QATAR UNIVERSITY

COLLEGE OF ENGINEERING

INVESTIGATING SPATIAL QUALITY IN URBAN SETTINGS: THE ASSESSMENT OF WALKABILITY IN THE STREETS OF DOHA, QATAR

BY

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ABSTRACT

Walking is not the only most basic, but also the most prevalent form of transportation in cities. In the case of Doha, the capital city of Qatar, and the rapid development it is going through, urban planners are in need of an efficient user-friendly tool that would facilitate their objective in defining the quality of walkable areas and spaces. After investigating and reviewing several studies on the walkability issues, it was found that the majority of previous work in the field lack a comprehensive approach that combines qualitative and quantitative methods in measuring walkability. The purpose of this thesis is to investigate the factors that affect walkability in Doha and attempt to adopt and develop a Walkability Index Model (WIM) that will enable architects, urban planners and other decision makers to translate the perceptual qualities of streets, which are qualitative in nature, to a reliable quantitative value. To achieve this, the methodology of a previous study by Maryland Inventory of Urban Design Qualities (MIUDQ- 2006) was adopted. Based on the methodology adopted in this study and in order to gain the input required to develop the WIM, video footage of 30 streets across Doha were recorded and then rated by 10 professional experts in terms of walkability, and a set of selected urban design qualities. Physical features that proved to affect urban design qualities were counted offering a tangible input for the study. Finally several statistical computations were used to make sense of all the numbers proving that walkability is best perceived when all the selected

urban design qualities were addressed. Legibility proved to be the most influential urban design quality on walkability followed by Coherence, Linkage, Human Scale, Imageability, Complexity, Enclosure, Tidiness and Transparency.

The final product is an arithmetic equation that is integrated into a Microsoft Excel model to assess and compute the final score of walkability in the selected context.

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CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Research Significance

Walking is not the only most basic, but also the most prevalent form of transportation in cities. A walkable environment yields health benefits, creates social value and promotes vibrant streets & livable cities. Designers and urban planners today are charged with the task of creating more human-driven spaces that can ultimately improve the quality of public urban spaces and attract more people to interact with them. When it comes to outdoor experiences, no element is more important than streets. Streets are where daily interactions take place between humans and the built environment. Streets connect the entire built environment together to form the cities where we do almost all of our daily life activities. But what makes a street walkable? What makes a street more inviting than another? How can we measure the "walkability" of a street? Finally, how do streets contribute to the overall attractiveness of an urban space? This thesis aims to answer all those questions by focusing on the qualities that make some streets more walkable and inviting than others. The study introduces and adopted tool that will enable urban planners in Qatar to quantifiably measure how walkable a street is.

Over the last 60 years, a large number of studies have been conducted in order to understand the design of transportation space for vehicular modes. Pedestrian transportation, however, is a much more recent addition to urban planning studies, yet it is still addressed with less seriousness (Lo, 2009).

Several urban design studies have researched the correlation between the built environment and the quality of space in terms of walkability. However, today the measures used to describe the built environment have been mostly aggregate qualities related to neighborhood density, street connectivity, air pollution and distance to parks (Ewing, Reid; et al., 2006). Through reviewing different walkability indices and walkability assessment tools, it was deduced that perceptual design qualities of the physical environment affect the behavior of users within these spaces. Nevertheless, there were no reliable approaches to measure this effect.

This research study focuses on assessing the quality of walkable streets in the city of Doha by understanding the human perception of different urban qualities and related physical features. Through a series of standards and protocols, it will offer an effective Walkability Index Model (WIM) that can be used by urban designers, planners, architects, researchers and other decision makers to assess their design and create sustainable and active urban streets.

1.2 Contextual Implementation

Over the past few years Doha and other parts of Qatar have witnessed massive changes due a comprehensive development of the country's road network and infrastructure. What is often forgotten is how such changes affect the population, especially when people's needs are not taken into consideration. Nowadays, and because of high reliance on motor transport, less attention is given to the needs of pedestrians in urban environments. According to the American Association of State Highway and Transportation, "It is often very difficult to make adequate provisions for pedestrians. Yet provisions should be made, because pedestrians are the lifeblood of our urban areas, especially in the downtown and other retail areas" (AASHTO, 2011).

In order to make the adequate provisions mentioned above a reality, this dissertation aims to provide quantitative measures that truly reflect the perceptual and actual experiences of Doha's urban street pedestrians.

By reviewing several studies of walkability and understanding the perceptual qualities that measure a human's satisfaction in a certain walkable area, this study can help encourage more urban planning studies in this part of the world. This can be done by first understanding what people really appreciate about walkable streets and second by giving designers and non-designers a reliable tool to quantify it.

Through its current expansion of the built environment and infrastructure, Qatar has the opportunity to use this study to consider human preferences in developing welcoming and vibrant walkable streets, especially after quantitative measurement tools such as LEED and GSAS have become mandatory requirements for future projects.

The WIM tool can be used by governmental institutions such as the Ministry of Municipalities & Urban Planning, urban planners, designers, and even students as a reference and recommendation guide for improving existing walkable areas and creating new ones. In addition, the conclusions and findings of this study can be used as a reference for future researchers and professionals in the field to help them asses what matters most to pedestrians. Thus, WIM will provide insights and practical suggestions to professionals on how to develop and sustain not only streets in Doha but also the Gulf in general and minimizing the gap between qualitative and quantitative approaches. This can also help take GSAS into another level of assessment in terms of walkability, enabling it to quantify and grade the perceptual and intangible qualities.

1.3 Research Problem

The urgent need to adopt WIM as an assessment tool stems from several dire realities that have become a norm in Doha. The emphasis on developing roads to primarily serve motor vehicles instead of pedestrians resulted in a disjointed city where it is practically impossible to get from one point to another without relying on a vehicle. This problem is evident when a short stroll in any major urban street leaves the pedestrian with an unpleasant experience due to the lack of necessary pedestrian-friendly urban qualities such as pedestrian bridges, strategically placed landscapes and commercial strips.

The absence of a coherent master plan that merges all the previous and upcoming projects into one livable environment created deserted urban streets in Doha. Barricaded villas and gated projects (The Pearl, Katara, etc.) transformed the city's urban fabric into small isolated islands, creating urban voids useless to pedestrians.

Finally, the absence of an effective walkability assessment tool that is enforced by local legislation is another reason behind the current condition of urban streets in Doha when it comes to walkability. Despite the presence of a local initiative to establish sustainable built environments, GSAS ND aims to evaluate projects under construction rather than focusing on the city's connectivity as a whole.

1.4 Research Objectives and Questions

Despite all the urban studies that are taking place in Doha, there is no emphasis on walkable urban streets outside gated projects. This thesis is driven by the hypothesis that creating a walkable infrastructure can help weave Doha’s fabric together.

The main objective of this study is to develop WIM, a Walkability Index Model that can quantify the perceptual qualitative indicators of an urban street through measuring its physical attributes.

Research Questions:

- RQ1: What are the physical and perceptual features that affect human references/perceptions on urban streets?

- RQ2: How can the qualitative perceptual indicators be quantified in order to come up with a tool that can address the relationship between the physical and perceptual ones?

- RQ3: How can the results of the study aid in assessing upcoming and existing walkable urban streets?

1.5 Research Approach

The approach of this thesis is based on an existing method implemented in the streets of the United States by the University of Maryland, Maryland Inventory of Urban Design Qualities (MIUDQ). The same process will be adopted to develop a new tool to measure walkability of different urban streets in Doha. This study aims to measure the relation between the human perception of different urban qualities and the existing physical urban forms and will focus on defining operational terms and measuring protocols for a number of intangible perceptual design qualities, related to the built environments. Thus, the relations between the physical features of the space and the pedestrian will be understood and ready to be quantified through measuring the perception of related urban design qualities.

The thesis is based on a certain statistical model where correlations between physical features observed in video clips by the focus group, and the selected perceptual urban design qualities rated by the experts are achieved. Furthermore, other statistical analyses will be used to confirm the importance and relevancy of the selected perceptual design qualities to walkability behavior in Doha.

After that, subjectivity will be eliminated from the research data through a statistical model. The main research outcome will be a tool, the WIM "Walkability Index Model" that can be applied to a wider sample of people. Moreover, the model will be validated by an expert in statistics to ensure its reliability. Finally, a number of recommendations will be given to further develop this tool in the future. The approach adopted in this thesis is as follows and as shown in Figure 1:

1- Review urban design literature exploring existing qualitative and quantitative walkability measurement tools, models and indicators.

2- Focus on the need of a combined approach that addresses and quantifies the qualitative urban design qualities.

3- Adopt MIUDQ ‘s study process to the current context

   a. Study the urban design qualities addressed in MIUDQ‘s research
   b. Create a library of video clips of 30 random streets in Doha
   c. Select an expert panel
   d. Rate the selected urban design qualities in the captured clips by selected expert panel
   e. Quantify the physical features in the video clips by a selected focus group
   f. Statistically measure to what extent each urban design quality individually affect walkability
   g. Statistically measure the significance each physical feature has on each urban design quality
   h. Develop a walkability tool that reflects the real weighting of each of the urban design qualities and physical features

4- Design a Guidebook for WIM user’s manual

5- Provide recommendations for future enhancements of WIM

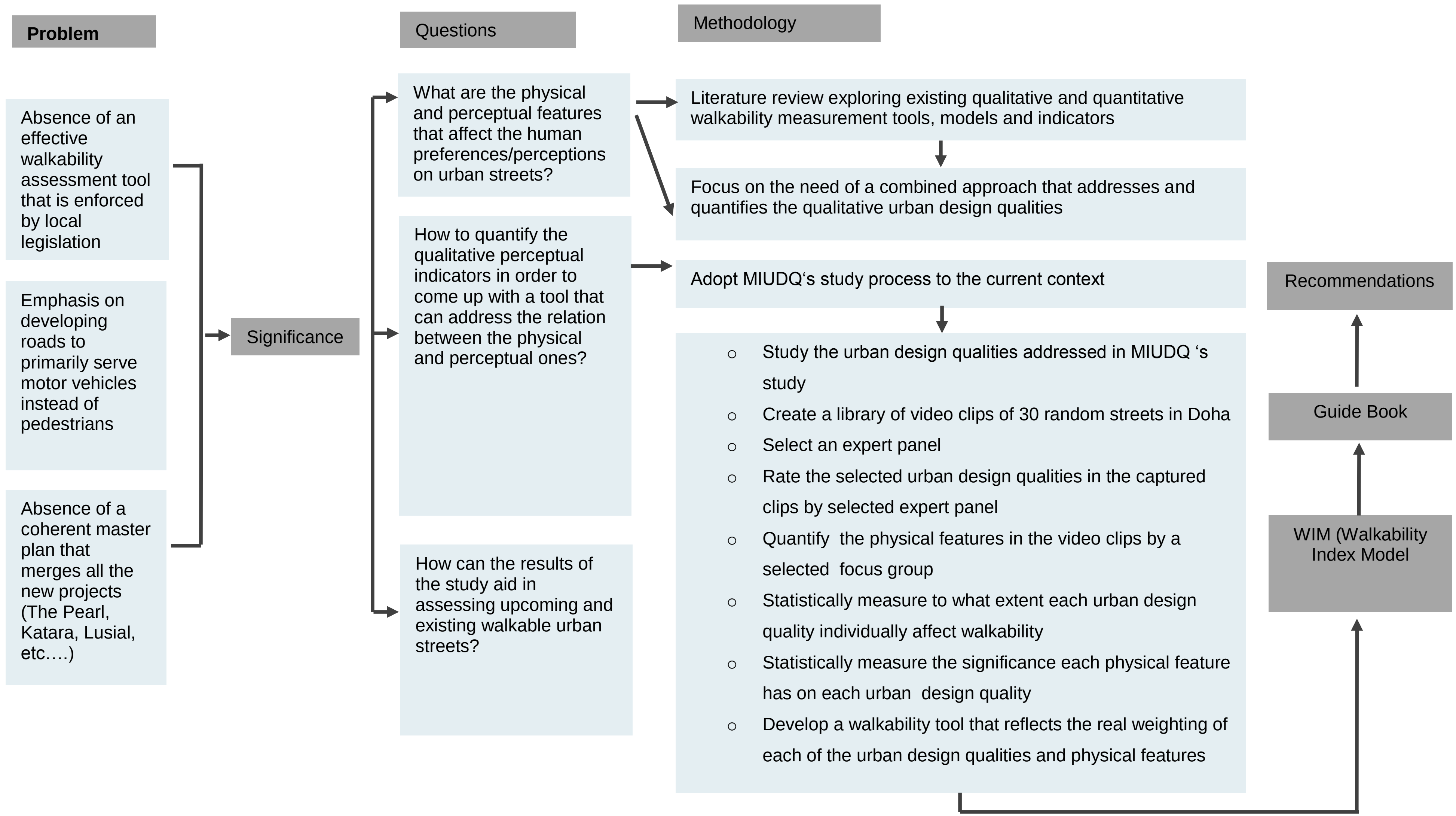


Figure 1: Thesis Framework Diagram

CHAPTER 2: LITERATURE REVIEW ON WALKABILITY ASSESSMENT TOOLS

2.1 Introduction: Overview of the Walkability Assessment Tools

Before investigating the indicators that enhance walkability it is important to understand what does this term really mean. How we define “walkability” has enormous effect on our understanding and design of walkable streets and, hence the basis of our definition is important. By going through literature from different disciplines that deal with pedestrian behavior and preferences, there appears to be different opinions and approaches to define walkability and to evaluate the quality of the pedestrian environment.

A number of approaches such as studies of transportation, public health, and visual aesthetics have been used to evaluate the walking behavior in urban spaces focusing on either quantitative or qualitative studies. Moreover, the audit instruments of the quantitative approach characterized the built environment with simple measures such as the number of travel lanes and presence of marked crosswalks ignoring the human experience of the place. On the other hand, classic qualitative studies have come up with non-metric codes based on descriptions that are unmeasurable by nature and unpopular with advocates of quantitative methods.

2.2 Quantitative Assessments Based Tools

2.2.1 Flow of Capacity: Highway Capacity Manual

In urban and transportation studies, the question of what is walkability is seldom addressed where "...pedestrian space is implicitly planned through efforts to achieve more dominant goals of facilitating vehicle flow, accommodating fire trucks, regulating land uses, or making money. These implicit influences may not appear to conflict with pedestrian planning since they do not even address the topic, yet they regularly dominate outcomes for the production of pedestrian space" (Lo, 2009).

Factors affecting the decision of using motorized or non-motorized transport are based primarily on two fundamental aspects of the way land is used which are proximity and connectivity. In general terms, proximity is related to the distance between trip origin and destination, while connectivity is how easy one can move in-between these two points. According to Brian E. et al, "Connectivity is high when streets are laid out in a grid pattern and there are few barriers to direct travel between origins and destinations" (Brian E., James F., & Lawrence D., 2003).

As per this study, Flow Capacity is considered to be the main walkability indicator in the United States, where the pedestrian space is best perceived when people can move freely within unrestricted environments.

The first editions of Highway Capacity Manual HCM, 1950 to 1985, stressed on the importance of flow capacity by defining traffic flow, speed, density and delay in terms of level of services. At that time, the aim was to assess road conditions to suit vehicles and motors more than focusing on pedestrian modes of transportation (Lo, 2009).

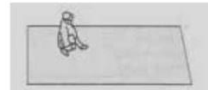
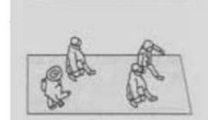
In response to criticisms to include the human experience into their manual, the (HCM) 2000 edition was developed to embrace non-motorized modes of transportation. As shown in Table 1, four quantitative variables with descriptions were suggested to rate pedestrian Level of Service within the built environment as follows:

1. The square-feet area each person has within the sidewalk.
2. The flow rate of pedestrians (in people per minute per foot of sidewalk width).
3. The speed of pedestrian flow (in feet per second).
4. The ratio of sidewalk volume to capacity.

Limiting the pedestrian comfort to the sidewalk capacity only without considering a wide range of other factors was a poor attempt to come up with measures of successful walkable areas. In his paper “Walkability: What is it?” Lo criticized this method as it “treats pedestrians as atomistic and antisocial entities” without considering the human factor (Lo, 2009).

Besides neglecting the contextual features of the built environment that add up to the walkable experience, the HCM manual contradicts the notions that make a street livable. Rating empty sidewalks with a higher value than busy sidewalks might indicate a superior level of privacy but not a successful walkable urban space.

