Ain Shams University
Egypt

Towards an Optimized Street Design for Walkability: Developing a Framework for a More Efficient Street Design Process in Egypt

A Thesis submitted in the Partial Fulfillment for the Requirement of the Degree

of Master of Science in Integrated Urbanism and Sustainable Design

by

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Acknowledgment

الْحَمْدُ لِلَّهِ حَمْدًا كَثِيرًا طَيِّبًا مُبَارَكًا فِيهِ

Praise be to Allah, much good and blessed praise.

For my mother, the strongest woman in the world.
Hi, “Mama”. I hope I made you proud.
For my siblings/kids; Rola, Kareem, Maya
For Yara, this beautiful girl who somehow was supportive and enthusiast about me getting this MSc. Degree more than I ever was.

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Sa’eed Helal

Ibrahim Ezz

For me.

Abstract

The roads networks upgrading strategies have gained major focus in the Egyptian government's agenda; many major projects have been constructed since 2016. Although there's plenty of experts & scientific knowledge regarding the livability of urban streets and specifically the walkability as a main quality, in most of these projects, the streets are dealt with as vehicular connection axes and the human aspect is ignored. This indicate an obvious gap between the academic researches and field practice. Hence, this thesis aims towards having a more efficient street design process for walkability, through developing an objectiveapproach framework that benefits from the large body of academic research and translates it into field practice guidelines.

To attain this objective, the structure of the thesis starts by building a theoretical background through a literature review of many studies that addressed the relationships between the built environment setting and the user's walking needs then concluding it by constructing a model that illustrates the significant data. This model is then used in field application on a case study in order to explore the benefits of having an objectivebased frame-work for the efficiency of the street design process. Since the model was concluded mainly from studies done in different contexts, it had to be validated for application; contextualized for the case study area environment and, more importantly, users which was done through holding a field survey among users and the results were used to tailor the model accordingly. Lastly, a comparative analysis was drawn between the introduced framework and previous work on the same study area in order to point out benefits, weaknesses and future vision for incorporating the introduced methods in the conventional street design process in Egypt.

The results suggest that the adopted objective framework shows very promising results towards a more efficient street design process. It provides a more precise site mapping procedures through focusing on specific built environment parameters. Additionally, it eliminates the subjectivity in identifying the issues through following a systematic scoring system. Lastly, by relying mainly on quantitative data collection & analysis methods, it paves the way for potential evolution in the urban design tools & methods by being able to benefit from computational tools like optimization algorithms to explore much larger number of different solutions than it can be achieved through the conventional street design process.

Thesis Contents

Acronyms

BE	Built environment
CI	Composite indicator
CWI	Composite walkability index
CWNI	Composite walkability needs indices
HBELP	Hierarchical built environment list of parameters
NEWS	Neighborhood environment walkability scale
WN	Walkability need
AHP	Analytical hierarchy process
UDQ	Urban design quality

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Chapter 1:Introduction

Walkability is recognized as one of the crucial qualities in any urban street design. Walkability of a street has many definitions but generally, it is described as the extent to which walking is an accessible, safe, connected as well as pleasant mode of transportation (Turner, Singh, & Albey, 2011). It has been a rising topic of research since the 1960s as researchers started to discuss the implications of car-oriented planning that resulted in the creating 'automotive cities'* on the social aspect (Jacobs, 1961; Norton, 2008; Alexander, Silverstein, Ishikawa, Jacobson, & Shlomo, 1977; Rowe & Koetter, 1978; Trancik, 1986; Kashef, 2011) and personal health of people (Barnett & Cerin, 2017; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Grasser, Dyck, Titze, & Stronegger, 2013; McCormack & Shiell, 2011; Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018). Since then, a major shift in planning strategies started to take place by incorporating concepts like human-centered urban design (Wen & Wallace, 2019; Al Maghraoui, Vallet, Puchinger, & Yannou, 2017), place making (Jacobs, 1961; Project for Public Spaces, 2007) and other concepts that focuses on the human more than the vehicle in the design thinking process.

Unlike some other qualities of the urban street design, walkability is a multi-level quality; it cannot be assessed or enhanced through straight forward methods that

* The notion of automotive cities describes the cities that promotes private modes of transportation as a result of the built environment design strategies (Norton, 2008; Clapton, 2005).

can be generalized to alter any built environment to become more walkable for the people (Lo, 2009; Alfonzo, 2005; Mehta, 2008; Hinckson, Smith, & Bozovic, 2020) but it requires deep analysis because it's affected by the whole socio-economic structure of the user through which he decides whether a street achieves his basic needs for walking (Alfonzo, 2005; Ewing, Clemente, Handy, Brownson, & Winston, 2005; Ewing, Handy, Brownson, & Tian, 2009; Forsyth, 2015; Sallis, 2009). However, today's urban street design processes tend to have walkability assessment & enhancement frameworks, guidelines or manuals in order to help both the designers and decision makers to reach an accurate street design assessment as well as having insights about the effect of the design decisions on the users (for example see (Kansas City Departments of Planning and Development and Public Works, 2015; Abu Dhabi Urban Planning Council, 2013; Rockefeller Foundation, n.d.; وزارة الشئون البلدية و القروية, 2005)). What determines the accuracy of any walkability-related framework is how clearly it constructs the link between the built environment and the users' walkability needs (Alfonzo, 2005; Forsyth, 2015; Mehta, 2008).

These frameworks can be categorized into two groups according to the type of data collection followed in each. Firstly, and the most common, are the perceptual frameworks that focus mainly on capturing the human perception towards the built environment through qualitative data collection methods then analyzing this data and using it to assess the street design; in order to identify issues and propose solutions (for example see (Adams, Frank, & Norman, 2009; Ball, Bauman, Leslie, & Owen, 2001; Kerr, et al., 2016; Barnett & Cerin, 2017; Cerin & Barnett, 2019)). On the other side, objective frameworks are rising as well in which researchers are trying – through different methodologies - to operationalize walkability; to dismantle the walkability of a street into the built environment parameters that affect it so that objective measurements for these parameters can be used as indicators to determine how walkable a street is for its users (for example see (Deng, et al., 2020; Ewing, Clemente, Handy, Brownson, & Winston, 2005; Ewing, Handy, Brownson, & Tian, 2009; Grasser, Dyck, Titze, & Stronegger, 2013; Hinckson, Smith, & Bozovic, 2020; McCormack & Shiell, 2011)).

In Egypt, there's an obvious gap between the academic research and field practice, planning & applications regarding this topic. Previous researches asserted the importance of treating the urban streets in the design processes as livable spaces that should promote community interaction and place making qualities among which is the walkability of the streets (Shedeed, 1998; EL Serafi, 2019; Ibraheem & Alattar, 2017; Ahmed, Elshater, & Afifi, 2019). However, when reviewing the Egyptian code for urban and rural streets works (the main reference for any road engineer for the street design process in Egypt); the lack in any regulations or guidelines for the people's rights in the street design is clearly noticed (مركز بحوث الإسكان و البناء, 1998).

The reason behind this is, designing for people (for example, the integrated urban design approach) requires relatively longer process when compared to just providing infrastructure for vehicular movement which is the case in Egypt. Furthermore, with the fast pace that the roads network development & upgrading projects are required to be achieved in Egypt to meet certain national plans (for example see (The Cabinet of ministers , 2020)); the decision makers do not have the tolerance in time or resources for the designers to benefit from the previous scientific researches to design walkable streets for people.

Additionally, there's a lack of any significant role for the local administrative in districts regarding these projects. As a result, during the development or upgrading plans, the streets are dealt with as vehicular movement connection axes on an urban planning scale while the pedestrian aspect is almost ignored. This shows the need for a more efficient urban street design process regarding the time and resources needed for assessment as well as proposing inclusive solutions that achieves the macro-scale roads network upgrading plans while providing an adequate walkable streets for the people.

1.1. Research objectives

This thesis is fed by two different, but sequential approaches. Firstly a theoretical framework is developed out of the existing scientific literature that studied the relationships between the built environment and users' walkability needs. This aims to construct a model illustrating a list of all BE parameters (that gained a general consensus to be the most associated with walkability) and how they are linked to the basic walkability needs of the street users. [Refer to Chapter 3]

The second main objective is to use this model as the core to explore, based on a field case study, the benefits of having an objective framework (focused on the physical aspect of the street design for walkability enhancement) on the efficiency of the conventional urban streets design process in Egypt. [Refer to Chapter 7]

In order to attain these two objectives, the thesis aims to address some other research objectives:

- Understanding the socio-economic structure (the complexity of walkability): Although the scope of this research is the physical aspect of the street, the link between the physical aspect and the human perception should be clear to avoid having a meaningless objective framework that does not reflect the real needs of people. [Refer to Chapter 2]
- Tailoring the model for the users: The output model according to the first objective is built based on conclusions of international researches with different contexts. So to be able to use it on a case study in Egypt, the model should be verified for application on the case study context and modified according to the users' socio-economic background. [Refer to Chapter 6]
- Utilizing computational methods: The objective framework provides some room for relatively unconventional methods to be utilized in the street design process. So contributing to the aim of reaching a more efficient process; the beneficiality of utilizing computational tools is explored during the empirical implementation. [Refer to Chapter 7: Step 3]
- Constructing composite walkability needs indicators: This method is borrowed from economics & statistics studies and utilized in this research to build the link; for translating the type of data between the walkability needs model (which outputs urban-studies related data) and the computational tools that only deal with numbers and mathematical relations. [Refer to Chapter 4]

1.2. Research questions

The process of designing walkable streets is a wide topic of research to address and this thesis includes multiple different sub-topics along the way towards achieving the main objective which is trying to reach a more efficient street design process for walkability. That's why a clear set of questions that this thesis aims to address has to be pre-identified to guide this research.

Part I:

- Which parameters evolve out of the street design physical aspect as the main built environment parameters affecting the walkability of a street setting or design?

- What are the main street design qualities that should be provided in order to satisfy the basic walkability needs of the users?
- Which of the basic walkability needs does each of the identified built environment parameters affect in both direct and indirect ways?
- How to assess the walkability needs of the street as well as overall walkability through field measurements of the built environment parameters?

Part II:

- How does the model for the basic users' walkability needs and built environment parameters that fit the socio-economic background of the users in the case study area?
- How can the model be used on the case study to assess the current situation and propose solutions?
- How to utilize the optimization algorithms as a tool to propose solutions for the street design?
- How the introduced framework is compared to the conventional process in terms of methods, outputs and process efficiency?

1.3. Study scale & scope

There are multiple scales for designing walkable streets, so in order to set the focus of this thesis, the scale and scope should be clearly pre-defined to guide the research as follows:

A. Street type: Walking and Streets each has different types individually and also different types combined; this research focuses on walking in public mixed-used streets as they are the main veins of city life (Jacobs, 1961) while in the same time are the most deteriorated or uninviting for walking.
B. Street aspect: It's highlighted previously that the needs of a pedestrian user are subjective to a full socio-economic model related to the surrounding context with three main aspects (Alfonzo, 2005; Mehta, 2008):

- The physical aspect of the street; meaning the surrounding built environment (BE).
- The socio-economic aspect; that relates to the background, the mindset of the person as an individual and also the surrounding community.

▪ The environmental aspect; which is the micro climate of the street or district.

This study focuses mainly on the design of the street; the physical aspect of the environment, but it is explained how it reflects in other aspects.

C. The study area scale: There're multiple scales to study walkability on; it can be studied on the scale of a city, a neighborhood, a district, multiple districts and so on. This study focuses on the smallest scale; which is the street scale.

1.4. Study methodology

As a general overview (Fig.1), this is an application led thesis based mostly on the empirical case study approach to build an understanding of the benefits of having an objective framework for walkability enhancement on the efficiency of the conventional urban streets assessment & upgrading process in Egypt. But firstly, a theoretical background is built through a cross-sectional literature review of scientific publications, studies and empirical work that explored the basic walkability needs, the relationship between the built environment & the street design walkability and the relationship between the built environment parameters & the users' needs for walking. Then few studies were used as the main references in order to construct the model of walkability needs and built environment parameters which concludes (Part I) of the thesis.

Then the empirical part of the thesis (Part II) starts by a miniature verification of the constructed model for application on the case study area which was done through holding a field survey, online questionnaire and observations among the users. The results were then used to refine the constructed model previously for the users in the study area so that it is applicable to be used in following steps.

The second part of the empirical part is focused on the methodology of using the constructed model as a part of an objective framework to assess and propose alterations to enhance the walkability in the study area. Then a comparative analysis is done between the methods used for assessment & proposing solutions in this thesis and previous scientific research published by the ministry of housing that aimed to assess and enhance walkability in the same study area. Lastly, a conclusion is drawn about the benefits and weaknesses of the introduced framework to set future vision for this stream of research development. It's important to mention that the focus of the case study are few steps within the whole street design process (methods and tools) not the design output itself.

The detailed description of methodology followed in each step in both sections of the thesis is discussed in its related chapter as follows:

Part I:

- The walkability needs model construction methodology is discussed in chapter 3.
- The methods followed for constructing composite walkability needs indices is discussed in chapter 4.

Part II:

- The detailed methodology for the case study is discussed in chapter 5 including the site survey methodology & the framework application.

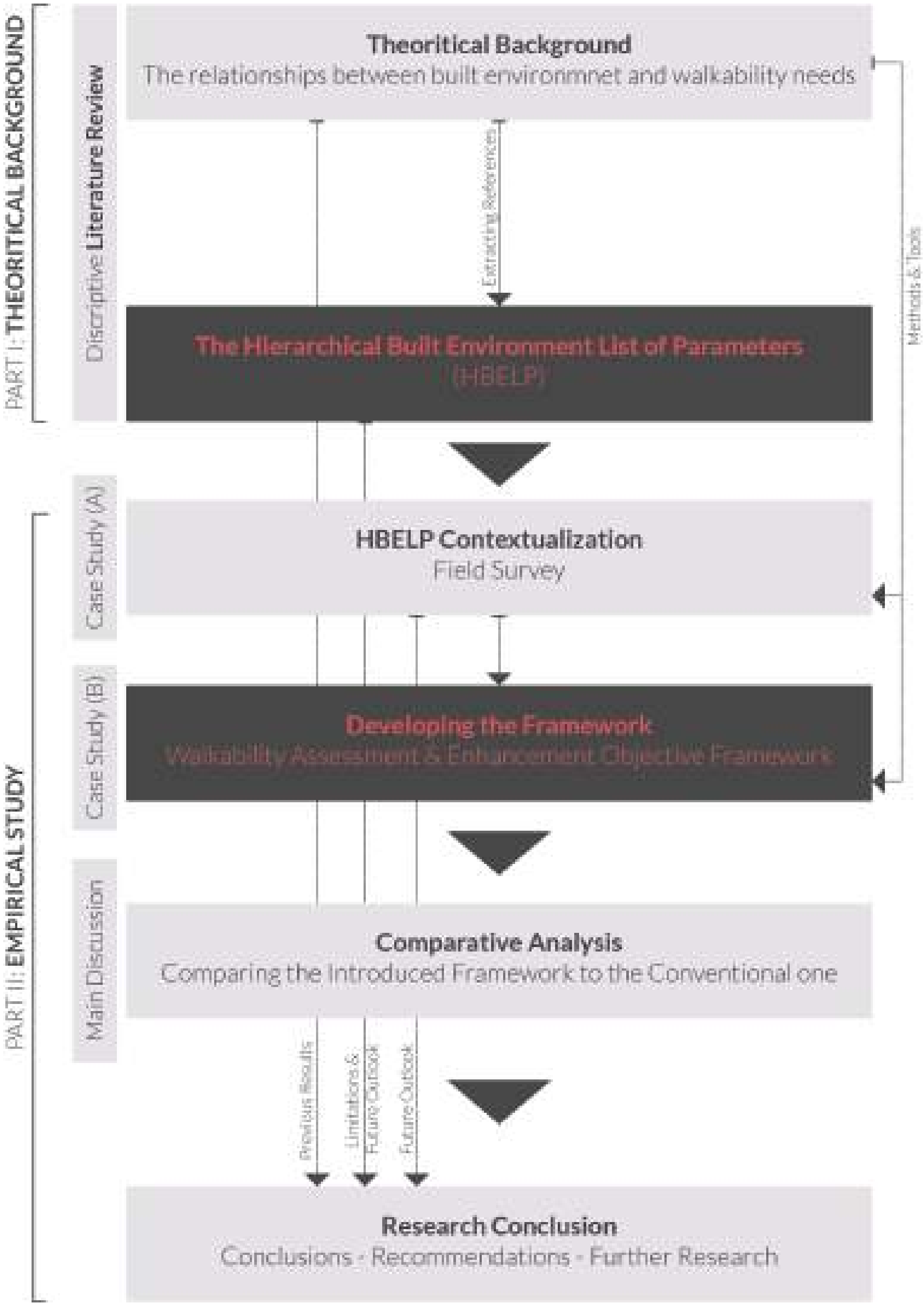

Fig.1 Overall Research Methdology, author

Part I

Chapter 2:Built environment and walking behavior

Identifying the relationships between the built environment and walkability has been the topic of a wide body of research in the past few decades. It has been studied across different disciplines as well as different scales and as a result; it has been studied through multiple different approaches. Till the date of this research, there isn't one specific model (defining the relationships between the built environment and walkability) that gained general consensus among academics or field practitioners in walkability-related projects. However, some elements of the built environment have been redundant in the results of studies to be associated with walkability.

This chapter articulates the results of some researches that discussed the relationship between built environment and walkability. Kashef (2011) categorized the body of literature, in a convenient way; under two major categories: the first part reviews studies from health fields while the second one reviews studies from urban design/planning and transportation fields because these are the two main fields with large body of research related to the topic.

Furthermore, in each part the two categories, two points are noted in the reviewed studies. Firstly the elements within the studies focus; studies that focused only on BE parameters, urban design qualities, walkability needs or undistinguished group of elements. Secondly, the scale of the studies; like city, district or neighborhood and street scales. These two points are important because they help positioning this thesis among the body of literature in chapter 3. It should be mentioned that this categorization is not mutually exclusive; there are lots of points that overlap across categories and this is just presented as an organizational framework for the literature addressed below. Lastly in this chapter, data synthesis section illustrates the conclusion of this literature review and links to the following chapters of the thesis.

2.1. Health-related studies

Walkability as a general topic has been studied extensively in human health-related studies. Some researchers dealt with it as a sort of activity or active living style and just related it to the health of the people who walk or don't (for example see (Morris & Hardman, 2012; Duncan, Gordon, & Scott, 1991; Rippe, Ward, Porcari, & Freedson, 1988; Gilson, McKennaa, Cooke, & Brown, 2007; Howell, Tu, Moineddin, Chu, & Booth, 2019)). Other studies – which are more related to the scope of this research - focused on the relationship between the built environment and walkability; trying to understand the factors, elements, qualities or parameters that make any urban space more walkable than the other.

In 2017, (Barnett & Cerin) conducted a large meta-analysis that aimed to identify correlations between the built environment elements and older adults' overall physical activity through reviewing and quantifying one hundred peer-review and grey literature on this topic. The results were then meta-analyzed and weighted by article quality and sample to reach final findings. The results showed strong correlations with some elements like street walkability, safety from crime, destination diversity, existence of recreational facilities, walk-friendly infrastructure, etc… This study showed sound results towards building an understanding about what elements in the built environment affects the activity of users.

One other meta-analysis was held in the same year as a further analysis for the same topic. Relatively similar results for correlations between active living and some BE elements; street walkability, residential density and access to public transportation. Additionally, results suggested correlations to other elements like destination diversity, streets connectivity on an urban planning scale, presence of other people walking (which is not related to the BE environment) (Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017). It should be noted that the two previous studies provide important data due to the wide range of researches meta-analyzed to reach these results and the difficulty in comparing data across studies due to the inconsistency in defining walkability itself in addition to BE parameters, elements, urban qualities and walkability needs.

Adlakha D., et al (2017) tried to be more focused on the BE parameters them-selves. They conducted a study that aimed to explore the correlations between some elements (residential density, land use mix-diversity, land use mix-access, street connectivity, infrastructure for walking and bicycling, aesthetics, traffic safety, and safety from crime) and the physical active living in India. These elements are mostly BE parameters that can be directly measured and for the few elements that are not, they used the Neighborhood Environment Walkability Scale (NEWS) to measure the indirectly measurable elements. NEWS offers measurement methods for these elements [refer to chapter 3].

A more inclusive model was constructed by (Rhodes, Courneya, Blanchard, & Plotnikoff) as they integrated personality, urban planning and perceived environment into one model of planned behavior (TPB) framework. The research included many measurements for personal traits, neighborhood design in general (architecture language, aesthetics, etc...) and users' attitude towards physical activity for leisure. They worked with a sample of 358 adults to self-report walking behavior multiple times with the aim of being able to predict the users' behavior in leisure time walking. Results showed that mixed-usage of land uses, the design elements generally of the neighborhood and aesthetics affects the users' attitude towards physical activity which interprets to them making the decision whether to walk (Rhodes, Courneya, Blanchard, & Plotnikoff, 2007).

The body of research in health-related studies is much larger than that mentioned but the ones illustrated previously show an example of the approaches and focus of these studies. Health-related studies had sound findings for the correlations between some BE elements (in general) and walkability but they were mostly based on subjectivity of the people (due to the methods of conducting the studies like self-reporting of behavior, questionnaire, interviews, etc...; meaning that the results were mostly based on the respondents perception towards the surrounding environment and the researchers kept it that way (qualitative correlations) without further development.

Furthermore, the conclusions of studies show some confusion in the mere understanding of the term walkability itself among researchers. For example some studies dealt with walkability as one of the urban qualities that the street provides, equally deep with other BE parameters like existence of facilities and access transportation and walkability needs like sense of safety from crime, feasibility of walking, etc… (For example see (Barnett & Cerin, 2017; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Duncan, Gordon, & Scott, 1991; Frank, Engelke, Schmid, & Killingsworth, 2003)). Others dealt with it as a major quality that includes some BE parameters underneath which were mostly the studies that relied on NEWS for assessing the walkability (for example see (Adlakha, Hipp, & Brownson, 2016; Adlakha D. , et al., 2017)).

Additionally, for the studies that identified walkability as a higher quality than other BE elements, it is noticed that their results are all listed altogether as an uncategorized combination of BE parameters (which are elements that the designer can control directly in a design) like destination diversity along with elements that depend on the users' perception to the built environment; that are not directly controlled in a design process like sense of safety from crime (for example see (Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Kashef, 2011)).

As a result, the only point of consensus among health-related studies is that the street design (or the surrounding urban space) does affect the opportunity for walkability (Kashef, 2011); the street design has the potential of affecting the people's decision to walk. However, due to the un-specifications when dealing with BE elements in general in the studies, they were not able to reach a solid model for how does each of the BE parameters affect walkability. Furthermore, there would be some confusion if the results are to be used in further field applications due to the non-discrimination between BE physical parameters, urban qualities of the street and walkability needs for the users, instead dealing with them all as 'elements' that affect walkability.

2.2. Urban design/planning studies

Urban-related studies had some different approaches and outputs. Southworth (2005) tackled walkability on a city scale; his results suggests that the strategy and concepts by which the city is designed can promote walkability among users. Based on a wide review of related studies; he listed six main criteria that should be followed to be able to design a walkable city. These criteria are connectivity, linkage with other modes, fine grained land use patterns, safety, quality of path and path context. In 2018, (Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack) had similar results related to the association between walkability and street network connectivity on scale of districts as well as other studies (McCormack & Shiell, 2011) while the results of the later also suggests associations between walkability and other parameters; land-use mix, population density and overall neighborhood design.

Relating to a smaller scale of studies but with relatively similar aim; Ewing and Cervero (2010) conducted a meta-analysis with the goal of building a generalized understanding of the relationships between built environment and travel modes within cities in order to reach results that help in proposing designs towards promoting less vehicular usage. As for the methodology, they used the D variables to measure the built environment which are six elements developed through three different studies and are used as indicators for the built environment. They are density, diversity, design (Cervero & Kockelman, 1997), destination accessibility and distance to transit (Cervero, 2001) and demand management which is not related to the scope of urban studies. The results suggested associations between travel modes and both land-use mix and street network connectivity. However, the results were context-based; they provide some useful understanding in general for the relationships between built environment and travel modes but the results are only applicable for the study areas where they conducted their research (Ewing & Cervero, 2010).

