthesis of the Measurement Invariance Literature: Suggestions, Practices, and Recommendations for Organizational Research. *Organizational Research Methods*. SAGE Publications Inc.

https://doi.org/10.1177/109442810031002

Vemuri, A. W., Morgan Grove, J., Wilson, M. A., & Burch, W. R. (2011). A Tale of Two Scales: Evaluating the Relationship Among Life Satisfaction, Social Capital, Income, and the Natural Environment at Individual and Neighborhood Levels in Metropolitan Baltimore. *Environment and Behavior*, *43*(1), 3–25. https://doi.org/10.1177/0013916509338551

Verma, V. K. (1995). *The human aspects of project management*. Project Management Institute.

Wai, S. H., Yusof, A. M., & Ismail, S. (2012). Exploring Success Criteria from the Developers' Perspective in Malaysia. *International Journal of Engineering Business Management*, *4*, 33. https://doi.org/10.5772/51096

Wang, J., Wei, M., & Ruan, X. (2020). Characterization of the acceptable daylight quality in typical residential buildings in Hong Kong. *Building and Environment*, *182*, 107094. https://doi.org/10.1016/j.buildenv.2020.107094

Wangel, J., Wallhagen, M., Malmqvist, T., & Finnveden, G. (2016). Certification systems for sustainable neighbourhoods: What do they really certify? *Environmental Impact Assessment Review*, *56*, 200–213. https://doi.org/10.1016/j.eiar.2015.10.003

Wedding, G. C., & Crawford-Brown, D. (2007). Measuring site-level success in brownfield redevelopments: A focus on sustainability and green building. *Journal of Environmental Management*, *85*(2), 483–495. https://doi.org/10.1016/j.jenvman.2006.10.018

Weidemann, S., & Anderson, J. R. (1985). A Conceptual Framework for Residential Satisfaction. In *Home Environments* (pp. 153–182). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4899-2266-3_7

Williams Carlos Alberto Gomez Grajales Dason Kurkiewicz, M. N., & Alberto Gomez, C. (2013). Assumptions of Multiple Regression: Correcting Two Misconceptions. *Practical Assessment, Research, and Evaluation*, *18*, 11. https://doi.org/10.7275/55hn-wk47

Williams, P., Ashill, N. J., Naumann, E., & Jackson, E. (2015). Relationship quality and satisfaction: Customer-perceived success factors for on-time projects. *International Journal of Project Management*, *33*(8), 1836–1850. https://doi.org/10.1016/j.ijproman.2015.07.009

Wong, L. T., Mui, K. W., & Hui, P. S. (2008). A multivariate-logistic model for acceptance of indoor environmental quality (IEQ) in offices. *Building and Environment*, *43*(1), 1–6. https://doi.org/10.1016/j.buildenv.2007.01.001

Yang, Y. (2008). A tale of two cities: Physical form and neighborhood satisfaction in Metropolital Portland and Charlotte. *Journal of the American Planning Association*, *74*(3), 307–323. https://doi.org/10.1080/01944360802215546

Yang, Y., & Stockard, J. (2013). Do Smart-Growth Environments Benefit Single Mothers? Evidence from Thirty MSAs Using the American Housing Survey Data. *Journal of Planning Education and Research*, *33*(4), 411–426. https://doi.org/10.1177/0739456X13499935

Yoo, C., & Lee, S. (2015). Neighborhood Environment, Social Capital, and Social Sustainability of Community : Explanatory Study on Causal Relationships. *Journal of Korea Planners Association*, *50*(7), 5. https://doi.org/10.17208/jkpa.2015.11.50.7.5

Yoo, C., & Lee, S. (2016). Neighborhood built environments affecting social capital and social sustainability in Seoul, Korea. *Sustainability (Switzerland)*, *8*(12), 1–22. https://doi.org/10.3390/su8121346

Zeng, Y., Yang, C., Zhang, J., & Pu, W. (2007). Feasibility investigation of oily wastewater treatment by combination of zinc and PAM in coagulation/flocculation. *Journal of Hazardous Materials*, *147*(3), 991–996. https://doi.org/10.1016/j.jhazmat.2007.01.129

Zientek, L. R. (2008). Exploratory and Confirmatory Factor Analysis: Understanding Concepts and Applications. *Structural Equation Modeling: A Multidisciplinary Journal*, *15*(4), 729–734. https://doi.org/10.1080/10705510802339122