Table 1: Pedestrian Walkways Level of Service Diagram from Highway Capacity Manual (Board, 2000)

LOS \ Parameter	Ped space (ft²/p) *(m²/p)*	Flow rate (p/min/ft) *(p/min/m)*	Speed (ft/s) *(m/s)*	Volume/ Capacity Ratio	Description	Illustration
A	>60 *>5.6*	≤5 *<16*	>4.25 *1.30*	≤0.21	Pedestrians move in desired paths without altering movements in response to other pedestrians. Walking speeds freely selected, & conflicts between pedestrians are unlikely.	
B	>40–60 *3.7–5.6*	>5–7 *16–23*	>4.17–4.25 *1.27–1.30*	>0.21–0.31	Sufficient area for pedestrians to select walking speeds freely, bypass other pedestrians, & avoid crossing conflicts. Pedestrians begin to be aware of other pedestrians & to respond to their presence when selecting a walking path.	
C	>24–40 *2.2–3.7*	>7–10 *23–33*	>4.00–4.17 *1.22–1.27*	>0.31–0.44	Space sufficient for normal walking speeds, & for bypassing other pedestrians in primarily unidirectional streams. Reverse-direction or crossing movements can cause minor conflicts, & speeds & flow rate are somewhat lower.	
D	>15–24 *1.4–2.2*	>10–15 *33–49*	>3.75–4.00 *1.14–1.22*	>0.44–0.65	Freedom to select individual walking speed & bypass other pedestrians is restricted. Crossing or reverse-flow movements face high probability of conflict, with frequent changes in speed & position. Reasonably fluid flow, but friction & interaction between pedestrians likely.	
E	>8–15 *0.7–1.4*	>15–23 *49–75*	>2.50–3.75 *0.76–1.14*	>0.65–1.00	Virtually all pedestrians restrict normal walking speed, frequently adjusting their gait. At the lower end, forward movement only possible by shuffling. Space is insufficient for passing slower pedestrians. Cross- or reverse-flow movements possible only with extreme difficulty. Design volumes approach walkway capacity, with stoppages & interruptions to flow.	
F	8 *0.7*	Varies	≤2.50 *0.76*	Variable	All walking speeds severely restricted & forward progress made only by shuffling. Frequent unavoidable contact with other pedestrians. Cross- & reverse-flow movements virtually impossible. Flow is sporadic & unstable. Space more like queued than moving pedestrian streams.	

As a trial to fill the gaps, New York City's Department of City Planning took the initiative to develop HCM pedestrian Level of Service Manual in 2006. By addressing the pedestrians' characteristics such as gender, age and size, it was hoped that this manual can be taken to another level. In studies that include human related activities, it is recommended to broaden the scope to include more qualitative factors that could reflect people needs and preferences.

2.2.2 Walkability in Neighborhood Sustainability Assessment Tools: LEED ND & GSAS District Assessment

In some countries around the world initiatives have been taken to pave the way for creating sustainable neighborhoods, where several tools have been developed to assess the sustainability performance of plans and their success in the way towards achieving better environments. However the question remains whether these sustainability assessments considered to be real indicators of what a livable street or neighborhood is. On one hand, “Assessment tools transfer data overload into information for better decisions” (Charlot, 2004). On the other hand, the results of a study done in Nagoya University revealed that “most of the NSA, Neighborhood Sustainability Assessment, tools are not doing well regarding the coverage of social, economic, and institutional aspects of sustainability; there are ambiguities and shortcomings in the weighting, scoring, and rating; in most cases, there is no mechanism for local adaptability and participation; and, only those tools which are embedded within the broader planning framework are doing well with regard to applicability” (Ayyoob & Murayama, 2013).

Nowadays, countries around the world are using these assessment strategies to develop their neighborhoods with walkability considered in the evaluation of sustainable neighborhoods. But perhaps a more perceptual qualitative tool can create livability. When it comes to considering how lively a street is, users have different opinions on what really makes a neighborhood or a street livable. Critically, these opinions are sometimes different from the considerations weighted on the prerequisites in these assessments. In light of these questions, this chapter reviews two important

Neighborhoods Sustainability assessment tools, LEED ND and GSAS District Assessment, specifically commenting on the effectiveness of their rating systems in terms of walkability and walkable Streets.

It is important to shed the light on the history of these two systems. Starting with LEED ND or Leadership in Energy and Environment Design for Neighborhood Development is a very well-known system for rating neighborhoods based on the sustainability of their designs and planning. It was an initiative to go beyond rating green buildings individually into integrating sustainable design at the level of the neighborhood as a whole. In 2007, in collaboration with the Congress for the New Urbanism (CNU) and the Natural Resources Defense Council (NRDC), the US Green Building Council (USGBC) introduced a new certification program called LEED for Neighborhood Development (LEED-ND), expanding certification beyond single buildings to include whole neighborhoods (Ayyoob & Murayama, 2013).

Separately, GSAS Districts 2013 is a new system initiated in Qatar aimed at evaluating the planning and design of urban development projects. Districts typically consist of various building typologies, and include several components such as infrastructure networks, transportation networks, and public or open spaces. GSAS Districts can be applied to any combination of buildings and any size of development (Fadli, Sobhey, Asadi, & Elserrag, 2014).

Similar to most NSA tools, these two systems are checklist based systems that rely on perquisites and credits with different weights. The higher the project accumulatively scores the more sustainable it is considered. For LEED-ND, to be considered for credits a built environment must meet three prerequisites: Walkable Streets requirements, Compact Development requirements, and Connected and Open Community requirements. After meeting these criteria, the development can then earn up to 44 points, distributed among 15 attributes such as proximity to schools, reduced parking footprint, access to recreational facilities, and tree lines and shaded streets. The maximum number of points available under each attribute varies. For example, a development can earn up to 12 points for meeting one attribute, but only 1 point for meeting another one (Clark, Aranoff, Lavine, & Suteethorn, 2013). This evaluation method does not reflect the relation and integration of the physical features along with the human perception of the space. As for GSAS, walkability is calculated based on the ratio of the walkable streets' length in comparison to the overall streets of the development and the provided shaded areas along the way, regardless of the attractiveness of the street or the experience it can provide as shown in Table 2 below (GORD, GSAS District Assessment V2.0, 2013).

Table 2: GSAS Walkability Indicators (GORD, GSAS V2.0 District Assessmennt , 2013)

Score	Ratio of Pedestrian Pathway Length to Vehicular Roadway Length (a)
-1	$a < 1.25$
0	$1.25 \leq a < 1.50$
1	$1.50 \leq a < 1.75$
2	$1.75 \leq a < 2.00$
3	$a \geq 2.00$
Score	**% of Pedestrian Pathways Shaded (b)**
-1	$b < 60\%$
0	$60\% \leq b < 70\%$
1	$70\% \leq b < 80\%$
2	$80\% \leq b < 90\%$
3	$b \geq 90\%$

Although these quantitative tools are important in transferring projects into data that can be assessed, it is essential that there exists a tool to emphasize the importance of each credit alone. In this tool, coefficients should be driven from their influence on the walkability experience of the user, not an accumulative score. Moreover, there is a need for a tool that assesses a separate weight for each factor with a minimum score that cannot be replaced. In current circumstances, this tool cannot be a reflection of what a walkable street is, as its sustainability score can be driven from other factors. Another reason is that this tool can be used only for new projects since, for example, it specifies the types of building material to be used – a criterion that is impossible to change once a building is completed or past a certain stage of development.

Quantitative tools like LEED and GSAS focus on the measurements of physical features of the built environment such as the building height, block length, and sidewalk width. In addition, they emphasize on criteria that don't support the human experience. As Mapes and Wolch state, these methods become more applicable for commercial business investments rather than long term sustainable image of the city (Mapes & Wolch, 2011).

2.3 Qualitative Assessment Based Tools

2.3.1 Global Walkability Index

As one of the major attempts to measure factors that affect walkable cities, the "Global Walkability Index" developed by H. Krambeck provides a new insight on how to conduct qualitative analysis of a walkable environments. It focuses on safety, convenience and the degree of policy support (Krambeck, 2006). From there, this method developed field walkability surveys that aimed to assess the various pedestrian infrastructures, reflect the human preferences, and analyze the governmental supported polices. Table 3 illustrates elements considered the most important indicators of walkability in Krambeck's assessment on a scale from 1 to 5 for each variable.

Table 3: Global Walkability Index Components & Variables (Krambeck, 2006)

Component	Variable	
Safety and Security	1	Proportion of road accidents that resulted in pedestrian fatalities (most recent year avail.)
	2	Walking path modal conflict
	3	Crossing safety
	4	Perception of security from crime
	5	Quality of motorist behavior
Convenience and Attractiveness	6	Maintenance and cleanliness of walking paths
	7	Existence and quality of facilities for blind and disabled persons
	8	Amenities (e.g., coverage, benches, public toilets)
	9	Permanent and temporary obstacles on walking paths
	10	Availability of crossings along major roads
Policy Support	11	Funding and resources devoted to pedestrian planning
	12	Presence of relevant urban design guidelines
	13	Existence and enforcement of relevant pedestrian safety laws and regulations
	14	Degree of public outreach for pedestrian and driving safety and etiquette

The Global Walkability Index (GWI) is comprised of two kinds of surveys; an agency survey, to be conducted with governmental entities, and a set of 10 public surveys to be collected along random streets within the selected area. Even though this method provides an easy direct tool to measure components that might affect walkability, the final calculated score of walkable space was not indicative for two main reasons. First, all the variables are weighted equally with no emphasis on one aspect over the other. Krambeck justified using this method to eliminate bias from certain population groups. For example, Krambeck argues that a female would consider safety and security as the most important factors affecting walkability. On the other hand, a handicapped person would consider infrastructure such as ramps, rails, and blind paths as most important.

Second, Krambeck chose perceptual qualities that by nature can only be rated based on subjective opinions and not constant measures. Thus, Krambeck's methodology is in fact subjective and not objective as he claims. Even with his trials to provide indicative visual guide that can describe how rating of each variable should be done, the numbers that reflect the final walkability measure are based on subjective judgments. This can be shown in "Figure 2: Maintenance & Paving Condition Variable in GWI", where the rating of this criterion is relevant to the person conducting the survey and not the general population.

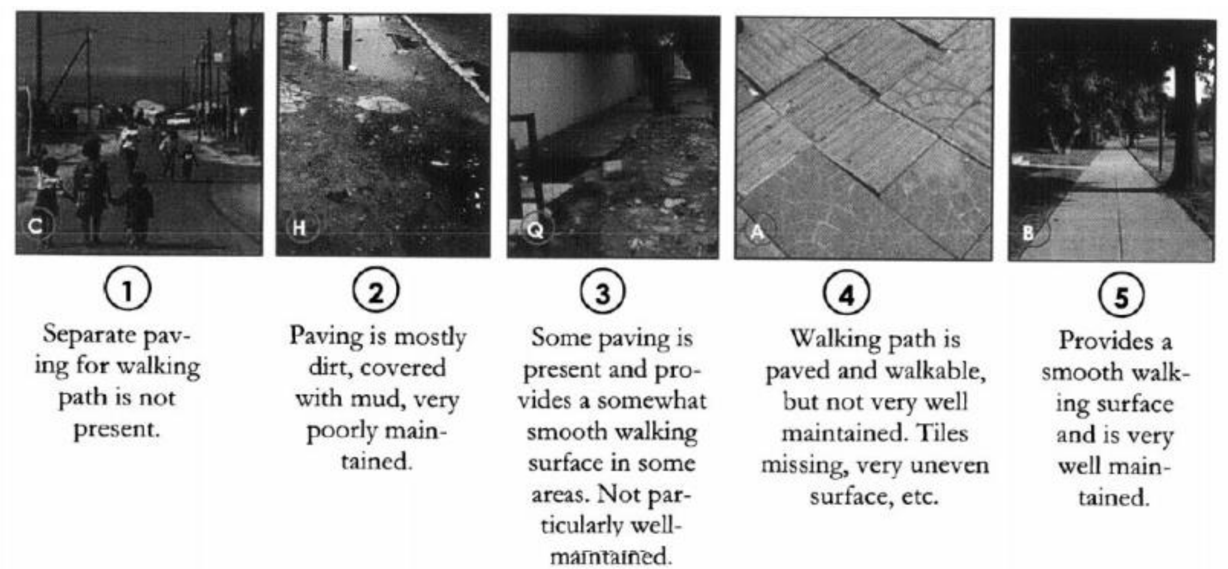


Figure 2: Maintenance & Paving Condition Variable in GWI Survey (Krambeck, 2006)

2.3.2 A Healthy City is an Active City: A Physical Activity Planning Guide

This guidebook was an initiative of the World Health Organization's- Europe Regional Office to create a healthy and vibrant city by enhancing physical activities in built environments (Edwards & D.Tsouros, 2008).

Strategies that were suggested tackled several disciplines including public health, social interaction and urban design. The urban design strategies can be summarized as follows:

- Reduce the phenomenon of urban sprawl and enhance walking and cycling by creating integrated neighborhoods with mixed use developments.
- Create interesting paths for people to walk and link the city to its natural views and resources.
- Develop the city run- down areas and replace it with urban green networks that can connect the city’s entities together.
- Maintain the condition of sidewalks to ensure that the city can be traversed by foot.
- Achieve the legible city by providing convenient signage system for its public spaces.

While all the pervious points are valid to create a walkable city, the focus of this study was to encourage physical activity more than reflecting the real factors that could encourage it. As such, it failed to reach a solid model that reflects what makes a city walkable.

CHAPTER 3: RESEARCH FRAMEWORK

3.1 Introduction

Walkability in itself is a vague term, thus its measurement is inherently susceptible to contention and debate. Despite all the proposed possibilities to define the individual physical features that comprise a successful walkable area, this thesis focuses on the cumulative effect of these components rather than its parts. This will be achieved by addressing urban design qualities. While physical features alone can't reflect the overall experience of the street environment, the conceptual model of this study addresses the role of perceptions as they can mediate between the physical features of the street and the walking behavior. Focusing on urban design qualities can set up the basis for an assessment tool that measures how people perceive the built environment around them. The relation between the physical features, perceptual qualities, and individual reactions can affect the individual's behavior towards the walkable environment as shown in Figure 3.

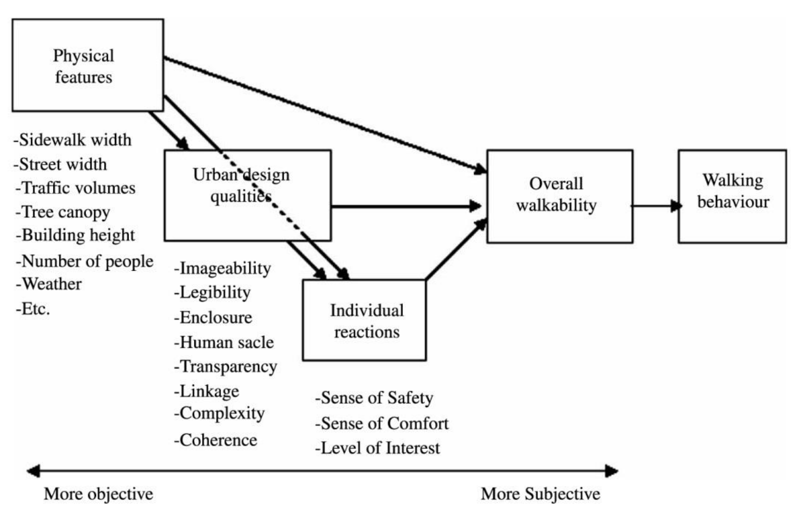


Figure 3: Conceptual Frame Work (Ewing, Reid; et al., 2009)

The aim of the conceptual framework model is to assess the physical features of the built environment that contribute to a pedestrian friendly environment and relate it to the urban design qualities that are associated with walking behavior. To achieve this, it was important to choose suitable urban design qualities that are relevant to walking behavior and its related physical features.

3.2 Methods and Frameworks for assessing Walkability

3.2.1 Adapted Conceptual Framework

Perception is the process of understanding sensory information sent by the environment around us. What we perceive as individuals is a result of the interaction between past experiences, culture, norms and the interpretation of the perceived. Based on this, it was not possible to take MIUDQ's last assessment as it is and apply it to Doha and assume the experts' opinions and reaction to be the same as a city in the USA. For the sake of weighting the real urban qualities that affect walkability behavior the most, the adopted methodology process was slightly modified to measure how people perceive the same perceptual qualities in this part of the world. The key perceptual qualities were quoted based on MIUDQ's definitions. In their research, the selected qualities were chosen based on a review of classic urban design literature, visual assessment literature, landscape architecture and environmental psychology in an attempt to measure how users perceive spaces around them and what values do they consider as important. Out of the fifty one reviewed qualities found in previous theories, eight were chosen based on their significance: imageability, human scale, transparency, enclosure, legibility, coherence, complexity and linkage. The definitions of these terms were standardized and given to the expert panel in order to help them in understanding the intended meanings prior to showcasing the videos to them.

Choosing the physical features that are related to each quality was done based on the physical elements that are stated and repeated in the literature review done by MIUDQ's group.

3.2.2 Urban Design Qualities

As mentioned earlier, walkability was determined by measuring the relation between existing physical features and human perception of different urban qualities. Based on the adopted study, it was found the selected nine urban design qualities are the perceptual qualities related to walkability. By Investigating urban design literature, these qualities where linked to a number of physical features.

Through this section, the urban design qualities were identified based on the MIUDQ's study and linked to group of physical features that can be quantified.

Imageability:

According to Ewing and Clemente in their study titled Measuring Urban Design: Metrics for Livable Places, imageability is "the quality of a place that makes it distinct, recognizable, and memorable. A place has high imageability when specific physical elements and their arrangement capture attention, evoke feelings, and create a lasting impression. It is probably not one element by itself that makes a street imageable but rather the combination of many" (Ewing & Clemente, 2013).