Multiple urban- related researches asserted that studying the associations between walkability and BE only through the eyes of urban studies is not enough; instead further studies need to be conducted through interdisciplinary approaches like transportation planning, road engineering, public health landscape architecture so that a synergy between all disciplines related to studying walkability can be achieved in order to build a more holistic & inclusive understanding of the relationship between walkability and built environment (Southworth, 2005; Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018).

Multiple points are noted from the studies related to this topic. Firstly, many studies that aimed to study the relationships, associations or correlations between the BE elements and walkability start with a hypothesis that specific elements might be related to walkability then the study is based on it. Although reaching sound results, studying walkability through examining the elements separately as independent indicators might leads to over simplistic or incomplete model; it might produce parts and bits of a puzzle but the holistic image would not be there (Abley, Turner, & Singh, 2011; Alfonzo, 2005; Mehta, 2008).

Additionally, the methods used in lots of studies mostly depend on interviews, questionnaires or any sort of consciously-collected information from the people (Hinckson, Smith, & Bozovic, 2020). This contradicts with the basic fact that many of the decisions the human mind makes are done subconsciously (Maslow, 1943; Maslow, 1954) which also applies to the decisions made according to the people's perception towards the surrounding built environment (Alfonzo, 2005; Mehta, 2008). That means that the results of these studies may not reflect the real decisions or perceptions of people towards the BE, resulting in misleading models constructed. Instead, observations as a method for collecting information shows more solid results (Ewing, Clemente, Handy, Brownson, & Winston, 2005; Ewing, Handy, Brownson, Clemente, & Winston, 2006; Ewing, Handy, Brownson, & Tian, 2009).

Furthermore, walkability can be studied on many different scales (Alfonzo, 2005; Mehta, 2008; Ewing & Cervero, 2010; Ewing, Clemente, Handy, Brownson, & Winston, 2005). However, many of the studies conducted (mostly in health-related studies) did not mention the scale of studying walkability, instead they were just focused on the sample size in order to have accurate results which is convenient given the type of output they're looking for but it might lead to misinterpretation if the results are used in design applications.

In contrast, most urban-related studies mentioned the scale of focus in the premises of their researches. However, they mostly focus on relatively macro scale that addresses urban planners & designers with the aim of providing better designs of cities or districts which is clear in the BE elements under studies like street network connectivity, availability of recreational areas, provision of parks and green areas, etc.... Fewer studies tackled the walkability on the human scale; the street scale. Studies suggest that the reason behind this is; studying walkability from the person's point of view can be much more complex as at this level it's totally subjective to the human perception (Alfonzo, 2005; Ewing, Clemente, Handy, Brownson, & Winston, 2005; Mehta, 2008; Tawfik, 2017) which makes it tricky to capture and interprete it into models for application. Multiple researchers who contributed to the previous body of research highlighted the need for a better understanding of the approaches through which the BE elements are associated with walkability or walking behavior (Alfonzo, 2005; Forsyth, 2015; Kerr, et al., 2016; McCormack & Shiell, 2011; Kashef, 2011).

2.3. Walkability as a multi-level concept (towards understanding the complexity of walkability)

Most studies mentioned previously had reached sound results that provide evidence for the relationships between the built environment elements and active living (Ewing, Handy, Brownson, Clemente, & Winston, 2006). However, due to the scale of the studies, as mentioned previously, many of them focused either partially or totally on gross qualities such as average walking distances to amenities, percentage of green areas, neighborhood density (for example see (Car, Dunsiger, & Marcus, 2010; Abley, Turner, & Singh, 2011; Cerin & Barnett, 2019)) without exploring how these qualities reflect the people's real needs for walking. Recent tools even interpreted these results for application to assess walkability of streets on a micro scale (Walk Score Methodology, n.d.).

Urban designers & sociologists refer to a higher level qualities that they think are more determinant for the active living and walkability; they are referred to as urban street qualities in some studies (Ewing & Cervero, 2010; Adams, Frank, & Norman, 2009; Tawfik, 2017) or walkability needs in other studies (Alfonzo, 2005; Mehta, 2008; Moayedib, et al., 2013). Either ways, this indicates that walkability is a multi-level notion that cannot be directly dismantled or abstracted into BE parameters.

In 2005, (Alfonzo) presented a theoretical scientific framework for a socio-economic model that is considered by many studies a breakthrough in the realm of building an understanding for the relationships between the built environment and walkability (Hinckson, Smith, & Bozovic, 2020; Mehta, 2008). The model consists of three main sections that create the link from urban studies to the decision of walking taken by the users which are Antecedents, Moderators and Outputs (Fig.2).

The last section; the outputs are obviously the decision taken by a person whether to walk and the period of time to walk. The first section represents the hierarchy of walkability needs (antecedents); which in concept of representation is similar

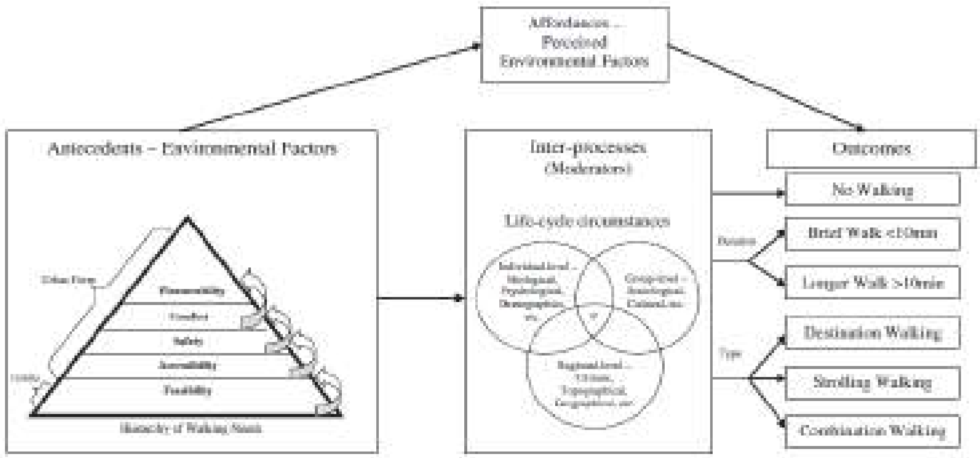

Fig.2 Hierarchy of walkability needs within Socio-Ecological framework, Alfonzo, 2005

to the pyramid of human needs (Maslow, 1943; Maslow, 1954) but instead of discussing overall needs for the people; it discusses the hierarchy of needs for users to walk in a street or any urban space. They represent five main variables that either exist or absent in an urban setting or street in which the decision for walking is made by people. The degree of affordance of these variables in many cases may be the main determinant in the walking decision-making process. Affordance means the set of elements that present to a certain acceptable degree within an environment that allows for occurrence of certain behavior (Gibson, 1977). The five basic walkability needs are organized according to the theoretical hierarchy of importance from the most basic need to the highest as follows: feasibility, accessibility, safety, comfort and pleasurability respectively (Fig.2). Theoretically, the five walkability needs can be considered as qualities that the BE offers for the users (Ewing, Handy, Brownson, Clemente, & Winston, 2006).

Although the pyramid of walkability needs is considered of important impact as it conceptualizes and frames the major aims of the urban spaces or street design, it cannot be used solely because, as discussed previously, the determinant for the level of acceptance of a certain quality or need is the human perception towards it. Since people differ in their degree of affordance for each quality, then the pyramid should be situated within the whole socio-economic structure of the person or group of people under study (Alfonzo, 2005; Mehta, 2008) which is the aim of the second section of the model; the moderators.

The moderators represent the subjectivity in the model towards each user; they include any life-cycle circumstances as an intersection between three levels of elements: individual level elements (biologically, psychologically, etc…), group level elements (community, sociological structure, cultural, etc…) and lastly, the regional level elements (climate, topography, geography, etc…). The combination of these three elements work as moderators that specify the degree of affordance for each of the basic walkability needs and they can lead to modifications in the hierarchy of needs according to each person's moderators degree of effect. As a result of the first two sections in the model, the output decision whether to walk, type of walking (destination, leisure or both) and duration of walking are determined (Alfonzo, 2005; Mehta, 2008).

The significance of Alfonzo's model lies within its provision for a whole socio-economic model that, for the first time, can be used to build a holistic understanding for how the decision of walking is made by people and what determines a specific existing street setting's - or proposed design - level of walkability. However, the model stops at being an important but theoretical framework while further studies are needed if to be interpreted into field applications or design processes framework or guidelines.

Although Alfonzo had set examples for BE parameters that might affect each of the basic walkability needs, the model is missing specifications of design parameters in the BE that affects the five main walkability needs. The issue in this point is the potential lack of consensus on both the definitions and the BE indicators for each of the five needs; meaning that different designers can deal with some BE elements that affect the safety for example while other designer may deal with different BE elements thinking they are the ones affecting the sense of safety; this can result in misleading or inconsistent results. That's why there's a need for a model that expands Alfonzo's sound theoretical background (Alfonzo, 2005) till reaching operational definitions for the walkability needs which links each of them to the corresponding BE parameters so that the model can become of more benefit for design processes which is the topic of the next chapter.

2.4. Summary

This chapter aimed to build a theoretical background through having a cross-sectional literature review of scientific researches that studied the relationships between BE and walka-bility in general. Two fields of researches had a wide body of research related to this topic; health-related studies and urban design/ planning studies. The conclusions of health-related studies show some confusion in the mere understanding of the term walkability itself among researchers as some dealt with it as one of the BE parameters while others identified it as a quality that can be achieved through shaping the BE parameters. As a result, the only point of consensus among health-related studies is that the street design (or the surrounding urban space) does affect the opportunity for walkability; it has the potential of affecting the people's decision to walk.

Urban-related studies had different approaches. Many of these studies relied on consciously collected information from the people as methods for data collection. This contradicts with the basic fact that many of the decisions the human mind makes are done subconsciously. As a result, these results may not reflect the real decisions or perceptions of people towards the BE, resulting in misleading models constructed. Additionally, many of these studies started with a hypothesis that specific elements might be related to walkability. Although the sound results, but studying walkability through examining the elements separately as independent indicators might lead to over simplistic or incomplete model.

Most studies mentioned previously had reached solid results that provide evidence for the relationships between the built environment elements and active living. However, due to the scale of the studies, many of them focused either partially or totally on gross qualities. Urban designers & sociologists refer to a higher level qualities that they think are more determinant for the active living and walkability; they are referred to as urban street qualities in some studies and walkability needs in other studies Either ways, this indicates that walkability is a multi-level notion that cannot be directly dismantled or abstracted into BE parameters.

In 2005, (Alfonzo) presented a theoretical scientific framework for a model that is considered by many studies a breakthrough in the realm of building an understanding for the relationships between the built environment and walkability. The significance of Alfonzo's model lies within its provision for a whole socio-economic model that, for the first time, can be used to build a holistic understanding for how the decision of walking is made by people. However, the model stops at being an important but theoretical framework while further studies are needed if to be interpreted into field applications or design processes framework or guidelines.

Chapter 3:The Hierarchical built environment list of parameters model (HBELP)

Having an operational model for walkability assessment & enhancement field applications or developing walkability indicators have been topics for many researches, studies and experiments (for example see (Moayedib, et al., 2013; Deng, et al., 2020; Reisi, Nadoushan, & Aye, 2019; Cerin & Barnett, 2019; Ewing, Clemente, Handy, Brownson, & Winston, 2005; Ewing, Handy, Brownson, & Tian, 2009; Kerr, et al., 2016)). Numerous cities around the world already have verified models for streets' design assessment and manuals that aims to provide walkable urban streets beyond the step of theoretical or empirical studies through regulations and guidelines followed by urban designers and planners (for example see (Kansas City Departments of Planning and Development and Public Works, 2015; Abu Dhabi Urban Street Design Manual, 2013; وزارة الشـئون البلديـة و القرويـة, 2005)). As mentioned previously, we lack such models, framee works or even guidelines in Egypt (Tawfik, 2017; مركـز بحـوث الإسـكان و البنـاء, 1998; Salama, Fouad, Mohamed, & A.Aziz, 2016).

This chapter discusses, firstly, a literature review of few studies that have reached sound results regarding this topic. The aim of this section is to highlight the approach, methods and results of these studies so that it can be used as a base for following sections rather than serving as a formal literature review. In the second section, there's the methodology description for constructing a model that aims to illustrate a holistic understanding of the links between the pyramidsof walkability needs and specific BE parameters through linking results from multiple studies in literature. Lastly, the output model is presented.

3.1. Operationalizing walkability

A growing body of research has been studying the topic of operationalizing walkability as a variable. A variable refers to a concept, quality, characteristic, etc... that is generic or general. So to operationalize this variable means to set a specific definition as well as procedures to measure it (Park, Choi, & Lee, 2016; Research Methods and Statistics, 2016; Park, 2008).

Many tools are provided via web for walkability measurement/rating. The theoretical background behind these tools is to operationalize walkability by determining some BE parameters related to it then using measurements of these parameters to provide a rating for walkability in a specific street, e.g. walk score. Walk score is one of the leading tools in this category; it's an online tool that the user can enter an address and the output is a rating on a scale for the level of walkability of the street of this address and surrounding few streets as well. However, the methodology behind this scoring depends mainly on average walking distances to amenities in the surrounding area of the given address (Rockefeller Foundation, n.d.). Being totally dependant on a gross qualitym, this disregards many elements that might affect the walkability of such street which is the point of weakness in many of the models or tools being used nowadays related to walkability (Car, Dunsiger, & Marcus, 2010; Cervero, 2001).

Ewing et al. (2005; 2006; 2009) worked on multiple large empirical studies in order to explore this topic deeper with the aim of identifying the urban design qualities of the street design most associated with walkability and then operationalizing these qualities. They were in agreement with the theoretical structure of Alfonzo (2005) that walkability is not directly linked to the BE parameters but the urban design qualities of the street act as moderators and according to the level of satisfaction of these qualities for people, the walking behavior is determined.

The aim of the studies was; firstly, to identify the urban design qualities of the street that affect the decision of walking. Secondly, trying to operationalize these

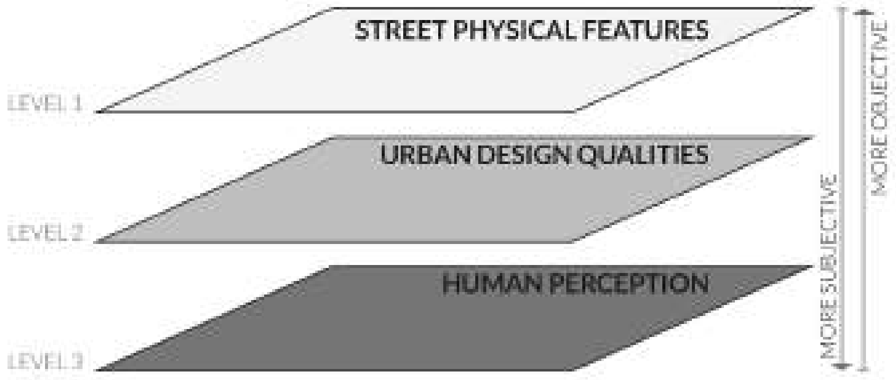

Fig.3 The Concept behind the model of Ewing, et. al, author

qualities; to translate them from being qualitative descriptions of street design elements to objective quantitative measurable elements. To attain these objectives; they explored one more level which is the relationships between each of the urban design qualities and the physical BE parameters of the street design.

Despite being, generally, in agreement with Alfonzo (2005) on the theoretical hypothesis, their approach in the studies was different. Alfonzo had a theoretical hypothesis to start with but Ewing et al. (2005; 2006; 2009) deduced the urban design qualities most associated with walkability, the BE parameters and the relationships among them through field observations for a wide sample of users. Also, they were able to determine corresponding weights derived through statistical methods for the degree of effect of each single BE parameter on the corresponding UDQ.

The significance of Ewing's model (Fig.3) lies within being one of the few that provides a holistic view for the urban design qualities affecting walkability as well as field measurements for specific BE parameters with corresponding weights to give scoring for these qualities. This reaches for a new step which is being able, as a designer, planner or decision maker, to objectively rate specific urban design qualities of the street. However, the model was not complete, they mentioned their incapability to operationalize all the urban design qualities which is the reason why they could not use the model for rating the overall walkability (Ewing, Clemente, Handy, Brownson, & Winston, 2005; Ewing, Handy, Brownson, Clemente, & Winston, 2006; Ewing, Handy, Brownson, & Tian, 2009).

To make the studies' results more efficient for field practice; a manual was published for the successfully operationalized urban design qualities (Ewing, Clemente, Handy, Brownson, & Winston, 2005). It presented a list of all the BE

Fig.4 Ewing's manual for BE measurements and UDQs scoring, Ewing et al (2005; 2006; 2009).

parameters that should be measured, field measurement methods for each BE parameter, which BE parameters affect which urban design qualities of the street setting and lastly, simple mathematical weighting and aggregation method to be able as a designer to rate each of the urban design qualities (Fig.4).

Relating to efficient field practice models, the neighborhood environment walkability scale (NEWS) is one of the leading assessment methods for perceived neighborhood walkability (Fig.5). It operationalizes the perceived neighborhood walkability into eight urban design qualities; residential density, land use-mix, street connectivity, pedestrian infrastructure, aesthetics, traffic safety, Crime safety and perceived distances to amenities. The assessment is done though a questionnaire that the users fill and according to the results, the designer can determine issues or needs within the BE under study (Saelens & Sallis, 2002). Many studies related to this topic have relied on NEWS model for walkability assessment (for example see (Adams, Frank, & Norman, 2009; Adlakha, Hipp, & Brownson, 2016; Cerin & Barnett, 2019)). However, it should be noted that

NEWS is an evaluation tool; meaning it can be used to assess an existing situation subjectively from the users' point of view but cannot be used during the design process of a new urban space or developing an existing one.

In 2017, (Tawfik) tried to construct a model for objective walkability assessment that is applicable to the Egyptian context. Although she didn't proceed to the solutions proposals step, it's one of the few available studies of this kind done on Egyptian context. Tawfik (2017) started by taking the model of Ewing et al. as a reference for both the list of BE parameters and the urban design qualities. She did some profound alterations to the model like removing few parameters (indicators); such as the noise level indicator. Also not depending on subjective experts' opinions to give weighting to each of the parameters & UDQs according to its importance as Ewing et al did (2006) and few other alterations. The output of Tawfik's study is a full model for rating the overall walkability on the street scale that is valid for the Egyptian context and as an application she used in the study to rate 46 of the main streets in Cairo according to her conclusion (Tawfik, 2017).

Many other studies are related to operationalizing walkability, walkability needs or identifying walkability indicators through different methodologies (for example see (Moayedi, Zakaria, Puan, & Klufallah, 2013; Deng, et al., 2020; Reisi, Nadoushan, & Aye, 2019)) but for the scope of this thesis, the ones mentioned previously (Alfonzo, 2005; Ewing, Clemente, Handy, Brownson, & Winston, 2005; Saelens & Sallis, 2002) with few additions from other studies (Hinckson, Smith, & Bozovic, 2020; Tawfik, 2017) are the foundation used in the following sections of this thesis.

The previous references were chosen, as the base of the following chapters in this thesis, due to their significant results in understanding the pyramid walkability needs (Alfonzo, 2005), the operational definitions, measurement methods of the urban design qualities (Ewing, Clemente, Handy, Brownson, & Winston, 2005), provision of a full list of BE parameters associated with walkability as a conclusion of all related studies (Hinckson, Smith, & Bozovic, 2020) and provision of field data measurements of 46 main streets in Greater Cairo (Tawfik, 2017).

The following section describes the data synthesis and methodology used to construct a model that aims to provide a clear representation of the basic walkability needs in addition to their link to the BE parameters that affect each one; towards building a full objective framework for walkability enhancement in following chapters.

Appendix. Neighborhood Environment Walkability Scale–Abbreviated (NEWS–A): IPEN Subscales and Items

Residential density (weighted rating of housing types in neighborhood) How common are…:
- Detached single-family residences
- Townhouses or rows of 1–3-story houses
- Apartments or condos with 1–3 stories
- Apartments or condos with 4–6 stories
- Apartments or condos with 7–12 stories
- Apartments or condos with > 12 stories
- Apartments or condos with > 20 stories

Land use mix–access
- Stores are within easy walking distance of my home.
- There are many places to go within easy walking distance of my home.
- It is easy to walk to a transit stop (bus, train) from my home.

Street connectivity
- The distance between intersections in my neighborhood is usually short (100 yards or less; the length of a football field or less).
- There are many alternative routes for getting from place to place in my neighborhood (I don't have to go the same way every time).

Pedestrian infrastructure
- There are sidewalks on most of the streets in my neighborhood.
- My neighborhood streets are well lit at night.
- Walkers and bikers on the streets in my neighborhood can be easily seen by people in their homes.
- There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.

Aesthetics
- There are trees along the streets in my neighborhood.
- There are many interesting things to look at while walking in my neighborhood.
- There are many attractive natural sights in my neighborhood (such as landscaping, views).
- There are attractive buildings/homes in my neighborhood.

Traffic safety
- There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood.
- The speed of traffic on the street I live on is usually slow (30 mph/50 kph or less).
- Most drivers exceed the posted speed limits while driving in my neighborhood.

Crime safety
- There is a high crime rate in my neighborhood.
- The crime rate in my neighborhood makes it unsafe to go on walks during the day.
- The crime rate in my neighborhood makes it unsafe to go on walks at night.

Perceived distance to local destinations. About how long would it take to walk from your home to the nearest…
- Supermarket
- Other food/grocery, small grocery/convenience, fruit/veg market, bakery, butcher shop
- Post office
- Any school, elementary, other, nursery
- Transit stop
- Any restaurant, fast food, non–fast food, café/coffee place
- Park/other public open space
- Gym/fitness facility, recreation center, swimming pool
- Library
- Video store
- Drug store/pharmacy
- Bookstore
- Other shops and services

Fig.5 NEWS framework, Adams, Frank & Norman, 2009.

3.2. Why constructing HBELP?

Generally, walkability assessment & enhancement frameworks or models can be categorized into two main groups. Firstly, and the most common, are the perceptual frameworks that focus mainly on capturing the human perception towards the built environment through qualitative data collection methods then using these data to assess the street design to identify issues and propose solutions (for example see (Adams, Frank, & Norman, 2009; Ball, Bauman, Leslie, & Owen, 2001; Kerr, et al., 2016; Barnett & Cerin, 2017; Cerin & Barnett, 2019)).

On the other side, objective frameworks are rising as well in which researchers are trying – through different methodologies - to operationalize walkability; meaning to abstract/dismantle the walkability of a street into the built environment elements that affect it so that objective measurements for these parameters can be used as indicators to determine how walkable a street is for its users (for example see (Deng, et al., 2020; Ewing, Clemente, Handy, Brownson, & Winston, 2005; Ewing, Handy, Brownson, & Tian, 2009; Grasser, Dyck, Titze, & Stronegger, 2013; Hinckson, Smith, & Bozovic, 2020; McCormack & Shiell, 2011; Ewing, Handy, Brownson, Clemente, & Winston, 2006)). Qualitative models need longer time & more human resources in information collection and data analysis while quantitative objective models are relatively more efficient but mostly, to date, less accurate in comparison.

As previously mentioned, in Egypt there's a clear gap between the academic research and field practice; there's already plenty of experts and academic studies but, unfortunately, the streets do not reflect this knowledge. Instead, main streets in Egypt (Greater Cairo specifically) do not provide appropriate urban spaces for pedestrians. That's why there's a need for models that construct the missing link between having sound theoretical background and field practice assessment & design processes. Having the socio-economic model (Alfonzo, 2005) can be a sigs nificant addition to that theoretical background but it needs further development in order to be used in field practice. The pyramid of walkability needs should be operationalized by identifying the BE parameters that affect each of these needs then objective measurement method for each should be provided as well. By achieving this; firstly, a more comprehensive socio-economic model is structured and secondly, the model becomes a lot more efficient for field practice, design processes and decision making which is the main goal of this chapter.

The aim of constructing the hierarchical built environment list of parameters (HBELP) is to, eventually, have an objective model that provides a set of data to be utilized for academic studies and mainly for field practice. Importantly, as described in the methodology below, the model is constructed totally from secondary data sources so it is subject to errors due to the difficulty in comparing primary data from these studies (because of the differences in scope, scale, aim and context of each study). However, the model is presented neither to be comprehensive nor used directly in the street design processes or field applications but to raise the conversation about the importance of having such model as a base for a whole objective framework for walkability enhancement and its effect on the efficiency of the street design process for walkability in Egypt.

