Sustainable urban mobility: Assessing Different Neighborhood Models in Greater Cairo Region, Egypt.

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1 ABSTRACT
Sustainable urban mobility aims to encourage movement behavior that reduces automobile dependency and induce non-automobile and public mobility. As cities continue to change, planners are facing the challenge of designing urban mobility systems that are sustainable on social, economic, and ecological levels. They aim to reduce transportation energy consumption; increase social interaction between residents; and increase subsidiary effects of side path through movement. There is a growing call for planners to shift the paradigm of urban mobility to enable economic activity, social connectivity, and ecology. Movement behavior is influenced by different factors, part of them due to socioeconomic variables, others due to urban form. Some neighborhoods seem to support alternative modes of movement of non-motorized or public motorized as feasible mobility solutions and meet resident's expectations and accordingly reduce the need for high level of motor vehicle ownership; Where other neighborhoods don't and encourages residents to depend on private alternatives accordingly increase fuel consumption, cost, and environmental pollution. Based on a case study of six neighborhoods that represent the chronological development of neighborhood types in the greater Cairo region, this research provides an understanding of how urban mobility was influenced by neighborhoods urban patterns. This research suggests that some specific neighborhood features can efficiently influence people mobility, demand and travel behavior than others, accordingly enhance achieving sustainable urban mobility and overall sustainability of development.

Keywords: Sustainable Urban Mobility, Movement Behavior, Mode choices, Mobility Pattern, Neighborhood Patterns, Greater Cairo Region.

2 INTRODUCTION
Sustainable urban mobility aims to achieve sustainability goals through movement behavior in environmental, economic and social level. Last decades, a massive scientific research worked to test the impacts of neighborhood pattern's urban form on movement behavior as a way to achieve sustainability in the built environment. Different scholars concerned the role of public transportation, walking and cycling in achieving this goal, through using an urban form that encourages such trends. This paper works on the way the neighborhood pattern could achieve efficient public transportation and so achieve sustainable transportation and enhance built environment sustainability.

Old neighborhoods, the grid pattern, high density with crowded streets; make public transport is un-useful, undesirable, and uncomfortable for residents. So it encourages them to depend on private alternatives accordingly increase fuel consumption, cost, and environmental pollution. Modern neighborhoods with low density, separate use, large distance caused a low feasibility in public transportation so it also increases private alternatives; accordingly increase fuel consumption, cost, and environmental pollution. The overcrowded and low quality in old towns and the low feasibility in new towns are key factors for reducing the impact of on movement behavior.

Different neighborhood models can play a significant role in shaping individual travel behavior. Land use patterns, housing income pattern, and street network pattern are factors that differentiate neighborhood models, and can affect movement behavior inside our cities. Neighborhood patterns impact the type, quality and quantity of mobility facilities that can be used and accordingly shape residents travel choices of movement behavior (Giles-Corti et al., 2013). Mode choices depend on residents socioeconomic characteristics like age, gender and socioeconomic level; at the same time, urban form characteristics creates conditions that can facilitate and encourage some kinds of travel behavior while discouraging other types of travel behavior. Most studies of movement behavior have focused on the impact of some neighborhood patterns like land use, housing income, and street network pattern and density.
2.1 Research Aim
Some neighborhood patterns' characteristics facilitate types of travel behavior and discourage other types, whereas other characteristics do not do so. An understanding of the reason that some neighborhoods provide more chances of pedestrian, cycle movement and public transportation and improve trip's distance and frequency than others is important to improve energy saving and reduce resource depletion and reduce environment pollution. The aim of this paper is to analyze current evidence relating to the impact of urban form patterns on travel behavior patterns, based on a case study in the greater Cairo region. The article examines how travel behavior was influenced by urban form in six neighborhoods. The results suggest that urban form can mediate the impacts of movement behavior on sustainability issues.

2.2 Research Hypothesis
This research suggests that neighborhood patterns can effectively influence people's mobility demand and travel behavior towards achieving sustainable urban mobility in Cairo. And that traditional neighborhood is pedestrian oriented that discourages motorized travel and increase non-motorized one, and could reduce trip distance and trip frequency. On the other hand, modern neighborhood is car oriented that encourage motorized travel and minimize the pedestrian one.

2.3 Research Method
An inductive analysis using comparative methods is used to test and compare the relation between neighborhood pattern and movement behavior. The research depends on two interlocking stages. First, a literature review to introduce the two variables of the research, movement behavior and urban mobility in terms of concept, historical development, and measurable variables. In addition, to introduce sustainable urban mobility in terms of concepts, types and measurable indices. Finally, Field study of six neighborhoods in the Greater Cairo Region to test the mutual relationship between the two variables. The field study goes through three steps: Measuring neighborhood patterns, measuring movement behavior and measuring resident's perception of sustainable development indicators, and testing the validity of their relations. The research is based on the spatial model for measuring land-use pattern and semi structured interview for measuring resident's satisfaction to urban development.

3 URBAN FORM AND SUSTAINABLE URBAN MOBILITY
This part intends to explore the meaning and factors of movement behavior, the paradigm shift to sustainable urban mobility, and based on previous studies to review the relation between urban form and urban mobility.

