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“Sidewalk” as a Realm of Users’ Interactions: Simulating Pedestrians’ Densities at a Commercial Street in Cairo City

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1 ABSTRACT

During the last four decades, researchers have developed many tools in order to investigate pedestrians’ behavior at sidewalks. Those tools tried to study sidewalks by investigating two main components: built environment and pedestrians’ movement. This paper presents a simulation for the pedestrians’ movement at a commercial street in Cairo, using an agent-based model. The model was designed in a way by which we could examine: pedestrians’ densities, the influence of types of uses on densities, the influence of flow-generators and destinations. In addition, we categorized the uses along the selected case of study by type of service and time spent by customer.

The method which we utilized for this work could be divided into two main phases: The first phase, included site video-based survey at different times and days, by which we could calculate flow rates at each generator point, and test the influence of uses on the density along the sidewalk. The second phase was to develop the model. In parallel, we focused on the uses’ types and how it affects controls pedestrians’ densities. Our results referred to a strong relation between use’s type and densities’ distribution along the street.

2 INTRODUCTION, PROBLEM AND OBJECTIVES

Cairo is one of the biggest metropolitan areas in the world, it locates in the 9th rank among the most growing mega cities with a population over 18 million residents (UN, 2015). In addition, it receives more than 2.5 million visitors daily. Transportation problems are considered the worst which Egyptians face daily. So, during the last three decades, the Egyptian government established and developed many projects to renovate this system, such as Cairo Metro, which daily transports more than 4 million passengers (NAT, 2015). However, these projects are considered as pain-killers for some temporary problems, because of lack of financial supports and absence of wider vision. For example, these trials haven’t included yet a project for revising the legislations related to urban problems, renovating pedestrians’ realms nor enhancing walkability.

This work is a part of a wider research project that aims to investigate pedestrian s’ movement characteristics at sidewalks, in Cairo, especially in the absence of clear and strict urban legislations. That research tries, to simulate the pedestrian movement at one/some sidewalks in Cairo.

Basically, the vague control of the urban environment in Cairo allows a lot of violations which we found. These violations could be seen not only in buildings or sidewalk’s occupancies, but also in pedestrians’ walking behavior such as, walking outside sidewalks and crossing areas. By observing many sites and investigating local urban regulations, we could easily understand that these behavioral violations are caused by: (1) Absence of pedestrians’ spaces identifying, (2) A lack of pedestrians’ services allowed such as: furniture, signage, lighting, and public transit stations, and (3) Some other violations caused by buildings’ residents/owners which force pedestrians to walk out of their own path. On the other hand, we observed some similar problems on the level of vehicle traffic too, which make the situation more chaotic.

So, in this paper we basically aim to simulate the pedestrians’ movement in the case of study as much realistic as we can. Also, we aim to develop a method for measuring pedestrians’ densities testing their relation with the distribution of uses. Accordingly, we can investigate and develop a list of pedestrians’ characteristics that would help us, then, to simulate the movement more realistically.

3 LITERATURE REVIEW

In recent years, many researches have been conducted to understand pedestrians’ movement and some related topics, such as: pedestrians’ flow, densities, and speed. Basically, most of those studies concluded that there are major factors affect the pedestrians’ movement behavior: (a) Pedestrians’ characteristics (Schelhorn, 1999), such as: gender, age, trip purpose (Willis, 2004), and physical fitness (Polus, 1983), (b)

Spatial and Urban Factors, such as: design, materials, regulations and property rights (Whyte, 2014), and (c) Environmental Factors (Whyte, 2014).

However, all of those studies have been studied the western European and American cities. Some more recent studies started to investigate pedestrians' movement in some Eastern and Arabic cities as a part of cities' outdoor spaces (Gehl, 2013) or as a part of physical built environment that affects outdoor spaces' life (Mortada, 2011 and Hakim, 2013). Originally, plazas and wide open areas were and still are the most attractive destinations and the base of public space life in the European and American cities (Moudon, 1987 and Whyte, 2014). Conversely, streets in Arabic cities, and Egyptian cities as well, are considered the basic public space where both pedestrians' generators and destinations mostly locate at (Akbar, 1989). We define this as a "Linear public spaces-based city", especially with the lack of outdoor spaces in Cairo which indicates that residents' proportion of outdoor space less than 1.0 m2 (Khorazaty, 2004 and Tadamun, 2014).