In his book The Image of the City, Kevin Lynch a well-known American Urban Planner, states that a highly imageable city is one that is instantly recognizable and memorable. Lynch argues that some of the most influential components of imageability are landmarks. It is important to note here that a landmark doesn't have to be a massive building or object, as Lynch puts it; it could be "a doorknob or a dome". However, what makes a landmark important is its location with respect to other components in the city and the visual reference point it creates to the city's inhabitants (Lynch, 1960). For example, the minaret belonging to the FANAR Qatar Cultural Islamic Center, located in Downtown Doha and shown Figure 4, serves as a very recognizable landmark that gives the area an identity. Reflecting this on Islamic architecture, the minaret used to serve as a symbolic landmark for the old city.

Figure 4: FANAR Islamic Center (Courtesy of the Author)

Furthermore, Gordon Cullen states in his book The Concise Townscape (1961) that a "sense of place" is another determinant factor that imprints the image of any city in the human mind. Cullen argues that a unique space will help create a feeling of connectivity with its goers, which will ultimately stimulate people to visit that place and spend more time in it (Cullen, 1961).

Finally on imageability, it is important to mention that in most cases imageability is positively correlated with the other urban design qualities. Places that rate high on the other urban design qualities are likely to rate high on imageability as well (Ewing & Clemente, 2013).

Thus, it was concluded that the following physical features were the most influential features that determine how high an urban space ranks on imageability.

Table 4: Physical Features related to Imageability

Imageability
1. Number of courtyards, plazas, and parks (both sides, within study area) (#)
2. Number of major landscape features (both sides, beyond study area) (#)
3. Proportion historic building frontage (both sides, within study area) (%)
4. Number of buildings with identifiers (both sides, within study area) (#)
5. Number of buildings with non-rectangular shapes (both sides, within study area) (#)
6. Presence of outdoor dining (your side, within study area) (y/n)
7. Number of people (your side, within study area) (#)
8. Noise level (both sides, within study area) (%)

A. Legibility:

“Legibility refers to the ease with which the spatial structure of a place can be understood and navigated as a whole. The legibility of a place is improved by a street or pedestrian network that provides travelers with a sense of orientation and relative location and by physical elements that serve as reference points” (Ewing & Clemente, 2013).

According to Kevin Lynch (1960), legibility is the clarity of the city scape. It is the ease by which it can be recognized and organized into a pattern. Legibility is to streets, courtyards, parks, and plazas what coherence is to buildings, street furniture and signage. In short, the difference between coherence and legibility is the scale of objects.

A highly legible city is one that allows newcomers to easily remember it through well-defined boundaries, landmarks, and distinct features. The whole idea of creating a legible space is to facilitate movement of pedestrians and to create a space which makes sense to the pedestrian and can be easily navigated through. This is best portrayed in a well-developed street network. Signage, “You Are Here maps, and distinct neighborhood features all positively contribute to legibility.

Thus, it was concluded that the following physical features were the most influential features that determine how high an urban space ranks on legibility.

Table 5: Physical Features related to Legibility

Legibility
1. Presence of Memorable Architecture (y/n)
2. Presence of Terminated Vista (y/n)
3. Number of buildings with identifiers
4. Presence of Common spacing and type (y/n)
5. Number of Public Art (#)
6. Number of Building /Business signs (#)
1. Presence of Memorable Architecture (y/n)

B. *Enclosure:*

“Enclosure refers to the degree to which streets and other public spaces are visually defined by buildings, walls, trees, and other vertical elements. Spaces where the height of vertical elements is proportionally related to the width of the space between them have a room-like quality” (Ewing & Clemente, 2013).

The significance of enclosure as an urban design quality lies in creating a sense of boundary for the pedestrian. Enclosure, also referred to as the outdoor room, is established when a pedestrians’ field of vision is limited by strategically placed objects to eliminate the feeling of empty space. In the urban setting, these objects are most commonly buildings. According to Ewing & Clemente, “the buildings become the walls of the outdoor room, the street and sidewalks become the floor, and if the buildings are roughly equal height, the sky projects as an invisible ceiling.”

The concept of enclosure reflects the true meaning of an old Islamic city, where the relationship between architectural typology and urban form was the result of cultural and climatic concerns. The compacted city fabric creates natural ventilation and shaded spaces that can be added to the enclosure importance.

However, this need not hold true in suburban environments or in spaces of low population density. In such areas the need for high rise buildings is lower than cities; hence a substitute to act as street walls is needed. In such environments, trees serve this purpose. Henry Arnold states that trees define spaces both vertically and horizontally. He also argues that in order to create a real sense of enclosure, trees have to be closely spaced (Arnold, 1993).

Limiting the pedestrians' field of vision from the sides is one thing, however the sense of enclosure in a well-designed street can be jeopardized if enclosure is not achieved in all directions, namely in the front. To achieve this, urban designers focus on the efficient use of termination points. Termination points intend to disrupt a pedestrian's line of sight. This becomes increasingly useful in rectilinear grid neighborhoods. According to Ewing & Clemente, "a rectilinear grid with continuous streets creates long sight lines that may undermine the sense of enclosure created by the buildings and trees that line the street. Irregular grids may create visual termination points that help to enclose a space." Furthermore, advertising boards, fountains and arches are some examples of objects that can be strategically placed in a space to effectively break a pedestrian's line of sight, thus creating a sense of enclosure from all sides.

Finally, a key element in creating a space with a high degree of enclosure is continuity. Ewing & Clemente argue that "enclosure is eroded by breaks in the continuity of the street wall, that is, breaks in the vertical elements, such as buildings or tree rows that line the street." Such breaks can be the result of empty land plots, recently demolished buildings, parking lots, and big road intersections.

Thus, it was concluded that the following physical features were the most influential features that determine how high an urban space ranks on enclosure.

Table 6: Physical Features related to Enclosure

Enclosure
1. Number of long sight lines (both sides, beyond study area) (#)
2a. Proportion street wall (your side, beyond study area) (%)
2b. Proportion street wall (opposite side, beyond study area) (%)

C. Human Scale:

“Human scale refers to a size, texture, and articulation of physical elements that match the size and proportions of humans and, equally important, correspond to the speed at which humans walk. Building details, pavement texture, street trees, and street furniture are all physical elements contributing to human scale” (Ewing & Clemente, 2013).

As individuals we experience the built environment in proportion to the scale of our own bodies. As such, successful spaces are the ones that meet and engage people in accordance with that scale. Interestingly, scale is not exclusively related to the size of things. For example, buildings can be subdivided (through step backs) to visually lighten the sense of mass and ultimately be more human friendly. Therefore, we can conclude that urban spaces with narrow streets, a number of parked cars, proportional sidewalks, medium sized buildings, and moderate sized street furniture will rank high in human scale.

As is the case with regards to enclosure, trees play a major role in determining the degree to which an urban space ranks high in human scale. According to Henry Arnold, trees play a positive role in enhancing the human scale of an environment. For example, a street lined with sky scrapers would seem hugely out of proportion to a pedestrian. However, if a line of trees was placed along the sidewalk parallel to the sky scrapers the huge difference in scale would be broken and the sense of intimacy would be greatly enhanced (Arnold, 1993).

Thus, it was concluded that the following physical features were the most influential features that determine how high an urban space ranks on human scale.

Table 7: Physical Features related to Human Scale

Human Scale
1. Number of long sight lines (both sides, beyond study area) (#)
2. Proportion windows at street level (your side, within study area) (%)
3. Consistent average building heights (your side, within study area) (%)
4. Number of small planters (your side, within study area) (#)
5. Number of pieces of street furniture and other street items (your side, within study area)

D. Transparency :

“Transparency refers to the degree to which people can see or perceive what lies beyond the edge of a street or other public space and, more specifically, the degree to which people can see or perceive human activity beyond the edge of a street or other public space” (Ewing & Clemente, 2013).

Transparency is highly affected by the total proportion of clear windows around the individual to the entire space. A commercial street with shops lining it on both sides usually ranks highly on transparency since shop owners are interested to show people what is inside in a bid to lure them in.

A common difficulty urban designers face when advocating for a highly transparent space is the negative effects this can have on enclosure. A very transparent environment can quickly turn to one without defined boundaries. However, urban designers have tools to avoid this, for example arches and see through fences are some urban objects that can positively impact transparency without having an adverse effect on enclosure.

However, transparent glass is not the only aspect that influences transparency. In fact, Jane Jacobs argues that one must not necessarily see what's happening around the corner, but a highly transparent street will let the individual imagine it. She goes on further by saying that streets with many entryways give the individual a feeling of human activity as opposed to a street with blank walls (Jacobs, 1961).

Thus, it was concluded that the following physical features were the most influential features that determine how high an urban space ranks on transparency.

Table 8: Physical Features related to Transparency

Transparency
1. Proportion windows at street level (your side, within study area) (%)
2. Proportion street wall (your side, beyond study area) (%)
3. Proportion active uses (your side, within study area) (%)

E. Complexity

"Complexity refers to the visual richness of a place. The complexity of a place depends on the variety of the physical environment, specifically, the numbers and kinds of buildings, architectural diversity and ornamentation, landscape elements, street furniture, signage, and human activity" (Ewing & Clemente, 2013).

In general, complexity can be synonymous with diversity. An urban space that rates highly in complexity is naturally a diverse place with many changing elements that keep the individual engaged. Naturally, human beings are attracted to complex environments because they provide a wide range of elements to look at and interact with thus eliminating boredom and monotony. A key indicator that an urban space ranks highly in complexity is when it successfully gives the pedestrian the psychological effect of making a walking journey shorter (Gehl, 1987).

Like in imageability and enclosure, trees play a major role in influencing complexity in an urban space. Henry Arnold states that one function of trees is to restore the rich textural detail missing from modern architecture. Furthermore, he argues that the ever changing combination of light filtered through moving leaves and branches and the alterations between sunlight and shadows gives the space life (Arnold, 1993).

Street furniture is possibly the most important object considered when measuring complexity. Variety and abundance of street furniture such as benches, fountains, shaded walkways, statues and monuments is important because these objects are those which humans interact with most.

With the evolvement of advertising strategies signage is becoming more and more important in determining the overall complexity of an urban space. According to Cullen, advertisement signs are “the most characteristic, and potentially, the most valuable contribution of the twentieth century to urban scenery”. However, excessive, unorganized, and poorly maintained signage can be detrimental to urban complexity (Cullen, 1961).

Last but not least is the effect human activity has on complexity. Human presence in a certain urban space creates life and interaction opportunities among individuals. Also, humans are in constant motion, a quality that helps paint a buzzing picture full of life.

Ultimately, no matter how complex and rich an urban space is, without a lively human population it will remain a silent gallery of concrete and glass.

Thus, it was concluded that the following physical features were the most influential features that determine how high an urban space ranks on complexity.

Table 9: Physical Features related to Complexity

Complexity
1. Number of buildings (both sides, beyond study area) (#)
2a. Number of basic building colors (both sides, beyond study area) (#)
2b. Number of accent colors (both sides, beyond study area) (#)
3. Presence of outdoor dining (your side, within study area) (y/n)
4. Number of pieces of public art (both side, within study area) (#)
5. Number of people (your side, within study area) (#)

F. Tidiness:

"Tidiness refers to the condition and cleanliness of a place. A place that is untidy has visible signs of decay and disorder; it is in obvious need of cleaning and repair. A place that is tidy is well maintained and shows little sign of wear and tear" (Ewing & Clemente, 2013).

Unlike other urban design qualities, this quality is a self-explanatory and maybe that was the main reason why very little urban literature tackles it. For a place to be tidy, it should be clean, visually organized and well maintained. In an urban environment the good pavement condition is assumed to reflect a high level of tidiness. This physical feature is not only aesthetical, it reflect how much the area is walkable.

Table 10: Physical Features related to Tidiness

Tidiness
1. Pavement condition (your side, within study area) (%)
2. Debris condition (your side, within study area) (%)
3. Overhead utilities (both sides, within study area) (y/n)
4. Landscape condition (your side, within study area) (%)

G. Linkage

"Linkage refers to physical and visual connections from building to street, building to building, space to space, or one side of the street to the other, which tend to unify disparate elements. Tree lines, building projections, and marked crossings all create linkage" (Ewing & Clemente, 2013).

Linkage is not to be confused with connectivity as both are well used urban planning terms. The later relates more to the connectivity of streets with each other on the city scale, however linkage is related to connections at the pedestrian perspective level.

Important elements of linkage are sidewalks. They provide a pedestrian with a safe walkway hence, having properly linked sidewalks across the entire neighborhood is essential for an urban plan to rate highly on linkage. Other important elements of linkage are once again trees. According to Arnold, continuous rows of trees can psychologically connect place at either end (Arnold, 1993).

Linkage can also be visual instead of physical. "Linkage can occur longitudinally along a street or laterally across a street" (Ewing & Clemente, 2013).

Thus, it was concluded that the following physical features were the most influential features that determine how high an urban space ranks on linkage.

Table 11: Physical Features related to Linkage

Linkage
1. Number of Street Connections to elsewhere (#)
2. Number of Visible Doors (#)
3. Proportion of recessed doors (%)
4.Presence of Common Building Heights (y/n)
5.Presence of Outdoor dining (y/n)

H. Coherence

"Coherence refers to a sense of visual order. The degree of coherence is influenced by consistency and complementarity in the scale, character, and arrangement of buildings, landscaping, street furniture, paving materials, and other physical elements" (Ewing & Clemente, 2013).

Coherence in urban spaces, in its simplest terms, means harmony between the various urban space elements. In other words, a coherent urban space is an organized complex space since coherence, without a certain degree of complexity, would be a boring space. A coherent environment does not have to be a boring one. On the contrary, a complex environment that ranks high on coherence is considered "rich and organized" (Kaplan & Kaplan, 1989).

Jacobs describes coherence as buildings that get along together. She goes further to explain that this does not mean that they should be the same but that they respect one another (Jacobs, 1961).

Thus, it was concluded that the following physical features were the most influential features that determine how high an urban space ranks on coherence.

Table 12: Physical Features related to Coherence

Coherence
1. Number of Pedestrians (#)
2. Presence of Number of Pedestrian-scale streetlights (#)
3. Presence of Common Window Proportions (y/n)
4.Presence of Common spacing and type (y/n)

3.3 Summary

As stated earlier, this study assumes that the overall walkability is affected by certain urban design qualities. Through reviewing the classical urban design literature and reflecting on the old Islamic city, number of physical features were linked to nice urban design qualities in theory.

The physical features were assigned and listed as numbers (1, 2, 3, etc...), proportions (%) and presence (y/n). The idea was to link the urban design qualities which are qualitative in nature to constant physical features. In the coming chapters, the effect of each physical feature will be measured in coefficients, reflecting the significance of this feature in relation to each urban design quality.

CHAPTER 4: DATA DERIVATION AND SYNTHESIS

4.1 Introduction

Choosing the accurate data collection methodology and planning for it was very essential to reach the intended goal of this thesis. Although the outline of this process was derived from MIUDQ's team, it was developed to suit the time and resources of my study. Through this chapter the methodology of data derivation and synthesis will be explained and justified including selected sample and used instruments.

4.2 Selected Streets

4.2.1 Random Sample of Streets

In statistical studies, it is typically preferable to use random samples to avoid bias. While the outlined methods of selection have their own qualities and standards, random components lend credibility to the statistical model's final results. In order to achieve this, a random spatial survey area was employed where list of all the streets was obtained through Google Maps, reflecting different areas and typologies. Thirty random streets across Doha were chosen to reflect different typologies of uses, classes and activeness.

4.2.2 Time of the Day

In addition to location considerations, it was important to think of the time of day factor. For instance, a commercial street might be very active during the day on a weekday compared to weekends or during the night. Under ideal conditions, the selected streets would be visited at least twice, during the peak and non-peak hours. However, as peak times might vary from street to street, and due to the limited time given to this study multiple visits were found to not be time and cost effective. Thus, this study was limited to one visit for each street and was conducted during day time on weekdays. Furthermore, visiting the same street at different times of day would have increased the variables and complicated the calculations. Moreover, the rate of activity of the streets was a small part of the equation since this study focused on relating constant physical features into certain urban design qualities rather than sense of safety for example.

4.3 Video Clip Recording

4.3.1 Justification of Instrument Tool & Equipment

In order to capture the true picture of urban design qualities in and to give a fourth dimension to the viewer, this study used short video clips in a visual assessment survey instead of still photographs.

The video clips were 30 seconds long and were recorded at 30 random streets in Doha, reflecting several streets. The scenes focused on the overall urban street settings, sidewalks, landscapes, pedestrian lighting, street furniture and building context within view.

The duration of each video clip was an important factor to consider in order to fully take advantage of the viewers' attention span which is the amount of time a person can remain concentrated on something without becoming distracted. For example, asking the viewers to watch and rate long video clips spanning for multiple minutes was not an option since they would be distracted from video clip details which would jeopardize the study of the outcomes.

Ranging from seconds to minutes, the question was: “What is the best duration for an online assessment video to be before people lose attention?” As per Wistia, a video hosting company, “the completion rate for 30 second video is close to 90 percent, but it drops to barely more than 50 percent if the video is 2 minutes” (Johnson, 2011). Therefore, and in order to achieve the highest completion rates among the viewers, the 30 seconds duration was selected.