3.1 MOVEMENT BEHAVIOUR
Movement behavior is a social behavior of residents, like any other behaviors, it is based on demand, constraints and potentialities. Movement behavior can be defined using different travel parameters, such as (trip frequency, trip distances, mode choices of travel, or overall vehicle kilometers traveled, trip rates, overall traveling distances, traveling distances by mode, modal shares, and energy consumption.

The variable "Modal Choices" means, whether and to what degree residents, willing to use certain travel modes (private versus public), (motorized versus non motorized), (motor, walking, cycling). To what degree they feel satisfied with public transportation, private car, walkability, cycling. To what degree they depend on each travel mode during day hours, during night hours, till late night. Percentage of Each mode trip per total trips.

The variable "Public Transportation" refer to available public transportation and their suitability. Resident satisfaction with the quality of public transportation, and the degree of proximity and accessibility to public transportation, and the main reason of using or not using public transportation (expense, availability, quality, safety, comfortability, flexibility).

The variable "Private vehicle" refer to no. of car ownership. Times of using private car per day, and the main reason of using or not using private car (available parking spaces, traffic jam, traffic information, safety, comfortability, flexibility, accident risk, fuel cost due to distance and frequency, minvatnce cost).

The variable "Cycling" refer to no. of cycle ownership. Times of using cycle per day, and the main reason of using or not using cycling (available cycle lanes and their quality, traffic jam, safety, comfortability, flexibility, accident risk, effort due to distance and frequency).
The variable "walkability" refers to times of using walkability per day, and the main reason of using or not using walkability (available walkways and their quality, safety, comfortability, flexibility, accident risk, effort due to distance and frequency).

The variable "Trip Frequency" includes the time residents can repeat this trip per week; it probes the degree to which resident found it easy to repeat the trip. Trip frequency in traditional neighborhoods is limited by car due to the lack of parking area.

The variable "Trip Distance" includes the actual network distance travelled by the residents from their own residence to various destinations. It measures residents willing to drive long or short distances.

The Variable "Travel Obstacles" was measured whether and to what degree there is a physical and psychological conditions that limit traveling by certain modes at certain times of the day.

The variable "Car Ownership" (vehicle ownership is high in high income neighborhoods, and the bicycle is higher in traditional neighborhoods). In traditional neighborhoods residents can afford cars, but due to the unavailability of parking area they prefer to reduce car ownership and reduce depending on them.

The variable "Parking Area Availability" include Questions regarding available public transportation and their suitability.

3.2 SUSTAINABLE URBAN MOBILITY

UN-Habitat in the global report of human settlements, reported a paradigm shift in transportation planning. It differentiated between two paradigm shifts in movement, the first that found efficiency in increasing traffic flow efficiency based on the speed, affordability and convenience of motorized transport. On the contrary, the current paradigm strives for sustainable mobility through accessibility based on minimizing the need for extended movement, Reducing the need for motorized demand, Reducing the Number of Motorized Trips, Reducing Travel Distances inside Cities, and Changing the Modal Split. As cities continue to change, planners are facing the challenge of designing urban mobility systems that are sustainable on social, economic, and ecological levels.

The development of sustainable mobility starts with the organization of urban form to reduce the need for mobility, reduces travel distances and reduce travel frequency in the first hand, and to concern mode choices to pedestrian and public transportation and shared modes instead of private alternatives. Accordingly, better the impact of urban form on movement behavior could enhance social, economic, and environmental impacts of sustainable development. There is a growing call for planners to make the paradigm shift in mode choices to enable economic activity, social connectivity, and ecological sustainability.

This shift puts forward an interest to urban planners. To develop an urban form that impact well on movement behavior and achieve sustainable urban mobility in term of social, economic, and environmental levels. There is a growing call for planners to make the paradigm shift in mode choices to enable economic activity, social connectivity, and ecological. Traditional neighborhood by mixed use between residential units and commercial, compaction, high community size, may encourage non-motorized community modes and reduce travel distance and. On the contrary, modern neighborhoods by separate use, low density, low community size, may encourage the reliance on private car, increase travel distance, trip frequency, the need for motorized demand, Reducing the Number of Motorized Trips, Reducing Travel Distances inside Cities, and Changing the modal Split.

Sustainable urban mobility should Enhance Movement behaviors in term of mode choices, trip distance, trip frequency and reduce pollution and traffic cognition and transportation cost including energy consumption, maintenance, time and effort. It should achieve the following criteria:

- Enhance Permeability increases the property of how easy it is to move through an environment and depends heavily upon the paths and objects placed within the space. There are two types of permeability: physical properties (e.g. A path) and visual appearance. For example, although a path may exist in some environment, if it is not visibly obvious it may remain unused (McCal et al, 2005). It means to avoid restrictions that distort the continuity of city urban fabric, and distort traffic movement, and make the residents looking for alternative roads that could be longer which reduces the movement functional efficiency. “Freezes” the urban fabric forever.
• Enhance Accessibility by providing a range of choices of safe routes, and removing barriers for movement to accessibility of residents to services, facilities, and urban spaces, reducing the degree to which "ability to access" and possible benefit of services, amenities and urban environment is accessible by as many people as possible. Hence it affects the urban, economic and social mutual and exchange benefit of the community in this urban fabric.

• Enhance Connectivity and Integration through promoting external dependency to connect people with each other and to facilities with a range of choices of saving routes.