Generators of pedestrians' movement in both cases may be a building, a shop, a vehicle's drop-off area or other similar points. But destinations are the critical points here, which make the difference. To explore differences, we should first investigate the pedestrians' trip purposes which definitely determine destinations in cities' outdoor spaces. We will follow the assumption of Jan Gehl that says there are three types of outdoor activities: necessary activities, optional activities, and social activities (Gehl, 1987). For the last type, social activities, they indirectly supported whenever necessary and optional activities are given better condition in public space (Gehl, 1987). So, the presence of the necessary and optional activities are the two major types that happen in outdoor spaces. The presence of necessary activity may not need specific condition to happen as they are "necessary". It usually refers to the daily duties, such as going to school, work, supermarket, and to mosque, in the case of Arabic cities, and Egyptians as well. But for the optional activities, and as per assumed by Gehl, they need some condition by which they will happen, such as: good weather, sitting areas, and community activities. They take place only when exterior conditions are optimal and inviting them (Gehl, 1987).

In our case, Cairo, we found that pedestrians' densities should be the major effective factor that affects the pedestrians' movement behavior, where pedestrians' generators and destinations locate at the same linear space. Also, uses distribution will be one of the focus points of our study.

So, and to understand and test our assumption above, we need to simulate the actual movement behavior of pedestrians at one dense and chaotic case at Cairo. Accordingly, we expect that we can a clearer vision about the influence factors on pedestrians' movement and densities' distribution too.

4 PROCEDURES

The method of this work is basically based on observing pedestrians' movement behavior using a video-based survey. Our procedure flow is formed by five phases followed by results and outputs:

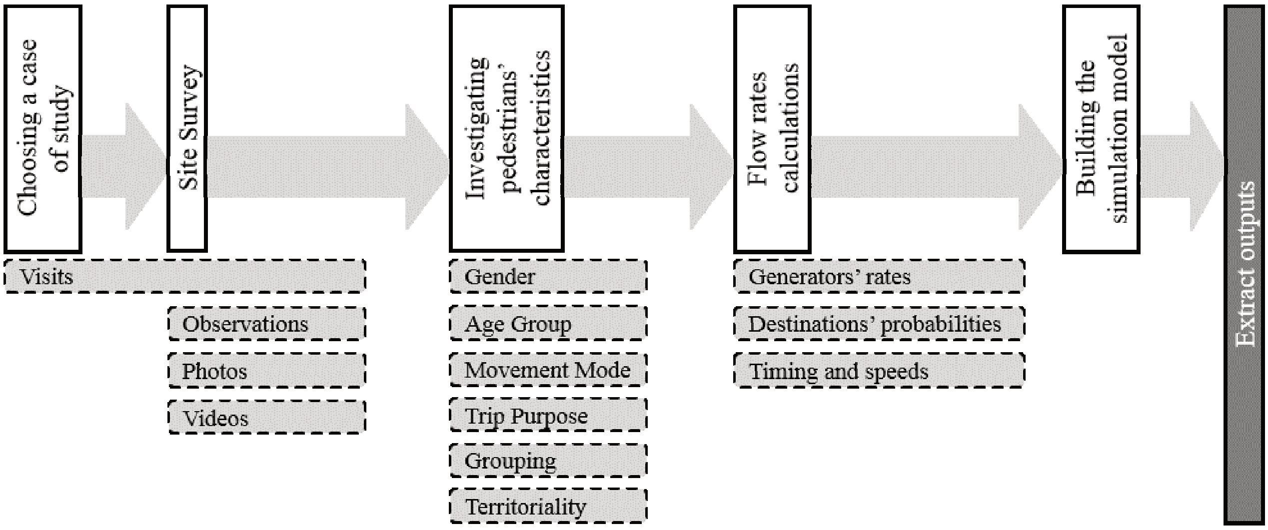

Fig 1: The procedures' flow of study.

4.1 Choosing a case of study

Primarily, during the last 18 months, 27 visits have been made to eight formal commercial streets at Cairo. These streets are located at 5 different districts sporadically. Among them, we chosen the case of El-Nasr Street at El-Basateen District south of Cairo. It borders two big districts, El-Maadi and El-Basateen, these two districts are populated with more than 540,000 residents (Governorate, 2016). We specified a 360 m length of the street to be our area of study. Four criteria have been applied to choose the case which were to: (1) Be formal and well regulated street, (2) Has a variety of uses connected directly to the sidewalk, and (3) Be safer from crime and crashes.

Fig 2: left, El-Basateen District boundary[1] and right, Elnasr Street map[2] with area of study.