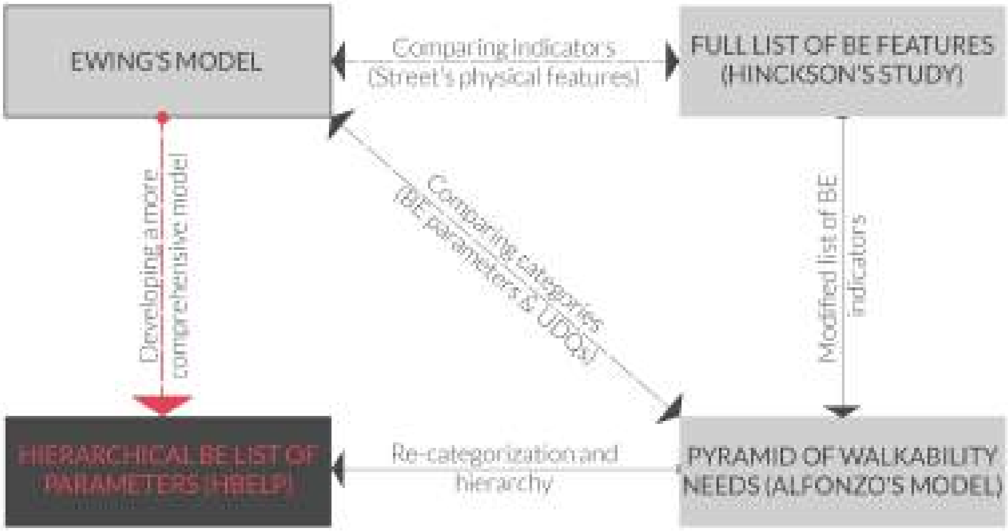

Fig.6 The methodology followed to construct the HBELP model, author.

3.3. HBELP construction methodology

3.3.1. Methodology steps

The methodology followed to construct the model is listed in the form of steps as follows (Fig.6):

- The model of Ewing et al. was taken as the main reference for the list of BE parameters.
- Since their model was incomplete (as mentioned previously, there were few urban design qualities that they could not operationalize) then the BE parameters listed were compared with the full list of BE parameters (results of all previous relatively similar studies) which are listed in the latest review of reviews published in April 2020 (Hinckson, Smith, & Bozovic). The missing parameters from Ewing's were completed from their results. Hence, a full list of all BE parameters was reached.
- Then the pyramid of walking needs (Alfonzo, 2005) was used to categorize the BE parameters according to each parameter effect on each of the basic five walkability needs. NEWS model (Adams, Frank, & Norman, 2009) was also used to gain more insights about the categorization so it's not single referenced to Alfonzo's (2005).
- The categorized BE parameters are then reordered (given hierarchy) according to their importance for overall walkability based on the pyramid of walkability needs (Alfonzo, 2005).

- Lastly, a full text review was done for all the studies tackling this topic listed in the review of reviews (Hinckson, Smith, & Bozovic, 2020) in addition to the three main references (Alfonzo, 2005; Ewing, et. al, 2005; Adams, Frank, & Norman, 2009) with the aim of understanding any potential interconnections between BE parameters, any redundancy in the list of BE parameters and lastly, any cross-connections between parameters and the basic walkability needs (if any parameter affects multiple needs, not just one of them).

3.3.2. Some considerations

Since the full list of BE parameters was completed from Hinckson's meta-analysis study whose aim was only to combine all BE parameters from all studies without cross analyzing these parameters together; then some points needed to be taken into consideration while working with their study results:

Associations: The list had all the BE indicators that are hypothesized to be affecting the overall walkability of a street. Many of the indicators were proved by experiments among studies to be associated to one – or more- of the walkability needs or to overall walkability. However, this wasn't the case in few indicators; as it couldn't be proved that they affect walkability. For example, Salvo (2018) hypothesized that existence of police on the street affects the sense of safety, but he couldn't find any correlations that proved his hypothesis. Also none of the other studies found such relation.

One other indicator is the availability of public toilets. In 2017, (Barnett & Cerin; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett) explored, in both studies, its relation to affecting the sense of comfort during walking but it couldn't be proved through case studies and no other study even mentioned such indicator. Few more indicators had the same issue like retail floor area ratio. All the indicators with the same case as these three were excluded from the final list of BE parameters.

Redundancy: When studying the notion of walkability in general, or the relation between the BE and walkability specifically; the lack of consensus on many terms, indicators, dimensions and definitions is expected. This results in having variety of definitions for each of the BE indicators, the walkability needs and walkability itself when reviewing the literature (Alfonzo, 2005; Ewing, Clemente, Handy, Brownson, & Winston, 2005; Hinckson, Smith, & Bozovic, 2020; Ewing, Handy, Brownson, & Tian, 2009). That's why in the full list provided by

Hinckson (2020), some indicators are either redundant or part of one another. For example, availability of destinations is one of the indicators discussed in four studies (Barnett & Cerin, 2017; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Eisenberg, Vanderbom, & Vasudevan, 2017; McCormack & Shiell, 2011) but when reviewing what it meant in them; it's found that it has almost the same definition of land-use mix which is one of the indicators within the feasibility quality of the street.

The same case happens with other indicators; like 'safety from crime' is already one of the main five qualities of the street. Furthermore, 'Detours', 'incomplete walking infrastructure' and 'crossing facilities' are all covered within 'barriers to walking indicator'. Additionally, 'Possibility to sit' is covered within 'number of street furniture items' and so on. An analytical filtering process was done to cross-check the definitions of the BE indicators with each other to avoid redundancy.

Scale: For the same reasons mentioned previously, every study might have slightly different scale from the others depending on the research team scope for their research. Since the scope of this thesis is to study the street scale, then any indicators that are measuring larger scale elements are excluded from the model; like street connectivity that is related to the accessibility of a specific street to the surrounding urban grid.

Also the scale was considered even in the higher level of the walkability needs themselves. For example, Alfonzo (2005) mentioned that accessibility is related to the destinations & distances, but since this study only focuses on the street scale, the average walking distances & perceived walking distances were not taken into consideration among the BE indicators that affect accessibility and it only focuses on the walking environment indicators; like barriers & obstacles to walking, room for walking and the connected pedestrian infrastructure. The distances indicators (average & perceived) should be taken into account in further development and studies on HBELP by the help of other tools like GIS that can be very beneficial in this sort of study (for example see (Adams, Frank, & Norman, 2009)).

Scope: The scope of this study is the mixed-use main streets with an integration between vehicular and pedestrian movement. That's why any indicators coming from studies with different scope were excluded which only applies to the residential density indicator as it is related to residential neighborhoods (Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Barnett & Cerin, 2017;

McCormack & Shiell, 2011; Grasser, Dyck, Titze, & Stronegger, 2013).

Subjectivity: Some indicators can be too subjective to be considered in such general model. This was the case of only one indicator which is presence of people seen as threat (Cerin & Barnett, 2019; Ewing, Handy, Brownson, & Tian, 2009; Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018), also the scope of this research is the physical aspect of the street aside from other social elements, so this indicator was excluded from the model.

Context: Since all the studies reviewed were done in a relatively different context; Europe, America and Australia which have both different communities and environmental conditions then some indicators that were not found to affect any of the users' walkability needs and the overall walkability in these contexts might be important elements in other parts of the world.

Two indicators were under this category which are protection from the sun (having shading elements) and air pollution. This goes back to one of the core concepts behind the pyramid of human needs; it's not until the minimum needs is met that people start to consider higher needs and if the people are used to higher needs they might not see the basic qualities as needs instead they become facts of life (Maslow, 1943; Maslow, 1954). This can explain why people in the contexts where all the studies were held did not see air pollution for example as an issue or a factor that affects their walking experience because they did not experience high levels of air pollution that can cause diseases like in Cairo for example.

Also due to different geographical location, having a shading element was not considered as a need because high intensity solar radiation is not an issue like in the gulf area or Egypt. That's why these indicators were included in the model because it's hypothesized to have major impact on the comfort level during walking. However, further studies are needed to accurately identify which of the walkability needs they affect and the intensity (weight) of their effect as well.

Lack of consensus: Different studies had different points of view for few indicators; according to which of the walkability needs they affect. So to deal with this, all the studies that mentioned this specific parameter were reviewed to check their context & scale as well as the definition of the parameter to identify which of the studies was more related to this thesis and this identified study was taken as the reference. For example the planting & grass maintenance is one of the BE parameters that was found to affect the overall walkability. In 1998, one of the studies concluded that it affects the sense of safety for residents in urban areas (Kuo, Bacaicoa, & Sullivan, 1998). However, more related studies concluded that it affects a higher level of needs for the users which is pleasurability (Barnett & Cerin, 2017; Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018). Since the latest are more related to this thesis in the theoretical background as well as the scale; then they were taken as references and the parameter was listed in HBELP under pleasurability. Deeper studies are needed to be done on each specific context to identify its effect accurately though.

3.4. The model output

The HBELP model was constructed based on an analytical review of previous literature (secondary data); including theories and studies that discussed the same topic or related ones as discussed previously in the methodology. The model structure consists of:

- The pyramid of walkability needs most associated with walkability (Alfonzo, 2005)
- The full list of all BE parameters most associated with walkability (Ewing, Clemente, Handy, Brownson, & Winston, 2005; Clemente, Ewing, Handy, Brownson, & Winston, 2005; Ewing, Handy, Brownson, Clemente, & Winston, 2006; Ewing, Handy, Brownson, & Tian, 2009; Hinckson, Smith, & Bozovic, 2020; Saelens & Sallis, 2002)
- The links between the first two; the categorization of which BE parameters affect which of the walkability needs (Clemente, Ewing, Handy, Brownson, & Winston, 2005; Hinckson, Smith, & Bozovic, 2020; Adams, Frank, & Norman, 2009).
- Lastly, a table with the list of all BE parameters is included with a short description and field measurement method for each parameter so that the walkability needs are efficiently operationalized.

Fig.7 shows the graphical representation of HBELP. The pyramid of walkability needs includes the five main needs of the walking users which are feasibility, accessibility, safety, comfort and pleasurability ordered from the base of the pyramid (basic needs) up, to the higher levels. On the other side the list of BE parameters includes a total of 26 BE parameters that affect these basic needs. As

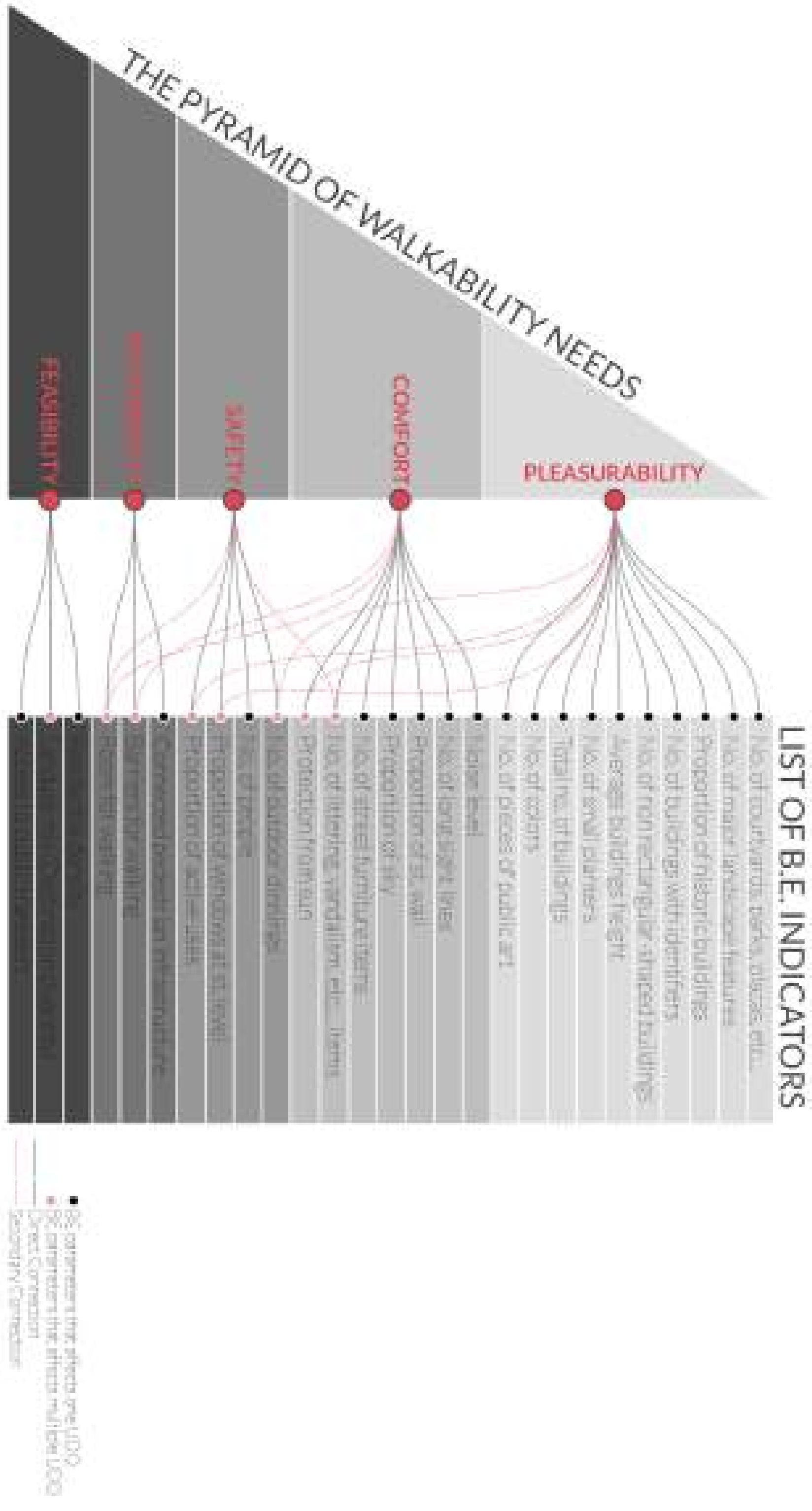

Fig.7 The Hierarchical Built Environment List of Parameters (HBELP), author

mentioned previously, they are categorized according to which BE parameters affect which of the walkability needs.

The feasibility of the street design is the very basic need for walking to walk; unlike the rest four walkability needs, it's more about creating the reason for people to walk not the street design itself (Alfonzo, 2005). The feasibility is affected by only two parameters; destination diversity and access to public transportation which is logic given that, for walking as a transportation mean – on a street scale – people will walk through a street only if it they're going for a destination or it has public transportation stops they want to catch (Hinckson, Smith, & Bozovic, 2020).

The street safety is affected directly by four BE parameters; number of people walking (which is not a BE parameter but it has a major effect on the sense of safety) (Adams, Frank, & Norman, 2009; Saelens & Sallis, 2002), number of outdoor dinings, proportion of active uses (Ewing, Clemente, Handy, Brownson, & Winston, 2005) and proportion of windows at street level (Ewing, Clemente, Handy, Brownson, & Winston, 2005; Jacobs, 1961). Additionally, the street safe5ty is affected by two other BE parameters indirectly; the connected pedestrian infrastructure and the room for walking (Adams, Frank, & Norman, 2009; Saelens & Sallis, 2002) . It's noted that the 4 directly linked BE parameters affect the sense of safety from crime while the latest two affect the safety while walking from vehicular movement.

The street accessibility is affected directly by three BE parameters which are existence of barriers to the walking space (negative effect), room for walking and connected pedestrian infrastructure. There isn't any BE parameters that affect the accessibility indirectly (Alfonzo, 2005; Mehta, 2008).

Comfort and pleasurability are considered to be relatively higher needs; without which there's good chance people would still walk (Alfonzo, 2005; Mehta, 2008; Hinckson, Smith, & Bozovic, 2020). The comfort is affected directly by 7 BE parameters; Protection from sun (Hinckson, Smith, & Bozovic, 2020), number of littering, vandalism, etc… (Cerin, Nathan, Van Cauwenberg, Barnett, & BarVnett, 2017; Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018; Adams, Frank, & Norman, 2009), number of street furniture items, proportion of the sky, proportion of the street wall, number of long sight lines and noise level (Ewing, Clemente, Handy, Brownson, & Winston, 2005). Also it's affected by two parameters indirectly which are room for walking and barriers to walk (Alfonzo, 2005).

Lastly, the pleasurability is affected by 10 parameters directly; number of courtyards, parks, plazas, etc... (Ewing, Clemente, Handy, Brownson, & Winston, 2005; Adams, Frank, & Norman, 2009; Hinckson, Smith, & Bozovic, 2020; Barnett & Cerin, 2017; Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018), number of major landscape features, average buildings height, number of small planters, total number of buildings, number of colors (Ewing, Clemente, Handy, Brownson, & Winston, 2005), proportion of historic buildings, number of buildings with identifiers, number of non-rectangular shaped buildings, number of pieces of public art (Ewing, Clemente, Handy, Brownson, & Winston, 2005; Adams, Frank, & Norman, 2009) while indirectly affected by two more which are protection from the sun and existence of outdoor dinings (Hinckson, Smith, & Bozovic, 2020).

For the graphical presentation of HELP (Fig.7), the pyramid of needs and the full list of BE parameters are put next to each other whereas each one of the five basic walkability needs have the corresponding BE parameters listed next to it and directly connected by the grey solid curves while the secondary connections are represented by the reddish dotted curves. Each of the BE parameters has a small circle on its left side; where a solid black circle indicates that this parameter only affects one of the walkability needs while a reddish circle indicates that this parameter affects more than one.

Although the graphical representation provides most of the data that the model offers for building an understanding, it must be accompanied with a table for field measurements to complete operationalizing the walkability needs and avoid being just a theoretical model. So a full list of the BE parameters; each with a minor description is listed in (table.1).

The table includes a list of 26 BE parameters. It must be noted that the data in this table is based firstly on Ewing's manual (Ewing, Clemente, Handy, BrownE son, & Winston, 2005; Ewing, Handy, Brownson, & Tian, 2009) for the parameters that are listed within it which are 18 parameters while the rest 7 parameters' data are identified based on the general consensus among the studies reviewed previously.

Table.1 BE parameters' operational descriptions

WN	BE Parameter	Description
Feasibility	Land use mix (Destination diversity)	Percentage of non-residential ground floor uses.
	Access to public transportation	Number of stops for public transportation (formal or informal) within the street under study.
Accessibility	Room for walking	The percentage of street where there's enough room for walking.
	Barriers for walking	The number of physical barriers to walking (major or minor).
	Connected pedestrian infrastructure	The number of physical interruptions to the sidewalk (crossings or deteriorated parts).
Safety	Proportion of active uses	The percentage of ground floor active uses of the total façade of the street.
	Proportion of windows at street level	The percentage of windows out of the total façade of the street.
	No. of people	The average number of people (flow density).
	No. of outdoor dinings	Number of restaurants/cafes with outdoor seating or open seating area.

Comfort	Protection from the sun	Average percentage of shaded area over the day.
	No. of littering, vandalism, etc.... items	Number of garbage piles or any other forms of littering.
	No. of street furniture items	Number of seats, ATMs, hanging plants, flower pots, chairs, lighting posts, pedestrian scale lighting, etc...
	Proportion of sky	Estimated percentage of how much the pedestrian's cone of vision sees open sky.
	Proportion of street wall	Estimated percentage of buildings facades directly facing the walking space (no setback, parking lots, etc...).
	No. of long sight lines	The ability of the pedestrian to see far ahead, right or left for continuous 3 blocks at any time while walking.
	Noise level	Estimated average level of noise on a 1-5 scale.

Pleasurability	No. of pieces of public art	Number of public art pieces (monuments, sculptures and any other artistic display that has free access).
	No. of colors	Counting colors in two groups (basic colors, accent colors).
	No. of buildings	Total number of buildings that can be seen by the pedestrian while walking.
	No. of small planters	Total number of fixed small planters.
	Average buildings height	An estimated average of buildings heights on the pedestrian side and the opposite side of the walking space.
	No. of non-rectangular shaped buildings	Total number of buildings with non-rectangular outline or not extruded in box-shaped forms.
	No. of buildings with identifiers	The number of buildings with any kind of unique identifier that can be described with (color, shop, unique element, etc...)
	Proportion of historic buildings	Percentage of historical buildings facades out of the total facade length.
	No. of major landscape features	Number of prominent landscape views such as bodies of water, or man-made features that incorporate the surrounding natural environment.
	No. of courtyards, parks, plazas, etc...	Number of courtyards, plazas, green spaces, parks, etc... that is accessible by the pedestrians.

3.5. Summary

The aim of this chapter was to reach a model (HBELP) that illustrates the list of all BE parameters of the street that gained general consensus among literature to be associated with walkability and discuss how each of them is linked with the basic walkability needs for users. Firstly, the idea of variables operationalization is highlighted which is the concept behind having an objective model for walkability. Then the chapter goes through a discussion of the body of literature related to the topic of operationalizing walkability; focusing on studies with sound results regarding this topic. Then building the argument; the need for having such model for field practice in Egypt which is done by linking the literature review to the current situation of the streets & streets design process in Egypt focused on walkability. Then the detailed methodology for constructing the model is discussed by highlighting the main references used to build it as well as secondary references. Lastly, the output model is presented through descriptive text that explains the links between different walkability needs and BE parameters as well as the scientific references behind these links from literature. Additionally, a diagram is presented for the graphical representation of the model so that the links can easily be illustrated and used during further studies. Further studies vision for the model is discussed in chapter 8.

Chapter 4:Composite walkability needs indicators (CWNI)

Composite indicators are some mathematical combinations and relations used originally in statistics and economics for measuring countries development. During the past decade the methodology has been adopted in urban studies through various methods and for different reasons. This chapter, firstly, discusses briefly the body of literature in urban studies related to this title. Then a discussion for the concept behind utilizing this methodology in the thesis is presented, followed by the detailed methodology procedures done during the empirical work.

4.1. Composite indicators and urban-related studies

Composite indicators are some mathematical combinations of a set of different indicators into one index or multiple indices (Saisana, 2004; Saisana, 2008). The idea behind composite indicators stemmed from the need for some sort of an analytical objective methodology for comparison across different elements. Initially, it was developed to compare countries with each other or measure the development of one country over a period of time. They were used mainly by governments and international enterprises around the world as an aid to take major decisions based on totally objective assessment. However, after a period of time the composite indicators methodology has proved to be very efficient that many researchers have been studying the applicability of utilizing it in different aspects of scientific studies. (Saisana, 2004; Saisana, 2008; ESSNET, 2012)

The concept behind composite indicators came from the fact that lots of different fields contribute to the development or descend of a country. Each of these fields has numerous elements that affect it, e.g. each country has a social aspect, economic structure, environmental aspect, technological development, etc… These are the different fields that contribute to a country's development. Each of these fields has numerous elements affecting it, e.g. the environmental aspect is affected by the pollution level, percentage of green areas of the total area, percentage of greenery per person, etc… So in order to, eventually, measure objectively the performance of a certain country, all the single elements (indicators) within one field should be measured and then combined to have a rating for this field (dimension) individually then all the dimensions are combined into one index; which indicates a 'rating' for the country at a specific point in time (Fig.8). (ESSNET, 2012; Saisana, 2008; Saisana, 2004; Tawfik, 2017; Reisi, Nadoushan, & Aye, 2019)

Year after year, the number of composite indices have been growing across the world and through different fields of science as well. Bandura & Del Compo (2006) mentioned that, by the time of conducting their study, the number of composite indices has reached 160; varying across different aspects of research. In the field of urban planning & design, few studies have tried adopting the methodology of composite indicators. This is mainly related to the obvious difference in type of data & information in each of the two fields.