• Encourage Movement Behavior by reducing travel distances, travel frequently, and accordingly avoids travel time and cost and reduce traffic volumes. In addition don't isolate people without vehicles, create efficient “day” and “night” districts (Masnavi, 2000).

• Encourage Alternative movement systems by increasing the degree that urban form could encourage potential for alternative movement options (pedestrian, cycling, public transport) and discourage car dependency and improve pedestrian oriented public realm. In addition, it refers to transit, pedestrian, and bicycle systems should maximize access and mobility. It refers to a framework of streets and urban spaces to be easy, safe, and pleasure (Urbed 1997).

• Improve public transportation: Refer to critical mass of activity and sufficient densities, and micro and macro connected street network (Frey 1999, Newton 2000, Buxton 2000). The public modes proved to achieve maximum sustainability in saving fuel consumption, and carbon dioxide pollution reduction. Metro, bus, minibus and tram are alternative public transportation options that move large no. of people in one trip, otherwise each of them would have his own car, and accordingly it will be replaced with a large no. of private cars that could consume more fuel consumption and increase co2 emission and accordingly environmental pollution. This research work on linking the relation between public transportation and neighborhood pattern. To how extent the neighborhood pattern can affect the efficiency of sustainable public transportation.

• Encourage walkability: Refer to ensuring that most people's needs are within walking distance, and providing an environment which is safe and pleasant for pedestrians.

3.3 THE IMPACTS OF NEIGHBOURHOOD PATTERNS ON MOVMENT BEHAVIOUR:

The Correlation between urban form and movement behavior has found in numerous studies. Some scholars found that urban form could facilitate movement behavior using different factors, including density (Cervero, 1996), better street connectivity (Boarnet and Crane, 2001), and the presence of mixed land uses (Cervero, 1996; Moudon et al., 1997; Saelens et al., 2003). A current debate exists among scholars for the role of modern versus traditional patterns on their impacts on achieving sustainable urban mobility. The paper rests on four characteristics of neighborhoods to test their impact on residents movement behavior. They have a continuing effect on transport demand, in terms of the number of trips, mode choice and trip lengths.

3.3.1 Regarding Density:

Scholars consider density as the main factor that could impact movement behavior. They found a relative dependency on private cars in low density communities compared to high density communities. They put four reasons how density impacts travel patterns (Banister, 2005, p: 106). They found high population densities widen the range of opportunities for the development of local personal contacts and activities, and services that can be maintained without resort to motorized travel, and reduce average distances between homes and services, reducing the need to travel and reduce travel distance. In addition, high densities may be more amenable to public transport operation and use and less amenable to car ownership and use which have implications for modal choice. On the other hand, low density could impact modal choices, since residents's forced to cut long distance trips, they mostly depend on motorized mode choices. The public motorized modes are unpractical in case of low densities and low community size, so residents's mostly depend on private motorized mode choices. In addition, density could impact trip frequency.
3.3.2 Regarding Socio-economic Level.

Scholars have argued that socio-economic patterns could be more significant in their impacts on movement behavior, commuting behavior among various income groups, income status is highly associated with certain commuting patterns. High income residents, mostly depend on private cars and neglect the public alternatives, they also depend on long distance trips with high frequency with private cars (Hanson, 1982). The higher the residents' income, the more likely to choose faster and more comfortable and more flexible modes.

3.3.3 Regarding Street Network Pattern:

Some street layouts can be more environmentally sustainable travel patterns than others. The street network pattern can impact the visibility of achieving public transportation. Grid pattern can increase the intersections and so increase the alternative ways so increase. Not only regarding conditions of individual streets, ranging from the dimensions and design of sidewalks to the prevailing level of environmental comfort that may encourage pedestrian movement (Gehl et al., 2006), but also the structure of street networks and street connectivity that encourages such behavior.

Grid-like patterns have high intersection and access points that provide greater connectivity and permeability and promotes short and direct routes that offers shorter trips and reduces travel distance, It provides different pass alternatives and chances. It is highly encouraging public transportation as it allows more direct access to public transport. It can be more transit friendly to the extent that they may allow greater penetration of an area by transit services. It is expected to enhance walkability, and increase trips frequency by foot and reduce trip frequency by private cars, especially with the lower parking area. But at the same time it could facilitate private car trips. On the other hand, tree like patterns have very low number of intersections and access points that reduces permeability, connectivity and accessibility, it promotes very long distances and increases travel distance, and reduce alternatives public transportation options. It is expected to increase private car dependency, high frequent trips by cars.

3.3.4 Regarding land use pattern

Moving from mixed to separate land use probably impact nonwork - travel behavior regarding mode choices, trip distance, trip time and frequency. Land use pattern affects the relation between residential and commercial uses, it could cause a separation between residents and services, accordingly impacts travel demand. Scholars found mixed use is determined for travel behavior and mobility. It could make mode choices depend on walkability than on cars. In addition, it reduces the average trip distance by cars, and the frequency of their use. On the other hand it could increase less energy intensive commuting modes, namely walking and cycling. It impacts its trip frequency and do not affect trip distances.

The literature defined the favorable neighborhood configuration to achieve sustainable urban mobility. Some of them are contradictory between studies according to different contexts, this paves the way to test such hypotheses in local context. These literatures will form guideline to assess the selection of neighborhood in Cairo, Egypt.