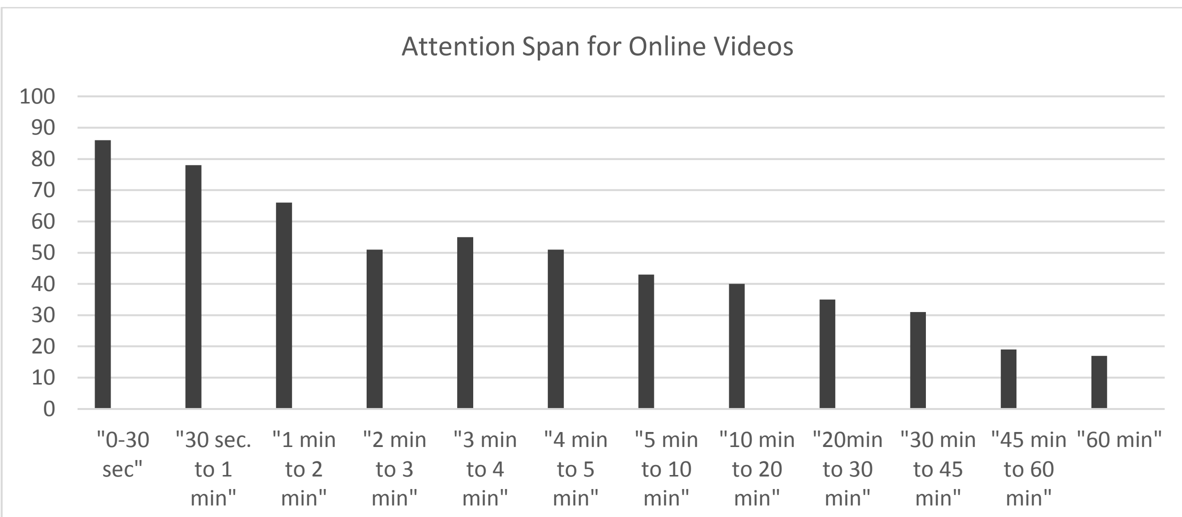


Figure 5: Attention Span for Online Videos (Johnson, 2011)

In order to show more details of the streetscape, the first couple of videos were recorded for duration of 2 to 3 minutes and speeded up to 30 seconds. Presenting the speeded up clips to number of people proved that this method of demonstration ruined the viewer’s experience of the street and gave the wrong indications about the overall context.

Based on that, the street life of 30 random streets in Doha was recorded in a series of 30 second clips that were proven to sustain the focus of the viewer and reflect the experience of the different streets.

4.3.2 Recording Protocol

To ensure that the experts' rating is not a reaction to the used filming techniques, one consistent filming protocol was used to record the 30 videos. In order to imitate the pedestrian experience and capturing the finest details of the street, a head mounted GoPro Hero 3+ camera was used as per the following protocol:

- The camera was set on wide angle view on 720p high resolution.
- First scene started 2 meters away from the selected street.
- A slow 45 degree right pan from straight head and back to straight head to show context.
- A slow 45 degree left pan from straight head and back to straight head to show context.
- A slow pan to the top of adjacent buildings and trees.
- Moderate speed steps towards/in the intended street.

4.3.3 Recording Extra Video

Eliminating the experts' subjectivity throughout the assessment was an important issue to be considered. Therefore, one of the sample streets was selected and recorded from a different angle, taking care to show the same physical features. Controlling the variables by fixing the physical features in two different videos will show how much an expert can change his/her mind based on subjective impressions rather than real judgment on captured fixed physical features.

Striking difference in rating between the two videos by the same expert for the same urban design quality was the indicator to eliminate the expert's score from the formula for this specific quality. Percentage errors ranging from 0% to 20%, i.e. 1 point score difference, were reasonably acceptable for this method, while errors exceeding 20%, i.e. more than 1 score point difference, were considered unreliable opinions. For example, Table 13 shows the scores given for the matching videos by the different experts for one urban design quality which is Imageability. The score experts E2 & E11 gave for the two videos show contradictive judgments with 40% percentage errors on the same physical features, thus their scores were removed from the assessment for this specific quality.

Table 13: Expert Panel Scores for UDQ1 & Percentage Error

UDQ 1: Imageability				
Video 29	**Video 31**	**Expert Name**	**Expert Title**	**Percentage Error**
3	3	E1	T1	0%
2	4	E2	T2	40%
4	3	E3	T3	20%
2	2	E4	T4	0%
3	3	E5	T5	0%
3	3	E6	T6	0%
2	3	E7	T7	20%
3	3	E8	T8	0%
2	2	E9	T9	0%
2	2	E10	T10	0%
2	4	E11	T11	40%
1	1	E12	T12	0%

4.3.4 Limitations

Like any other study, this one suffered from a few limitations. First, unstable weather patterns such as dust storms prohibited the recording of all videos on the same day of different weeks. However, I ensured that the videos were recorded on other weekdays and not weekends. Therefore, I don't believe this limitation impacted the results of the study severely since daily life in Doha during weekdays is very similar.

The other limitation was finding willing experts to spend time assessing the video clips. Although there are only 30 videos running for 30 seconds each, analyzing the environment and then rating the various urban design qualities is a time consuming exercise. I found difficulty finding experts willing to spend the time and effort to do the exercise since most of them are full time employees with very tight schedules. That being said, through extensive networking and personal connections, I managed to compile list of 10 high value experts that managed to get the job done perfectly.

Finally, and most importantly, was the difficulty of finding statistical experts with the knowledge of developing customized research statistical models. Therefore, Dr. Karim Abdel Warith, the statistical expert that assisted me with this study suggested a simpler model than the one employed by MIUDQ's team. Ultimately, and after extensive testing of the model, it was confirmed that the statistical model used in this thesis is a reliable one and serves the intended purpose.

4.4 Expert Panel

4.4.1 Expert Panel Criteria

Choosing an expert panel to judge and rate the previously mentioned video clips with respect to the selected urban design qualities was the second phase. As the experts' point of view and ratings will carry the weight of this study and create its solid base, it was important to choose them carefully to suit the purpose. The selection criteria of the panel members were based on their knowledge in urban design concepts and terminologies related to the filed which would support their subjective judgment.

The selected panel members had to represent a variety of different perspectives. Therefore, and in order to stay in line with the adopted study, there was a focus on achieving balance between urban designers and architects working in the field and urban design academics. Different age groups, genders, and familiarity with Arab culture were the other dimensions were added to the criteria of selection. Through networking process and nominations, the 12 selected expert panel members

4.5 Visual Assessment Survey

After the video clips were recorded and the experts' list was ready, the question of how to conduct a useful assessment was raised. Directing face to face meeting with all the experts at once was the ideal case where all the doubts can be clarified. But due to the time and logistical limitations, it was hard to set schedules for all the 12 expert members. Instead, a visual assessment survey was conducted electronically using Google Forms (refer to Appendix A). The survey was divided into two main parts. The first part consisted of an introduction where all the 9 urban design qualities were defined as per MUIDQ's definitions. Second, the videos section where each clip was displayed and under it a list of the 9 urban design qualities waiting to be rated on a scale from 1 (very poor) to 5 (very good) in a Radio Button format.

The video samples were displayed in random order with no tags. Even though the experts who are living in Doha would recognize some of the places depicted in the videos, the streets were not identified in the online assessment survey in order not to promote biased ratings associated with positive or negative experiences felt by members of the expert panel during previous visits to the place.

Before sending the survey link, the experts were contacted and asked for their help in watching the videos and rating the defined perceptual qualities. A brief idea about the project and the role expected from them was explained.

4.6 Physical Features Quantification

4.6.1 Development of Focus Group

To ensure the actual number of physical qualities and minimize human error, a small focus group of 5 university students was selected to quantify the number of these physical qualities from the recorded video clips. No subjectivity or opinions were addressed through this stage and any inaccuracy was accounted to human error only. One meeting was arranged with all the students together where the video clips were presented to them one by one to count the number physical features accompanied with each street. To eliminate any confusion, students were asked to watch the videos individually for the first time and give their own count and compare it among the group.

The videos were played for a second time to achieve a final count of the physical features. This stage was so important for the development of the statistical model since the number of the physical features were considered to be the constant values of the model.

CHAPTER 5: DATA ANALYSIS AND RESEARCH FINDINGS

5.1 Introduction:

The purpose of this thesis is to develop an assessment tool that will enable urban planners to reliably measure the effect of urban design qualities on walkability. To do this, I first had to study the extent to which urban design qualities affect walkability and how certain physical features can contribute to these qualities.

Figure 6: Factors Affecting Overall Walkability

In this chapter, I used statistical regression analyses to quantify the correlation between the relationships mentioned above. To achieve this, the following process was followed:

1. Collect the raw data to be used in the statistical model which are:
    a. The expert panel's walkability score for each video
    b. The expert panel's score for each urban design quality score for each video
    c. The focus group's input on the number of each physical feature related to each urban design quality

2. Prepare and refine the raw data into meaningful and unbiased input to be used in the regression models.
3. Run the following regression models:
    a. The first regression model reflects the extent to which each urban design quality has on the overall perceived walkability. This is determined by the highest R-Squared output.
    b. The second phase of regression models reflect the significance each physical feature has on each urban design quality. We ran the regression 9 times, once for each urban design quality. The significant physical features were considered those that returned a t-statistic value higher than 0.80 (80%) for the highest Adjusted R output.
4. Use the coefficients generated through the regression models to assign appropriate weights to each urban design quality and physical features. It is important to note that the coefficients selected for the physical features were those corresponding to their respective t-statistic value.
5. Develop the final equation in the following form:

$$W = C_1\left[\left(a_{f1(c1)} \times f_{1(C1)}\right) + \left(a_{f2(C1)} \times f_{2(C1)}\right) + \cdots + \left(a_{fn(C1)} \times f_{n(C1)}\right)\right] + \cdots$$
$$+ C_9\left[\left(a_{f1(C9)} \times f_{1(C9)}\right) + \left(a_{f2(C9)} \times f_{2(C9)}\right) + \cdots$$
$$+ \left(a_{fn(C9)} \times f_{n(C9)}\right)\right]$$

Where:

Function	Description
W	Walkability Score
C_n	Coefficient of each urban design quality
a	Coefficient of the physical feature
f	Quantity of physical feature determined by

5.2 Data Analysis

5.2.1 Survey Testing & Enhancement

Although it was agreed with the 12 experts that the visual assessment survey will be sent to them, it was important for me to do number of test surveys to see the experts' reaction and determine if any extra data is required. To do so, the test surveys were sent to 5 experts only.

By the time the 5 surveys were completed and returned, it was noted that different videos reflect different scores among the 5 experts. Although most of the received data showed steady scores and opinions in relation to the same video or the same expert, some alerted that some experts were inconsistent in their assessment.

Therefore, it was very important to find a way to eliminate irrational subjectivity related to the experts themselves and come up with reliable input that can be used for the statistical model.

After consulting the statistical expert, Dr. Abdel Warith, it was agreed to record one extra video for one of the previously selected streets, but this time from another angle of the street. The aim was to measure how one individual expert can contradict his/her own judgment on the same presented physical features if they did not know that two videos were recorded from the same street. This video was added to the list to have a total of 31 untagged videos that were ready to be sent to the 12 experts again including the already contacted experts.

5.2.2 Analysis of the Expert Panel's Scores

5.2.2.1 Preparing the Raw Data

Before going through the analysis process, the first step was to collect and organize the data received by the experts. For this matter, I will be using "Video 01" as an example to reflect the type collected data as shown in Table 14. Similar tables were prepared for the other 30 videos reflecting the 12 experts' scores on each one of the selected urban design quality, defined earlier in Chapter 3, and the overall walkability score for that individual video. (Refer to Appendix C)

While the experts were asked to rate the urban design qualities on a scale 1 to 5 (Very Poor to Very Good), they had the option to use decimals to rate the overall walkability with a highest score of 5.

Table 14: Experts Judgments on UDQs and Overall Walkability Score for “Video 01”

Video 01										
Expert	Imageability	Legibility	Enclosure	Human Scale	Transparency	Linkage	Complexity	Coherence	Tidiness	Walkability
E1	5	4	4	3	5	3	3	4	3	4
E2	2	2	2	4	3	2	2	2	2	2.5
E3	2	4	3	2	3	2	1	2	3	3.5
E4	3	2	3	2	3	3	3	2	3	3
E 5	1	2	2	2	3	2	2	2	3	2.5
E6	1	3	1	1	1	2	1	1	1	2
E7	2	2	2	3	3	3	2	2	2	3
E8	2	2	2	3	2	2	2	2	3	2.5
E9	1	3	3	3	3	2	2	2	1	3
E10	3	2	2	4	4	3	2	3	4	3.5
E11	3	3	2	3	3	2	2	2	3	3
E12	4	4	3	5	4	4	3	4	3	4

In addition to the urban design qualities rating, the experts were asked to give an overall walkability score for each street. The main reason was to confirm whether or not an individual urban design quality influences the overall walkability ratings. By comparing the independent score of overall walkability given by the experts and the mean value for the 9 urban design qualities for each video, it was noted that most of the scores are close to each other. This reflected how the overall walkability is directly related to the proposed urban design qualities. However, there were some outliers that were not in line with the above assumption.

5.2.2.2 Eliminating Unreliable Scores

Part of preparing the data was eliminating the biased judgments to get reliable input ready for regression. To do this, data pertaining to the two similar videos were compared. As expected, the experts showed inconsistency in scoring these two videos. The determent factor was the error percentage between the two scores given by the same expert for the same urban design quality. Experts that showed high discrepancy in scores with more than 20% percentage error, i.e. more than 1 point score difference, was removed from the sample only for the studied urban design quality. This step was done 9 times for the 9 urban design qualities as shown in Table 15. As an example, expert (E2) might be unreliable in “UDQ 1: Imageability” but he showed consistent scoring in other qualities, thus his/her judgment where influential in 8 out of the 9 urban design qualities.

Table 15: Percentage Error for two UDQs (Imageability & Human Scale)

UDQ 1: Imageability					UDQ 4: Human Scale				
Video 29	**Video 31**	**Expert Name**	**Expert Title**	**Percentage Error**	**Video 29**	**Video 31**	**Expert Name**	**Expert Title**	**Percentage Error**
3	3	E1	T1	0%	4	4	E1	T1	0%
2	4	E2	T2	40%	2	3	E2	T2	20%
4	3	E3	T3	20%	4	3	E3	T3	20%
2	2	E4	T4	0%	3	3	E4	T4	0%
3	3	E5	T5	0%	4	4	E5	T5	0%
3	3	E6	T6	0%	4	4	E6	T6	0%
2	3	E7	T7	20%	1	3	E7	T7	40%
3	3	E8	T8	0%	3	3	E8	T8	0%
2	2	E9	T9	0%	3	3	E9	T9	0%
2	2	E10	T10	0%	2	2	E10	T10	0%
2	4	E11	T11	40%	4	4	E11	T11	0%
1	1	E12	T12	0%	2	2	E12	T12	0%

5.2.3 Running the Regression Model

Since most of the experts overall walkability scores confirmed that urban design qualities affect the overall walkability, it was important to measure to what extent each urban design quality individually affects walkability. Thus, the aim of the regression model was to search through all possible combinations of different urban design qualities to obtain the best set of matches. For this purpose, running a simple excel regression model was not an option since it wouldn't compare all the possible probabilities. Instead, the "Optimized Regression Code" designed by Dr. Karim Abdel Warith was used to go through all the possible scenarios.

The model was run for the first time depending on the mean-value of the experts' walkability scores and the mean-value of each urban design quality. From the output, we will look for the highest R-Square since this value represents the goodness of fit. In other words, it shows how good the generated equation is in predicting the score of Walkability.

Table 16 is sample of the regression output showing the highest R-Square values (Rsq) were obtained when all 9 urban design qualities (Z) were considered. This further confirms that walkability is most reliably tested when all 9 urban design qualities are factored in.