4.2 Site Survey: observations, photos and videos

Almost three weeks have been spent at site by daily visits which basically focused on observing pedestrians' movement. We noted and classified observations which were supported by photos. In addition, we have made a video based survey using video cameras watching sidewalks from different locations and at different days and times. In the following part we will represent these observations and the technical procedures of photography and filming:

4.2.1 Observations:

The most important observations noted were as follows:

- Most of pedestrians walk outside the planned sidewalk where many obstacles, stairs and occupancies locate. They, the pedestrians, walk at a virtual lane with 2.50 m width at least from the asphalt road.
- A 2.0 m wide lane of cars permanently park attached to sidewalks, and no specified parking areas for retail shops exist. As a result, this lane of parking cars separates walking pedestrians into two groups, inside and outside the sidewalk, which enhances the dis-connectivity of sidewalks.

4.2.2 Filming technique:

The data which we use in this study have been collected by watching and recording pedestrian traffic using a digital camera and external multi-configured lenses. The camera's shutter speed ranges from 30 seconds to 1/4,000 second with high ISO sensitivity up to 3200 and high focal more than 200 mm. Our survey has been executed in three weeks, during November and December 2014. We have been recorded separate video-clips each of which was 5 to 8 minutes in average. Totally, we have recorded more than 5 hours in different times of the day from 8:30 to 23:30. The study time which we chosen is on Saturday, from 19:00 to 23:00. In average, the weather was moderate and the temperature ranged from 14 °C to 23 °C, the humidity was 65%, the wind speed was less than 15 km/h, and the visibility ranged from 3 to 9 km.

We specified seven locations for fixing the camera as shown in Fig 3, in order to watch most of the pedestrians' routes and to avoid the high dense trees which are located in the mid island. The videos recorded respectively and we have calculated average number of each measurement in the same time weekly.

[1] Cairo Governorate's Official Website, 2016.
[2] from The Egyptian Survey Authority's CAD maps, Cairo City, 1998, and Google Earth Pro.

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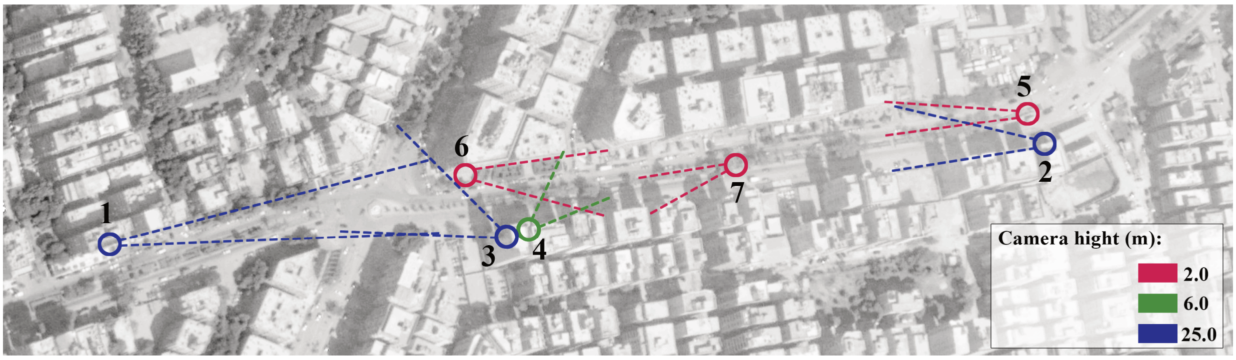

Fig 3: Video cameras’ locations at the field of study.

4.3 Investigating pedestrians’ characteristics

This step is the most important one by which we could later determine types, numbers and behavioral characteristics of each agent in the simulation model. We classified the pedestrians’ characteristics into six basic categories, which describe most of the pedestrians’ personal and physical conditions. These basic categories were: 1. Age Group, 2. Movement Mode, 3. Trip Purpose, 4. Gender, 5. Grouping, and 6. Location. We have surveyed a sample of 635 pedestrians whose trips were completed in the video-clip records. So, we could determine all characteristics shown in (Table 1, left). Then, we filtered this sample by eliminating all values which were under 10 percent. We, could, then, determine three fixed characteristics: Walking, Individuals, and Adult pedestrians, and set up both genders, and three different types of trip purposes as per shown in (Table 1, right). These extracted the characteristics that formed the agents’ types in the model which we will explain in details in a latter part.