4 THE CASE STUDY OF SIX NEIGHBORHOODS IN CAIRO

The objective of this research is to trace any statistical significant differences in responses to resident's movement behavior across different categories of neighborhoods, starting from the traditional, to the sprawled contemporary. Shoubra and Abasia represent early developed urban growth, Masr Elgdida and Nasr City represent early planned urban growth, and 1st district, and Jasmin in New Cairo represent new planned growth. They represent three different chronological ages of Cairo development ranging from

![Figure (1): Street network patterns](image-url)
traditional, mixed-use, pedestrian-oriented neighborhood to the contemporary, separate use, car-oriented neighborhood.

### 4.1 SELECTION OF CASE STUDY

Six neighborhoods were selected to present different categories of physical and social attributes, as shown in Figure 2. They should be developed as public property, not a private. They should satisfy variables incorporated within the study regarding configuration difference in urban form, including the historical development, street network patterns, land-use pattern, housing patterns, population demographics and household characteristics ranging between traditional and contemporary.

<table>
<thead>
<tr>
<th>Early Developed</th>
<th>Early planned</th>
<th>New Planned</th>
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</thead>
<tbody>
<tr>
<td>1) Shoubra 1850 (Early planned)</td>
<td>3) Masr EL-Gdida 1900</td>
<td>5) 1st district 1985 (New Cairo)</td>
</tr>
<tr>
<td>2) Abasia 1850 (Early planned)</td>
<td>4) Nasr City 1960</td>
<td>6) Jasmin 2000 (New Cairo)</td>
</tr>
</tbody>
</table>

Figure (2): Case Study Selection (Greater Cairo Region)

Cairo urban form revealed different typologies of adopted urban development patterns that are different in density, land-use pattern, housing income pattern, and street network pattern. Four typologies of urban form are traced starting from Fatimid old Cairo. Followed by early developed districts that informally grow over green land and adjacent to the planned settlements, like Shoubra, Abassia, Sharabia and others. Followed by early planned by private developers in end of 18th and the early 19th century like Khedewi Cairo, Maadi, EL Muhandssin, and Heliopolis and early planned by the government like Nasr City. Finally, the latest modern new planed Egyptian settlements surrounding Cairo like new Cairo, Shorouk and El Obour to the east and six October and Sheikh Zayd to the west.

The Fatimic traditional urban form will be excluded from the analysis due to deep socio-economic changes take that place along 1500 years from the establishment to now; and due to the inconsiderable design trend for considering the automobile as it was not a exist mobility solution. Accordingly the research will depend on three typologies: the early developed, the early planned, and the new planned. In most of the following analysis, the neighborhood arranged according to such categorization to present the movement behavior moving between these categories. Six neighborhoods are selected to present different chronological patterns in Cairo development.

- Early developed: Abasia and Shoubra are selected to present the early developed neighborhoods.
- Early planned: Masr EL-Gdida and Nasr City, are selected to present the early planed neighborhoods.
- New planned: 1st district and Jasmin are selected to present the new planed neighborhoods.
4.2 Data collection and classification:
The purpose is to measure the impact of neighborhoods urban form on resident's movement behaviour and accordingly on sustainable urban mobility. Two forms of data collection were used – the first to measure urban form patterns, and the other to measure resident's movement behavior in their neighborhood in term of behavior and satisfaction. Finally, the correlation between both is measured.

4.3 Measurements of Neighborhood urban configuration patterns:
Urban form data were collected using surveying maps, observation, satellite maps, photographic images to document and explore neighborhoods urban configuration patterns, including land-use pattern, housing income pattern, and street network pattern including density.
1- The street network pattern can be classified under three categories between the grid to the hierarchical as (grid, loop, and cul-de-sac) patterns. Their spatial structure can be classified under heading of type of street, linear meter of streets, No. of blocks, Intersections density, No. of access point, No. of cul-de-sacs, percentage of streets are per community area, and the no. of continuous routes (Ghonimi 2014).
2- The land use pattern can be classified under heading of land use type, variation and density. They can be measured using the length in meter of (dividing vs. connecting) line between different land-use represents the degree of land use mix vs. separation (Ghonimi et.al, 2011).
3- Housing pattern can be classified under heading of housing type, variation and density; They can be measured using the length in meter of (dividing vs. connecting) line between different housing types represents the degree of housing exclusion vs. segregation (Ghonimi et.al, 2010).
4- Community density range between low density (60 -150 Person/Fedan), Middle density (300 -600 Person/Fedan) and High Density (800-1500 Person/Fedan). Also the community size is measured and ranged between small, medium and large community size.

The urban form analysis results, for each case study, are gathered, measured and scored in Table 2. It is categorized starting from the traditional type ending with the modern type. The traditional pattern is higher in percentage than the modern pattern.
Table (1): Main Socio-Spatial Characteristics of Case Study Areas.
4.4 Measurements of sustainability of Movement behavior:
Two forms of data collection, the first objective, quantitative data concerns resident's movement pattern and behavior. The second is subjective qualitative data concerns the resident's satisfaction to movement.