The concept of composite indicators is built totally on mathematical relations which means they rely on quantitative data as the core type of information to be processed (Saisana, 2004; Saisana, 2008; ESSNET, 2012). On the other side urban studies mostly produce qualitative data related to people's life in different aspects. However, as mentioned in previous chapters, there has been some trials over the past two decades for quantifying & operationalizing urban planning notions & concepts to develop more objective assessment & enhancement frameworks (for example see (Adams, Frank, & Norman, 2009; Ewing, Clemente, Handy, Brownson, & Winston, 2005; Ewing, Handy, Brownson, & Tian, 2009; Grasser, Dyck, Titze, & Stronegger, 2013; Moayedi, Zakaria, Puan, & Klufallah, 2013; Ewing, Handy, Brownson, Clemente, & Winston, 2006)). Then the results reached

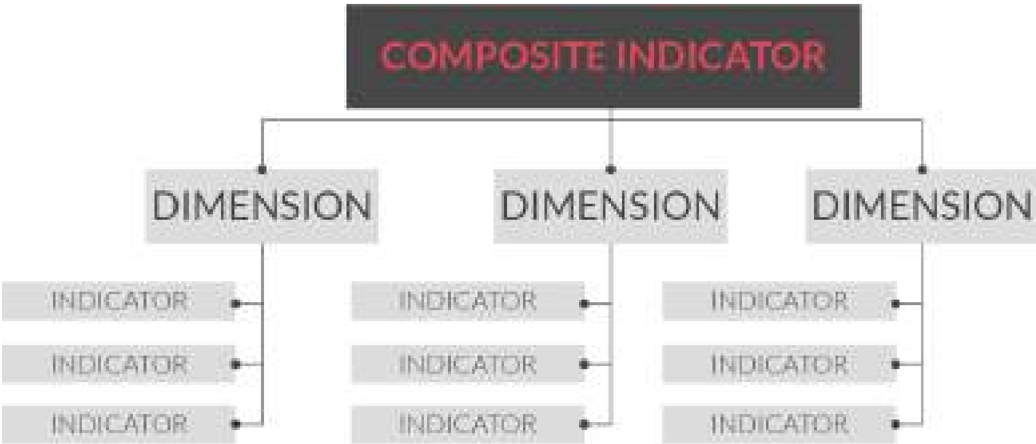

Fig.8 Composite walkability needs indicators concept, author

through conducting these studies were taken further by other researchers trying to process them through adopting the methodology of composite indices in urban studies; specifically related to the walkability of streets for various reasons (for example see (Tawfik, 2017; Reisi, Nadoushan, & Aye, 2019; Deng, et al., 2020)).

4.2. Why constructing composite walkability needs indices (CWNI)?

This study attempts to construct an objective framework as a part of the street design process enhancement for walkability; where HBELP is the core part of this framework. HBELP offers a list of BE parameters affecting the main walkability needs (Fig.7) as well as the measurement method of each BE parameter (table.1). However, towards a more comprehensive framework, there's a need for assessment tool or methodology within it; to be able as a designer during the design process to objectively measure whether the situation of a street has deficiency in one or more of the basic needs for walking. Furthermore, it is also needed as an evaluation tool in the step of proposing solutions and making decisions; so that it provides an objective indication for the effect of changes in BE parameters on each of the walkability needs as well as the overall walkability.

For the previous reason, the strength of adopting composite indicators methodology lies within its provision for a scoring/rating system for each of the five main walkability needs within HBELP (Feasibility, Accessibility, Safety, Comfort and Pleasurability) then being able to combine these five into one score for walkability which objectively measures the overall walkability of a specific street. So during the design process, there can be instant objective insights about each of the main walkability needs; making the design process more efficient.

In order to attain this aim, this assessment methodology needs to, firstly, combine all the BE parameters within each of the walkability needs into one number (score). This score objectively represents the current situation of this specific need, e.g. to measure the accessibility of a street, the three BE parameters affecting it (having connected pedestrian infrastructure, barriers to walking and room for walking (Fig.7)) has to be measured individually and then all three should be combined into one number; this number objectively measures/rates the accessibility of the street design.

The issue within this concept lies within the fact that each single BE parameter in HBELP has its own measurement method, measurement unit and weight (its effect on the walkability needs & overall walkability). This is the main reason behind adopting the methodology of composite indicators as it offers methods for weighting & aggregation of different indicators into one index which is the goal of this section within the methodology of this research.

Furthermore, adopting this methodology pave the way for potential evolution in the field of urban studies specifically when incorporated within the rising body of research that is trying to operationalize and quantify urban design concepts as it builds towards having a link with other field of science which is computational design. Utilizing tools from computational design fields have been rising in architectural uses for over a decade, yet it has to be tackled on a large scale in urban-related studies due to the major differences in type of data between both fields. Adopting the composite indicators methodology can work as the translator; creating a new link that didn't exist before between qualitative results (outputs) of urban studies and mathematical processes in computational design field. This thesis explores the potential in incorporating computational tools on a minor scale in the case study [refer to chapter 7].

Importantly, the composite indicators construction is a wide field of science; numerous researches are published discussing its benefits and the different methods for doing it. This research is neither an analytical study into the composite indicators construction methodology nor setting definite guidelines for adopting these methods in urban studies or walkability. This thesis only benefits from the basic concepts and methods of composite indicators as a tool & step towards building the objective framework for street design process enhancement for walkability. So it's recommended to have deeper analysis in this step, by benefiting from statisticians, in order to reach more robust guidelines for constructing composite walkability needs indices in further studies.

Composite indicators construction is a 10-step process (Organization for economic cooperation and development, 2008; ESSNET, 2012). In the next section, the methodology towards creating the CWNI is briefly illustrated as well as the different methods used in each step.

4.3. The methodology to construct CWNI

4.3.1. The process

Composite indicators are widely accepted as useful tools to measure development across different dimensions. However, they can be misleading if they are constructed poorly (Tawfik, 2017; Saisana, 2008; Bandura & Del Campo, 2006; Saisana, 2004). This is why in 2008, the (Organization for economic cooperation and development) has published a handbook with the full process so that any user can avoid any pitfalls while attempting to construct a CI. The 10 steps are categorized into three sections listed as follows:

Building the base: It contains the first three steps; the starting point is building sound theoretical background about the indicators to measure (BE parameters in this study), the dimensions (walkability needs) and the index (Walkability). In this study, they are all discussed within the previous chapters. The second step is data selection; it defines the basis for selecting the indicators according to analytical soundness, relevance to the phenomenon under study and measurability. Then Imputation of missing data and multi-variant analysis to explore the overall structure of the dataset structured previously.
Constructing the CI: It is the core of the process as it contains the three main steps starting with the fifth step; normalization which translates all the indicators into unitless measurements to fix the issue of having different units so all the indicators become comparable. Then weighting which gives a corresponding weight to each indicator according to its effect to the overall phenomenon. After weighting the indicators, they're all combined into one index (CI) and this step is called aggregation.
Assuring robustness: It contains the last few steps that are related to assuring the reliability of the constructed CI. These steps goes start by holding a sensitivity analysis (uncertainty analysis), then going the opposite way in the process by decomposing the CI into its original dimensions then individual indicators and

linking the constructed composed indicator to other related indicators to correlate any relative measurements.

In this research, the first section of the methodology is partially covered in previous chapters while for the second section, HBELP is used to feed in the individual indicators (BE parameters) and the dimensions (The five walkability needs).

Each of the steps in the second section has different methods to be done with; because composite indicators methodologies are used in a wide variety of science fields so the choice of compatible method in each step goes back to the constructor of the CI according to what he sees appropriate for each situation. However, in 2013, (Mazziotta & Pareto) built a flow chart to be used in order to choose the most fitting path to build the CI (Fig.9). This flow chart is used to determine an appropriate methods choices to apply in each of the next three steps; Normalization, Weighting and Aggregation.

4.3.2. Normalization

The method used for normalization is the min-max method. This method converts all the indicators measurements to unitless scales with a range from 0 to 1 by using the following formula:

$$I_{qc}^{t} = \frac{x_{qc}^{t} - min_c\left(x_q^t\right)}{max_c\left(x_q^t\right) - min_c\left(x_q^t\right)}$$

In this formula, is the measurement of the indicator x (BE parameter) at time t in street c (current measurement of the BE parameter), is the minimum value of this parameter across all streets, is the maximum value of this parameter across all streets and is the normalized value that can be used afterwards (Organization for economic cooperation and development, 2008).

In order to get minimum and maximum values for each single BE parameter, a cross sectional study has to be done across a large sample of streets in Greater Cairo. In 2017, (Tawfik) has conducted a study in which she took the model constructed by Ewing et al. (Ewing, Clemente, Handy, Brownson, & Winston, Measuring Urban Design Qualities Related to Walkability, 2005) as the reference for the BE parameters and used it to build a composite walkability index methodology to rate streets in Cairo. Then she used this model to rate 46 main streets across Cairo. Tawfik's measurements are used to get the minimum and maximum value for the BE parameters. However, not all the BE parameters have measurements in her study; so when facing this kind of situation while constructing CI; of indicators that might not have other measurements elsewhere or building a CI that is a first of its type, the following formula is used (ESSNET, 2012):

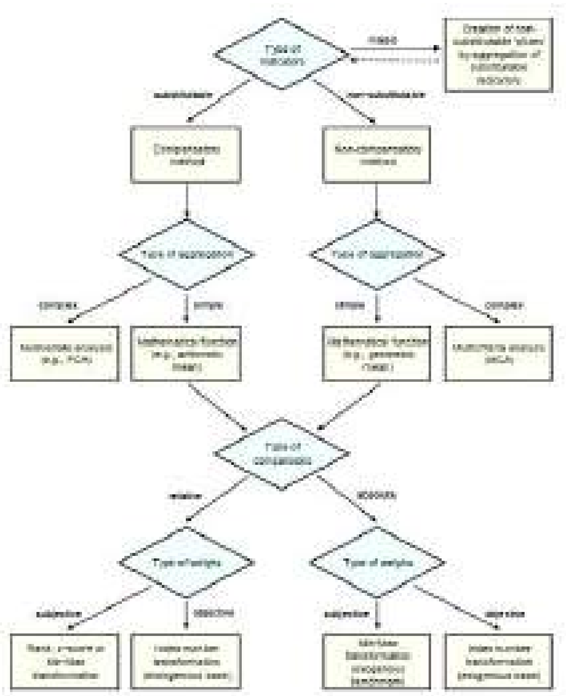

Fig.9 Flowchart for the choice of the best method, Mazziotta & Pareto, 2013

$$I_{qc}^{t} = \frac{x_{qc}^{t} \; - \; Ref_{c}\left(x_{q}^{t}\right)}{max_{c}\left(x_{q}^{t}\right) - \; min_{c}\left(x_{q}^{t}\right)}$$

This formula is the same as the previous one except for one modification which is the method of determining the values. The is the threshold between the status of the indicator being acceptable or not. The reference values are determined subjectively based on the theoretical background fed with the constructor point of view. Similarly, the minimum and maximum values in this formula are determined based on the theoretical background. However, many of the basic indicators are determined as percentages with minimum and maximum values set to 0% and 100% which can result in a meaningless CI because it ignores the fact that some indicators might not even have this wide range. There are multiple methods to determine the reference, minimum and maximum values but in this study they are all determined based on previous studies.

4.3.3. Weighting & Aggregation

The weighting step can be very effective on the output composite index. There are multiple directions to follow to achieve the weighting step; where three decisions should be made:

<u>Method:</u> There are multiple weighting methods; the easiest (but questionable) method is to assign equal weighting for all parameters and dimensions. It should

be noted that; the equal weighting method was used by Tawfik in her study to construct composite walkability indicators for streets in Greater Cairo (Tawfik, 2017). Alternatively, subjective weighing can be set by relying on the opinions of experts in the field to which the composite indicators are related (for example see (Ewing, Clemente, Handy, Brownson, & Winston, 2005)) or the users of the study area to capture their real needs (Alfonzo, 2005; Mehta, 2008). Lastly, objective weighting methods can be used; it refers to assigning weights to the different indictors – which are the BE parameters in this thesis - according to variability (indicators with a low level of variability will have less weight and indicators with a high level of variability will have much more weight). In this study, subjective weighing method is used according to the results of a field survey conducted among the study area users [refer to chapter 6].

<u>Type:</u> The assigned weights can either be absolute (the general effect of the indicator on the overall phenomenon i.e. the effect of a specific BE parameter on the overall walkability) or relative; which is the relative effect of the indicator, compared to other indicators under study, on the overall phenomenon. Deciding which type to use during the process falls back on whether the indicators are compensatory; if the overall phenomenon (or dimensions) can be achieved through different equilibrium states of the indicators measurements.

To clarify, for example, the safety (dimension) is affected by 4 BE parameters where the sense of safety can reach an acceptable level if each of these parameters has a certain score, but it can also be achieved if one of these parameters is not achieved at all but the other three are increased in score and so on, this is a compensatory dimension. That's why in this study, the relative weighting type of methods is used.

<u>Technique</u>: They are the specific mathematical relations followed to assign weights (Organization for economic cooperation and development, 2008). In this study, the analytical hierarchy process (AHP) is used. The AHP is one of the techniques widely used in multi-attribute decision making (Saaty, 1987). According to (Forman, 1983):

> *AHP is a compensatory decision methodology because alternatives that are efficient with respect to one or more objectives can compensate by their performance with respect to other objectives. AHP allows for the application of data, experience, insight, and intuition in a logical and thorough*

> *way within a hierarchy as a whole. In particular, AHP as a weighting method enables decision-makers to derive weights as opposed to arbitrarily assigning them.*

The significance of this technique is facilitating the decomposition of a problem into hierarchical structure while assuring the incorporation of both the quantitative as well as qualities aspects. Importantly, the weights assigned using the AHP technique represent trade-offs between indicators; as they measure the ability to give up a given indicator relative to another one. Thus, these weights are not importance coefficients as if understood this way, they can lead to misunderstanding (Organization for economic cooperation and development, 2008).

After assigning the weight to each of the BE parameters. The aggregation step is then conducted through simple mathematical mean method (fig.) (Organization for economic cooperation and development, 2008; Matteo & Pareto, 2013).

4.4. Summary

The goal of this chapter is to build the argument behind adopting the composite walkability needs indicators methodology in this thesis and its potential for further research in the field of urban studies. Firstly, the concept of composite indicators is discussed then its relationship to the urban studies is explained through a brief literature review linking to the topic of operationalizing walkability in the previous chapter. Then a discussion for the needs and possible benefits behind utilizing this methodology is described; which can be summarized in the following points:

- The HBELP mode, reached in the previous chapter, is useful for building an understanding of the link between BE parameters and walkability needs. However, towards building an objective framework for walkability, there's a need for an assessment method to objectively highlight any deficiency in the walkability needs of a street setting.
- There's also a need for an evaluation method that can be beneficial during the street design process for the designers to have instant objective insights about the effect of changes in BE parameters on the walkability needs.
- CWNI methodology provides the methods for objectively assessing and evaluating the walkability needs and overall walkability through simple mathe-

matical relations for weighting and aggregating the BE parameters measurements (according to HBELP) to objectively rate (give scoring) the walkability needs.

- This methodology paves the way for introducing evolutionary tools in the field of urban studies like computational and optimization methods; by acting as a translator for the data types.

Lastly, the full methodology of constructing composite indicators is discussed then the detailed methodology followed in this thesis during the empirical part is described.

Importantly, as mentioned previously, the thesis is not an extensive analysis in the ways of adopting composite indicators methodology in urban studies. It does not go through all steps thoroughly in first section and stops at the second section of the methodology for constructing the CI which is aggregation of the individual indicators to have an objective assessment method for the five main walkability needs (dimensions) without perusing to the last section.

Part II

Chapter 5:The Case Study–Al-Tahrir St.

This chapter focuses on introducing the case study empirical work done in this thesis. Firstly, this it presents a general overview, then the site selection process is explained as well as a short introduction to the case study area. Then it presents a detailed description for the methodology of the case study.

5.1. Structure overview

To attain the proposed research objectives; the case study is structured into two main sections as follows:

HBELP contextualization: The pyramid of walkability needs is a general model that needs to be structured within the socio-economic model for each group of users under study (Alfonzo, 2005; Mehta, 2008). As discussed previously, the socio-economic model differs from one person to the other in minor ways and from one group of users to the other in major ways [refer to chapter 3]. That's why the model cannot be directly used on a case study without validation which is the aim of this section of the empirical study. It tests the validity of HBELP for the study area users which is done through holding a field survey. The results are used to modify the model so that it's contextualized according to the users and valid for application on the study area.

Application: The contextualized HBELP model is used as the core to explore, based on a field case study, the benefits of having an objective framework (focused on the physical aspect of the street design for walkability enhancement) on the efficiency of the conventional urban streets design process in Egypt. The model is used for the study area assessment and proposing solutions then the framework is compared with previous research held on the same study area with the same aim by the ministry of housing (Salama, Fouad, Mohamed, & A.Aziz, 2016).

5.2. Site selection

Based on the two sections of the empirical part illustrated previously, the goals projected from the case study and the scale & scope of this research; the site selection followed a specific criteria listed as follows:

- The selected street should be mixed-usage; having a variety of ground floor uses.
- According to the roads hierarchy & importance on the macro scale; the selected street should be a main street.
- The scale of the area under study within the street should be in the range of 0.5-1.5 km. length; because working on this scale adresses the human aspect of the street. Additionally, having a similar scale to the studies upon which this research was built.
- It should have undergone previous work; either an upgrading project or even a theoretical study. The aim is to have a reference process to compare with in order to build solid results about the benefits of the introduced objective framework to the field practice in Egypt.
- Generally, the previous work done should've followed the same conventional analysis & design process of most field work in Egypt.
- The physical aspect should be a main core in the previous work done; as it's the main aspect in this research so the comparison can be done.

Many streets in Cairo fit the previous criteria but it came down to the point of having previous studies or projects held in the street. By exploring the available literature; only one study was available done one a street that fits the criteria which is Al-Tahrir Street, Al-Dokki. From the physical aspect the street fits the selection process and the available study was a scientific research done by the ministry of housing on the street to identify issues with the walking environment and propose solutions to enhance it (Salama, Fouad, Mohamed, & A.Aziz, 2016).

5.3. Site introduction

Al-Tahrir Street is one of the main mixed-use hubs in Giza city within Giza governorate (Fig.10). It accommodates a variety of land uses; commercial, entertainment, residential and administrative. According to the administrative distribution; the street lies within the boundaries of Al-Dokki district (Fig.11). The total length of the street is 2.21 km starting from the intersection of the Nile St. and Al-Galaa Bridge east to Sudan St. west (Fig.12). The selected section for the study area starts from the Nile St. east to the intersection with Dr. Michael Bakhom St. west (Fig.13) with a total length of 1.32 km. This section of the street is selected as a study area as it accommodates most of the mixed-uses and transportation hubs like the metro station and multiple bus stations while the remaining section is mostly residential uses which is out of scope in this research.

The street is an integrated main street that accomodates vehicular and pedestrian movement. However, the pedestrian space is deteriorated in many spots along the study area in addition to, during the current state of the street, the pedestrians rights are ignored in general (Fig.14). Full photo documentation for the current situation of the study area in Annex 1.

5.4. Case study methodology

The case study was built on both primary and secondary data collection methods with multiple empirical research methods varying between its two sections in order to attain the projected objectives of the research (Fig.15). Because of some research limitations related to available time & human resources; the case study focuses only on the first three needs in HBELP; feasibility, accessibility and safety (Fig.7). These three needs are the main ones in the pyramid so they are taken as a pilot implementation just to illustrate the validity of HBELP; how it relates closely to the community & environment in Egypt and how it can be developed into more comprehensive model in further studies.

5.4.1. The field survey

5.4.1.1. The survey structure

The first section focused on the contextualization of HBELP for the selected site. This was done by holding a site survey as well as an online questionnaire for the frequent users of the area. The survey was descriptive analytical and it collected information that describes the users as well as exploring their perceptual views towards walkability needs. The different aspects of HBELP are taken as hypotheses to be tested through the survey.


Fig.10 Giza city - Site location, author


Fig.11 Al Dokki district, Al Tahrir St., author

The survey aimed to test three main points:

- The model structure: This is related to whether feasibility, accessibility and safety are the most basic needs for users to walk and if the BE parameters within each one of them are actually the ones affecting it.
- Hierarchy: To test whether the hierarchy of walkability needs concluded from previous studies is the same here in Egypt for the walking needs and the BE.
- Relative weighting: To determine relative weighting that describes the effect of each of the BE parameters on the corresponding walkability need.

Due to the variety of needed data from this survey; the information was collected in three formats; nominal, ordinal and interval data each according to different types of questions and projected output. These information were collected in three types:

- Attributes: Users categorization by different kinds of information like age, gender, frequency of visiting the site, etc...

Fig.12 Al-Tahrir St., Case study area, author

Fig.13 Case Study area blow-up, author

- Behavior: Questions related to users walking behaviors & habits.
- Attitude & opinions: which is the core of the survey as the questions are related to the preferability of walkability needs over other or checking the relative importance of different BE parameters.

The survey consists of three main sections; each correspond to one of the walkability needs under experiment; feasibility, accessibility and comfort while the last section is related to cross analyzing accessibility and comfort together.

Also due to the nature of the questions and the projected output; some considerations needed to be taken while building the survey:

- The survey was written in local Arabic accent so that it's easily understood by people with minimum education level.
- While building the core part of the survey related to understanding

Fig.14 Al-Tahrir St. Aerial image of Al-Dokki square, author
Fig.15 Lack of pedestrians crossing facilities and people walking along with cars in the same space

which of the needs is more important or which of the BE parameters are more effective; the questions were made in the form of images that people react to or give rating for. That's because this survey aims to refine HBELP for the Egyptian context and since HBELP is the link between the built environment and people perception; then the questions need to capture that perception and translate it into quantitative data in order to have an objective model that reflects what people actually think.

- All the images in the survey were taken from human's eye view so that the perception of people can be captured as accurately as possible.
- The full field survey questions are provided in Appendix.

5.4.1.2. The field work

This survey was done on a total of 30 respondents. The sample size of the survey was calculated by an online sample size calculator through which the total population, confidence level and margin of accepted error was entered to get the needed sample size (Raosoft). The information about the population size was not available so it had to be estimated. The case study area lies within Al-Dokki district; so the total population as well as the total area of the district (الجهاز المركزى للتعبئة العامة و الإحصاء, 2017) were used to calculate an estimate population of the case study area.

Of course the estimate population cannot be accurate following this methodology because it hypothesizes that the total population of the area is only based on

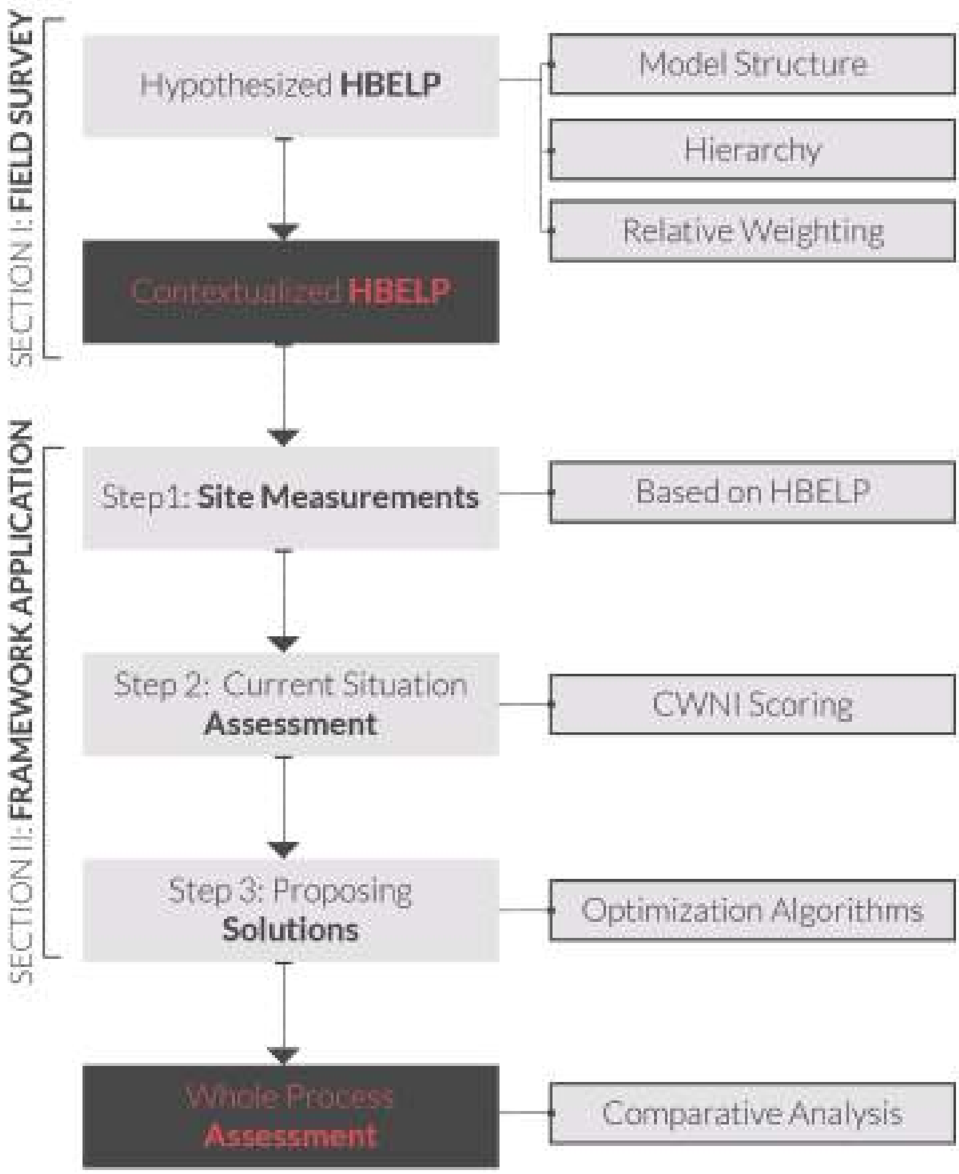

Fig.16 Case Study detailed Methodology, author

residents while in this area many users come daily for work or leisure uses, so a margin of increase in population is estimated during site visits by 10%. Even by doing this the margin of error will be relatively high (10-15%) due to these limitations, so it’s recommended to redo this survey with more accurate information about the population in future studies to ensure reliability.