		number	%		number	%
Age Group	0~12	33	5			
	13~22	207	33	13~22	207	38
	23~50	335	53	23~50	335	62
	51+	60	9			
Total		**635**	**100**		**542**	**100**
Movement Mode	Walk	620	97	Walk	620	100
	Run	0	0			
	Bike	5	1			
	Wheelchair	0	0			
	Assistance	10	2			
Total		**635**	**100**		**620**	**100**
Trip Purpose	Transients	209	33	Transients	209	40
	Partial user	218	34	Partial user	218	41
	Full user	102	16	Full user	102	19
	Waiter/Sitters	106	17			
Total		**635**	**100**		**529**	**100**
Gender	Male	459	72	Male	459	72
	Female	176	28	Female	176	28
Total		**635**	**100**		**635**	**100**
Grouping	Individuals	297	70	Individuals	297	100
	2 per group	35	9			
	3 per group	28	6			
	more than 3	13	2			
Total		**373**	**100**		**297**	**100**
Location	Semi -public	174	28	Semi -public	174	28
	Public	192	30	Public	192	30
	Out of Sidewalk	269	42	Out of Sidewalk	269	42
Total		**635**	**100**		**635**	**100**

Table 1: Left, Pedestrians survey sample and right, setting up the simulation sample.

4.4 Investigating obstacles

In addition, we investigated obstacles' types found in the case of study. The obstacles could be classified into three classifications according to their effects. The first group is obstacle that appears when pedestrians face a different mode of movement, such as bikes, cars, or wheelchairs, as they differ in speed, volume, and other movements' characteristics, we call this group as Dynamic-Physical obstacles. The second group includes the obstacles which are perceived by human sensory, such as daylight/dark and weather, we call this group as Dynamic-Nonphysical obstacles. The third group we call it Static-Physical obstacles, which include all built environment's elements, parked cars and other physical permanent elements. In our model we considered both of static and physical obstacles.

4.5 Investigating retails' uses

In our case, we had 49 uses that were currently open and working at that time (Saturdays' evenings and nights). We surveyed how long does each pedestrian spends at each of them. Then, these uses have been categorized into four major groups (A, B, C, and D), by the type of service provided and the average waiting time that each pedestrian spends. These four groups are:

(A) Emergency and quick needs (less than 130 seconds), such as: pharmacies, ATM, and newspapers.

(B) Daily needs (1200 seconds), such as: groceries and take-away restaurants.

(C) Food Facilities (2000 seconds), such as: coffee-shops and sitting-based restaurants.

(D) Usual needs (more than 2000 seconds), such as: wearing, furniture and cars showrooms.

4.6 Calculations

4.6.1 Generators and Destinations:

In this phase, we specified 25 points that could be considered as "Generators" of pedestrians' flows. We counted the average number of pedestrians generated per second during the period of study specified. Additionally, we specified 74 destinations to which pedestrians intend usually. These destinations were divided into two main types: (a) In-between destinations (39 points) which some pedestrians intend once or several times during his trip, and (b) Final destinations (35 points) after which pedestrians go out of the area of study. The calculations were made using a O/D Matrix (Origin/Destination Matrix) filled with 635 pedestrians' trips. The calculations extracted the probabilities of flow from and to each point.

4.6.2 Walking-Flow Rates:

Also, we counted the "Walking-Flow Rate", it means the rate of coming pedestrians at a specific point in a specific time. This rate has been measured by counting the number of pedestrians who come from each generator point in either one a second or a minute.

4.6.3 Speeds and waiting times:

Using the same survey's data, we measured the average regular speed of pedestrians, and it was found that the adult male who is under 50 years old walks with an average speed of 1.4 m/second (5.04 km/h), and for females, it was 1.25 m/s (4.5 km/h). We, also, observed some other changes happen in speed if some other variables are considered in walking, such as existence of: (a) a physical barriers or level change, (b) densities, (c) a dangerous zone, and (d) trip purpose's change. Table 2 shows the change that happens in the constant speed when any variable changes. The zero speed, which refers to the waiting time of each pedestrians, was counted according to the category of use mentioned above.

	Age Group				Movement Mode			Gender		Grouping			Trip Purpose			Obstacles				
	50+	23~50	13~22	0~12	Walk	Run	Bike	Male	Female	3 Ped	2 Ped	Individual	Transient	Partial User	Fully User	Stairs/level	Vehicles	Neighbor pedestrian	Narrow width	walls/fences
Pedestrian typical speed is counted as 5.04 km/hour	0.6	1	1		1	2	3	1	0.9	0.7	0.8	1	1	0.85	0.75	0.5	Varies			

Table 2: Changes in agents' speed value according to change in type (1 = 100%).