4.4.1 Measuring urban mobility in term of behavior:
The study of movement behavior is based on different forms of data collection, first, a questionnaire administered to district residents, second different spatial analysis techniques (transit maps, walk score, spatial analysis). The questionnaire was designed to explore the influence of urban form to residents' movement behavior. Sample selection and characteristics depend on 40 residents per each neighborhood with total 240 questionnaires. They are randomly selected in each case study area, to represent different socio-economic characteristic age, gender, education, income level and to measure key factors of travel behavior indicators (Table 2):

The variable "Sustainable Mode Choices Measure": Questions regarding modal choices of certain travel modes (private versus public) (motor, walking, cycling). And Percentage of each mode trip per total trips. The larger percentage depending on public transportation and walkability will be more sustainable. On the other hand a walk score measure and transit maps were used to give a second indicator for walkability.

The variable "Sustainable Trip Distance Measure": Questions regarding average travel distance per week for different uses including work, shop, school, college, health facilities, restaurant, garden, the smaller distance will be more sustainable. On the other hand, some special measures were used to give a second indicator for trip distance.

The variable "Sustainable Trip Frequency Measure": Question regarding no. of trips per week using each mode choice trips, the lower frequent trips by cars will be more sustainable; in addition the high frequent trips by public transportation and cycling, and walkability will be more sustainable.

At five points Likert scale (1 to 5) were used to compute each indicator score from the household survey and the average scores have been converted into percentage scale. These dependent variables were measured as described in the following paragraphs:

<table>
<thead>
<tr>
<th>Movement Behavior Assessment Factors</th>
<th>NH1</th>
<th>NH2</th>
<th>NH3</th>
<th>NH4</th>
<th>NH5</th>
<th>NH6</th>
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<tbody>
<tr>
<td>Car Ownership</td>
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<td>Mode Choices</td>
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<td>Walkability</td>
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<td>Sustainable mode choice index</td>
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<td>Public transportation</td>
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<td>Walkability</td>
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<td>Sustainable low Trip frequency index</td>
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<td>Trip Distance</td>
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<td>Private car</td>
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Table (2): Measured Neighborhood Urban Mobility in term of behavior (in percentage).

4.4.2 Measurements of urban mobility in Term of Satisfaction:
Satisfaction is measured using 5 Liker scale is to measure resident's attitude and preferences of their neighborhood. Questions first explore resident's socio-economic characteristics, then it investigates their satisfaction to movement, including: Functional aspects (parking space, crowding, delay, travel accessibility; services accessibility), Social aspects (safety, attractiveness, interaction) Environmental aspects (air pollution, noise pollution, resource consumption and traffic cognition), Economic aspects (commuting cost, maintenance).
Table (3): Measured Neighborhood Urban mobility in term of resident's satisfaction (in percentage).

5 CONCLUSION AND DISCUSSION
This part aims to discuss two interlocking issues, the first regarding the relation between neighborhood model and urban mobility in term of behavior, including mode choices, travel distance, travel frequency, trip lengths to different destinations and to define how it varies across the neighborhood categories. The second is regarding the relation between urban characteristics and urban mobility in term of behavior and satisfaction.

5.1 SUSTAINABILITY MOBILITY MEASURE IN TERM OF BEHAVIOUR

5.1.1 Mode Choices:
Figure (3) compares different mode choices in the six case studies, it illustrates that traditional one recorded mostly non-motorized, and public modes and reduce reliance on private cars, this in comparison to modern neighborhoods, that recorded private car dependency and reject public transportation. Higher walkability is noted in traditional neighborhoods where high mixed use and high density. People do not prefer to walk in a contemporary neighborhood due to great long distance trips. Public transportation does not depend on neighborhood type. Car trips are noted in modern car oriented neighborhoods.

5.1.1.1 Private Car:
In traditional neighborhoods, residents depend on public transportation due to their low cost, accessibility to their home; they will not take time, effort to get home from the bus station, on the other hand other residents found it dirty, not comfortable, noisy, and crowded. On the other hand, modern neighborhood, public transportation revealed that it does not fit to their needs, it is not flexible for their daily trips, they refuse to cut very long distance and consume time and effort from the bus station to get their distortion due to long distance and unsafe and environmentally uncomfortable context; they found private car would be more flexible for them.

5.1.1.2 Public transportation:
Traditional neighborhoods, associated with high dependency on public transportation due to their low cost, accessibility to their home; they will not take the time or effort to get home from the bus station. But some consider it as not welcomed due to it is dirty, uncomfortable, noisy, and crowded. On the other hand, modern neighborhood associated with low dependency on public transportation, it does not fit to their needs, it is not flexible, they will cut very long distance and consume time and effort from the bus station to get their distortion due to long distance and unsafe and environmentally uncomfortable context. Private car would be more flexible and save for them.

5.1.1.3 Walkability:
Traditional neighborhoods associated with public transportation and walkability. This is due to the short distance trips in livable, safe and attractive street's residents need to walk in areas where residential parking

<table>
<thead>
<tr>
<th>Movement Satisfaction Assessment factors</th>
<th>NH1</th>
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\[
\text{Table (3): Measured Neighborhood Urban mobility in term of resident's satisfaction (in percentage).}
\]

[Figure (3): Mode Choices in Percentage]
is limited to retain their parking space. Residents seek to reduce the number of journeys and hence the number of times they have to search for a parking space on their return home. On the contrary, modern neighborhoods associated with low walkability, due to the long distance trips and unsafe and unattractive streets make them depend mainly on private automobile alternative.