The site survey was done in three field visits; from which two visits were done during mid-week days in order to get it filled by people who only come to the area for work as it is considered one of the administrative & business centers in greater Cairo. One more visit was done during a vacation day so that it catches any different category of users if it exists. Two rounds were done in each of the three days; one during morning-noon time (10am4-pm) and other one during night time (6pm9-pm). The survey was handed to people after the author introduction about the survey and reasons it's done; then the author keeps nearby till people fill the survey in order to offer HBELP if needed.

The field survey was not enough to get the calculated sample size, so the same questions were done on an online platform (Google forms) and sent to people via social media through groups with users of the area. The online questionnaire was open to responses for 10 days which was enough to reach the minimum sample size. The full survey questions are in the annex.

5.4.2. Framework application

After refining HBELP for the case study's context and users; it was used to work on enhancing the walkability of the study area design. However, it's important to highlight that the aim was neither to assess Al-Tahrir Street nor propose solutions to be implemented but to explore the benefit of having such objective framework; i.e. how it can make the street design process in Egypt more efficient by any means. In other words; the focus of this case study are some steps within the design process (methods and tools) not the design output itself. This section of the methodology describes the flow of steps along with methods used in each one during application and then comparing this whole framework with the previous work done on the same study area.

This section of the case study methodology goes through the conventional design process steps but with differences in the methods used to reach the output of each one. Generally, it starts with the current situation mapping with HBELP (measurements results) then assessment (results discussion) to identify issues followed by proposing solutions.

Chapter 7 goes through the results of the different steps in detail and then the discussion. Lastly, the comparison was done between this walkability enhancement framework and the work done previously on the same study area by ministry of housing (Salama, Fouad, Mohamed, & A.Aziz, 2016); to explore any added value, potential inclusion of such framework & methods in future design process for streets in Egypt and future development vision for this stream of research as well.

5.4.2.1. Step 1 - Site measurements

Using the list of BE parameters to measure on site provided from HBELP and the description for each parameter (table 1), site measurements were done by author during two site visits. One visit was done during morning time 11-9 am and the other after noon 7-5 pm. The timing of the visits was determined based on previous site visits observations of the traffic rush caused by pedestrians going to and leaving from work as the street is considered one of the main axes for public transportation as well as having a metro station so they generate lots of traffic.

The results (measurements) were then compared with the reference values (thresholds) to identify if any of the BE parameters is below the minimum accepted level. This objectively indicates a potential development needed in the following steps. The methodology for determining the threshold values is explained in the following step.

5.4.2.2. Step 2 – Current situation assessment

The BE measurements were then used to reach an objective assessment for the walkability needs (Feasibility, Accessibility and Safety) by following the CWNI methodology introduced [refer to chapter 4]. So in this step; the BE measurements were firstly normalized then, given the relative weighting based on the discussion of the field survey results, they were aggregated into scores of the basic walkability needs. Afterwards, this scoring was compared with the reference scoring values.

Then any walkability needs with a score below the reference value was highlighted as it indicates a deficiency in the design (issues identification). The underlying BE parameters affecting these identified walkability needs were analyzed to propose solutions or alterations for them in the following steps.

According to the CWNI methodology, to reach the normalized values for each of the BE parameters; reference values of them should be determined as well as minimum and maximum values. They are all determined based on secondary data reviewing. Some measurements are taken from the cross-sectional study held by (Tawfik) in 2017 in which she did measurements for 46 main streets all over Greater Cairo region. For some of the BE parameters (that she didn't measure); they were estimated from previous studies or from other indicators measurements. Also the same method is used for determining reference walkability needs scoring. The data sources used to determine reference, minimum and maximum values for each of the BE parameters are detailed as follows:

- The destination diversity is one of the parameters estimated from other indicators measurements in Tawfik's study (2017); it refers to the percentage of non-residential land uses. So the 'proportion of active usage' measurements are used to estimate the destination diversity values.
- Access to public transportation: Estimated from the average & minimum number of public transportation stops needed in a walking distance similar to the study area in the studies that discussed this parameter (Barnett & Cerin, 2017; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018).
- Connected pedestrian infrastructure: An estimate of the average & maximum number of interruptions to the sidewalk that affects the people's decision to walk in a street. They are estimated based on previous studies that discussed this parameter (Ewing & Cervero, 2010; Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018; McCormack & Shiell, 2011).
- Room for walking: Determined by reviewing previous studies to calculate the needed walking space for a given number of people in a street (Salama, Fouad, Mohamed, & A.Aziz, 2016).
- Barriers to walking: Some previous studies discussed this parameter but from a different point of view than the Egyptian context (for example see (Salvo, Lashewicz, Doyle-Baker, P.K., & McCormack, 2018; Ewing & Cervero, 2010; Haselwandter, et al., 2014)). So no estimation could be made based on any previous researches. As a result it's just subjectively assumed by the author from field visits observations.
- Proportion of windows at street level: Secondary data from Tawfik's study (2017).
- Proportion of active uses: Secondary data from Tawfik's study (2017).
- Number of outdoor dinings: Secondary data from Tawfik's study (2017).
- Number of people: Secondary data from Tawfik's study (2017).

As mentioned previously, these measurements were estimated through secondary data methods so they should not be regarded as real indicators for the study area, instead they are just used as an illustration to continue with the process which is the focus of this research. However, it's strongly recommended to hold further studies with the aim of identifying objective threshold values for each of the BE parameters in HBELP because they can give a rough but direct, instant and objective indication about whether a specific design proposal meets the minimum needs of people.

Lastly, similar to the first step, the scores of the basic walkability needs were compared with the reference values for each of them to determine any deficiency or weakness in the design of the street. The identified walkability needs with weaknesses were taken to the further step by analyzing the underlying BE parameters affecting them to spot root issues in the design of the built environment itself which gives direction for the next step of proposing solutions.

5.4.2.3. Step 3 – Proposing solutions

In this step, different alterations for the BE parameters were explored with the aim of reaching an acceptable scoring for each of the walkability needs. This step can consume much time for the trial and error process to be done manually so in order to perform it more efficiently; optimization algorithms were used as they provide tools that enables the designer to explore much more number of possible solutions in much shorter time.

Many software offer optimization algorithm tools; in this thesis Microsoft excel was used to perform this step. The BE measurements as well as the composite walkability needs indices mathematical calculations were done in excel to set the relations between parameters and produce the current walkability needs scoring.

The methodology of working with the optimization algorithm within Microsoft excel in this case study went as follows:

1. Excel's optimization solver offers the option of setting an objective value (fitness) that can be maximized or minimized or set to a target value. The fitness is set to the walkability need cell (for example accessibility scoring).
2. The changing variables were identified (the BE parameters affecting accessibility); which are the cells that the algorithm will change in order to reach the goal fitness (the goal scoring of accessibility).
3. Constraints were set for each of the BE parameters; like setting minimum values, maximum values, non-negative solutions, minimizing the changes for specific parameters and so on.
4. The target value of the fitness (accessibility scoring) was set manually to increase by increments of 0.3 in each run.

Microsoft excel offers multiple solving methods; which is the method by which the algorithm reaches the solution. In this case study the solving method was set to evolutionary because it is the most precise and offers more options to control the process like the mutation rate, population size, etc… Also the evolutionary solver method is compatible with other software methods that are more related with spatial allocations of the street design like Catia, Grasshopper, etc… which build towards the vision of further research of this study.

5. The optimization algorithm was run for multiple times and in each time it produces many different solutions and alterations for the BE parameters to reach the target value of the fitness (accessibility scoring). These solutions were then manually analyzed with the current situation of the case study to choose the fittest ones.

6. The process was repeated for each of the two walkability needs under study; accessibility and safety while feasibility didn't need these procedures because it's just affected by two BE parameters (fig.). The algorithm was run 6 times to explore different alterations for the accessibility enhancement and 2 times for the safety.

7. The algorithm was run on the three needs altogether to see the change in the overall walkability score of the street. In this step; it was assumed that these three walkability needs are the only ones affecting the overall walkability. Also it was assumed that they have equal weighting; equal effect on the overall walkability which is totally hypothetical but it was done to explore the potential of having such framework. Three runs were done to explore different alterations for this step. Then a section is designated for the discussion of the results from this step.

5.4.2.4. Framework comparative analysis

In this section, a descriptive comparative analysis was done between the walkability enhancement framework introduced in this thesis and the previous work done on the same study area by the ministry of housing. The comparative analysis is represented by the process main steps; it goes through step by step along the process focusing on the methods used by each of the two frameworks, types of outputs and how both of them affected the flow of the process. The process steps are: Site mapping, Current situation analysis, Identifying issues and proposing solutions. Lastly a conclusion is drawn about the benefits and weaknesses of the introduced framework and how it can be incorporated within future studies.

The information about the process done previously on the study area is obtained through both primary and secondary data methods. Secondary data represented by reviewing the final report published about the project (Salama, Fouad, Mohamed, & A.Aziz, 2016) from which the final results & conclusions are identified while primary data method is represented by a semi-structured interview done with Eng. Salama, Hamed; one of the team members who worked on this project to gain more insights about the background of the process, time and effort needed to hold it, any circumstances they faced during the work that they might have not publish in the report and the future of their study.

5.5. Summary

This chapter aimed to act as the introduction for the case study part of this thesis. Firstly, there's an overview of the structure of the whole empirical work. Then the site selection criteria to select Al-Tahrir street is discussed which was mainly related to having an available study held previously on the same street with the same aim of enhancing walkability through assessing and proposing alteration for the BE. Followed by a brief introduction to the study area; basic information like area, location, etc... Lastly, the detailed methodology followed during the empirical work on the study area; the process, tools, methods and limitations. The main objective of the case study is to explore the benefits of having an objective model for walkability and how this can make the street design process in Egypt more efficient. This methodology followed to attain this objective can be summarized in the following points:

- A field survey was done among the users of the area to contextualize the HBELP model.
- The results of the survey are used to modify the model which makes it valid for application as it reflects the needs of people and how they perceive the surrounding BE.
- The framework application steps are discussed starting by doing field measurements according to HBELP.
- The measurements results are processed according to the CWNI methodology [refer to chapter 4] to provide scoring for each of the walkability needs

- The scoring of the walkability needs are compared with reference values (assumed) to identify if any of them is below the reference (identifying the issues).
- Then optimization algorithms within Microsoft Excel software are used to explore different solutions to reach the goals.
- Lastly, the process followed is compared with the process followed by the previous work done on the study area to determine potential benefits of incorporating such framework in the conventional street design process in Egypt.

Chapter 6:HBELP contextualization (Field survey)

This chapter focuses on the first section of the empirical case study in the thesis; the field survey. As discussed in the previous chapter, the aim of this section is to modify HBELP according to the users in the study area so that it can be used in the second section of the case study. According to the case study methodology, this chapter articulates, firstly, the results and then the discussion of the field survey. For organizational purpose, both of the results and discussion are divided into three main sub-titles according to the three main walkability needs under study; Feasibility, Accessibility and Safety.

It must be mentioned that most of the empirical work discussed in this thesis was done during the spread of COVID19- pandemic and for the largest percentage of time while conducting the field work, Egypt was under partial lockdown. That's why reaching out for people to fill a field survey on the street was not easy and as a result, the sample size of users who filled this survey was relatively low as mentioned in the case study methodology. However, the aim of this thesis is to tackle the street design process itself (not the street design output) and that's the reason why these results were accepted because this survey acts as a miniature validation of the applicability of HBELP model on the case study area while further research vision is discussed in chapter 8.

6.1. Survey results

6.1.1. First section: Feasibility

The demographic general categorization of people results shows that the majority of users in the study area are under 50 years old (Fig.16) who are divided almost equally between male and female users (Fig.17). These users walk through the street for all the different uses in the study area. However, the majority of users come to work in the area. The second largest group of users walk through the street for shopping & leisure and the third are users who visit the area for the medical uses (clinics). The rest of users are mostly visiting the area for other uses (mostly passersby). Importantly, the least percentage of pedestrian users are the residents of the area who represent only %3.3 (Fig.18).

Regarding the frequency of usage; most users are either walking through the study area on a daily basis or visit it rarely (less than once a month). The majority of the rest walk through the street once or twice a week while less than %15 visit it once a month (Fig.19). The majority of the users reach the area during morning times (6am11-am). The second largest group of users are in the area during night times (after 5pm) while less than %15 reach it during mid-day times from 11am-5pm and the rest of users don’t have a fixed schedule (Fig.20).

The types of transportation to reach the area are divided into two halves; first half is the category of people coming with private transportation; most of them are car owners and the rest use private transportation companies like Uber & Careem. The second half are people who reach the area by walking, public transportation (underground, buses, microbuses & mini buses) to the closest stop then walking to their destination (Fig.21). However, more than %60 of users walk on a daily routine (Fig.22) and almost %50 don’t feel tired before 15 min of continuous walking (Fig.23). It’s important to mention that it takes an average of 25 min. to walk the whole Al-Tahrir St. and it only takes an average of 11 min. to walk the whole study area.

Out of the people coming to the area with public transportation, almost half of them use the underground subway while the other half almost totally rely on informal public transportation (microbuses, mini-buses) to reach the study area. Only %10 of the users use formal public transportation like buses (CTA) or mini-buses as their frequency is relatively low.

6.1.2. Second section: Accessibility

When rearranging (according to importance) the three different BE parameters that affect the accessibility (ease of walking), people gave the highest rating for street (C) (Fig.27); which has the connected pedestrian infrastructure as the main parameter while the second place is for street (A) (Fig.25) which has a decent room for walking but the sidewalk is interrupted. The worst street according to the users is the one with major physical obstacles to walking (Fig.26) (Fig.28).

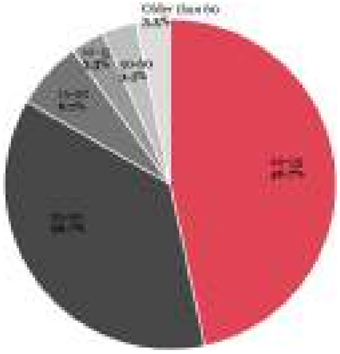

Fig.17 Demographic categorization of users, author

The users are divided into two groups; one of them chose the street with connected pedestrian infrastructure as the most crucial element for the sidewalk accessibility while the other half preferred having room for walking firstly and then the connected pedestrian infrastructure is the second element to come. The majority of users decided that if given the choice, they would never use a sidewalk with major physical obstacles.

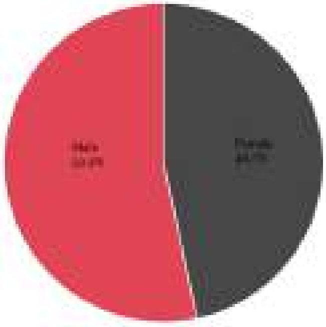

Fig.18 Categorization by gender, author.

When people were asked about the reasons for their choices in the two previous questions, more than half of the users said that having a room for walking is the main reason, less than half of the users highlighted that the existence of obstacles affected their choices while, interestingly, only %20 acknowledged that the connected pedestrian infrastructure is one of the main elements for creating a proper sidewalk design (Fig.29).

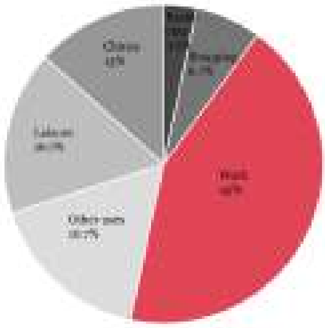

Fig.19 Reasons for visiting the area, author

Importantly, the users mentioned some other features that affect the sidewalk accessibility like the finishing material of the sidewalk, absence of handicapped-friendly elements and the consistency of the sidewalk width. These are the most related features as the rest were not related to the scope of this study like bad

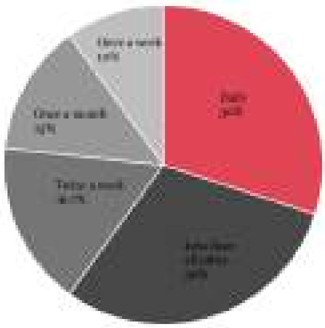

Fig.20 Frequency of visits, author.

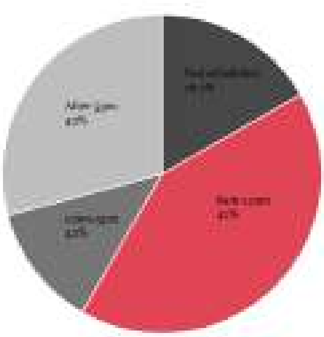

Fig.21 Time of visits, author.

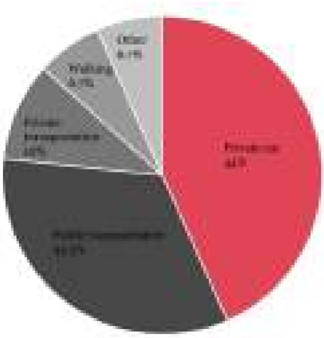

Fig.22 Transportation Methods, author.

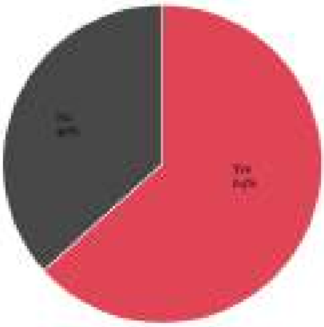

Fig.23 Walking as a routine, author.

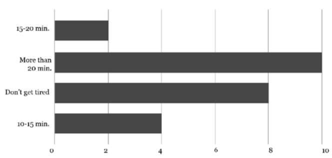

Fig.24 Walking exhaustion period, author

odors from trash and sexual harassment. However, one of the elements that more than %50 of the users mentioned it affects the ease of walking is having shading elements for the sidewalk.

6.1.3. Third section: Safety

The users where asked to choose between different street sections, each image had only one of the BE parameters that affect user feel of safety. The majority of people chose the street with outdoor dinings (Fig.30) as the safest street to walk through. Then the street with the most number of walking people (Fig.31) came in second place after which came the street with most active uses (without any outdoor dinings) (Fig.33) and the worst street for people to walk through is the vacant one even if it had lots of windows on street level (Fig.32) (Fig.34).

When asked about the elements affecting their choices, most people acknowledged that having lots of other people walking is effective. Additionally, almost half of the users said that having shops (active uses) affects their feel of safety and around %30 highlighted that having outdoor dinings increases it as well.

People gave similar results when asked about the most effective element in the street design regarding safety as they chose the number of people walking as the most effective element. Then having outdoor dinings and active uses almost have the same effect then comes other elements like having light poles (Fig.35). Interestingly, less than %1 of the users mentioned that the existence or absence of cars affects their safety (only pedestrian street vs. integrated street).

When comparing between the feel of safety and the sidewalk design accessibility as two main walkability needs, people are almost divided into two halves; the first half sees the ease of walking is more important while the other half sees that safety is more crucial then comes the ease of walking (Fig.36). However, when asked about the reason for their choice, the majority of users mentioned elements like having people walking around, having shops and having a designated space for pedestrians without cars. Importantly, although the questions were about the physical aspect of the street and the author highlighting this multiple times before handing the people the survey, almost %20 of users mentioned the word “safety” in their answer.

Lastly, people were asked to highlight the most important element to change in the case study area design, they had different opinions about this and from the given answers, the most related elements are mentioned. Many of them identified elements related to the sidewalk design itself like having handicapped-friendly elements, ramps for babies’ carts, having more room to walk and having consistent continuous sidewalk without obstacles, informalities or street vendors’ stands. Others mentioned items related to the street furniture like having sitting benches and light poles. Many users mentioned greenery as a missing element that they need in the street and also lots of people expressed the need for street crossings there isn’t even one in the study area.

6.2. Survey discussion

The findings from the survey results suggest that with some modifications according to each study area context & users, HBELP can be valid for application on main streets in Greater Cairo. This section discusses the survey results with the aim of tailoring HBELP for

Fig.25 Street (A): Decent room for walking but the sidewalk is interrupted

Fig.26 Street (B): Major physical obstacles to walking

Fig.27 Street (C): Connected pedestrian infrastructure provided but tight room for walking and existence of physical obstacles.

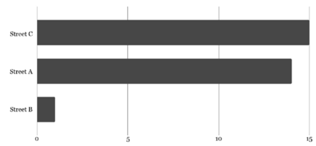

Fig.28 Preferability of walking among the 3 streets according to ease of walking.

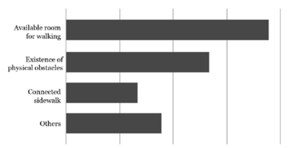

Fig.29 Elementes affecting ease of walking, author

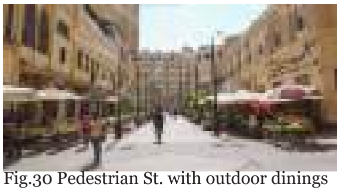
Fig.30 Pedestrian St. with outdoor dinings


Fig.31 Pedestrian St. with relatively large number of people walking


Fig.32 Street with many windows at street level


Fig.33 Integrated St. with active uses

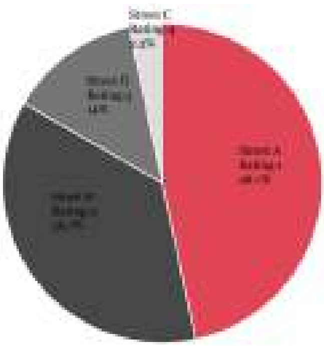
Fig.34 Streets arranged by preferability according to feel of safety

the study area as well as assigning weights for each of the BE parameters.

Generally, HBELP reflects the real needs of a large percentage of pedestrian users in the study area. The feasibility of walking in Al-Tahrir St. is high which is expected as it is part of the main mixed-usage hubs in Giza governorate. Nonetheless, the results show that both of accessibility and safety can be considered as basic needs for users that the street design should provide as both of them are equally important. However, people consider the sense of safety as a quality that the street design should provide while walking is more crucial than accessibility.

6.2.1. First section: Feasibility

The survey results suggest that the BE parameters affecting feasibility can be arranged as provision of destination diversity as the most effective followed by access to public transportation.

The geographical location of the study area (Fig.11) being part of one of the main CBDs in Greater Cairo (Abdel-Samad, 2016) contributes greatly to its provision for feasibility of walking. Being a mixed-usage area creates destinations for people which in Egypt can be enough because transportation in some areas can be just a result of accommodating these variety of destinations. This is clear in the study area by the percentage of users reaching it through informal public transportation as they represent almost 50% of the users using public transportation means. This indicates that having destinations is the most effective parameter within feasibility. However, it also requires the provision of public transportation. Weights were assigned to both parameters accordingly.

Table 2 Feasibility parameters relative weighting

	Access to public transportation	Destinations diversity	Relative weight
Access to public transportation	1	0.5	**0.75**
Destinations diversity	2	1	**1.5**

When dealing with an existing urban setting (like the case study in this thesis); if people are already walking in the street then it's a clear indication that this area has one destination or more for those people (Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Ewing & Cervero, 2010; McCormack & Shiell, 2011) that's why it's more logical to start assessing other parameters like degree of accessibility to public transportation or higher BE parameters within HBELP. However, when planning for a new community; it's crucial to start by planning for destinations diversity as the first main BE parameter to provide in the design for a walkable urban street.