Table 16: Sample of Data Derived from the First Regression Model

Z	C	C1	C2	C3	C4	C5	C6	C7	C8	C9	Rsq	AdjR
8	-2.022	0.347	0	-0.110	0.981	1.153	-0.640	-0.103	-0.181	0.258	0.544	0.378
9	-2.010	0.3525	-0.027	-0.103	0.982	1.155	-0.642	-0.099	-0.181	0.2652	0.5443	0.3491
8	-1.980	0.357	-0.066	-0.045	0.992	1.131	-0.626	0	-0.267	0.2113	0.5438	0.378
8	-2.002	0.367	-0.091	0	0.946	1.168	-0.645	-0.042	-0.239	0.2348	0.5438	0.3779
7	-2.007	0.344	0	-0.0575	0.992	1.13	-0.618	0	-0.28	0.188	0.544	0.405
7	-1.986	0.364	-0.0927	0	0.965	1.15	-0.6339	0	-0.27	0.212	0.544	0.405
7	-2.046	0.348	0	0	0.934	1.16	-0.6372	-0.04	-0.25	0.200	0.544	0.405
6	-2.0306	0.346	0	0	0.953	1.144	-0.625	0	-0.29	0.176	0.543	0.429
7	-2.011	0.332	0	-0.184	0.949	1.17	-0.661	-0.21	0	0.305	0.543	0.404
8	-2.000	0.337	-0.025	-0.178	0.949	1.17	-0.662	-0.21	0	0.310	0.543	0.377
7	-2.035	0.392	0.046	-0.046	0.979	1.15	-0.569	0	-0.25	0	0.542	0.403
8	-2.044	0.392	0.0592	-0.058	0.977	1.15	-0.570	-0.02	-0.24	0	0.542	0.376
6	-2.018	0.406	0	-0.036	0.979	1.15	-0.57	0	-0.24	0	0.542	0.428

That being said, the highest R-Squared value obtain was still relatively low. The justification for these low values was the result of the previously mention outlier scores by some of the experts. For that reason, it was essential to omit the three outlier videos and use a polynomial equation to generate refined overall walkability scores that would compensate for the omitted videos. The following equation was generated through an Excel Polynomial Regression derived from the original walkability scores and the summation of the mean-value of all the urban design qualities.

$$y = -0.3956x^2 + 3.5505x - 3.3812$$

Where:

y	The refined Walkability Score
x	The original overall Walkability score given by the experts

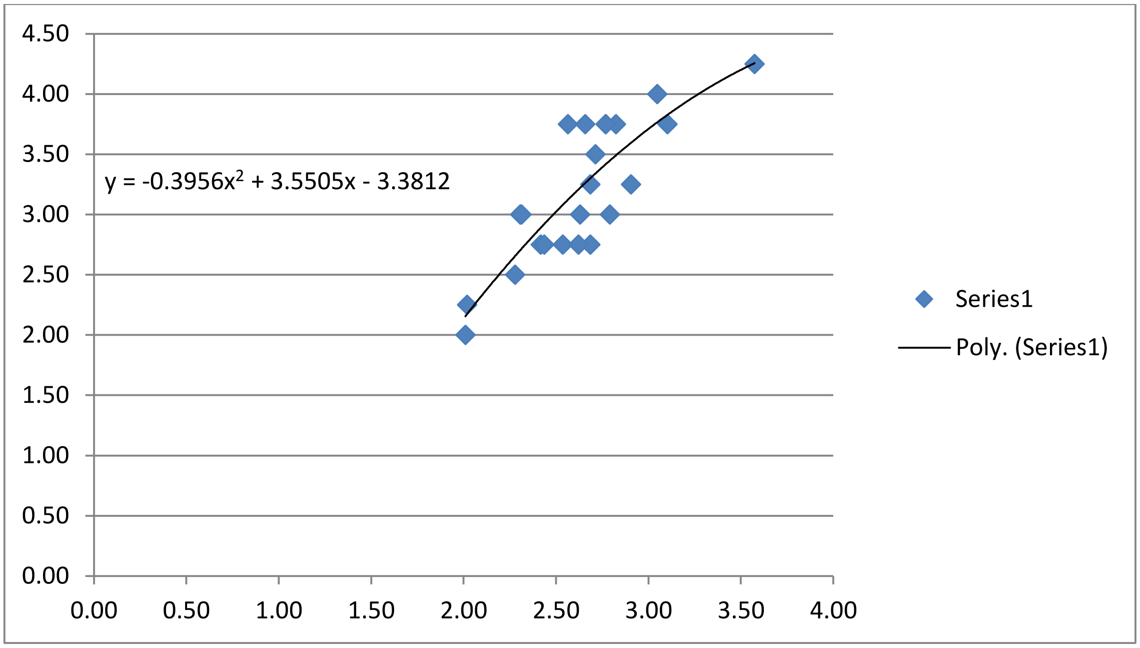


Figure 7: Polynomial Equation Regression Line

Using the refined overall walkability scores, the model was run again to get more reliable output with a better value for R-Squared.

The entire exercise to refine and reach a reliable and logical R-Squared value was to enable us to derive coefficients for each urban design quality. These coefficients will act as the weights/multipliers that reflect how walkability is affected by each urban design quality.

Table 17: Final Data - Refined Regression Model

Z	C1	C2	C3	C4	C5	C6	C7	C8	C9	Rsq
9	0.1345	0.3336	0.0446	0.1875	-0.0367	0.0718	0.0438	0.2861	0.31	0.6791

Also in the refined regression model the best R-Squared value was obtained using a combination of all 9 urban design qualities (Z). Legibility (C2) proved to be the most influential urban design quality on walkability with a coefficient of 0.3336. Followed by

Coherence (C9, 0.31), Linkage (C8, 0.2861), Human Scale (C4, 0.1875), Imageability (C1, 0.1345). After that, the coefficient multiplier drops significantly for urban design qualities Complexity (C6), Enclosure (C3), Tidiness (C7) recording values of 0.0718, 0.0446, and 0.0438 respectively.

We faced a single negative coefficient, (C5, -0.0367) which corresponds to Transparency. We did not remove this urban design quality from our calculations because we considered it to be an indicator that transparency is inversely proportional to the overall perceived walkability based on the expert panel's scoring.

5.2.4 Analysis of the Physical Features' Regression Output

After analyzing the expert panel's scores and deriving coefficients for each urban design quality using sophisticated statistical calculations, the next step was to analyze the work done by the focus group assigned to count the physical features related to each urban design quality.

The ultimate objective of this step was to quantify the urban design qualities discussed throughout this thesis. However, to reach that goal many smaller objectives had to be met. First, I had to assign quantifiable physical features for each urban design quality that were considered relevant and important according to the classic literature review discussed in Chapter 3. The importance of quantifiable physical features and not qualitative ones lies in eliminating subjectivity. For example, if an urban designer is trying to quantify the Imageability of an urban scene, one prominent and quantifiable physical feature would be the number of trees. In this case the number of trees would be the same regardless of the background, culture, or preference of the assessor, thus eliminating any subjectivity and returning constant results however much tested. After that, I had to test if the selected physical features really had an effect on the urban design qualities, and if so, to what degree. Although the experts were not asked to quantify physical features in the video clips, it was assumed that the score they gave for each urban design quality was based on the existence or lack thereof of physical features. Continuing in the quest to test the effectiveness of physical features on the various urban design qualities, the focus group was given a list of the physical features per urban design quality and asked to quantify them in each of the 30 videos. Table 18 below shows a sample of the counted physical features list that was given to the focus group for Video 01.

Table 18: Physical Features Count Sheet - Video 01

Physical Features Count Sheet (Video 01)	
UDQ 1: Imageability	**Recorded Value**
1. Number of courtyards, plazas, and parks (both sides, within study area) (#)	1
2. Number of major landscape features (both sides, beyond study area) (#)	1
3. Proportion historic building frontage (both sides, within study area) (%)	0.7
4. Number of buildings with identifiers (both sides, within study area) (#)	3
5. Number of buildings with non-rectangular shapes (both sides, within study area) (#)	2
6. Presence of outdoor dining (your side, within study area) (y/n)	0
7. Number of people (your side, within study area) (#)	13
8. Noise level (both sides, within study area) (%)	0.3
UDQ 2: Legibility	**Recorded Value**
1. Presence of Memorable Architecture (y/n)	1
2. Presence of Terminated Vista (y/n)	0
3. Number of buildings with identifiers	3
4. Presence of Common spacing and type (y/n)	0
5. Number of Public Art (#)	0
6. Number of Building /Business signs (#)	5

UDQ 3: Enclosure	Recorded Value
1. Number of long sight lines (both sides, beyond study area) (#)	1
2a. Proportion street wall (your side, beyond study area) (%)	0.9
2b. Proportion street wall (opposite side, beyond study area) (%)	0.5
3a. Proportion sky (ahead, beyond study area) (%)	0.1
UDQ 4: Human Scale	**Recorded Value**
1. Number of long sight lines (both sides, beyond study area) (#)	1
2. Proportion windows at street level (your side, within study area) (%)	0.8
3. Consistent average building heights (your side, within study area) (%)	0.6
4. Number of small planters (your side, within study area) (#)	2
5. Number of pieces of street furniture and other street items (your side, within study area)	1
UDQ 5: Transparency	**Recorded Value**
1. Proportion windows at street level (your side, within study area) (%)	0.8
2. Proportion street wall (your side, beyond study area) (%)	0.9
3. Proportion active uses (your side, within study area) (%)	0.7
UDQ 6: Complexity	**Recorded Value**
1. Number of buildings (both sides, beyond study area) (#)	3
2a. Number of basic building colors (both sides, beyond study area) (#)	2
2b. Number of accent colors (both sides, beyond study area) (#)	2
3. Presence of outdoor dining (your side, within study area) (y/n)	0
4. Number of pieces of public art (both side, within study area) (#)	0
5. Number of people (your side, within study area) (#)	13
UDQ 7: Tidiness	**Recorded Value**
1. Pavement condition (your side, within study area) (%)	0.7
2. Debris condition (your side, within study area) (%)	0.2
3. Overhead utilities (both sides, within study area) (y/n)	1
4. Landscape condition (your side, within study area) (%)	0.3
UDQ 8: Linkage	**Recorded Value**
1. Number of Street Connections to elsewhere (#)	3
2. Number of Visible Doors (#)	3
3. Proportion of recessed doors (%)	1
4.Presence of Common Building Heights (y/n)	1
5.Presence of Outdoor dining (y/n)	0
UDQ 9: Coherence	**Recorded Value**
1. Number of Pedestrians (#)	13
2. Presence of Number of Pedestrian-scale streetlights (#)	0
3. Presence of Common Window Proportions (y/n)	1
4.Presence of Common spacing and type (y/n)	1

The next step was to generate a statistical regression for each urban design quality i.e. I generated a regression 9 times, once for each of the 9 urban design qualities.

Unlike the regression model done in the section 5.2.3, the significant statistical output in this step to measure to what extent each physical feature had on the urban design quality was the t-statistic or t-stat value for each physical feature. In statistics, t-stat is used to indicate the significance of the constant being studied with respect to the population. In other words, the t-stat values generated from the regressions indicated how important each physical feature was to the urban design quality being studied.

For the sake of this thesis, I considered the physical features returning a t-stat value equivalent to a p-value of 0.8 or higher as significant, and disregarded all other physical features returning a value less than 0.8 (80%). I will explain the methodology described above in more detail by taking each of the urban design qualities and describing the output reached through the regression analysis.

Imageability: The physical features that were studied and assumed to be relevant to measuring Imageability are found in Table 19.

Table 19: Imageability Physical Features

UDQ 1: Imageability
1. Number of courtyards, plazas, and parks (both sides, within study area) (#)
2. Number of major landscape features (both sides, beyond study area) (#)
3. Proportion historic building frontage (both sides, within study area) (%)
4. Number of buildings with identifiers (both sides, within study area) (#)
5. Number of buildings with non-rectangular shapes (both sides, within study area) (#)
6. Presence of outdoor dining (your side, within study area) (y/n)
7. Number of people (your side, within study area) (#)
8. Noise level (both sides, within study area) (%)

There were numerous physical features to count in Imageability, however, before running the regression it was assumed that not all of them would be significant in determining Imageability. The reason behind this assumption is because many of the physical features mentioned above are not abundantly present in Doha, or at least in the neighborhoods where the videos were recorded. Hence, it was unlikely that all of these physical features had a big effect on the expert's ratings.

Table 20 shows the results of the regression analysis, and as expected, not all of the physical features proved significant. In fact, only half of them were significant enough to be included in calculating a value for this urban design quality. As mentioned above, the indicator used to determine this conclusion was the t-stat value. The 4 physical features that were considered significant were features 2, 3, 5, and 6 returning t-stat values of 2.1324, 1.3605, 1.245, and 3.0471 respectively. It comes as no surprise that the highest factor influencing Imageability is the presence of outdoor dining as this is a physical feature that is hard to come by in Doha, and surely caught the attention of the experts.

Table 20: Imageability Regression Analysis

Z	tC1	tC2	tC3	tC4	tC5	tC6	tC7	tC8	Rsq	AdjR
4	0	2.1324	1.3605	0	1.2497	3.0471	0	0	0.5841	0.5201

Legibility:

The physical features that were studied and assumed to be relevant to measuring Legibility are found in Table 21.

Table 21: Legibility Physical Features

UDQ 2: Legibility
1. Presence of Memorable Architecture (y/n)
2. Presence of Terminated Vista (y/n)
3. Number of buildings with identifiers
4. Presence of Common spacing and type (y/n)
5. Number of Public Art (#)
6. Number of Building /Business signs (#)

Referring to the definition of Legibility discussed in Chapter 3, it was initially assumed that Legibility would rank fairly high in Doha. This assumption was based on the relative ease of navigating around the city due to the city's ring-road layout, which made it easy to create a mental photographic map. However, after looking carefully at the physical features by which Legibility would be scored on, it quickly became evident that the initial assumptions may not hold true.

The regression analysis results shown in Table 22 confirmed my doubts. Out of the six physical features only two proved significant enough based on the returned t-stat values. The significant features were 1 and 4 returning t-stat values of 2.2386 and 2.5428 respectively. It was surprisingly to find that feature 6, building signs, was perceived with a low value of t-stat.

Table 22: Legibility Regression Analysis

Z	tC1	tC2	tC3	tC4	tC6	Rsq	AdjR
2	2.2386	0	0	2.5428	0	0.3627	0.3172

Enclosure:

The physical features shown in Table 23 were studied and assumed to be relevant to measuring Enclosure.

Table 23: Enclosure Physical Features

UDQ 3: Enclosure
1. Number of long sight lines (both sides, beyond study area) (#)
2a. Proportion street wall (your side, beyond study area) (%)
2b. Proportion street wall (opposite side, beyond study area) (%)
3a. Proportion sky (ahead, beyond study area) (%)

Making assumptions regarding the overall effect of physical features on Enclosure was challenging. On one hand, I was confident that the overall effect would be high due to the long sight lines created by residential compound walls and single-story commercial buildings. But on the other hand, I was also concerned that the perceptual “out-door room”, which highly characterizes Enclosure, would be compromised since the streets, where the mentioned compounds and commercial buildings were located, were relatively wide compared to the height of the walls and buildings. Figures 8 & 9 show the two situations mentioned above. I was eager to know which physical feature was considered subconsciously more important to the experts.

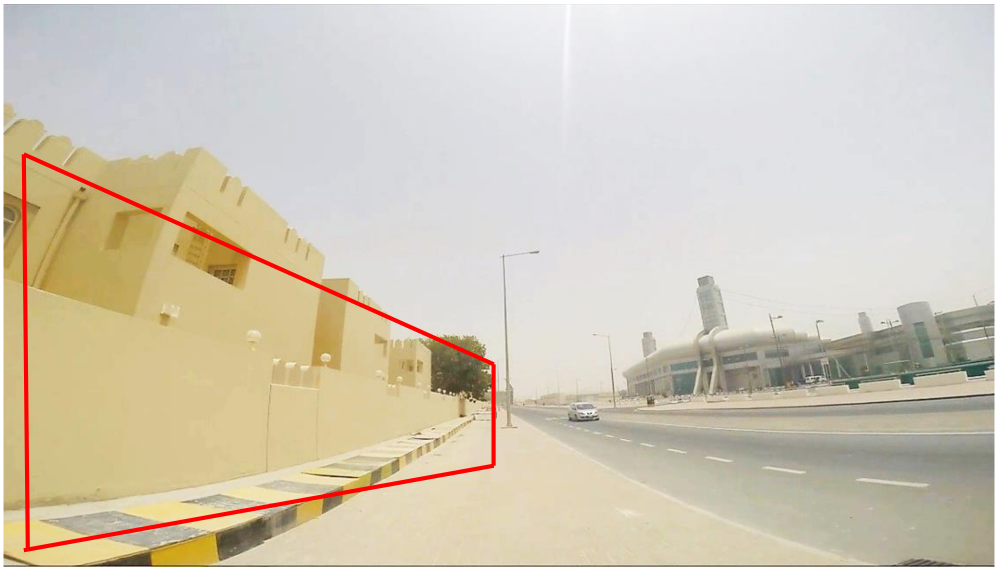


Figure 8: Long Sightlines Created By Compound Walls (Snapshot from Video 24)

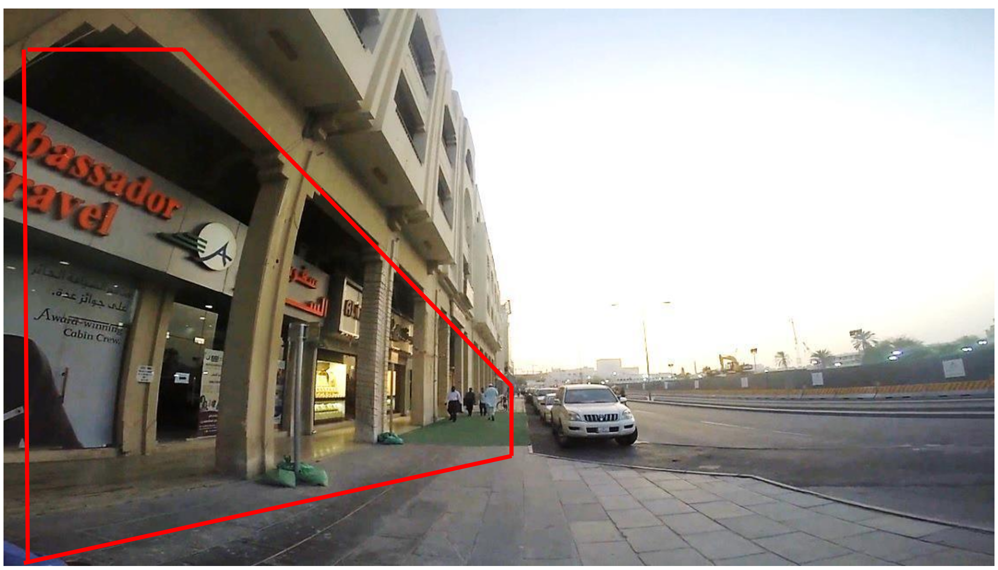


Figure 9: Long Sightlines Created by Commercial Building (Snapshot from Video 03)

The regression analysis results shown in Table 24 revealed the results. Out of the four physical features, only physical features 1 and 3a were considered significant. It turned out that both the number of long sightlines and proportion of sky are important to the experts, but returning a t-stat value of 3.1989, which is higher than the 1.1319 value returned by 3a, the number of long sightlines is ultimately the most influential physical feature affecting Enclosure.