It is noted that traditional urban form makes using motorized modes more difficult compared to non-motorized modes such as walking and cycling that are easier in traditional communities on the other hand modern urban form tends to increase the private motor vehicle use because it can provide travel options of a range of household activities.

5.1.2 Trip frequency:
Figure (4) Traditional neighborhoods associated with high pedestrian frequent trips. Due to the short distance trips with safety. On the other hand it is associated low car frequent trips and hence the number of times they have to search for a parking space on their return home. Difficulties in finding a parking space may not necessarily deter car ownership or intentions to acquire additional vehicles even with increasing parking problems. On the contrary, modern neighborhoods are associated with low frequent private car trips; residents try to avoid long trips with great effort and cost.

5.1.3 Trip distance:
Figure (5) Modern neighborhoods are associated with high travel distances, residents are forced to cut long distance due to the low densities and small community sizes that lack to provide residents with a sufficient range of services and facilities, accordingly impacts residents' travel needs they are forced to cut long distances to have required facilities and services.

It is noted that traditional urban form reduces trip frequency and trip distance for private cars compared to trip distance and frequency done by walking and cycling that are higher in traditional communities. On the other hand, the modern urban form tends to increase trip distance using private car, public transportation, and walkability; at the same time, it noted to reduce travel frequency for using private car public transportation, and walkability because it reduce residents willing to move due to the long distance trips that are associated with cost and time, it may impact social engagement and interaction, an impact residents' health.

5.1.4 Private Car Ownership:
Figure (6) Modern neighborhoods associated with high rates of car ownership ranges between two to three car lot per family, compared to traditional cities that revealed the lower value of car ownership. Residents found their car very essential for living, As stated by one of the residents. Accordingly, they require large no. of parking lots, accordingly cause low efficiency in meeting residents huge demand of car parking.

5.2 SUSTAINABILITY MOBILITY MEASURE IN TERM OF SATISFACTION:
Perception measurement in reference to different parameters, socially (Safety, attractiveness, Social interaction, Accessibility, crowding, delay). Environmental (Air pollution, noise pollution, resource consumption and traffic cognition), Economics (commuting cost, maintenance cost,...).
5.2.1 Attractiveness of mode choices:
Figure (7) all neighborhoods are recorded lower attractiveness for public transportation. Resident’s starts to think twice to move to public transportation options. They only need to have good quality public transportation, to effectively discourage use of private cars and encouraged to public transportation. On the other hand walkability and cycling recorded lower attractiveness in modern neighborhoods, residents found neighborhoods unsafe for walkability. On the other hand it records higher values in Masr El-Gdida and Nasr City.

5.2.2 Travel Cost:
Figure (8) Modern neighborhood is associated with high commute cost due to long distance that discourage walkability and increase dependency on private cars with high frequent trips that consume more travel time, effort, and fuel consumption cost to reach services in addition to cost of car maintenance. Traditional neighborhoods are associated with lower commuting costs, service in proximity to residents, they can walk, use public transportation, to get services. They do not have to use private cars for every trip.

5.2.3 Environmental pollution:
Figure (9) Modern neighborhood is associated with lower noise and air pollution, due to low traffic density caused by low frequent trips with large green areas. On the contrary, traditional neighborhood associated with high noise and air pollution due to the high traffic density caused by high frequent trips and high traffic jams, with the minimum green area.

5.2.4 Social Interaction:
Figure (10) Modern neighborhood is associated with lower social interaction, due to the long distances and low frequent trips using all travel modes, residents are not willing to move, to avoid travel cost, effort and waste time. They become un-socialized to meet their friend and neighbor. On the other hand traditional neighborhood associated high social interaction.

5.2.5 Traffic Cognition:
Figure (11) Traditional neighborhood is associated with high traffic cognition, it's also associated with lower parking requirements. Also traditional neighborhood associated with high traffic cognition at main streets and high traffic cognition at peak hours greater than traffic cognition that take place in old traditional neighborhoods.

Traditional communities with high density and mixed housing types were livable communities encourage walking and biking. Communities where the users find all services, especially daily one with walkable distance were more secure, livable and attractive to residents to make all travel to be more depending on alternative transportation options, public transport, walkability, and biking; and discourage private cars.

On the contrary, modern neighborhood isolates its residents away from everything, to go anywhere one must leave the community and go on arterial road its boundaries just a wall, which pedestrian walks are long, inconvenient and unsafe, so residents should have their cars for any daily needs increasing car dependency, and generate traffic cognition in the outer city that should increase noise and air pollution and accordingly
reduce sustainability. All these characteristics affected the movement behavior that becomes less depending on alternative transportation options, public transport, walkability, and biking; versus encouraging private car dependency.

In modern neighborhood, Walking or biking has become a main problem, daily needs are out of walking distance, to walk from a point to another it takes to longer paths which consumes more distance and time. Even all passes turned into arterial roads its boundaries do not have any use, only some fences which increase street. It is unsafe, unpleasant environment, and just walls. It encourages criminality and reduce sense of safety. In additions there is no motivations inside these streets to encourage walkability, so make its residents depend mainly on private car as a primary mode of transportation.