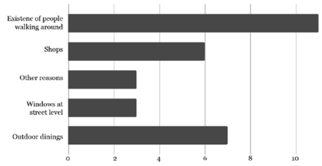

Fig.35 Elements affecting sense of safety

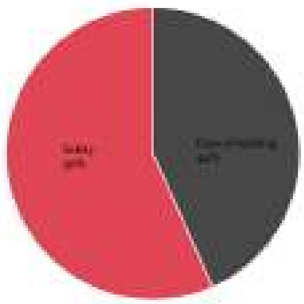

Fig.36 Comparing safety to accessibiltiy

The survey results show that the types of transportation the people use to reach the area are almost divided in half between private cars and public transportation means in general (Fig.22). Interestingly, if this is cross-analyzed with the percentage of people who walk on a daily basis (Fig.23), the contradiction between the recent ongoing development strategies of urban streets in Greater Cairo (specifically in central districts) and the real needs of people is clearly noticeable. Since 2017, there's been a major upshift in pace of streets "upgrading" projects in Egypt. By April 2020; a total of 38 flyover projects has been constructed only in east Cairo districts within a total timespan of 5 months and it's planned to reach a total of 45 flyovers in the same districts by the end of 2020

(فيديــو لمشــروعات تطويــر مناطــق شــرق القاهــرة, 2020; The Cabinet of ministers , 2020). This indicates that the planning strategies are focused on the streets as axes of transportation while ignoring the pedestrian aspect of the street. A major review for the strategic upgrading plans of streets in Egypt is recommended because it seems that a large percentage of the people will be having lots of basic unmet needs for walking.

In this thesis, feasibility as a quality of the street design is only studied from the physical aspect; focusing on the BE parameters affecting it. However, feasibility can be explored from a whole different point of view related to the users themselves. For example, studying the average age of users and cross analyzing it with the health status can provide more insights about what to provide as destinations and design language of the street as well based on the strategic plan for the area (for example see (Barnett & Cerin, 2017; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Eisenberg, Vanderbom, & Vasudevan, 2017; Frank, Engelke, Schmid, & Killingsworth, 2003)). It's recommended to include such demographic studies within future researches in order to make HBELP more comprehensive.

6.2.2. Second section: Accessibility

The survey results suggest that the BE parameters affecting accessibility can be arranged from the most effective to the least as follows: barriers to walking, room for walking, connected pedestrian infrastructure.

The survey results shows how effective, on the overall walkability, each of the accessibility BE parameters are compared to each other. Firstly, it's obvious that the existence of physical obstacles has the most recognizable effect for users' perception to the walking path as it's the first and most noticeable parameter in the multiple choices questions (Fig.28) as well as open ended ones (Fig.29). This indicates how, its existence, badly affects the users' decision whether to walk in a street. As a result, it's moved down the pyramid of needs to represent that it's more basic need than the two other parameters (Fig.37). Also it's given the highest relative weight among the three of them (Table 3).

Regarding the connected infrastructure and room for walking, the direct answers of people suggest that having a connected pedestrian sidewalk for walking is more important as a street design parameter. People chose street (C) (street with connected pedestrian infrastructure but not enough room for walking) as a better place to walk than street (A) (which provides enough room for walking but inconsistent interrupted sidewalk). However, when analyzing these results it must be taken into consideration that given the very basic needs, the human mind will always aspire for higher ones and might not pay attention to these basic achieved ones (Maslow, 1943; Maslow, 1954). This theory is adopted in urban studies as well (for example see (Appleyard, 1976; Mehta, 2008; Alfonzo, 2005; El-Ghandour, 2016)) and can explain these results as follows: Street (C) has a clear walking distance of 0.8m. (Fig.27) (Note that the minimum needed room for walking in the study area is 4m.), however, for some people this might be enough because their minds relate to other spaces with no side walk or less walking space than 0.8m. That's why they interpret that street (C) has room for walking as well as connected pedestrian infrastructure (two parameters achieved) which makes it the best place to walk among the given three. This interpretation of the results is supported by the following questions related to the BE parameters affecting ease of walking where only 20% of the users acknowledged that the connected pedestrian infrastructure affected their choices while having enough room for walking is the most recognized BE parameter with more than 50% of the users highlighting it (Fig.29).

Based on the previous interpretation; the BE parameters affecting accessibility were rearranged starting with the physical obstacles to walking as the most effective (in a negative way) then the room for walking is the second parameter followed by the connected pedestrian infrastructure lastly (Fig.37). Importantly, in HBELP, it should be noticed that accessibility is one of the basic walkability needs, which means that all the BE parameters affecting accessibility are basic needs for walking. They are all equally important but differ in their degree of effect on ease of walking which is expressed in the relative weighting of each one (Table 3)

Table 3 Accessibility parameters relative weighting

	Connected infrastructure	Room for walking	Barriers to walking	Relative weight
Connected infrastructure	1	0.93	0.48	**0.8**
Room for walking	1.07	1	0.5	**0.86**
Barriers to walking	2	1.93	1	**-1.64**

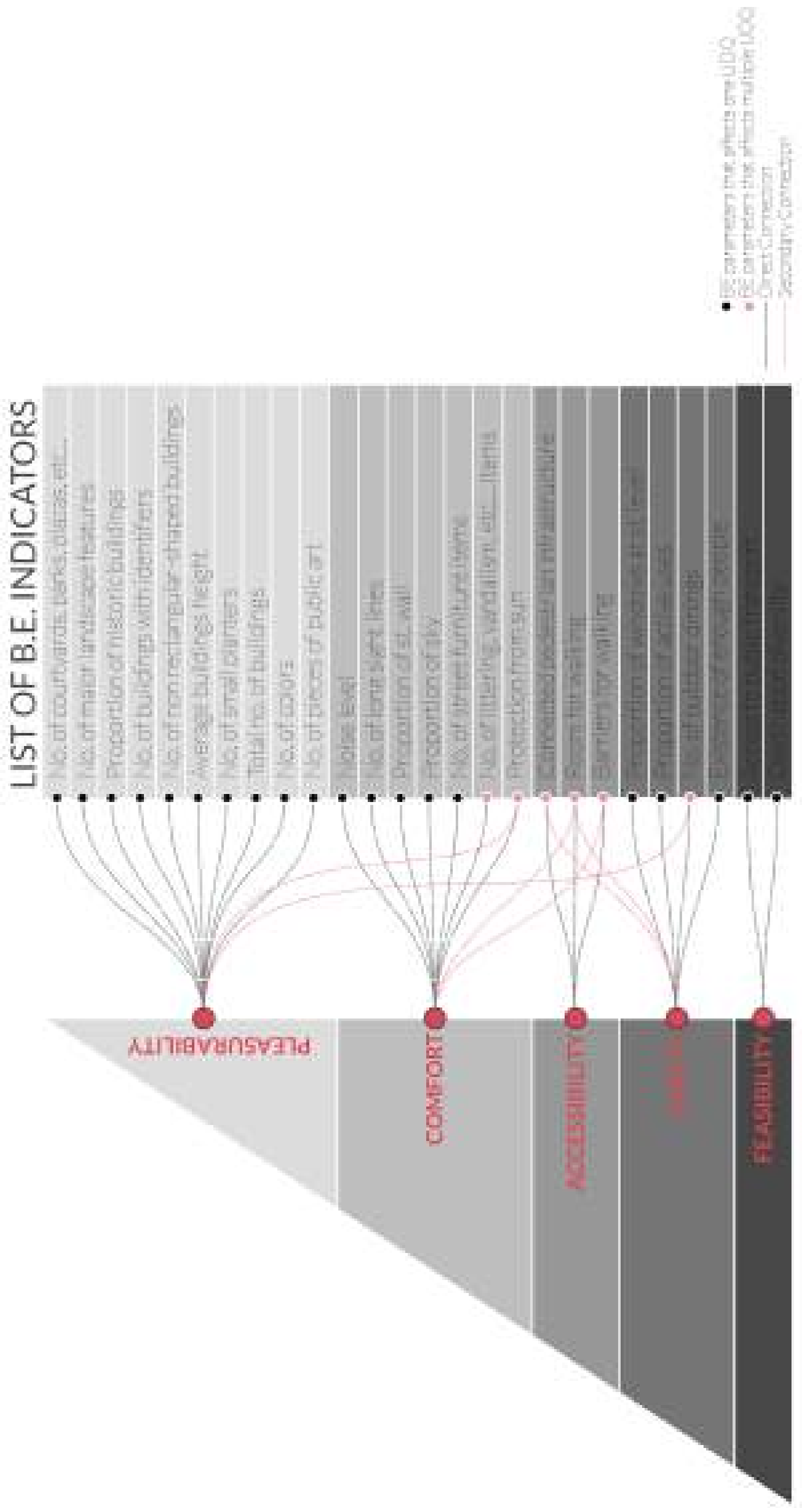

Fig.37 The HBELP after contextualization acorrding to the field survey results

6.2.3. Third section: Safety

The survey results suggest that the BE parameters affecting safety can be arranged from the most effective to the least as follows: The existence of people as the most effective, followed by proportion of active uses then the outdoor dinings and the windows at street level lastly.

The direct result of the survey shows that people perceived the place with outdoor dinings (and a few people walking around) (Fig.30) as the safest place, followed by the fully crowded place (Fig.31) then the street with some active uses but fewer people (Fig.33) and lastly the vacant street with windows at street level (Fig.32). However, in the following questions; the respondents always acknowledged that having people walking in the street is the most effective element to their feel of safety while only %30 mentioned that outdoor dinings is effective at all (Fig.35) which contradicts with the previous results.

By going back to the same theory, as the accessibility section previously; people always aspire for higher needs when the basic ones are satisfied (Maslow, 1943; Alfonzo, 2005; Mehta, 2008; El-Ghandour, 2016; Maslow, 1954), this means that people might have perceived the place with outdoor dinings as better place because it already has ‘enough’ people walking (Fig.30) which makes people aspire for higher needs like having the dinings so when compared with the second image with only people walking (Fig.31), the users’ preferred the first one. But if it weren’t for the people walking, this might’ve been the last choice or pre-last. Accordingly, the “no. of people walking” is modified to become “having enough people walking” (Fig.37) and moved to become the most effective element on the safety in HBELP.

Due to the time and resources limitations of this research, it was not possible to study the “having enough people” parameter deeper so its measurements in the following chapters just go back to the author’s experience in the case study area. But it’s recommended to be included in further development studies for HBELP to determine a more precise measurement method and definition for this specific parameter. However, it doesn’t affect the results of the following sections (identifying issues and proposing solutions) because it’s out of scope for this research which is related to the physical aspect only of the street design process. Also it’s noticed how the number of people might be a double edged weapon, because when exceeding a certain limit, it starts to have a negative effect on the sense of safety (or comfort) while walking, this is deduced by the percentage of people mentioning the word “crowded” in their answers. It is recommended to include the double effect probability of BE parameters in future studies.

The rest of the answers for the safety section were straight forward giving a direct indication for the arrangement of the BE elements affecting safety. So they were arranged and assigned relative weights accordingly (Table 4).

Table 4 Safety parameters relative weighting

	Proportion of windows at St. level	Proportion of active uses	No. of outdoor dinings	Existence of enough people	Relative weight
Proportion of windows at St. level	1	0.5	0.43	0.27	**0.55**
Proportion of active uses	2	1	0.85	0.54	**1.09**
No. of out-door dinings	2.33	1.17	1	0.63	**1.28**
Existence of enough people	3.67	1.8	1.5	1	**1.99**

Regarding the comparison of safety and accessibility; the results suggest that they are equally important. However, for this specific context, safety is more crucial because people might endure some deficiencies in street accessibility but not their sense of safety. This contradicts with some of the previous studies that explored the pyramid of walkability needs (Hinckson, Smith, & Bozovic, 2020), but the leading studies in this matter suggest that this specific comparison (safety vs. accessibility) is totally up to the socio-economic community of the users under study (Alfonzo, 2005; Mehta, 2008) so the pyramid of needs should be tailored for them.

The validation for HBELP through this survey is just miniature of the validation needed for the whole framework constructed in this research. The goal was just to validate the applicability of HBELP on Egyptian context to be able to proceed with the following steps in this research. However, it’s recommended to benefit from the help of urban planning experts & sociologists in constructing a more thorough survey to get deeper results and also having more experiments for the BE identifications. These would be important steps for constructing a more precise HBELP towards building a more comprehensive framework for objective walkability enhancement in different districts in Greater Cairo.

6.3. Summary

This chapter aimed to discuss the results as well as the discussion of the first section of the case study part in this thesis which is the field survey. The goal of this survey was to contextualize the HBELP model for the users in the case study area through testing three main points in the model: the model structure, the hierarchy of walkability needs & BE parameters and lastly, assigning relative weights for the BE parameters [refer to chapter 5]. The results of the survey can be summarized in the following points:

- Regarding the model structure; feasibility, accessibility and safety are the basic needs for the users in the street setting (design), the feasibility is the deal breaker in determining whether to walk through a street.
- The accessibility and safety are equally important but for the users in the study area; the safety is more crucial as a need for walking than the accessibility; the HBELP is modified accordingly.
- The survey results suggest that the BE parameters affecting feasibility can be arranged as provision of destination diversity as the most effective followed by access to public transportation.
- The survey results suggest that the BE parameters affecting accessibility can be arranged from the most effective to the least as follows: barriers to walking, room for walking, connected pedestrian infrastructure.
- The survey results suggest that the BE parameters affecting safety can be arranged from the most effective to the least as follows: The existence of people as the most effective, followed by proportion of active uses then the outdoor dinings and the windows at street level lastly.
- As a result for the previous interpretations, the HBELP model is modified accordingly (Fig.37) and the BE parameters are given relative weights (The geographical location of the study area being part of one of the main CBDs in Greater Cairo (Abdel-Samad, 2016) contributes greatly to its provision for feasibility of walking. Being a mixed-usage

area creates destinations for people which in Egypt can be enough because transportation in some areas can be just a result of accommodating these variety of destinations. This is clear in the study area by the percentage of users reaching it through informal public transportation as they represent almost 50% of the users using public transportation means. This indicates that having destinations is the most effective parameter within feasibility. However, it also requires the provision of public transportation. Weights are assigned to both parameters accordingly (Table 2)., Table 3 Accessibility parameters relative weighting, Table 4 Safety parameters relative weighting).

Chapter 7:The framework application

According to the case study methodology discussed previously [refer to chapter 5], this chapter focuses on the second section of the case study part in the thesis. The structure of this chapter goes through the steps of the walkability enhancement framework which are relatively similar to the conventional design process but through introducing different methods & tools with the aim of tackling the main research objective; towards a more efficient street design process.

The first step is illustrating the site measurements results and using them to reach a scoring for the walkability needs. Then in step 2, these scores are used to identify the issues within the existing setting of the study area followed by step 3 which is focused on proposing the solutions. Lastly, a comparative analysis is drawn between this framework and the work done before on the same study area (by the ministry of housing) as an example of the conventional street design (assessment & enhancement) process in Egypt.

7.1. Step 1: Site measurements results

7.1.1. Built environment parameters

The field measurements show that, when compared with the reference values, 5 out of the 9 BE parameters under study are on the less favorable side from the threshold values; they are either higher when they should be lower or vice versa (Table 5) which are highlighted in bold text within the table.

Feasibility: The BE parameters affecting the street design feasibility for users show good signs as both of them are higher than the reference values. However, the access to public transportation stops within the study area sums up to 6 stops (Fig.38) which is higher than the maximum possible value found in all previous studies that discussed this parameter in the street design physical aspect. From these 6 stops, only one is formal while the rest are all informal stopping nodes .

Fig.38 Public transportation stops spatial allocation, author
The white dot is the only formal stop while the rest red ones were all informally generated by people

Fig.39 The formal bus stop

Fig.40 People waiting for microbuses at an informally generated stop

Fig.41 Microbuses waiting for people at an inforamally generated stop

Table 5 BE parameters site measurements

WN	BE Parameter	Value	Min.	Reference	Max.	Normalized Value	Relative weight
Feasibility	Destination diversity	80	10	59.2	100	0.77	1.5
	Access to public transportation*	**6**	1	1	2 (6)	1	0.75
Accessibility	Connected pedestrian infrastructure	**69**	60	85	100	0.2	0.8
	Room for walking	**0-10**	4	5.2	8	0.25	0.86
	Barriers for walking	**20**	0	8	12 (20)	1	-1.64
Safety	Proportion of windows at St. level	65	20	65	92	0.625	0.55
	Proportion of active uses	75	10	59.2	100	0.72	1.09
	No. of outdoor dinings	**0**	0	1.43	8	0	1.28
	Number of people*	90	20	60	100	0.875	1.99

Accessibility: All three BE parameters affecting the street accessibility for the users have measurements that are on the unaccepted side related to the threshold (reference) values for each of them. Starting with the connected pedestrian infrastructure parameter where almost 31% of the study area length have disconnections in the physical walking space for people either on the side walk (Fig.42) or at the crossings (Fig.43,Fig.44) which makes the score of this parameter far below the needed percentage (85%). This score is given be adding all the values for different forms of disruptions to the physical walking space detailed in (Table 6). However, among all these disruptions; only one major


Fig.42 Sidewalk infrastructure


Fig.43 Minor crossing


Fig.44 Major crossing

crossing exists while the rest are either minor crossings or deteriorated parts of the sidewalk.

Table 6 Details of connected pedestrian infrastructure scoring

Forms of unconnected pedestrian infrastructure		Value	Weight	Total effect on accessibility scoring
Street crossing	Major	1	10	10
	Minor	6	3	18
Sidewalk deteriorates		2	1.5	3
Total				**31**

The second parameter regarding street accessibility is the room for walking available to people which, along the study area, is totally inconsistent. It ranges from being a 10 clear meters at maximum (Fig.45) and goes all the way down to vanishing for not a short walking spaces without any sidewalk (Fig.47) with lots of variations in between.

Within the study area there are a total of 20 physical barriers to the walking space among which some totally block the sidewalk (Fig.48) image and others can be considered minor barriers where the pedestrians still have few space left on the sidewalk to bypass them (Fig.49). Nonetheless these barriers are more than the threshold value.

<u>Safety:</u> The results don’t show much significant weaknesses; as only one parameter was found to be below the reference value which is the number of outdoor dinings. However, the study area has 3 restaurants where people stand in front of it to order and eat without sitting (Fig.50)

The number of people is not related to the physical aspect but it affects the room

Fig.45 Plenty of walking space

Fig.46 Intermediate walking space

Fig.47 No walking space

for walking parameter so it's taken into consideration. However the methodology behind calculating the number of people in reference studies was not clear (Tawfik, 2017) so it is assumed that they measured with the people/min. unit.

7.1.2. Walkability needs

By following the CWNI methodology introduced in chapter 4 and given the relative weights assigned in chapter 6, the BE parameters are aggregated to have a scoring for each of the walkability needs. The results show that 2 out of the 3 basic walkability needs are below the reference value detailed as follows: The feasibility of the street design does not show any significant weakness while both the accessibility and safety show weaknesses where the accessibility shows major weakness with a negative score while safety shows minor weakness being below the reference value by only 0.8 (Table 7).

Table 7 Walkability needs scoring & reference values
Bold text indicates issues.

Walkability need (WN)	WN scoring	Ref. WN score
Feasibility	0.95	0.75
Accessibility	**-0.42**	0.85
Safety	**0.72**	0.8

7.2. Step 2: Current situation assessment

The results from the site measurements step suggest that Al-Tahrir St. is relatively walkable but it has some deficiencies in the basic walkability needs and the users can benefit for some upgrading strategies to provide a better walking environment. In this step, the issues within the current situation measurements of the study area are identified based on analyzing the previous results and then these issues are prioritized to give direction for the following steps in the process.

Fig.48 Physical barriers totally blocking the sidewalk

Fig.49 Semi-blocking physical barriers

Fig.50 People standing & sitting on the sidewalk to eat

7.2.1. Issues identification

7.2.1.1. Feasibility

The feasibility as the very basic walkability need in the study area is higher than the reference value which indicates high feasibility with no significant issues. Regarding the BE parameters affecting feasibility, as previously discussed, in some areas the destination diversity can be the main parameter provided and access to public transportation can be just a result which is the case in Al-Tahrir street.

This can be deduced from the percentage of informal public transportation stops within the area. The street was designed to have only one public transportation stop (Fig.38) while at the time of this study it has a total of 6 among which 5 are informal which – even if it was planned not generated informally – are higher than the maximum needed number of stops within this walking distance (Kashef, 2011) which indicates some sort of weakness in the street design. Fig. shows how this interpretation coincides with the walking experience in the street as these informal stops generate traffic nodes in spaces that were not planned to contain this kind of traffic neither on the street nor the sidewalk.

7.2.1.2. Accessibility

The accessibility of the street design shows significant weakness when comparing its score to the reference value which indicates that a critical development strategy is needed. This coincides with the survey results when people were asked through an open question about the most critical thing that they need to be done in the street design in any future development; many mentioned elements related to the street accessibility.

Clearly, all the BE parameters affecting accessibility show deficiencies in the walking space as none of them meet the minimum required score to be accepted by users (Table 5). The hieratical importance of these BE parameters effect on the street accessibility (Fig.37) shows that the physical barriers to the walking space contributes with the biggest share to this result.

The room for walking shows some potential because for sections along the street, there's enough room (more than the 4m. needed) for people to walk (Fig.45, Fig.46). So firstly, the street design needs to provide more room in some spaces (Fig.47) but more importantly, the street design needs to provide a relatively consistent sidewalk width to create an appropriate walking space for the people.

The total measurements regarding the connected pedestrian infrastructure parameter shows critical need for development (Table 5). However, by reviewing the detailed measurements (Table 6); it's found that among all the physical disconnections to the walking space; only one is a major crossing that needs some critical alterations while all the others are either minor crossings or deteriorated parts of the sidewalk which indicates that the connected pedestrian infrastructure is relatively an easy-fix issue.

7.2.1.3. Safety

The safety aspect does not show any significant need for development. However, people can benefit from some alterations that can provide higher sense of safety for the walking realm. This coincides with the survey results as only few percentage of users mentioned that there's a need for alterations of BE parameters related directly or indirectly to their sense of safety which means that people are almost satisfied with the street safety.

The BE parameters affecting safety show some room for development. For example there isn't any outdoor dinings (Table 5). However there are few open-door food places that people stand on the sidewalk to order or eat (Fig.50). Also from the site observations it's noticed that there are some ground floor uses that are closed or not used which is a potential development for the 'proportion of active uses' parameter as well.

7.2.2. Issues prioritization

The issues with some BE parameters identified previously are already categorized in groups based on their effect on each of the basic walkability needs. Although the safety is more basic as a walking need than the street accessibility (Fig.37) according to the tailored HBELP model for the study area, the results suggest that the top prioritized walkability need that requires to work on is the street accessibility as it shows major deficiencies then comes the safety with much less alterations needed and the feasibility lastly.

Within the street accessibility, it's recommended to start by working on the 'barriers to walking' parameter as a top priority. Then the 'room for walking' parameter which needs much less but critical work according to the previous analysis and lastly the connected pedestrian infrastructure.

Regarding the safety; it's recommended to explore potential solutions for providing some outdoor dinings firstly and then redoing the rating step to check if the safety score has met the needed level. If not, then it's recommended to explore the availability of increasing the proportion of active uses along the study area by reactivating the closed or abandoned ground floor uses.

For the street feasibility; further analysis should be done for the access to public transportation to determine whether people need all that number of stops so that it can be included within future development plans.

7.3. Step 3: Proposing solutions

7.3.1. Objective optimization results

As mentioned in the case study methodology, the feasibility doesn't require optimization tools because it achieves an acceptable scoring and according to HBELP (Fig.37), it's only affected by two parameters among which the destination diversity is almost fixed so only one parameter can be altered which is access to public transportation. So the results in this section focus on the different alterations explored for accessibility, safety and overall walkability. This section discusses combined results data while raw results are provided in Annex 2.

7.3.1.1. Accessibility

When optimizing the accessibility, the increments of 0.3 increase in score were not valid for application; as the minimum bounds set for each of the BE parameters prevented the algorithm of producing an accessibility score with a negative sign. In the first run (A_Run_01) for the algorithm; the target value for the accessibility fitness was set to zero which is the minimum possible value. The algorithm modified the 3 BE parameters to make each at its minimum accepted value according to the constraints (Table 8).