Table 24: Enclosure Regression Analysis

Z	tC1	tC2	tC3	tC4	Rsq	AdjR
2	3.1989	0	0	1.1319	0.2677	0.2153

Human Scale:

The physical features presented in Table 25 were analyzed and expected to be pertinent to quantifying Human Scale.

Table 25: Human Scale Physical Features

UDQ 4: Human Scale
1. Number of long sight lines (both sides, beyond study area) (#)
2. Proportion windows at street level (your side, within study area) (%)
3. Consistent average building heights (your side, within study area) (%)
4. Number of small planters (your side, within study area) (#)
5. Number of pieces of street furniture and other street items (your side, within study area)

There were five physical features to be considered for Human Scale. The objective here, as with the other urban design qualities, was to test if any of these physical features had an effect on Human Scale and if so, to what extent. As an initial prediction, and based on the definition of Human Scale, it was assumed that physical features 3 and 5 would have the highest effect, but for different reasons. Physical feature 3, average building heights, is an important factor in measuring Human Scale because buildings are the most abundant and largest physical features in any urban scene. So building heights was bound to have an effect on Human Scale, albeit a negative effect. The reason that higher the average height of buildings the lower Human Scale would be

– *ceteris paribus* – is because this would leave the pedestrian with a box-like experience. This brings me to the second physical feature I assume will have an effect on Human Scale which is the number of pieces of street furniture (No. 5). If average building height is inversely proportional to Human Scale, how much furniture there is in a street is definitely directly proportional. Street furniture such lighting poles, newspaper and food stalls, benches, payphone booths, trees, and fire hydrants are all, in general, closer to the human scale than buildings. The abundance of these items gives the pedestrian a feeling of belonging and ease in a street since he/she can relate to it, on a size basis at least. Furthermore, street furniture breaks down the scale of adjacent buildings lowering the overall out-of-scale effect a human might otherwise feel.

The regression analysis results found in Table 26 not only confirm my assumptions, but also introduce another significant physical feature; I did not think would be as significant which is the number of long sightlines, similarly as discussed in Enclosure. Therefore, physical features 1, 2, and 5 were the three significant physical features regarding Human Scale returning t-stat values of 1.3227, 3.3617, and 1.8547.

Table 26: Human Scale Regression Analysis

Z	tC1	tC2	tC3	tC4	tC5	Rsq	AdjR
3	1.3227	3.3617	0	0	1.8547	0.4122	0.3469

Transparency:

Table 27 shows three physical features related to Transparency that was tested in the regression analysis.

Table 27: Transparency Physical Features

UDQ 5: Transparency
1. Proportion windows at street level (your side, within study area) (%)
2. Proportion street wall (your side, beyond study area) (%)
3. Proportion active uses (your side, within study area) (%)

Understanding the specifics of the city being measured such as the culture, weather, and demographics is very important in order to make sense of the results obtained, and in order to make improvements to walkability in the future. This is not as important in any urban design quality as it is for Transparency. As such, and being one of its residents for a long time, I assumed that the physical feature 1 mentioned above will not have a big impact on Transparency in Doha. The reason behind my assumption was because Doha is a hot city most of the year. Hence, I assumed that for physical feature 1 the proportion of windows (with transparent glass) on street level will be very low since windows will be either tinted with dark reflective film or covered up with vinyl to block out the sun.

Table 28 shows the regression analysis results which, to a certain extent, confirm my assumptions. Physical feature 1 was indeed insignificant returning a t-stat value of 0 since, as assumed, the proportion of windows on street level is very low in Doha. The significant features 2 and 3 returned t-stat 1.7369 and 0.1528 respectively.

Table 28: Transparency Regression Analysis

Z	tC1	tC2	tC3	Rsq	AdjR
2	0	1.7369	1.5206	0.1528	0.0923

Complexity:

Table 29 shows the physical features related to Complexity that were tested in the regression.

Table 29: Complexity Physical Features

UDQ 6: Complexity
1. Number of buildings (both sides, beyond study area) (#)
2a. Number of basic building colors (both sides, beyond study area) (#)
2b. Number of accent colors (both sides, beyond study area) (#)
3. Presence of outdoor dining (your side, within study area) (y/n)
4. Number of pieces of public art (both side, within study area) (#)
5. Number of people (your side, within study area) (#)

Complexity is perceived to be how detailed and diverse an urban scene is. The physical features mentioned above are considered to be most important in determining Complexity. When discussing Complexity with the experts I rarely noticed positive reactions. The same thing happened with the focus group. This led me to assume that the experts did not perceive Complexity as a strong trait of Doha's urban streets and that only a few of the physical features would really be of significance.

The regression results reflected the experts' position on this urban design quality. Only two of the possible six physical features were deemed important. They were 1 and 3 returning t-stat values of 1.3757 and 1.1664 respectively.

Table 30: Complexity Regression Analysis

Z	tC1	tC2	tC3	tC4	tC5	Rsq	AdjR
2	1.3757	0	0	1.1664	0	0.1278	0.0655

Tidiness:

Table 31 shows four physical features related to Tidiness that were tested in the regression.

Table 31: Tidiness Physical Features

UDQ 7: Tidiness
1. Pavement condition (your side, within study area) (%)
2. Debris condition (your side, within study area) (%)
3. Overhead utilities (both sides, within study area) (y/n)
4. Landscape condition (your side, within study area) (%)

The results of the regression revealed that 3 out of the 4 physical features of Tidiness had a high degree of impact on the overall score given to it by the experts. As mentioned above, the indicator used to determine this conclusion was the t-stat value. The 3 physical features that were considered significant were features 1, 3, and 4 (from Table 31) returning t-stat values of 3.7109 (tC1), 2.7992 (tC3), and 2.9861 (tC4) respectively. This data is shown in Table 32 which is an extract of the regression analysis done on Tidiness. The numbers reveal that the pavement condition is the most important physical feature affecting tidiness followed by landscape condition and over-head utilities.

Table 32: Tidiness Regression Analysis

Z	tC1	tC2	tC3	tC4	Rsq	AdjR
3	3.7109	0	2.7992	2.9861	0.5923	0.547

Linkage:

The physical features shown in Table 33 were analyzed to see how important they are in determining Linkage.

Table 33: Linkage Physical Features

UDQ 8: Linkage
1. Number of Street Connections to elsewhere (#)
2. Number of Visible Doors (#)
3. Proportion of recessed doors (%)
4.Presence of Common Building Heights (y/n)
5.Presence of Outdoor dining (y/n)

Linkage, or how well connected a city is, is a vital urban quality design for any urban street. If urban developers want to create a walkable city, it is essential they make walking a more sensible option than driving or using public transportation. They can do this by creating street connections between streets and blocks to shorten the distances for pedestrians. However Linkage is not only about physical street links. It can also be achieved with features that are not related to streets at all, yet are important in giving the pedestrian a feeling of connectivity. These features can be visible doors which contribute to Linkage by giving the pedestrian a sense of anticipation. They can also be related to buildings, specifically common heights of buildings, which contribute to Linkage by giving the pedestrian an unbroken line of sight. As such, I assumed that Linkage will be affected the most if all the physical features mentioned in Table 34 were factored in.

After running the regression, it was revealed that my assumption was partially wrong. It turned out that to achieve the highest reliability, only physical features 1 and 5 should be considered significant. Physical feature 1, number street connections to elsewhere, which is the second most significant feature according to our analysis, returned a t-stat value of 1.7871. Physical feature 5, presence of outdoor dining, appeared to be the most significant feature in creating a sense of Linkage in Doha, returning a t-stat value of 2.7724.

Table 34: Linkage Regression Analysis

Z	tC1	tC2	tC3	tC4	tC5	Rsq	AdjR
2	1.7871	0	0	0	2.7724	0.2506	0.1971

Coherence:

The physical features shown in Table 35 were considered significant in determining Coherence.

Table 35: Coherence Physical Features

UDQ 9: Coherence
1. Number of Pedestrians (#)
2. Presence of Number of Pedestrian-scale streetlights (#)
3. Presence of Common Window Proportions (y/n)
4.Presence of Common spacing and type (y/n)

Regression analysis results revealed that existence of common window proportions and common spacing are the most significant features in achieving coherence.

Table 36: Coherence Regression Analysis

Z	tC1	tC2	tC3	tC4	Rsq	AdjR
2	0	0	1.1025	3.2889	0.3204	0.2718

5.3 Summary & Research Findings

Referring to the above regression outputs from sections 5.2.3 and 5.2.4, I was able to derive an equation to calculate a Walkability Index. It is highly important to note that the result of the equation will return an index and not a defined score out of a total. Like any other index, the results of the Walkability Index will only be indicative if the urban design quality coefficients and physical feature t-stat values remain the same. In other words, the results will only be useful if the assessed neighborhoods or streets were confined to a certain geographical location. That is because in other regions, Europe for example, the coefficients (weights) that would be derived for each urban design quality from any expert opinion would most likely be different from those derived in Doha. And the same holds true for physical features.

Referring to the results obtained in 5.2.3, the first phase of the equation, that will eventually be used to calculate walkability, was formulated. From here on, I was able to make sense of the statistical output generated previously to calculate walkability based on assigned weights (C_n) to each urban design quality. The weights will then be multiplied by the total urban design quality (UDQ) score which will be discussed below.

$$W = C_1(UDQ_1) + C_2(UDQ_2) + C_3(UDQ_3) + \cdots + C_9(UDQ_9)$$

Where:

Function	**Description**
W	Walkability Score
C	Coefficient of each Urban Design Quality
UDQ	Value of Urban Design Quality

Referring to the results obtained in 5.2.4, I was able to formulate the second phase of the equation. The regression analysis returned the degree of impact each physical feature has on the urban design quality as a whole, which was used as a multiplier to calculate the "value" urban design quality. As such, the second part of the formula was complete.

$$UDQ_n = C_{(UDQ_n)} \times V_{(UDQ_n)}$$

Where:

Function	Description
UDQ	Value of Urban Design Quality
C	Coefficient of each Physical Feature
V	Value of each Physical Feature

CHAPTER 6: RESULTS INTERPRETATION, WALKABILITY INDEX MODEL (WIM) DISCUSSION & GUIDEBOOK

6.1 Introduction

The results interpretation and initial findings that were done through the last chapter reveal how assessing certain physical features can help in quantifying intangible urban design qualities. Moreover, it was proved that these urban design qualities can be computed to assess and measure the overall walkability score of a street. Through this chapter, I'll present this thesis outcome in a form of an easy walkability assessment tool that can be used by urban planners and designers. To do so, it was suggested to keep the complicated statistical analysis away from the end-user and provide a "Walkability Index Model" that require simple and direct inputs. To facilitate the assessment, reach the representative walkability score and answer all the queries that the end-user might have, a small "Guidebook" was also designed.

6.2 Walkability Index Model

6.2.1 Introduction

After achieving the Walkability formula from the statistical analysis done in Chapter 5, developing a user friendly Walkability Index Model (WIM) was possible. I chose to develop the calculator on Microsoft Excel since it is a simple, functional, and a widely used program. In order for the model to be useful, I determined that it should have three key characteristics which are reliability, functionality, and ease of use. In this chapter, I will discuss how I achieved each of these characteristics through describing the features of the model.

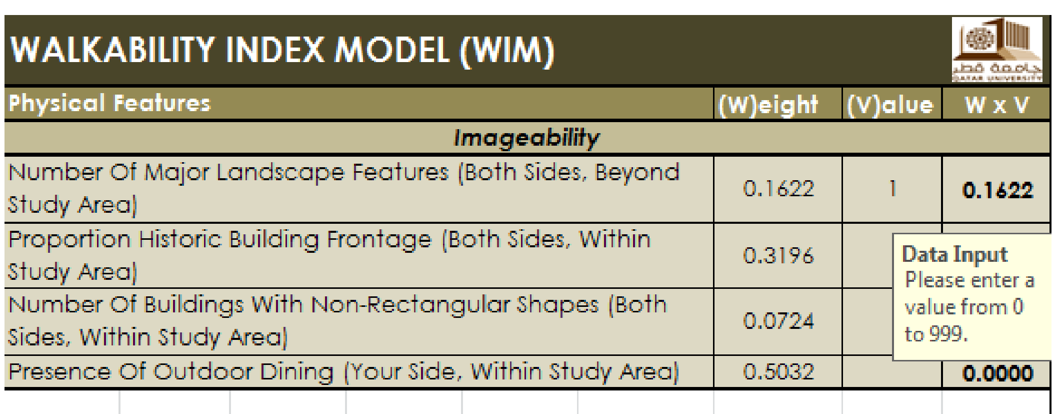
6.2.2 Features

The main objective of the present study was to create a reliable model. To achieve this goal, I introduced the following features:

Workbook Protection: This feature allows locking key cells using a password, disabling users from editing formulas, formatting layouts, or changing constants. This is a key control in ensuring the integrity of the model is not compromised and that the Walkability score it calculates is accurate.

Data Validation: This feature prohibits the user from entering input values that will result in a calculation error. The data validations that I used in the model are as follows:

Number validations: this type of validation was introduced to input cells that require a number to be entered according to the physical feature being studied. For example, if the user is asked to count the number of trees they are not permitted to enter a letter in the input field; only numbers from 0 to 999 are accepted.



WALKABILITY INDEX MODEL (WIM)

Physical Features	(W)eight	(V)alue	W x V
Imageability			
Number Of Major Landscape Features (Both Sides, Beyond Study Area)	0.1622	1	**0.1622**
Proportion Historic Building Frontage (Both Sides, Within Study Area)	0.3196		
Number Of Buildings With Non-Rectangular Shapes (Both Sides, Within Study Area)	0.0724		
Presence Of Outdoor Dining (Your Side, Within Study Area)	0.5032		**0.0000**

Figure 10: WIM Data Validation (Snapshot from Filled WIM)

Proportion validations: this type of validation is similar to the above validation but the accepted numbers are between 0 and 1 only since if the required physical feature is a proportion the result cannot be greater than 1.

WALKABILITY INDEX MODEL (WIM)

Physical Features	(W)eight	(V)alue	W x V
Imageability			
Number Of Major Landscape Features (Both Sides, Beyond Study Area)	0.1622	1	**0.1622**
Proportion Historic Building Frontage (Both Sides, Within Study Area)	0.3196	0.7	**0.2237**
Number Of Buildings With Non-Rectangular Shapes (Both Sides, Within Study Area)	0.0724		
Presence Of Outdoor Dining (Your Side, Within Study Area)	0.5032		

Data Input
Please enter a value between 0 and 1.

Figure 11: WIM Proportion Validation (Snapshot from Filled WIM)

Yes or No validations: this type of validation is created for physical features that require a Yes or No answer and not a numerical value. The user is only permitted to enter either Y or N as input (not case sensitive).

Legibility			
Memorable Architecture (Y/N)	0.2429		**0.0000**
Common Spacing And Type (Y/N)	0.3402		
Enclosure			
Number Of Long Sight Lines (Both Sides, Beyond Study Area)	0.3090		
Proportion Sky (Ahead, Beyond Study Area)	-0.5855		**0.0000**

Data Input
Please enter either Y or N.

Figure 12: WIM “Yes or No” Validation (Snapshot from Filled WIM)

Minimum Data Entry: When possible, I entered data using either formulas or through referencing to other sheets and not number punching. This method greatly decreases the risk of data entry error, thus enhancing the overall reliability of the model.

After the reliability of the model was achieved and maintained it was essential to make it functional. In order to increase functionality I introduced the following features:

Multi-stage formulas: I used several small formulas instead of one big formula to make calculations lighter and decrease the risk of “program freeze”. This also helps if a change is desired at any level of the calculation, were it won’t be necessary to rewrite the whole formula again, but only change the desired one.

“CALCULATE” button: I introduced a calculate button that calculates Walkability score after the user has finished inputting the data. I thought that this approach is more professional than keeping the constantly changing value of the cell that contains the score visible to the user.

“RESET” button: This is a simple reset button that clears all the input the user entered to facilitate starting over.

Printable format: I ensured that the format of the model makes it easy to be printed without having to change margins, font sizes, or compensate readability through using the “fit width” function. If desired, the user just has to press print and the output would be the model as shown on his/her screen.