Public transportation has become the unpractical movement solution. Public transportation need connected permeable street network, and need accessibility to bus stop, which is not acceptable, hence public transportation is not a practical transportation option. Private car has become the available way for movement inside the city. Impracticality of alternative transportation options makes private car becomes the only available choice for residents. No walking, biking or any alternative transportation options, Only private car. To go anywhere one must leave and get out the gate and go on collector roads its boundaries become just a wall, where pedestrian walks, cycling are long, inconvenient and unsafe, and where public transportation, inconvenient, invisible.

Therefore, residents should depend on their private cars for all daily life needs, increasing car dependency. Even they use inside the or outside the community in the city streets or even on the regional roads that are connecting the city with Cairo. The approval for road closures in many cases depends on the nature of the roads, as well as the road layout. The closure of major through routes is not allowed. Bearing this in mind, it is usually neighborhoods designed on a closed road network system that are likely to be granted approval, since these have a limited number of traffic intersections (therefore less roads to close). Which affect patterns of movement (land man, 2002:9).

Traffic cognition has existed on city scale and regional roads that connect new towns to Cairo; it was a result of two reasons. The first is due to restricting public transportation and centering movement of private cars, make traffic volume increase especially in the major arterial road networks. The second, as more residential roads are withdrawn from public use, the car's movement in the city is restricted and diverted to alternative adjacent roads, which are subjected to increased traffic volumes, that they are not originally designed for. This could affect the functional efficiency of local, regional street networks. Commuting cost was a result of two factors, the first due to increased car dependency and the other due to long distances and increased travel time journeys that required to go anywhere. This could increase of commuting time and fuel cost for residents, visitors and other road users.

6 THE RELATION BETWEEN URBAN FORM AND SUSTAINABLE MOBILITY:
Deducing the correlation between urban form patterns in one hand and sustainable mobility represented in movement behavior and movement satisfaction in the other hand.

Figure (12): the relation between urban mobility on sustainability and satisfaction level.

Moving between different neighborhood models, starting from traditional to modern one, reveals a negative relation between movement in behavior level and moving in satisfaction level. It is clear that traditional neighborhood records a high value of sustainable mobility on a behavioral level, and lower level on satisfaction level. On the contrary, modern neighborhoods records learn sustainable mobility value in
behavior level and records medium value on satisfaction level. A moderate neighborhood types will achieve optimum sustainable mobility in term of both behavior and satisfaction level.

6.1 The relation between Crime Prevention measure and Density pattern:

Figure (13) reveals that sustainable movement behavior is achieved by moving from low density to high density community. This can be explained because the increasing density causes a relevant increase in community size accordingly widen the range of opportunities, contacts, activities and services that can be supported in neighborhood, and reduce average distances between homes and services. Accordingly reduce the need for long distances trips, frequency and concern public and walkability and increase sustainable urban mobility. Density is inversely proportional with trip distance, private car ownership, commuting cost. Increasing density reduces trip distance and trip frequency by car and increase trip frequency by walkability, and reducing the density increase trip distance.

On the other hand, both high and low density communities are associated with low satisfaction level, the first cause high traffic, crowdness, delay, cognition, air and noise pollution and unattractiveness for public transportation and the second records high commuting cost and traffic cognition on arterial roads.

6.2 The relation between movement behavior measure and street network pattern:

Figure (14) reveals that sustainable movement behavior increases with moving from hierarchical network to the grid network. This can be explained because increasing access points and intersection density create fine grained spatial fabric that provide greater connectivity, portability, and accessibility connectivity and promotes short and direct routes that offers shorter trips and reduces travel distance, It provides different pass alternatives and chances. It is highly encouraging public transportation as it allows more direct access to public transport. It can be more transit friendly to the extent that they may allow greater penetration of an area by transit services. It is recorded to enhance walkability, and increase trips frequency by foot and reduce trip frequency by private cars, especially with the lower parking area, accordingly increase sustainable urban mobility.

On the other hand, both extremely grid and hierarchical street pattern are associated with low satisfaction level, the first increases the flow of private car and accordingly reduce the safety and security of nodes and increase accidents, through traffic, and traffic jams and the second records high commuting cost due to the complete dependency on private cars and lack of any other alternative.
6.3 The relation between movement behavior measure and land use pattern:

Figure (15) reveals that sustainable movement behavior increases with moving from separate to mixed land use. This can be explored because it could cause a separation between residents and services, accordingly impacts their travel demand. Mixed use makes neighborhoods more secure, livable and attractive for residents to use all mode choices walkability and cycling than private cars. In addition, it recorded low average trip distance by cars, with low trip frequency. On the other hand, it recorded less energy intensive namely walking and cycling. It impacts its trip frequency and do not affect trip distances. Accordingly increase sustainable urban mobility. On the other hand, urban mobility in term of satisfaction records lower values in both extremely mixed and extremely separate use, the first cause high traffic cognition, crowds, and do not provide sufficient parking areas, at the same time streets are full of strangers that make it unsafe for walkability and crowded, noisy, and recorded high cognition. The second cause reduces the existence of unknown persons and avoid sharing, parking of residential area with non-residential users.