By each run, the target value for the fitness is increased by increments of 0.3; according to which the algorithm adapts the combination of the BE measurements to achieve this target. By the 4th run (A_Run_04), the algorithm had reached the reference value for accessibility scoring (0.85). However, it increased the 'room for walking parameter' to have a measurement of 7m which is not possible in some parts of the street.

One more run was done with the same target fitness of 0.85 but with tightening the value constraints for the available room for walking to have a maximum of 5m which is the possible, achievable, most consistent walking space along the street. The algorithm reached an optimized situation according to these constraints that achieves an acceptable scoring for accessibility as shown in Run_05 results (Table 8). For further enhancement; A_Run_06 shows how to make the accessibility scoring exceeds the reference value. Full results for each run calculations are listed in annex.

Table 8 Optimization algorithm results for enhancing accessibility score

BE Parameter	**Current Situation**	**A_Run_01**	**A_Run_02**	**A_Run_03**	**A_Run_04**	**A_Run_05**	**A_Run_06**
Connected pedestrian infrastructure (%)	69	60	60.4	85.9	100	99.4	100
Room for walking (m.)	0	4	4.90	4.9	7.0	4.6	5
Barriers for walking (count)	20	12	7	4	4	0	0

Accessibility (score)	**0.59**	**0.00**	**0.30**	**0.60**	**0.85**	**0.85**	**0.89**

7.3.1.2. Safety

The target for optimizing the safety score of the street was set to 0.8 which is a relatively minor upgrade since the current situation score is 0.72. In the two runs, the algorithm could achieve the target value for the fitness. However, in the second run (S_Run_02), a constraint was added to make the value of 'proportion of street windows' value fixed to explore this solution so it modified the two other BE parameters and could reach an optimized situation (Table 9).

Table 9 Optimization algorithm results for enhancing safety score

BE Parameter	Current situation	S_Run_01	S_Run_02
Proportion of windows at St. level (%)	65	72	65
Proportion of active uses (%)	75	90	75.14
No. of outdoor dinings (count)	0	1	2
Safety (score)	**0.72**	**0.80**	**0.80**

7.3.1.3. Overall walkability

The walkability score of the current situation is 0.24. In the first run (W_Run_01), the goal was to reach a score of 0.3 which the algorithm could not achieve precisely. However, the closest score it could reach is 0.37. In this run, the final score of the feasibility was the same as the current situation, Accessibility score increased by 0.59 while Safety is less than the current situation with a score of 0.52 (Table 10).

In the second run (W_Run_02), the target walkability score was 0.6 which the algorithm achieved by altering the BE parameters to reach a Feasibility score of 0.62, Accessibility score was enhanced by almost 35% and Safety increased with almost the same percentage. The third run was the fittest, as the algorithm could reach a walkability score of 1 and the scoring of each of the walkability needs is around 1 as well (Table 10).

Table 10 Optimization algorithm results for enhancing overall walkability score

BE Parameter	Current situation	W_Run_01	W_Run_02	W_Run_03
Destination diversity	80	80	80	80
Access to public transportation	1	1	1	2
Feasibility	**0.58**	**0.58**	**0.62**	**0.95**
Connected pedestrian infrastructure	69	60	71.1	93.9
Room for walking	0	4	4.75	6.8
Barriers for walking	20	12	7	0
Accessibility	**-0.59**	**0.00**	**0.35**	**0.96**
Proportion of windows St. lvl.	65	65	65	65
Proportion of active uses	75	10.0	85.9	92.9
No. of outdoor dinings	0	0	2	8
Number of people	90	90	90	90
Safety	**0.72**	**0.52**	**0.83**	**1.09**
Overall walkability	**0.24**	**0.37**	**0.60**	**1.00**

7.3.2. Objective optimization discussion & further research

Revolutionary algorithms work in a way similar to the concept of survival to the fittest. It starts with some random values for the changing parameters then perform computational process that defines the relationship between these parameters and the fitness then explore the value of the fitness compared to the objective target value. It keeps repeating the process for as much number of times as needed to reach the fittest solution. The designer has the ability to check all these steps that the algorithm went through to reach the fittest situation.

The application results suggest that utilizing the optimization algorithm tools to be used for the walkability enhancement process can be very beneficial. The automation procedures to reach a target objective gives unlimited degrees of freedom to solutions exploration. It makes the process more efficient because, compared to the conventional methods, it requires less time and resources while providing a larger number of solutions with significant results. This methodology needs further research related to constructing the theoretical background that controls how this step can be performed more accurately and which software can be more effective than Microsoft Excel which was used in this thesis.

It's noticed how some altering the constraints set for the BE parameters during constructing the algorithm can change the final result significantly. For example during the runs regarding the accessibility objective, the algorithm could reach the same 'acceptable' solution with a room of walking equals 7m in A_Run_04 and with a value equals 4.6m in A_Run_05 as well. Furthermore it could reach a noticeable higher accessibility score with a room for walking equals 5m (Table 8). This shows how setting the minimum and maximum values is a critical input in the process as they construct the bounds for the algorithm to search for an optimum solution. This is also clear in the runs regarding safety as the algorithm could reach the same safety scoring with two different 'proportion of active uses' bounds values (Table 9).

The application also shows how much the results can change according to the objective of the optimization. For example if the goal is to optimize the accessibility scoring of the street, the algorithm with tweak the BE parameters measurements in order to reach that objective. But if the objective fitness is set to the overall walkability scoring, it will be the only reference for all modifications done to the BE parameters; this might lead to making some walkability needs worse instead of enhancing it which can be noticed from the first run (W_Run_01) in optimizing the overall walkability (Table 10) as the algorithm altered the parameters to enhance walkability but it lead to a decrease of the safety scoring by almost 30%. So careful observations should be given to the change in walkability needs scoring while optimizing the overall walkability.

The application results suggest that utilizing the optimization algorithms makes the walkability enhancement process more efficient in three main aspects.

Firstly, during the whole step of proposing solutions within the design process, it took a total of 11 runs for the algorithm. Behind each of these 11 runs; the algorithm checked around 5000 different alterations when working with each of the walkability needs (safety, accessibility) and around 72,000 for the runs that had the overall walkability as the objective fitness and among all these trials it outputs the fittest solution. The time needed for each run ranged between 30 seconds and 3 minutes at most which gives a total time of 13 minutes for the whole process. These runs represent 11 different design proposals that if to be done manually would take much more time to think, plan and assess.

Secondly, the number of solutions experimented using the algorithm are way more than it can be done manually; it's impossible for any team to check this number of different alterations towards reaching an optimized situation. The utilization of this tool diminishes time and effort spent to explore wide range of solutions. The focus shifts to gaining insights about the analysis of the fittest solutions which also contributes to making this process a lot more efficient.

Also, due to the limitations of this research, this process is carried out only by the author while if working manually to explore these amount of solutions in a given time bound it would need at least a full team of urban designers which indicates how resources-efficient this tools is.

Multiple aspects in this step can be developed in further research. For example, setting the minimum and maximum values is done manually while the same process can be done using other software that offers a 3D workflow directly connected with the algorithm (for example Catia or Rhinoceros with grasshopper) from which it can read that physical environment and translate it into numbers to compare with and move on with the process.

Also checking the doable solutions in this thesis was done manually; the outputs were compared with the reference values and linked back to the physical environment to choose the fittest, as illustrated previously regarding the 'room for walking' parameter. This process can also be automated if using a software that offers 3D workflow instead of Microsoft excel spreadsheets.

7.4. Two frameworks comparative analysis

This section focuses on the comparative analysis between the framework followed in this thesis and the process done by the research team from the ministry of housing on the same study area (Salama, Fouad, Mohamed, & A.Aziz, 2016). The focus of the two frameworks is the physical aspect of the street design, how it affects the street walkability and aim to propose solutions to enhance to provide better walking space for the people. The two frameworks goes almost through similar steps but differ in the methods & tools used to do them which is discussed in this section.

Importantly, there are many different approaches followed in field practice as well as the academic studies in Egypt related to the topic of walkability enhancement frameworks. That's why comparing with that specific study, done by the ministry of housing, does not imply that it's identical to all street design processes in Egypt, instead it was just the only available study done on a similar street with almost the same scope as this thesis. Additionally, it illustrates some of the general steps followed by designers in field practice so it can be related to when reading this thesis.

The differences between the two frameworks falls back on the approach of collecting, analyzing and processing the data in addition to proposing solutions. The ministry of housing's research is an example of the conventional street design & upgrading projects in Egypt which is the qualitative methodology; of collecting qualitative information (through methods like field observations and interviews with people) then trying to analyze them to propose solutions. In contrast this thesis aims to explore the benefits of following quantitative & systematic objective methods and steps in the same process. This difference in the approach acts as the main reason for the different directions followed in each study along the way as discussed in this section.

<u>Site mapping:</u> As the first step; site mapping was done in order to be analyzed in following steps. In both studies; a pedestrians density study was part of the site mapping step. Although multiple previous studies done on different contexts did not take this parameter into consideration (for example see (Barnett & Cerin, 2017; Ewing & Cervero, 2010; McCormack & Shiell, 2011)), in both studies here it was thought of as an important aspect to build better understanding for the study area.

In the ministry of housing's research, in addition to studying pedestrians density, the site mapping also included a master plan of the study area with different land uses spatially allocated zoning (Fig.51) while in this thesis; the mapping was mainly focused on site measurements for specific BE parameters based on

HBELP model (Table 5). In the ministry of housing's study, field observations were not structured; the research team went on site visits to observe the walking behavior in general without any specifics in mind. In contrast; the field measurements in the introduced framework are more systematic and structured as the BE parameters under study are precisely set according to the data inputs from the HBELP model. This suggests more efficiency of having such framework regarding the time needed for mapping as well as human resources needed to do the mapping.

Furthermore, the field observations as data collection method in the ministry of housing's work were subject to the researcher personal interpretation of what can be identified as an issue and what won't while in the introduced framework, the procedures ensure the objectivity of the process as they are related to specific BE measurement methods according to HBELP.

<u>Issues identification:</u> The current situation analysis of the study area was done, in the ministry of housing's research, through observations on the pedestrian walking behavior as well as the physical environment of the walking space within the study area while in the introduced framework it was done through comparing the BE parameters current measurements to the reference values as well as comparing the scoring of the basic walkability needs (feasibility, accessibility and safety) to the reference scores (Table 5, Table 7). This shows two different approaches being used in this step; as in the first study the analysis was done subjectively based on the research team's interpretations of their field observations results; building the analysis upon qualitative data methods while in this study the analysis is totally objective based on measurements and scoring.

The subjectivity of issues identification in the first research acquires the need for further testing for these issues because some of them might be different from what the users will identify as issues with the walking spaces while in the introduced framework, HBELP was tailored for the users' needs (through the field survey) so when a scoring does not meet the reference value; there's a much higher degree of certainty it tackles the real people's needs.

The outputs of the current situation analysis step is a map with all noticed issues with the physical aspect of the street (BE parameters) spatially allocated altogether in the ministry of housing's report while in this study, firstly, the main deficiencies with any of the basic walkability needs were highlighted then the underlying BE parameters affecting these basic needs were identified. This

Fig.51 Mapping the current situation landuses, Source: Salama, Fouad, Mohamed, & A.Aziz, 2016

method provides a more precise and time efficient issues identification as they are categorized so it's known which issues affect which walkability need. Also these issues are also prioritized by importance according to the tailored HBELP for the study area users (Fig.37) which sets the direction for following steps. Furthermore, it's known how much a specific issue affects the corresponding walkability needs since each BE parameter has a relative weight (Table 2, Table 3, Table 4).

Proposing solutions: Lastly, in the ministry of housing's report, a list of alterations and additions was proposed for the street design to fix the identified issues previously while in this research computational algorithms were used to explore a wide range of different possibilities and alterations among which an optimized combination for the BE parameters was reached that enhances the scoring of each walkability need as well as the overall walkability scoring of the street.

The proposed solutions by the ministry of housing's team needed verification as it was subjected the personal points of views of the research team; so it needs field tests to explore if it actually tackles the identified problems. In contrast, HBELP was tailored for the users' needs so when enhancing the scoring of the identified list of BE parameters, there's a higher degree of certainty that the proposed solutions will work which affects the decision making during in the design process.

Additionally, by comparing the proposed recommendations in the ministry of housing's report with the proposed solutions in this thesis, it's clear that they are totally covered; if the proposed solutions through the introduced framework are to be implemented, they will overcome all the issues identified in the ministry of housing's study while noticing that this thesis only tackles the three basic walkability needs in HBELP. This means that if the higher needs in the pyramid (comfort & pleasurability) were considered, a much more inclusive solutions could be reached; resulting in better walking urban spaces for people.

Lastly, although reaching the step of proposing solutions, the introduced framework is less applicable compared to the conventional process. The reason for this is, it's almost totally objective model, and it still needs more development in further studies so that the outputs are translated back to qualitative data to be applied or projected on the street design.

7.5. Summary

- This chapter aimed to focus on the results and discussion of the second section of the case study part in this thesis. The structure of the chapter goes through the introduced framework steps towards walkability enhancement in the study area as follows:
- Firstly, field site measurements were done according to HBELP. The results showed that measurements of 5 out of the 9 BE parameters under study were less than the required values; they are access to public transportation, connected pedestrian infrastructure, room for walking, barriers to walking and number of outdoor dinings.
- As a result, two of the three walkability needs were less than the required scoring (accessibility & safety). The accessibility showed a significant weakness while the safety needs minor upgrading to reach an acceptable score.
- The previous issues were identified, categorized and the priorities for the following steps were set by reviewing the tailored HBELP model for the study area in chapter 6.
- Within the street accessibility, it's recommended to start by working on the 'barriers to walking' parameter as a top priority then the 'room for walking' parameter and lastly the connected pedestrian infrastructure.
- Regarding the safety; it's recommended to explore potential solutions for providing some outdoor dinings firstly and then redoing the rating step to check if the safety score has met the needed level. If not, then it's recommended to explore the availability of increasing the proportion of active uses along the study area by reactivating the closed or abandoned ground floor uses.
- For the street feasibility; further analysis should be done for the access to public transportation to determine whether people need all that number of stops so that it can be included within future development plans. Fig. shows a flow chart of the recommended prioritized issues to work on in the study area

for the coming solutions proposals steps.

- Proceeding to proposing solutions; numerous different alterations were explored by utilizing the optimization algorithms embedded in Microsoft Excel software.
- Then a discussion was drawn about the beneficially of utilizing such method in proposing solutions and further research vision for these tools. Lastly, this introduced framework was compared with the process followed in the scientific study held by the ministry of housing on the same study area to determined benefits, pitfalls, further research needed.
- The introduced methodology shows very promising results regarding the adoption of objective walkability enhancement frameworks for the efficiency of the street design in Egypt.

Chapter 8: Research conclusion

8.1. Conclusions

The motive behind this thesis was, as an urban designer, seeing how much knowledge is available in the academic field in all aspects related to urban studies in general and in the topics of livable streets & walkability specifically while in the same time noticing how the roads networks upgrading plans in Egypt deal with the streets as vehicular connection axes on the macro scale with almost total ignorance of the pedestrian aspect; people's rights in the streets. In January, 2020, (The Egyptian center for public opinion research) had published a report mentioning that the total number of vehicles owners was 4.9 million; which represents a percentage of around 4.6% of the total population in Egypt. Of course the roads networks target much more users than private car owners but this highlights the minor percentage of people who benefit directly from the upgrading plans compared to the large percentage of people who walk on a daily basis for transportation; whose needs are not targeted in the implemented plans.

As a result, this thesis aimed to address the gap between the scientific studies and field practice process of street design through adopting an alternative framework that integrates different tools & methods in the process; exploring the potential benefits of adopting such framework with the objective of reaching a more efficient street design process. The adopted framework benefits from the large body of scientific research available to build a sound theoretical background that acts as a mediator; translating these data into design process procedures. The main difference from other street design processes in Egypt is relying mainly on quantitative data collection methods and objective assessment instead of qualitative data collection & synthesis.

To attain this objective, this thesis started by developing a theoretical background out of the existing scientific literature that studied the relationship between the built environment and users' walkability needs. This aimed to construct a model that focuses on the relationships between the built environment (street design) and the walkability of the street; which was done through building HBELP; a model that illustrates a list of all BE parameters (that gained a general consensus to be the most associated with walkability) and how they are linked to the basic walkability needs of the street users in addition to field measurement description of each parameter.

Proceeding to the empirical part of the thesis, its aim was to explore the benefits of having that objective framework (focused on the physical aspect of the street design for walkability enhancement) on the efficiency of the conventional urban streets design process in Egypt. However, in order to use HBELP in field application; it had to be, firstly, verified for application which was done through holding a field survey among users in Al-Tahrir street (case study area). Its results were used to modify HBELP to fit the socio-economic background of users in the study area. The main finding from the survey results suggest that with some modifications according to each study area context & users, HBELP can be valid for application on main streets in Greater Cairo.

After tailoring the model for the users, it was used to address the street walkability in order to enhance it. Firstly, field measurements were done for the BE parameters according to HBELP. Then, by following the CWNI methodology, these measurements were used to objectively rate each of the basic walkability parameters according to a scoring system. By comparing the scores of the current situation to the reference values; the issues with the walkability needs could be objectively identified. Then by reviewing HBELP along with the survey results and field observations, the issues were prioritized to set direction for any upgrading or development plans.

Contributing to the exploration of a more efficient process; computational tools were utilized in the step of proposing solutions. Optimization algorithm within Microsoft Excel software was used to explore wide range of different alterations that can be done to the BE parame-ters in order to reach an acceptable scorings for the walkability needs that had issues (Accessibility & Safety). A separate discussion section was drawn for this step to highlight the benefits of utilizing these tools. The main synthesis of this application results discussion suggests that utilizing the optimization algorithm tools to be used for the walkability enhancement process can be very beneficial. The automation procedures to reach a target objective gives unlimited degrees of freedom to solutions exploration. It makes the process more efficient because, compared to the conventional methods, it requires less time and resources while providing a larger number of solutions with significant results.

Lastly, in order to determine the benefits of adopting an objective-approach framework, a descriptive comparative analysis was drawn between the procedures followed in the application section of the case study in this thesis and previous work done by the ministry of housing on the same study area, as an example of the conventional street design process in Egypt, with the same process aim which is enhancing the street walkability. The comparison focused on the methodology, methods and tools used in each one and their effect of the efficiency of the street design process.

Reflecting on the main research objective, this comparative analysis indicates that the adopted objective framework in this thesis shows very promising results towards a more efficient street design process. Starting from the site mapping where having a defined set of BE parameters to measure on site saves much time and resources compared to unstructured observations. Then identifying the issues through comparing scoring of the walkability needs to references values eliminates the subjectivity that mostly exists when working in the conventional process; specifically if the users of the area were not integrated in the design process. Lastly, utilizing optimization algorithms to propose alterations allows for a much more number of solutions explored in shorter time in addition to provision of total control on the constraints for these alterations so the at the algorithm can reach the same result through different proposals.

8.2. Future outlook

This thesis benefited from multiple sources of data, tools and methods; that each can be regarded as a different topic of research but they all admix together towards reaching the output framework. Accordingly, the future vision for the development research stream ta-gets single sections as well as the framework overall but for organizational purposed, this section separately discusses, firstly, the vision for the framework overall connecting it to the current situation in Egypt then proceeds to target each of the different sections.

8.2.1. Full framework

The framework adopted to enhance street walkability in this thesis was developed based on an educated hypothesis of the benefits it might achieve for the street design process in Egypt. The core of any framework related to walkability is how clearly and accurately it creates the link between the BE and real needs of people. That's why after developing HBELP in this thesis it had to be taken further and modified (contextualized) through the field survey. Assuming the accuracy of the contextualization, then there's a model that interprets the needs of users in Al-Dokki district into objective measurements.

This model can then be of benefit for, firstly, any urban designer/planner working on the area; as he'll have it as a starting point instead of, almost blindly, going on site visits to start from the very beginning of building an understanding about the people's needs and so on. Also it will be beneficial if - according to the process of most roads upgrading projects implement-ed in the last 4 years – the people's opinion will not be taken into consideration due to the lack of time and resources resulting in designing streets that are better for the vehicular movement but worse for the people. Instead the designer will at least have the minimum insight about the effects of his decisions on the people's lives.

When overlooking how it can be implemented in a larger scale, Greater Cairo can be divided into homogenous zones, in urban morphology and user's socio-economic background (many urban planning experts had already done that). Then for each zone, the model can be contextualized and modified to fit that specific district. These contextualized models can then be translated into guidelines for streets design in each zone. As a result, if required to work with the same pace, the designers will be able to address the pedestrian aspect and the street livability without consuming any major additional time in field researches or sur-veys. Furthermore, these guidelines can be, after extensive analysis, translated into street design regulations and set among other regulations that the urban planner/designer or even roads engineers will have to achieve otherwise the design proposal will be rejected by the government.

8.2.2. The hierarchical built environment list of parameters model (HBELP)

General future vision: Firstly, for the theoretical background for the model, Ewing's model was compared with the review of reviews by Hickson (2020), Hickson's work was based on studies only written in English and published in Scopus. There might be other studies relat-ed to the same topic written in other languages or published elsewhere.

Also, the model provided a graphical representation of the BE parameters & pyramid of walkability needs, in addition to a table with field measurement description for each parameter. However, towards a more accurate & objective measurements it's recommended to include images for examples of the BE measurements; transforming the model into being a full field manual to be used by anyone not just urban designers or planners. If combined with the recommendations of the CWNI (discussed below), this point can be very beneficial for the model to be used by other entities like the local administrative of districts to accurately assess their current situation in order to apply for funding for the government for example.

The model theoretical structure: In this thesis, feasibility as a quality of the street design was only studied from the physical aspect; focusing on the BE parameters affecting it. Ho-ever, feasibility can be explored from a whole different point of view related to the users themselves. For example, studying the average age of users and cross analyzing it with the health status can provide more insights about what to provide as destinations and design language of the street as well, based on the strategic plan for the area (for example see (Barnett & Cerin, 2017; Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Eisenberg, Vanderbom, & Vasudevan, 2017; Frank, Engelke, Schmid, & Killingsworth, 2003)). It's recommended to include such demographic studies within future researches in order to make HBELP more comprehensive.

In HBELP's construction methodology, the redundancy in BE parameters was taken into consideration. However, each BE parameter was regarded to be totally independent while affecting the walkability needs. But to critically think about this assumption, there might be correlations among the BE parameters themselves; if one of the BE parameter changes, it affects other parameters which can result in misleading results. That's why a further research should be done to explore the interactions, connection and correlations among the identified list of

BE parameters.

Regarding the sense safety, some intangible indicators should be included in the model, like the existence or absence of threatening groups (Alfonzo, 2005), but since this study only focused on the physical aspect of the street and since the perceived sense of safety can differ totally from one culture & community to the other, then this kind of indicators was not included. However, it's highly recommended to be included in future enhancement of this model as this is a crucial element specifically if studied alongside with the age & gender of the users, the context of the study; urban or rural and the type of streets; main or secondary

Some BE parameters should be further tested for their effect on the users' feel of comfort while walking; for example the width of the vehicular section of the street and its consequences like the average vehicles speed, street crossing availability, and traffic volume. These indicators were not included in this study due to scale and time limitations that made the output model of HBELP from this research focus mainly on the sidewalk design. But they were found to be related to the comfort of the pedestrian users so they should be taken into consideration (Frank, Engelke, Schmid, & Killingsworth, 2003).

The model contextualized structure: The validation for HBELP through the field survey was just miniature of the validation needed for the whole framework constructed in this research. The goal was just to validate the applicability of HBELP on Egyptian context to be able to proceed with the following steps in this research. However, it's recommended to benefit from the help of urban planning experts & sociologists in constructing a more thorough survey to get deeper results and also having more experiments for the BE identifications. These would be important steps for constructing a more precise HBELP towards building a more comprehensive framework for objective walkability enhancement in different districts in Greater Cairo.

Furthermore, from the survey results, it was noticed in the open ended questions that some BE parameters might not have been mentioned in HBELP. For example, two respondents mentioned the relation between having lighting posts and their feel of safety, which can logically be true but it need to be tested. This articulates the point discussed previously about the differences in contexts from the walking environment and socio-economic structure of people in Egypt. Additionally, although the survey only focused on the three main walkability needs (Feasibility, Accessibility and Safety), many respondents mentioned shading ele-ments as one of the main missing elements in the street design. When reviewing the literature, having shading elements was a parameter that is regarded among top needs in the pyramid. However, in Egypt due to the climate it might be more crucial than other BE parameters discussed in the thesis. This indicates that further analysis, through surveys and observations, should be done towards exploring the BE parameters that affect walkability needs for the Egyptian context.