Finally, and after ensuring reliability and functionality, the model had to be user friendly. To do this, I implemented the following:

Neat formatting: I used an easily readable font (Century Gothic) in size 10 to make the model easily readable for most people. I also used easy on the eye fill colors that were inspired by QU’s logo color. Finally, I alternated between font characteristics such as Bold and Italics when appropriate to enhance overall readability.

Simplicity: To obtain a Walkability score, all the user has to do is enter the values of physical features, and the model does the rest. This limited amount of user input makes it easier for the user to use, and decreases calculation error risk.

WALKABILITY INDEX MODEL (WIM)			
Physical Features	(W)eight	(V)alue	W x V
Imageability			
Number Of Major Landscape Features (Both Sides, Beyond Study Area)	0.1622	1	**0.1622**
Proportion Historic Building Frontage (Both Sides, Within Study Area)	0.3196	0.7	**0.2237**
Number Of Buildings With Non-Rectangular Shapes (Both Sides, Within Study Area)	0.0724	2	**0.1448**
Presence Of Outdoor Dining (Your Side, Within Study Area)	0.5032	N	**0.0000**
Legibility			
Memorable Architecture (Y/N)	0.2429	Y	**0.2429**
Common Spacing And Type (Y/N)	0.3402	N	**0.0000**
Enclosure			
Number Of Long Sight Lines (Both Sides, Beyond Study Area)	0.3090	1	**0.3090**
Proportion Sky (Ahead, Beyond Study Area)	-0.5855	0.2	**-0.1171**
Human Scale			
Number Of Long Sight Lines (Both Sides, Beyond Study Area)	0.1095	1	**0.1095**
Proportion Windows At Street Level (Your Side, Within Study Area)	0.6012	0.8	**0.4810**
Number Of Pieces Of Street Furniture And Other Street Items (Your Side, Within Study Area)	0.0459	1	**0.0459**
Transparency			
Proportion Street Wall (Your Side, Beyond Study Area)	-0.3433	0.9	**-0.3090**
Proportion Active Uses (Your Side, Within Study Area)	0.3191	0.7	**0.2234**
Complexity			
Number Of Buildings (Both Sides, Beyond Study Area)	0.06570	3	**0.1971**
Number Of Pieces Of Public Art (Both Sdies, Within Study Area)	0.46280	0	**0.0000**
Tidiness			
Proportion undamaged pavement in 1 Square Km	1.9260	0.7	**1.3482**
Overhead Utilities (Both Sides, Within Study Area) (Y/N)	-0.3963	Y	**-0.3963**
Landscape Condition (Your Side, Within Study Area)	1.1250	0.3	**0.3375**
Linkage			
Number Of Street Connections To Elsewhere	0.1495	3	**0.4485**
Outdoor Dining (Y/N)	0.8192	N	**0.0000**
Coherence			
Common Window Proportions (Y/N)	0.1356	Y	**0.1356**
Common Spacing And Type (Y/N)	0.4813	Y	**0.4813**
CALCULATE	YOUR CITY'S WALKABILITY SCORE IS 0.674		RESET

Figure 13: WIM - Filled Example for Video 01

6.3 User’s Guidebook

The main aim of this thesis was to enable the end-user to measure urban design qualities that are related to walkability through tangible subjective measures. Here, specific physical features were assigned for this purpose. While the “Walkability Index Model” will help the assessor to get an overall walkability score through quantifying the listed physical features, it was essential to have a sort of manual on how to get the right input. To eliminate any potential subjectivity by the assessor, this guidebook is created give clear and direct instructions on how to measure the physical feature.

The following steps were demonstrated through the “Guidebook”:

Step 1: Prepare Yourself

In this step, a general idea about what is required from the assessor is given. It aims to prepare him/her for a good amount of walking through the assessed area along with the focus on what to observe. This protocol will ask the user to give definite input values for some of the physical features under the title of each urban design quality. The type of input values will be in the form of numbers, percentages or (Yes/No) answers with no range of subjectivity. For example, to assess UDQ1: Imageability the instructions will require the user to count the number of major landscape features on both sides of the study area, count the number of buildings with non-rectangular shapes, give a percentage of the historic buildings frontage proportion to the overall area and finally indicate the presence of outdoor dining by (Y/N).

Through the same step, the assessor is advised to walk through the study area for more than one time to make sure that he/she is aware of all the surroundings that should be quantified. Creating a group of two or more is desirable so it will minimize the chance of missing some of the physical features.

Step 2: Get Your Walkability Assessment Kit Ready

Before heading to assess the study area, the assessor is advised to make sure that he/she has all the required materials. Although, the "Walkability Index Model" is designed as an electronic calculator, it is required to print it to record the input values. In addition to some pens, papers and a map of the selected area, a hard copy of this guidebook is also preferable if the user needed to refer back to some of the steps.

Paying attention to the small details in the study area is very important. Here and in order to help the assessor focusing on the physical features without being distracted, it was recommended to wear a comfortable pair of shoes and sunglasses.

Step 3: Define Your Study Area

In this section, the assessor is asked to draw the boundaries of the area to be assessed. To do so, it was important to give the end-user an estimated range of what a study area is. As the urban design qualities are captured at the human scale, the study area can't be on a scale of a neighborhood or a city. On the hand, it cannot be very small so the urban design qualities are not reflected any more. The protocol in the guidebook suggested the study area to be around a block in length, typically around 90 meters.

While some of the physical features can be counted directly within the boundaries of the selected study area, others can be quantified based on the overall perceived environment. They may not physically exist inside the study area, yet they can be observed from it. Therefore, this section provides the assessor with some definitions of “General Terms” that are used through the assessment tool such as Study Area, Beyond the Study Area, Proportion, Street level, etc. as shown in Table 37.

Table 37: General Terms of the Guidebook

Study Area	Your study area should be around one block in length, typically around 90 meters.
Within & Beyond the Study Area	For some measurements, you’ll find instructions like “Within the study area” & “Beyond the study area” please pay attention to the difference. **Within the Study Area:** Consider it anything physically located in your study area. **Beyond the Study Area:** This term is only used with some input values that engage long sightlines. They might not be physically included in your study area, but they can be quantified visually from this area.
Your Side & Both Sides	**Your Side:** Quantify the physical features on your side of the street only. **Both Sides:** Quantify the physical features both on your side of the street and the opposite side.
Proportion	For quantifying some physical features, you’ll be asked to find the proportion. This simply indicates the percentage that this element represents of the entire block length.
Street Level	This is the ground floor level that is directly accessible from the sidewalk level, usually around 3 meters in height.

Step 4: Collect Your Data

Using the attached Walkability Index Model, the assessor is asked to quantify and fill in the required data for all the mentioned physical features. Below is the guidebook itself in its final format as given to the end-user.

WALKABILITY INDEX MODEL GUIDEBOOK (WIMG)

Step 1: Prepare Yourself

This guidebook will assess you to measure the data required for the “Walkability Index Model”. You’ll be asked to give definite input values for some of the physical features under the title of each urban design quality. The type of input values will be in the form of:

- Numbers (1,2,3,......n)
- Percentages (%)
- Yes or No answers (Y/N)

Example:

For UDQ1: Imageability, the instructions will ask you to count the number of major landscape features on both sides of the study area, count the number of buildings with non-rectangular shapes, give a percentage of the historic buildings frontage proportion to the overall area and finally indicate the presence of outdoor dining by (Y/N).

It’s preferable to:

- Walk through the study area for more than one time to make sure that you are aware of all the surroundings that should be quantified.
- Ask for a friend help, this will minimize the chance of missing some of the physical features.

Step 2: Get Your Walkability Assessment Kit Ready

Don’t Forget to:

- Print a copy of the “Walkability Index Calculator”.
- Print a copy of this guide
- Get some pens and notebook
- Print a map of the selected area
- Wear a comfortable pair of shoes and sunglasses.

Step 3: Define Your Study Area

As the urban design qualities are captured at the human scale, the study area can’t be on a scale of a neighborhood or a city. On the hand, it cannot be very small so the urban design qualities are not reflected any more. The protocol in this guidebook suggests the study area to be around a block in length, typically around 90 meters.

Useful Definitions:

Study Area: Your study area should be around one block in length, typically around 90 meters.

Within the Study Area: Consider it anything physically located in your study area.

Beyond the Study Area: This term is only used with some input values that engage long sightlines. They might not be physically included in your study area, but they can be quantified visually from this area.

Your Side: Quantify the physical features on your side of the street only.

Both Sides: Quantify the physical features both on your side of the street and the opposite side.

Proportion: For quantifying some physical features, you’ll be asked to find the proportion. This simply indicates the percentage that this element represents of the entire block length.

Street Level: This is the ground floor level that is directly accessible from the sidewalk level,

Step 4: Collect Your Data

Collect the required input values using the Walkability Index Model (WIM)

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Conclusions

The thesis sheds light on the shortcomings facing walkability studies and assessment tools across the world. It emphasized the ineffectiveness of current initiatives in converting qualitative urban features into meaningful data that can be quantified.

Through in depth research carried out into urban design literature the methodology employed in the study done by MIUDQ was the only framework that eliminated subjectivity to a high degree and still managed to come up with logical relationships between quantitative elements such as physical features, and qualitative elements such as urban design qualities, by using a set of statistical correlation models. However, the mentioned framework lacked an arithmetic formula that calculates a final score for walkability. The limitation in MIUDQ’s framework enticed me to undertake the challenge of finding a reliable equation that will return a final numerical value for walkability. The process to achieve this was by no means simple for several reasons; finding willing experts to rate the urban design qualities, recording videos outdoor in unfavorable weather conditions, and most importantly understanding the complex statistical analyses of MIUDQ’s study all made the thesis a challenging yet rewarding experience. After meeting with Dr. Karim Abdel Warith, Post-Doctoral Researcher at Qatar University, he suggested a simpler statistical model to reach our goal. Eventually, coefficients for the urban design qualities and related physical features were calculated and incorporated into an arithmetic equation. The end result was “WIM, Walkability

Index Model", a walkability calculator. The biggest advantage of the WIM is that users are not required to enter large amount of data. The potential user only had to fill in the physical features count fields and the walkability index will be automatically calculated. Moreover, a guide book (user's manual) was developed to explain the requirements needed to conduct a successful audit that defines key technical terms used in the calculator.

At the beginning of this research, meaningful outcomes were not guaranteed especially that I didn't have the statistical know-how required to achieve the desired results. However, with the extensive research and hands-on testing of the statistical models, It was concluded that walkability can in fact be numerically measured.

7.2 Potential Uses

The WIM can be used for many architectural, urban design, planning and landscape objectives. Its flexibility and ease of use make it a handy tool for urban planners and designers. Some of the objectives that can be achieved by using the WIM are:

- Enhancing existing streets: The WIM can enable urban planners to detect weaknesses in urban streets and run scenario analyses to achieve a better environment by changing the quantity of some variables and observing how it might increase the walkability index. For example, the urban planner is able to measure the effect of adding extra pieces of street furniture without adding a single piece. To illustrate the above scenario, Figure 14 shows the current number of trees in Street "A"

Human Scale			
Number Of Long Sight Lines (Both Sides, Beyond Study Area)	0.1095	2	**0.2190**
Proportion Windows At Street Level (Your Side, Within Study Area)	0.6012	0.4	**0.2405**
Number Of Pieces Of Street Furniture And Other Street Items (Your Side, Within Study Area)	0.0459	1	**0.0459**
Coherence			
Common Window Proportions (Y/N)	0.1356	Y	**0.1356**
Common Spacing And Type (Y/N)	0.4813	N	**0.0000**
CALCULATE YOUR CITY'S WALKABILITY SCORE IS	0.478		RESET

Figure 14: Scenario 1 for Street "A"

By increasing the number of street furniture pieces from 1 to 3 and keeping the other variable constant, the Walkability Index value increases by 1.7% as shown in Figure 15.

Human Scale			
Number Of Long Sight Lines (Both Sides, Beyond Study Area)	0.1095	2	**0.2190**
Proportion Windows At Street Level (Your Side, Within Study Area)	0.6012	0.4	**0.2405**
Number Of Pieces Of Street Furniture And Other Street Items (Your Side, Within Study Area)	0.0459	3	**0.1377**
Coherence			
Common Window Proportions (Y/N)	0.1356	Y	**0.1356**
Common Spacing And Type (Y/N)	0.4813	N	**0.0000**
CALCULATE YOUR CITY'S WALKABILITY SCORE IS	0.495		RESET

Figure 15: Scenario 2 for Street "A"

- Designing new streets: Through offering a list of physical features that proved to directly affect walkability scores, WIM can focus the designers' attention on the important physical features that need to be incorporated in their designs. In addition, it will give designers a valid argument when presenting their project by showing the client reliable walkability scores for the design instead of sketches and assumptions.

- Building up on the walkable environments research: This study can be the foundation for researchers in this part of the world to develop a better understanding on what makes a space more walkable. Researchers can objectively and reliably measure different physical features as independent variables in efforts to explain walking, use of urban space and other potential outcomes.

7.3 Recommendations

7.3.1. Recommendation for Enhancing NSA Tools

Neighborhood Sustainability Assessment (NSA) tools, such as GSAS NH, LEED ND, etc., were initiated at the beginning as formal guides to predict the environmental consequences of a project prior to its implementation. As stated in Chapter 2, these assessment tools are acknowledged in transferring the data overload into quantifiable information for better decisions-making.

While NSA assessment tools were successful in addressing the technical aspects of a project, they fell short in capturing the qualitative features of it. However, WIM is a flexible model that can be easily adopted to fill the gap and measure walkability in different urban contexts. As it was originally designed and experienced in this part of the world, WIM can be a great addition to the GSAS District Assessment tool. Both WIM and the GSAS District Assessment tool are based on an Excel

Model. The similarity of the user interface and numerical data outcome would support merging WIM into GSAS as an effective indicator of walkable streets.

For LEED ND and other international assessment tools, it is not easy to adopt WIM in its current state. The process the study can be adopted perfectly, but the data that WIM is built on reflect local assessments that may not necessarily be true in other parts of the world. The same study approach can be done on a much larger sample of streets and using more experts from around the world.

7.3.2. Future Recommendations for Developing WIM

In a further attempt to develop this thesis, the analysis and discussion of urban design qualities that affect walkability will continue, and may produce a more developed version of WIM that can reflect an understanding of human preferences worldwide. The same process can be implanted on number of streets in different cities around the world. It would be interesting to compare the results obtained for different cities and then explore the possibility of creating one global assessment tool that can be applicable in any city in the world.

While the condition of the built environment and the qualities the pedestrians look for might affect their preferences of a walkable area, this thesis is concerned with perceptual qualities that make some streets more inviting than another regardless of the goal of the walking activity. It is important to encourage walking through the condition of the built environment, and as such, I believe that the built environment should be attractive whatever the purpose of walking is.