![Figure (15): Relation between land use pattern and movement behavior.](image)

6.4 The relation between urban mobility and housing-income pattern:

Figure (16) reveals that moving from separate housing income to mixed housing income increase sustainable movement behaviour. This can be explored because it causes diversity of transportation options that meet different levels. Taken in mind the basic fact that, different mixed housing types generate different kinds and amounts of mobility standards. On the other hand, lack of diversity reduces transportation standards, and reduces the diversity and choices of allowed transportation options. Accordingly reduce sustainable urban mobility. On the contrary, urban mobility in term of satisfaction revealed lower values in both extremely mixed income and extremely separate income. Both reduce the possibility of alternative travel choices to meet different income levels.

![Figure (16): Relation between land use pattern and movement behavior.](image)

7 CONCLUSION AND RECOMMENDATIONS:

This research suggests that the way we design our neighborhoods affects our movement behavior and thus affects achieving sustainability. This study gives evidence of the relation between travel behavior and different urban forms to try and identify the current drivers of travel behavior. It is hoped that this provides an understanding how to make future developments be more sustainable and be more low carbon-based on their transport activities. The results indicate three conclusions:

The first indicates that residents' movement behavior does not coincide with their movement satisfaction.
Sustainable urban mobility: Assessing Different Neighborhood Models in Greater Cairo Region, Egypt.

The second that traditional (early developed) neighborhoods recorded lower value in car ownership, trip distances, trip frequency by car, its modal choice based on public transportation and walkability, high trip frequency by pedestrians, it recorded the highest walkability score, in addition it records lower trip frequency by private car; accordingly it recorded lower travel expenses and lower energy consumption. On the other hand it recorded lower satisfaction level for movement behavior in term of traffic cognition, lower safety and security, lower parking area, and high air and noise pollution.

The third that Modern (New planned) neighborhoods recorded high value of car ownership, modal choices by private car, with minimum share, high trip frequency, and distances by cars, lower public transportation and private car dependency; accordingly, it causes high travel cost and consumption of resources. On the other hand, it recorded high satisfaction level of movement in term of low traffic cognition, low air and noise pollution.

The fourth that moderate (early planned) neighborhoods like Masr El-Gdida and Nasr City, recorded moderate sustainability with modest satisfaction level. It recorded relatively high satisfaction, like new planned neighborhoods, in term of moderate traffic cognition, moderate air and noise pollution, moderate commuting cost. On the other hand it recorded high sustainability, like traditional neighborhoods, in term of depending on walkability, public transportation and short distance trips and low frequency.

The research found that traditional neighborhood is sustainable in term of movement behavior that depend on short trips, mode choices that encourage walkability and discourage private car, and low private car frequent trips. On the other hand, they are not prefersed in satisfaction level due to the high traffic cognition, noise and pollution, and delay. On the contrary, modern neighborhood proved to be unsustainable in term of movement behavior, it consumes more trip distance and more time and cost to get services, with a complete dependency on private cars; but they are un-preferred in satisfaction level for residents due to different externalities, such as traffic cognition, high pollution.

Accordingly planners and urban designers are recommended to take into their consideration the impacts of physical characteristics on movement behavior and movement satisfaction.

1. Good design should in one hand facilitate public modes and walkability to increase sustainability on the other hand should give resident's participation a greater role in urban design, to find what is suitable for their movement satisfaction.

2. Both high and low density could reduce sustainability. The first increase community size to an extent that facilitate sustainable mobility at the behavioral level, but reduces community sustainable mobility at the perceptual level, it increases crowds, delay, cognition, air and noise pollution. And the second reduce community size to an extent that reduce sustainable mobility by restricting travel modes to private motorized and increase trip distance. A moderate community density and size values proved to be efficient to enhance movement behavior and satisfaction.

3. Both high mixed and high separate use community reduce sustainability. The first in one hand increase travel behavior by reducing travel distance, private modes, and reduce trip frequencies by private car. On the other hand it reduces movement satisfaction, residents do not find sufficient parking areas, at the same time streets are full of strangers that make it unsafe for walkability and crowded, noisy, and recorded high cognition. The second with one hand reduce sustainable movement behavior by increasing travel demand and increase private mode and trip distance; on the other hand, it increases the satisfaction level by reducing the existence of unknown persons and avoid sharing parking of residential area with non-residential users. A moderate community land use mix could be sustained on movement behavior and satisfaction level.

4. Both high income and low income residents could reduce travel behavior and satisfaction. The first Reduce diversity of transportation options that meet different income levels. The second enables residents to interact with different social groups and encourage a sense of trust and sense of connection between them. A moderate mix is recommended.

5. Both grid and hierarchal street network pattern could achieve sustainable mobility. The first increases permeability, connectivity and accessibility that make better behavior by reducing trip distance, trip frequency by private car, and orient mode choices to discourage private car and...
encourage walkability; on the other hand it reduces the resident movement satisfaction by increasing flow of private car and accordingly reduce safety and increase traffic cognition. The second reduces permeability and increase trip distances that make residents seek private solution and discard walkability on the other hand residents are satisfied with low carbon emissions. A moderate value is recommended.

A further research with more case studies needs to be carried out to obtain clear conclusions about the relationship between movement behavior and satisfaction and neighborhood patterns.

8 REFERENCES
Boarnet, M.G.; Crane, R. (2001) Travel by Design; the influence of urban form on travel. New York, Oxford University Press.