8.2.3. Composite walkability needs indices methodology (CWNI)

General future vision: The CWNI methodology was mainly adopted in this thesis just as a mediator to translate the type of data between different science fields. However, utilizing this too to be used for assessment as done in the issues identification step in the case study can be very beneficial. Relating to the point of setting regulations, this methodology can be translated to become an official rating system for the urban streets in Cairo. This system can then be used to assess the current situations of streets all over the city to determine major deficiencies. Additionally, this will help in categorizing the upgrading projects on a scale normal-urgent for example which contributes to setting more accurate priorities for the projects to be funded and implemented in Cairo.

Importantly, the composite indicators construction is a wide field of science; numerous re-searches are published discussing its benefits and the different methods for doing it. This research was neither an analytical study into the composite indicators construction methodology nor setting definite guidelines for adopting these methods in urban studies or walkability. It only benefits from the basic concepts and methods of composite indicators as a tool & step towards building the objective framework for street design process enhancement for walkability. So it’s recommended to have deeper analysis in this step, by benefiting from statisticians, in order to reach more robust guidelines for constructing composite walkability needs indices in further studies.

8.2.4. Computational tools & urban studies

Working with urban-related issues with such objective framework that translates everything into numbers is not very common among researchers of field practice. Also providing num-bers as results & design proposals is not the language used by urban designers or planners. In this thesis, Microsoft Excel was used to reach an optimized situation totally concerning the measurement of BE parameters and walkability needs scoring. However, this step has to be translated back in the form of sketches, plans, 3D models, etc…

Working with 3D software will enable some more automation possibilities, for example the minimum and maximum values for the BE was done manually during the case study while the same process can be done using other software that offers a 3D workflow directly con-nected with the algorithm (for example Catia and Rhinoceros with grasshopper) from which it can read that physical environment and translate it into numbers to compare with and move on with the process. Additionally, the outputs were compared with the reference val-ues manually and linked back to the physical environment to choose the fittest as illustrated previously regarding the 'room for walking' parameter. This process can also be automated if using a software that offers 3D workflow instead of Microsoft excel spreadsheets. Refer to the full discussion of utilizing the optimization algorithm in the workflow in chapter 7.

8.3. Recommendations

The future outlook discussed previously, sets the directions for different sections in this thesis. However, few recommendations are provided more related to the general current status of streets designs & projects that has been going on a fast pace for the last 4 years:

For both the Egyptian government and specifically Ministry of Transportation along with Cairo & Giza, being the main - potentially only – stakeholders in the process of the roads networks upgrading plans. A major review for these plans should be done because, as no-ticed from the implemented projects, the human aspect in the street design is ignored; available walking spaces are diminishing and pedestrian friendly streets are diminishing by projects.

Furthermore, multi-disciplinary projects take more time and effort. However, it's recom-mended to benefit from the experience of academic experts in different fields before im-plementing a project or even as an evaluation phase for the already finished ones, so that lessons can be learnt from these projects towards an enhanced street designs. Additionally, it's known how tight the budgets for projects are in Egypt right now. However, few invest-ments in scientific analysis and studies focused on the roads development plans can avoid potential pitfalls in the future which will cost much more to repair or undo.

Adopting an objective framework to assess and enhance walkability has shown promising results in this thesis. As a result, the author recommends that urban designers & planners and even health and sociology expects in Egypt, should start to widen the body of survey to explore the notion of objective walkability frameworks to be incorporated within the conven-tional scientific research stream related to walkability. This can help the designers and deci-sion makers to create livable urban environments for the people which is crucial in the age when Egypt is finally striving to come out of the Nile Delta and expand across the country.

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Annex 1: Study area photo documentation

Fig.52 Panorama shot for Al-Tahrir St.

Fig.53 Deteriorations in the available walking space

Fig.54 Littering on almost every corner

Fig.55 Disconnected pedestrian infrastructure

Fig.56 Inappropriate sidewalk height for elder peopl, children or disabled users

Fig.57 Microbuses stop to pick up users anywhere along the street

Fig.58 Sidewalk suddenly diminshes

Fig.59 Street vendors take most of the available walking spaces

Fig.60 Informal on street parking

Fig.61 Sidewalk diminshes; for whole blocks; forcing people to walk on the street

Fig.62 Street vendors sitting by the fence; affecting the walking decisions of users (1/2)

Fig.63 Street vendors sitting by the fence; affecting the walking decisions of users (2/2)

Fig.64 Lack of any pedestrians crossing facilitites (1/3)

Fig.65 Lack of any pedestrians crossing facilitites (2/3)

Fig.66 Lack of any pedestrians crossing facilitites (3/3)

Fig.67 Informal practices on the sidewalk by shops; taking up any available room for walking (1/2)

Fig.68 Informal practices on the sidewalk by shops (2/2)

Fig.69 Disconnected pedestrian infrastructure

Fig.70 Abandoned shops

Fig.71 Top view for minor crossing space; note the lack of any pedestrian-friendly design elements

Fig.72 Decent available room for walking in some sections along the street

Fig.73 Some sections of the sidewalk are closed by the government; resulting in people walking on the street

Fig.74 Insuffecient room for walking and informal drop and pick up practices

Fig.75 Few abandoned buildings

Fig.76 Decent available room for walking in some sections (1/2)

Fig.77 Decent available room for walking in some sections (2/2)


Fig.78 Aerial view of Al-Tahrir St. (1/4)


Fig.79 Aerial view of Al-Tahrir St. (2/4)

Fig.80 Aerial view of Al-Tahrir St. (3/4)

Fig.81 Aerial view of Al-Tahrir St. (4/4)

Annex 2: Optimization algorithm raw results

Accessibility:

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Current Situation	Connected pedestrian infrastructure	69	85	60	100	0.23	0.8	0.18	
	Room for walking	0	5.2	4	8	-1.00	0.86	-0.86	
	Barriers for walking	20	8	12	0	-0.67	1.64	-1.093333333	
	Accessibility							**-0.59**	**0.85**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Algorithm definition	Connected pedestrian infrastructure	100	85	60	100	1.00	0.8	0.8	
	Room for walking	5	5.2	4	8	0.25	0.86	0.215	
	Barriers for walking	0	8	12	0	1.00	1.64	1.64	
	Accessibility							**0.89**	**0.85**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Run_01 Target_score_ 0	Connected pedestrian infrastructure	60	85	60	100	0.00	0.8	0	
	Room for walking	4	5.2	4	8	0.00	0.86	0	
	Barriers for walking	12	8	12	0	0.00	1.64	0	
	Accessibility							**0.00**	**0.85**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Run_02 Target_score_ 0.3	Connected pedestrian infrastructure	60.4	85	60	100	0.01	0.8	0.008	
	Room for walking	4.90	5.2	4	8	0.22	0.86	0.193354899	
	Barriers for walking	6.90	8	12	0	0.43	1.64	0.697099636	
	Accessibility							**0.30**	**0.85**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Run_03 Target_score_ 0.6	Connected pedestrian infrastructure	85.9	85	60	100	0.65	0.8	0.517650008	
	Room for walking	4.9	5.2	4	8	0.23	0.86	0.195732096	
	Barriers for walking	4.1	8	12	0	0.66	1.64	1.084315927	
	Accessibility							**0.60**	**0.85**

Accessibility, continued:

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Run_04 Target_score_ 0.85	Connected pedestrian infrastructure	100	85	60	100	1.00	0.8	0.8	
	Room for walking	7.0	5.2	4	8	0.75	0.86	0.647528673	
	Barriers for walking	3.9	8	12	0	0.67	1.64	1.105875009	
	Accessibility							**0.85**	**0.85**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Run_05 Target_score_ 0.85 Room for walking_<5	Connected pedestrian infrastructure	99.4	85	60	100	0.98	0.8	0.787698817	
	Room for walking	4.6	5.2	4	8	0.15	0.86	0.124728242	
	Barriers for walking	0	8	12	0	1.00	1.64	1.64	
	Accessibility							**0.85**	**0.85**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Run_06 Max_possible _score Room for walking_<5	Connected pedestrian infrastructure	100	85	60	100	1.00	0.8	0.8	
	Room for walking	5	5.2	4	8	0.25	0.86	0.215	
	Barriers for walking	0	8	12	0	1.00	1.64	1.64	
	Accessibility							**0.89**	**0.85**

	BE Parameter	Current situation	Run_01	Run_02	Run_03	Run_04	Run_05	Run_06
Runs_Combined	Connected pedestrian infrastructure	69	60	60.4	85.9	100	99.4	100
	Room for walking	0	4	4.90	4.9	7.0	4.6	5
	Barriers for walking	20	12	7	4	4	0	0
	Accessibility	**-0.59**	**0.00**	**0.30**	**0.60**	**0.85**	**0.85**	**0.89**

Safety:

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Current Situation	Proportion of windows at St. level	65	65	20	92	0.625	0.55	0.34	
	Proportion of active uses	75	59.2	10	100	0.72	1.09	0.79	
	No. of outdoor dinings	0	1.43	0	8	0	1.28	0	
	Number of people*	90	60	20	100	0.875	1.99	1.74	
	Safety							**0.72**	**0.8**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Algorithm definition	Proportion of windows at St. level	65	65	20	92	0.63	0.55	0.34	
	Proportion of active uses	75.140646	59.2	10	100	0.72	1.09	0.79	
	No. of outdoor dinings	2	1.43	0	8	0.25	1.28	0.32	
	Number of people*	90	60	20	100	0.88	1.99	1.74	
	Safety							**0.80**	**0.8**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Run_01 Target_score_0.8	Proportion of windows at St. level	72	65	20	92	0.72	0.55	0.40	
	Proportion of active uses	90	59.2	10	100	0.89	1.09	0.97	
	No. of outdoor dinings	1	1.43	0	8	0.07	1.28	0.09	
	Number of people*	90	60	20	100	0.88	1.99	1.74	
	Safety							**0.80**	**0.8**

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
Run_02 Target_score_0.8	Proportion of windows at St. level	65	65	20	92	0.63	0.55	0.34	
	Proportion of active uses	75.14	59.2	10	100	0.72	1.09	0.79	
	No. of outdoor dinings	2	1.43	0	8	0.25	1.28	0.32	
	Number of people*	90	60	20	100	0.88	1.99	1.74	
	Safety							**0.80**	**0.8**

	BE Parameter	Current situation	Run_01	Run_02
Runs_Combined	Proportion of windows at St. level	65	72	65
	Proportion of active uses	75	90	75.14
	No. of outdoor dinings	0	1	2
	Safety	**0.72**	**0.80**	**0.80**

Overall walkability:

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
	Destination diversity	80	59.2	10	100	0.78	1.5	1.17	
	Access to public transportation*	1	1	1	2	0	0.75	0	
	Feasibility							**0.58**	**0.55**
	Connected pedestrian infrastructure	69	85	60	100	0.23	0.8	0.18	
	Room for walking	0	5.2	4	8	-1	0.86	-0.86	
Current Situation	Barriers for walking	20	8	12	0	-0.67	1.64	-1.09	
	Accessibility							**-0.59**	**0.85**
	Proportion of windows at St. level	65	65	20	92	0.625	0.55	0.34	
	Proportion of active uses	75	59.2	10	100	0.72	1.09	0.79	
	No. of outdoor dinings	0	1.43	0	8	0	1.28	0	
	Number of people*	90	60	20	100	0.875	1.99	1.74	
	Safety							**0.72**	**0.8**
	Overall walkability							**0.24**	

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
	Destination diversity	80	59.2	10	100	0.78	1.5	1.17	
	Access to public transportation*	1.983192723	1	1	2	0.983192723	0.75	0.737	
	Feasibility							**0.95**	**0.55**
	Connected pedestrian infrastructure	93.88562916	85	60	100	0.85	0.8	0.678	
	Room for walking	6.765791488	5.2	4	8	0.691447872	0.86	0.595	
Algorithm definition	Barriers for walking	0.339128621	8	12	0	0.97	1.64	1.59	
	Accessibility							**0.96**	**0.85**
	Proportion of windows at St. level	65	65	20	92	0.625	0.55	0.34	
	Proportion of active uses	92.8698245	59.2	10	100	0.92	1.09	1.00	
	No. of outdoor dinings	8	1.43	0	8	1	1.28	1.28	
	Number of people*	90	60	20	100	0.875	1.99	1.74	
	Safety							**1.09**	**0.8**
	Overall walakability							**1.00**	

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
	Destination diversity	80	59.2	10	100	0.78	1.5	1.17	
	Access to public transportation*	1	1	1	2	2.06384E-05	0.75	2E-05	
	Feasibility							**0.58**	**0.55**
	Connected pedestrian infrastructure	60	85	60	100	0.00	0.8	0	
	Room for walking	4	5.2	4	8	0	0.86	0	
Run_01 Target_score_0.3	Barriers for walking	12	8	12	0	0.00	1.64	0.00	
	Accessibility							**0.00**	**0.85**
	Proportion of windows at St. level	65	65	20	92	0.625	0.55	0.34	
	Proportion of active uses	10.0	59.2	10	100	0.00	1.09	0.00	
	No. of outdoor dinings	0	1.43	0	8	0	1.28	0	
	Number of people*	90	60	20	100	0.875	1.99	1.74	
	Safety							**0.52**	**0.8**
	Overall walkability							**0.37**	

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
	Destination diversity	80	59.2	10	100	0.78	1.5	1.17	
	Access to public transportation*	1.085712939	1	1	2	0.085712939	0.75	0.064	
	Feasibility							**0.62**	**0.55**
	Connected pedestrian infrastructure	71.1	85	60	100	0.28	0.8	0.222	
	Room for walking	4.75	5.2	4	8	0.18673996	0.86	0.161	
Run_02 Target_score_0.6	Barriers for walking	7	8	12	0	0.41	1.64	0.67	
	Accessibility							**0.35**	**0.85**
	Proportion of windows at St. level	65	65	20	92	0.625	0.55	0.34	
	Proportion of active uses	85.9	59.2	10	100	0.84	1.09	0.92	
	No. of outdoor dinings	2	1.43	0	8	0.25	1.28	0.32	
	Number of people*	90	60	20	100	0.875	1.99	1.74	
	Safety							**0.83**	**0.8**
	Overall walkability							**0.60**	

	BE Parameter	Value	Reference Value	Min.	Max.	Normalized Value	Relative weight	Score	Reference WN score
	Destination diversity	80	59.2	10	100	0.78	1.5	1.17	
	Access to public transportation*	2	1	1	2	0.983192723	0.75	0.737	
	Feasibility							**0.95**	**0.55**
	Connected pedestrian infrastructure	93.9	85	60	100	0.85	0.8	0.678	
	Room for walking	6.8	5.2	4	8	0.691447872	0.86	0.595	
Run_03 Target_score_1	Barriers for walking	0	8	12	0	0.97	1.64	1.59	
	Accessibility							**0.96**	**0.85**
	Proportion of windows at St. level	65	65	20	92	0.625	0.55	0.34	
	Proportion of active uses	92.9	59.2	10	100	0.92	1.09	1.00	
	No. of outdoor dinings	8	1.43	0	8	1	1.28	1.28	
	Number of people*	90	60	20	100	0.875	1.99	1.74	
	Safety							**1.09**	**0.8**
	Overall walkability							**1.00**	

BE Parameter	Current situation	Run_01	Run_02	Run_03
Destination diversity	80	80	80	80
Access to public transportation*	1	1	1	2
Feasibility	**0.58**	**0.58**	**0.62**	**0.95**
Connected pedestrian infrastructure	69	60	71.1	93.9
Room for walking	0	4	4.75	6.8
Barriers for walking	20	12	7	0
Accessibility	**-0.59**	**0.00**	**0.35**	**0.96**
Proportion of windows at St. level	65	65	65	65
Proportion of active uses	75	10.0	85.9	92.9
No. of outdoor dinings	0	0	2	8
Number of people*	90	90	90	90
Safety	**0.72**	**0.52**	**0.83**	**1.09**
Overall walkability	**0.24**	**0.37**	**0.60**	**1.00**

Field survey questions [Translated]

There are a lot of changes and developments that are happening in the streets of Cairo and Giza nowadays. Streets are not just made for cars but also for walkers. This survey tries to collect some data from people who go to Al-Dokki and Al-Mohandessen in order to know more about their needs so that it can be accommodated in sidewalks design. We want to know more about how to make their walking experience better, more comfortable and more enjoyable.

There is no right or wrong answer, we just want to know your point of view.

This survey collects some non-personal data about people who use Al Tahrir Street.

This survey is made for a Master's Degree in Faculty of Engineering, Ain Shams University.

1. Age:
2. Sex

- Male

- Female

3. Why do you go to Al-Tahrir Street?

- I live there.
- I work there.
- Shopping or hanging out (cafes or restaurants)
- Clinics
- Other

4. If you chose Other, can you explain more?

5. How often do you go there?

- Everyday
- Once a week
- Once every two weeks
- Once a month
- Less than that
- This is your first time here

6. If you come once or more than once a week, when do you arrive?

- 11-6 AM
- 11 AM5- PM
- After 5 PM
- Other (you don’t have a specific time)

7. What kind of transportation do you use to come here?

- Walking
- I have a car
- Taxi/Uber
- Public transportation (Bus-Microbus)
- Other

8. Is it easy or is it hard for you to get here?

9. Why did you choose that answer?

10. Do you walk on daily basis?

- Yes
- No

11. If your answer is yes, when do you get tired of walking?

- 10-0 mins
- 15-10 mins
- 20-15 mins
- More than 20 mins
- I don’t get tired of walking

The easiness of walking in the street

Try to rearrange the following pictures according to what do you think is the easiest to walk in (-1 best, -2 medium and -3 worst)

12. Street A:

13. Street B:

14. Street C:

15. If you get to choose only one street of the following 3 to walk in everyday, which one are you going to choose?

16. Why did you choose that?

- The walking space
- There are obstacles
- The whole pavement connected

- Other

17. If there is any other reason that affected your choice then can you explain it more?

According to safety, can you rearrange the following places (-1best and -4worst)

18. Street 1:
19. Street 2:
20. Street 3:
21. Street 4:

22. What affected your choice? (you can choose more than one reason)

- The presence of restaurants
- The huge number of walkers
- There are windows which overlook the street
- The presence of shops
- Other

23. What do you think is the most important? (Choose one only)

- The presence of cafes and restaurants on the street
- The huge number of walkers
- There are windows which overlook the street
- The presence of shops
- Other

24. If you choose Other, please explain more?

25. If the design of the pavement can provide only one thing, which of the following do you think is the most important?

- It’s easy to walk on
- Safety

26. If you are put in a choice where you have to choose only one of the following two streets to walk in everyday, which one are you going to choose?

- Street A:
- Street B:

27. What is the reason for your choice?

28. If you can change/add anything to the pavement's design in Gamaat Al-Dwal street, what are you going to change/add?

29. Can you rate this survey according to how much you understood its questions?

المستخــلص

فى خلال الأربعة أعوام الماضية, هناك اهتمام واضح من الحكومة المصرية باستراتيجيات تطوير و رفع كفاءة شبكات الطرق المختلفة و هو ما يـمكن التأكـيد عليه بعدد المشاريع الخاصة بالطرق التى تم تنفيذها فى هذه الفترة و على الرغم من وفرة الخبراء و الخـبرات فى مـجال تصمـيم شوارع تحث المستخدمين علـى سـمات التعايـش المختلفة و بالأخص المـشى كأحد أهم مميزات المديـنة الحضـرية, إلا أنـه فى الغالبية العظمى من المـشاريع, يتـم التعامل مع الشـوارع على أنها طرق للسيارات حصرياً مع تـجاهل العنصر الإنسـانى فى التصميم و هذه دلالة على وجود فجـوة بين الدراسـات الأكاديـمية و المـمارسة الواقـعية للمـشاريع. نتـيجة لذلك, تهـدف هذه الرسـالة للوصـول إلى عمـلية تـصميمية أكثر كفاءة من خلال تطوير منهجية عمل قائـمة بالأساس على الموضوعية فى التعامل مع العملية التصميمية حيث تستفيد هذه المنهجية من الوفرة فى مجال البحث الأكاديمى و تحاول ترجمته إلى خطوات تنفيذية للمشاريع.

لهذا يتكون الهيكل الأساسى لهذا البحـث من مجموعة خطوات تبدأ بتكوين خـلفية نظرية من خلال مراجعة الدراسـات السابقة المتعلقة بدراسة العلاقة بين البيئة العـمرانية و احتياجات المشاة و اختتام هذا الجزء بتكوين نموذج يوضـح أهم المعلومات التى تم استنتاجها. بعد ذلك يتم استخدام هذا النموذج, كأساس جوهرى للمنهجية المسبقة, على دراسة ميدانـية من أجل استكشـاف أهم الفوائد المترتبة على تبنِّى هذه المنهجية و لكن نتيجة لأن هذا النموذج تم استنتاجه من خلال مراجعة دراسات تمت فى مناطـق مختلفة من العالم, فيتحتم فى البداية اجراء اختبار لصحة تطبيقه على دراسة ميدانية فى مصر من خلال إجراء استبيان بين مستخدمى المنطقة و استخدام نتائجه لتعديل النموذج السابق ذكره ليلائم احتياجات المستخدمين تفصيلياً. نهايةً, يتـم إجراء مقارنة تـحليلية بين المنهجية التى تم تبنِّيها فى هذا الرسالة و دراسة مسبقة تمت على نفس المنطقة و بنفس الأهـداف المتعلقة بالبيـئة العمرانية و المشاة.

تشير هذه الرسالة إلى الكثير من النتائـج الواعدة من خلال تبّنى المنـهجية الجديدة نحو عـملية تصميـمية أكثر كفاءة. أولاً, توفر هذه المنهجية أسالـيب أدق لخطوة دراسـة الموقع من خلال التدقيق على عناصر بعينها فى تصميم الشـارع. بالإضافة إلى إقصاء الآراء الذاتـية للمصممين من خلال توفير نظام تقييم منهجى لخطوة تقييم الوضع الحـالى و أخيراً, فإنها تـمهّد الطريق نحو تطور نوعى ضخم فى الأدوات و الطرق المستخدمـة فى العملية التصميميـة عن طريق الأستـفادة من أدوات تكنولوجية مثل خوارزميات التـحسين لإستكشاف عدد أكبر من الحلول المخـتلفة للتصميم مقارنةً بالعملية التصميمية التقلـيدية.

إقرار

هذه الرسالة مقدمة في جامعة عين شمس وجامعة شوتجارت للحصول على درجة العمران المتكامل والتصميم المستدام. إن العمل الذي تحويه هذه الرسالة قد تم إنجازه بمعرفة الباحث سنة ٢٠٢٠

هذا ويقر الباحث أن العمل المقدم هو خلاصة بحثه الشخصي وأنه قد اتبع الإسلوب العلمي السليم في الإشارة إلى المواد المؤخوذه من المراجع العلمية كلٌ في مكانه في مختلف أجزاء الرسالة..

وهذا إقرار مني بذلك،،،

التوقيع:

الباحث: عــمرو صلاح الدين

التاريخ:

نحو تـــصميم شـــارع مــحسَّن للــمشى: تطوير منـــهجية عمل نحو عملية تصميمية أكثـــر كفـــاءة للــشوارع فى مصر

مقدمة للحصول على درجة الماجستير في العمران المتكامل والتصميم المستدام

أعداد: عـــمرو صـــلاح الـــدين

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جامعـــة عين شمـــس

لجنة الحكم

أ.د. ....
أستاذ.............
جامعة ....

أ.د. ....
أستاذ.............
جامعة ....

أ.د. ....
أستاذ.............
جامعة ....

التوقيع

تاريخ المناقشة:..............

الدراسات العليا

ختم الإجازة

موافقة مجلس الكلية .../.../...

أجيزت الرسالة بتاريخ:.............

موافقة مجلس الجامعة .../.../...

جامعة عين شـــمس

جامعة عين شــــمس

نحــو تصميم شـــارع مُحسَّن للمشــى: تطوير منهجـية عمل نحو عمــلية تصميمية أكثر كفاءة للشـــوارع فى مـــصر

رسالة مقدمة للحصول على درجة الماجستير في العمران المتكامل والتصميم المستدام

إعداد

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(٢٠٢٠)