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APPENDIX A

Visual Survey Assessment

Refer to Attachment A

APPENDIX B

Walkability Index Model (WIM)

WALKABILITY INDEX MODEL (WIM)			
Physical Features	(W)eight	(V)alue	W x V
Imageability			
Number Of Major Landscape Features (Both Sides, Beyond Study Area)	0.1622		**0.0000**
Proportion Historic Building Frontage (Both Sides, Within Study Area)	0.3196		**0.0000**
Number Of Buildings With Non-Rectangular Shapes (Both Sides, Within Study Area)	0.0724		**0.0000**
Presence Of Outdoor Dining (Your Side, Within Study Area)	0.5032		**0.0000**
Legibility			
Memorable Architecture (Y/N)	0.2429		**0.0000**
Common Spacing And Type (Y/N)	0.3402		**0.0000**
Enclosure			
Number Of Long Sight Lines (Both Sides, Beyond Study Area)	0.3090		**0.0000**
Proportion Sky (Ahead, Beyond Study Area)	-0.5855		**0.0000**
Human Scale			
Number Of Long Sight Lines (Both Sides, Beyond Study Area)	0.1095		**0.0000**
Proportion Windows At Street Level (Your Side, Within Study Area)	0.6012		**0.0000**
Number Of Pieces Of Street Furniture And Other Street Items (Your Side, Within Study Area)	0.0459		**0.0000**
Transparency			
Proportion Street Wall (Your Side, Beyond Study Area)	-0.3433	0.9	**-0.3090**
Proportion Active Uses (Your Side, Within Study Area)	0.3191	0.7	**0.2234**
Complexity			
Number Of Buildings (Both Sides, Beyond Study Area)	0.06570		**0.0000**
Number Of Pieces Of Public Art (Both Sdies, Within Study Area)	0.46280		**0.0000**
Tidiness			
Proportion undamaged pavement in 1 Square Km	1.9260		**0.0000**
Overhead Utilities (Both Sides, Within Study Area) (Y/N)	-0.3963		**0.0000**
Landscape Condition (Your Side, Within Study Area)	1.1250		**0.0000**
Linkage			
Number Of Street Connections To Elsewhere	0.1495		**0.0000**
Outdoor Dining (Y/N)	0.8192		**0.0000**
Coherence			
Common Window Proportions (Y/N)	0.1356		**0.0000**
Common Spacing And Type (Y/N)	0.4813		**0.0000**
CALCULATE YOUR CITY'S WALKABILITY SCORE IS			RESET

APPENDIX C

Raw Data - Expert Ratings: A Sample from Video 01 to Video 05

Video 01										
Imageability	Legibility	Enclosure	Human Scale	Transparency	Linkage	Complexity	Coherence	Tidiness	Name	Title
5	4	4	3	5	3	3	4	3	N1	T1
2	2	2	4	3	2	2	2	2	N2	T2
2	4	3	2	3	2	1	2	3	N3	T3
3	2	3	2	3	3	3	2	3	N4	T4
1	2	2	2	3	2	2	2	3	N5	T5
1	3	1	1	1	2	1	1	1	N6	T6
2	2	2	3	3	3	2	2	2	N7	T7
2	2	2	3	2	2	2	2	3	N8	T8
1	3	3	3	3	2	2	2	1	N9	T9
3	2	2	4	4	3	2	3	4	N10	T10
3	3	2	3	3	2	2	2	3	N11	T11
4	4	3	5	4	4	3	4	3	N12	T12

Video 02										
Imageability	Legibility	Enclosure	Human Scale	Transparency	Linkage	Complexity	Coherence	Tidiness	Name	Title
2	2	2	3	3	3	1	2	2	N1	T1
2	2	2	3	3	2	2	2	2	N2	T2
1	2	3	2	3	2	2	2	2	N3	T3
1	1	2	2	3	2	1	1	2	N4	T4
1	2	2	2	1	1	1	1	1	N5	T5
1	2	1	1	1	1	1	1	1	N6	T6
1	1	1	2	3	1	1	1	2	N7	T7
2	2	2	2	2	2	2	2	2	N8	T8
2	2	1	2	2	2	1	1	2	N9	T9
1	2	1	3	4	1	1	1	1	N10	T10
2	2	2	2	2	3	3	2	2	N11	T11
3	3	2	3	2	2	2	2	1	N12	T12

Video 03									Name	Title
Imageability	Legibility	Enclosure	Human Scale	Transparency	Linkage	Complexity	Coherence	Tidiness		
2	3	1	2	3	3	2	2	2	N1	T1
2	3	3	3	3	2	2	3	3	N2	T2
3	3	3	4	3	4	2	3	3	N3	T3
3	3	3	3	3	3	3	3	3	N4	T4
2	2	2	1	2	1	1	2	2	N5	T5
3	2	2	1	1	1	2	2	2	N6	T6
3	3	3	4	4	3	3	3	4	N7	T7
2	3	3	2	2	2	2	2	2	N8	T8
3	4	3	3	3	2	2	2	3	N9	T9
4	3	1	4	3	3	1	2	5	N10	T10
3	3	3	3	3	2	2	3	3	N11	T11
3	3	3	4	3	4	4	3	4	N12	T12

Video 04									Name	Title
Imageability	Legibility	Enclosure	Human Scale	Transparency	Linkage	Complexity	Coherence	Tidiness		
1	2	4	4	3	3	3	2	1	N1	T1
2	2	2	2	2	2	2	2	2	N2	T2
2	2	3	3	2	2	3	2	2	N3	T3
3	3	3	2	4	4	2	2	2	N4	T4
2	3	3	2	3	2	1	1	1	N5	T5
1	2	1	1	1	1	1	1	1	N6	T6
3	3	3	4	3	3	3	3	2	N7	T7
2	2	2	2	2	2	2	2	2	N8	T8
2	2	3	4	3	2	2	2	2	N9	T9
4	3	5	4	4	3	5	2	4	N10	T10
3	3	3	3	2	3	3	3	3	N11	T11
4	4	5	5	4	4	4	5	4	N12	T12

Video 05									Name	Title
Imageability	Legibility	Enclosure	Human Scale	Transparency	Linkage	Complexity	Coherence	Tidiness		
1	2	2	3	3	3	1	2	3	N1	T1
2	2	2	3	2	2	2	2	2	N2	T2
3	3	3	4	4	4	3	4	3	N3	T3
3	3	2	2	3	3	2	3	3	N4	T4
1	2	3	2	3	2	1	1	1	N5	T5
1	1	1	1	2	1	1	2	1	N6	T6
3	4	3	3	4	3	3	3	4	N7	T7
2	2	2	2	2	2	2	2	2	N8	T8
3	3	4	4	3	3	2	2	3	N9	T9
4	3	5	3	3	4	4	3	4	N10	T10
3	3	3	3	3	3	3	3	3	N11	T11
5	4	4	4	4	4	3	3	3	N12	T12

Video		01	02	03	04	05
Name	Title	Walkability Score				
N1	T1	3.5	2	3	2	2
N2	T2	2	2	4	3	4
N3	T3	2	2	4	4	3
N4	T4	3	1	2	2	3
N5	T5	2.5	1.5	1.5	2.5	1.5
N6	T6	1.5	2	2	3.5	3.5
N7	T7	1	1	2.5	2	4
N8	T8	2.5	2.5	2.5	2	3
N9	T9	3	2	2	3.5	3.5
N10	T10	3	3	3	4.5	4.5
N11	T11	3	3	3	3.5	3
N12	T12	4	3	2.5	4.5	4.5

Raw Data - Physical Features Count: A Sample from Video 01 to Video 05

Video 01	Recorded Value
Imageability	
1. number of courtyards, plazas, and parks (both sides, within study area)	1
2. number of major landscape features (both sides, beyond study area)	1
3. proportion historic building frontage (both sides, within study area)	0.7
4. number of buildings with identifiers (both sides, within study area)	3
5. number of buildings with non-rectangular shapes (both sides, within study area)	2
6. presence of outdoor dining (your side, within study area)	N
7. number of people (your side, within study area)	13
8. noise level (both sides, within study area)	3
Legibility	
1. Memorable Architecture (y/n)	Y
2. Terminated Vista (y/n)	N
3. Buildings with Identifiers (#)	2
4. Common spacing and type (y/n)	N
5. Public Art (#)	0
6. Place /Building /Business signs (#)	5
Enclosure	
1. number of long sight lines (both sides, beyond study area)	1
2a. proportion street wall (your side, beyond study area)	0.9
2b. proportion street wall (opposite side, beyond study area)	0.5
3a. proportion sky (ahead, beyond study area)	0.1
Human Scale	
1. number of long sight lines (both sides, beyond study area)	1
2. proportion windows at street level (your side, within study area)	0.8
3. average building heights (your side, within study area)	15
4. number of small planters (your side, within study area)	2
5. number of pieces of street furniture and other street items (your side, within study area)	1
Transparency	
1. proportion windows at street level (your side, within study area)	0.8
2. proportion street wall (your side, beyond study area)	0.9
3. proportion active uses (your side, within study area)	0.7
Complexity	
1. number of buildings (both sides, beyond study area)	3
2a. number of basic building colors (both sides, beyond study area)	2
2b. number of accent colors (both sides, beyond study area)	2
3. presence of outdoor dining (your side, within study area)	0
4. number of pieces of public art (both sdies, within study area)	0
5. number of people (your side, within study area)	13
Tidiness	
1. pavement condition (your side, within study area) rating	0.7
2. debris condition (your side, within study area) rating	0.2
3. overhead utilities (both sides, within study area) (y/n)	1
4. landscape condition (your side, within study area) rating	0.3
Linkage	
1. Street Connections to elsewhere (#)	3
2. Visible Doors (#)	3
3. Proportion recessed doors	1
4.Common Building Heights (y/n)	Y
4.Outdoor dining (y/n)	N
Coherence	
1. Pedestrians (#)	3
2. Pedestrian-scale streetlights (#)	0
3. Common Window Proportions (y/n)	Y
4.Common spacing and type (y/n)	Y

Video 02	
	Recorded Value
Imageability	
1. number of courtyards, plazas, and parks (both sides, within study area)	0
2. number of major landscape features (both sides, beyond study area)	0
3. proportion historic building frontage (both sides, within study area)	0
4. number of buildings with identifiers (both sides, within study area)	3
5. number of buildings with non-rectangular shapes (both sides, within study area)	0
6. presence of outdoor dining (your side, within study area)	N
7. number of people (your side, within study area)	0
8. noise level (both sides, within study area)	3
Legibility	
1. Memorable Architecture (y/n)	N
2. Terminated Vista (y/n)	N
3. Buildings with Identifiers (#)	0
4. Common spacing and type (y/n)	N
5. Public Art (#)	0
6. Place /Building /Business signs (#)	4
Enclosure	
1. number of long sight lines (both sides, beyond study area)	1
2a. proportion street wall (your side, beyond study area)	0.4
2b. proportion street wall (opposite side, beyond study area)	0.7
3a. proportion sky (ahead, beyond study area)	0.3
Human Scale	
1. number of long sight lines (both sides, beyond study area)	1
2. proportion windows at street level (your side, within study area)	0.4
3. average building heights (your side, within study area)	10
4. number of small planters (your side, within study area)	1
5. number of pieces of street furniture and other street items (your side, within study area)	0
Transparency	
1. proportion windows at street level (your side, within study area)	0.4
2. proportion street wall (your side, beyond study area)	0.4
3. proportion active uses (your side, within study area)	0.5
Complexity	
1. number of buildings (both sides, beyond study area)	4
2a. number of basic building colors (both sides, beyond study area)	3
2b. number of accent colors (both sides, beyond study area)	2
3. presence of outdoor dining (your side, within study area)	N
4. number of pieces of public art (both sdies, within study area)	0
5. number of people (your side, within study area)	0
Tidiness	
1. pavement condition (your side, within study area) rating	0.6
2. debris condition (your side, within study area) rating	0.4
3. overhead utilities (both sides, within study area) (y/n)	Y
4. landscape condition (your side, within study area) rating	0.2
Linkage	
1. Street Connections to elsewhere (#)	2
2. Visible Doors (#)	4
3. Proportion recessed doors	1
4.Common Building Heights (y/n)	Y
4.Outdoor dining (y/n)	N
Coherence	
1. Pedestrians (#)	3
2. Pedestrian-scale streetlights (#)	0
3. Common Window Proportions (y/n)	Y
4.Common spacing and type (y/n)	N

Video 03	
	Recorded Value
Imageability	
1. number of courtyards, plazas, and parks (both sides, within study area)	0
2. number of major landscape features (both sides, beyond study area)	0
3. proportion historic building frontage (both sides, within study area)	0.5
4. number of buildings with identifiers (both sides, within study area)	4
5. number of buildings with non-rectangular shapes (both sides, within study area)	2
6. presence of outdoor dining (your side, within study area)	N
7. number of people (your side, within study area)	9
8. noise level (both sides, within study area)	4
Legibility	
1. Memorable Architecture (y/n)	Y
2. Terminated Vista (y/n)	Y
3. Buildings with Identifiers (#)	2
4. Common spacing and type (y/n)	Y
5. Public Art (#)	0
6. Place /Building /Business signs (#)	8
Enclosure	
1. number of long sight lines (both sides, beyond study area)	1
2a. proportion street wall (your side, beyond study area)	0.9
2b. proportion street wall (opposite side, beyond study area)	0.7
3a. proportion sky (ahead, beyond study area)	0.5
Human Scale	
1. number of long sight lines (both sides, beyond study area)	1
2. proportion windows at street level (your side, within study area)	0.8
3. average building heights (your side, within study area)	15
4. number of small planters (your side, within study area)	0
5. number of pieces of street furniture and other street items (your side, within study area)	3
Transparency	
1. proportion windows at street level (your side, within study area)	0.8
2. proportion street wall (your side, beyond study area)	0.2
3. proportion active uses (your side, within study area)	0.6
Complexity	
1. number of buildings (both sides, beyond study area)	4
2a. number of basic building colors (both sides, beyond study area)	2
2b. number of accent colors (both sides, beyond study area)	1
3. presence of outdoor dining (your side, within study area)	N
4. number of pieces of public art (both sdies, within study area)	0
5. number of people (your side, within study area)	9
Tidiness	
1. pavement condition (your side, within study area) rating	0.8
2. debris condition (your side, within study area) rating	0.3
3. overhead utilities (both sides, within study area) (y/n)	Y
4. landscape condition (your side, within study area) rating	0.05
Linkage	
1. Street Connections to elsewhere (#)	2
2. Visible Doors (#)	6
3. Proportion recessed doors	2
4.Common Building Heights (y/n)	Y
4.Outdoor dining (y/n)	N
Coherence	
1. Pedestrians (#)	4
2. Pedestrian-scale streetlights (#)	0
3. Common Window Proportions (y/n)	Y
4.Common spacing and type (y/n)	Y

Video 04	
	Recorded Value
Imageability	
1. number of courtyards, plazas, and parks (both sides, within study area)	0
2. number of major landscape features (both sides, beyond study area)	0
3. proportion historic building frontage (both sides, within study area)	0.1
4. number of buildings with identifiers (both sides, within study area)	4
5. number of buildings with non-rectangular shapes (both sides, within study area)	1
6. presence of outdoor dining (your side, within study area)	N
7. number of people (your side, within study area)	13
8. noise level (both sides, within study area)	4
Legibility	
1. Memorable Architecture (y/n)	N
2. Terminated Vista (y/n)	N
3. Buildings with Identifiers (#)	Y
4. Common spacing and type (y/n)	N
5. Public Art (#)	0
6. Place /Building /Business signs (#)	17
Enclosure	
1. number of long sight lines (both sides, beyond study area)	2
2a. proportion street wall (your side, beyond study area)	0.6
2b. proportion street wall (opposite side, beyond study area)	0.7
3a. proportion sky (ahead, beyond study area)	0.3
Human Scale	
1. number of long sight lines (both sides, beyond study area)	2
2. proportion windows at street level (your side, within study area)	0.8
3. average building heights (your side, within study area)	15
4. number of small planters (your side, within study area)	0
5. number of pieces of street furniture and other street items (your side, within study area)	4
Transparency	
1. proportion windows at street level (your side, within study area)	0.8
2. proportion street wall (your side, beyond study area)	0.2
3. proportion active uses (your side, within study area)	0.9
Complexity	
1. number of buildings (both sides, beyond study area)	5
2a. number of basic building colors (both sides, beyond study area)	3
2b. number of accent colors (both sides, beyond study area)	2
3. presence of outdoor dining (your side, within study area)	N
4. number of pieces of public art (both sdies, within study area)	0
5. number of people (your side, within study area)	13
Tidiness	
1. pavement condition (your side, within study area) rating	0.7
2. debris condition (your side, within study area) rating	0.4
3. overhead utilities (both sides, within study area) (y/n)	Y
4. landscape condition (your side, within study area) rating	0.05
Linkage	
1. Street Connections to elsewhere (#)	3
2. Visible Doors (#)	9
3. Proportion recessed doors	2
4.Common Building Heights (y/n)	Y
4.Outdoor dining (y/n)	N
Coherence	
1. Pedestrians (#)	13
2. Pedestrian-scale streetlights (#)	0
3. Common Window Proportions (y/n)	Y
4.Common spacing and type (y/n)	N

Video 05	
	Recorded Value
Imageability	
1. number of courtyards, plazas, and parks (both sides, within study area)	0
2. number of major landscape features (both sides, beyond study area)	0
3. proportion historic building frontage (both sides, within study area)	0.2
4. number of buildings with identifiers (both sides, within study area)	4
5. number of buildings with non-rectangular shapes (both sides, within study area)	2
6. presence of outdoor dining (your side, within study area)	0
7. number of people (your side, within study area)	7
8. noise level (both sides, within study area)	3
Legibility	
1. Memorable Architecture (y/n)	N
2. Terminated Vista (y/n)	N
3. Buildings with Identifiers (#)	2
4. Common spacing and type (y/n)	N
5. Public Art (#)	0
6. Place /Building /Business signs (#)	13
Enclosure	
1. number of long sight lines (both sides, beyond study area)	2
2a. proportion street wall (your side, beyond study area)	0.4
2b. proportion street wall (opposite side, beyond study area)	0.3
3a. proportion sky (ahead, beyond study area)	0.4
Human Scale	
1. number of long sight lines (both sides, beyond study area)	2
2. proportion windows at street level (your side, within study area)	0.7
3. average building heights (your side, within study area)	15
4. number of small planters (your side, within study area)	0
5. number of pieces of street furniture and other street items (your side, within study area)	1
Transparency	
1. proportion windows at street level (your side, within study area)	0.7
2. proportion street wall (your side, beyond study area)	0.2
3. proportion active uses (your side, within study area)	0.6
Complexity	
1. number of buildings (both sides, beyond study area)	5
2a. number of basic building colors (both sides, beyond study area)	3
2b. number of accent colors (both sides, beyond study area)	2
3. presence of outdoor dining (your side, within study area)	0
4. number of pieces of public art (both sdies, within study area)	0
5. number of people (your side, within study area)	7
Tidiness	
1. pavement condition (your side, within study area) rating	0.9
2. debris condition (your side, within study area) rating	0.1
3. overhead utilities (both sides, within study area) (y/n)	1
4. landscape condition (your side, within study area) rating	0.05
Linkage	
1. Street Connections to elsewhere (#)	5
2. Visible Doors (#)	9
3. Proportion recessed doors	2
4.Common Building Heights (y/n)	Y
4.Outdoor dining (y/n)	N
Coherence	
1. Pedestrians (#)	7
2. Pedestrian-scale streetlights (#)	0
3. Common Window Proportions (y/n)	N
4.Common spacing and type (y/n)	N