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4.7 Building the simulation model

For our model, we used ArtiSoc-V3.5. It is a multi-agent simulator software which was originally released by Kozo Keikaku Engineering, Inc. Japan, in the spring of 2006 (Yamakage, 2009). The measuring area unit of ArtiSoc equals (40*40 cm) in real, and the time measuring unit is a (time slice) which could be coded to equal more or less than the time units in real. This one (time slice) is the time length which is enough to make only one step of the simulation, and usually it is measured as one second. Our assumption is based on the actual pedestrians speed in our survey sample which equal 1.4 m/s. So, we coded the agents' behavior to walk 3.5 ArtiSoc's units (40 cm* 3.5) per second (one time slice). According to our pedestrians' classification mentioned above, we have developed six agents which behave differently, Fig 4. We have counted the probabilities of generating each type from one generator point. Also, we coded the simulation to count the destinations probabilities which each agent seeks, whether they are in-between or last destinations.

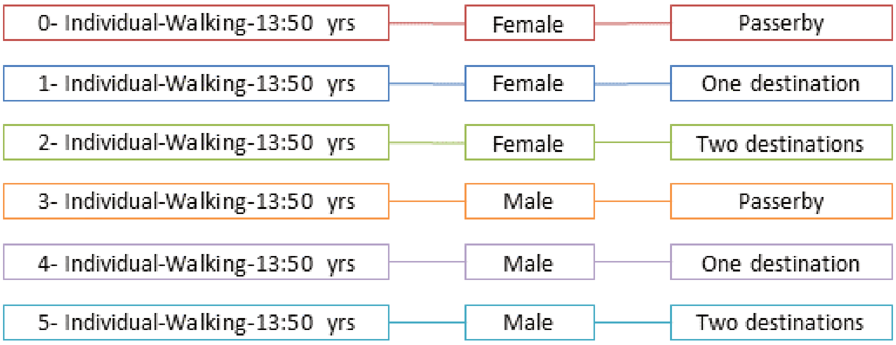

Fig 4: Agent types and characteristics in the model.

For the movement method, we developed a "Waypoint Map" by determining the most frequent nodes and links for walking in real situation. Then, we have coded a waypoint matrix to count each link's connection, location and length. Then we added this matrix data in the model. We assume that all pedestrians got to their destinations seeking the shortest path. Accordingly, we have calculated "Shortest Path" using the Dijekstra's Algorism to be the agents' method for reaching a destination.

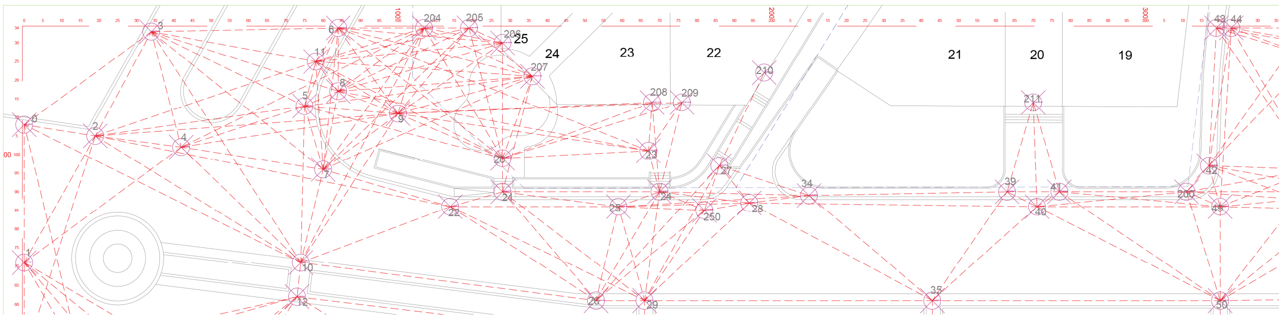

Fig 5: A part of the Waypoint Map, micro-scale (1:2000).

The next step was to code the agents walking behavior. Using the Flow-Chart in Fig 6, we coded the walking behavior of each agent considering many variables, such as: starting point, walking speed, barriers which agent faces, avoiding other pedestrians, and trip purpose which determines destinations.

Accordingly, we can explain each agent's route structure in few steps, as per shown in Fig 7:

- The generator locates itself and generates six types of agents considering given probabilities.
- Each agent intends to reach a destination by counting the shortest route.
- In case of multi-destinations trips, each agent waits for a specific time according to the uses changes as per mentioned above.

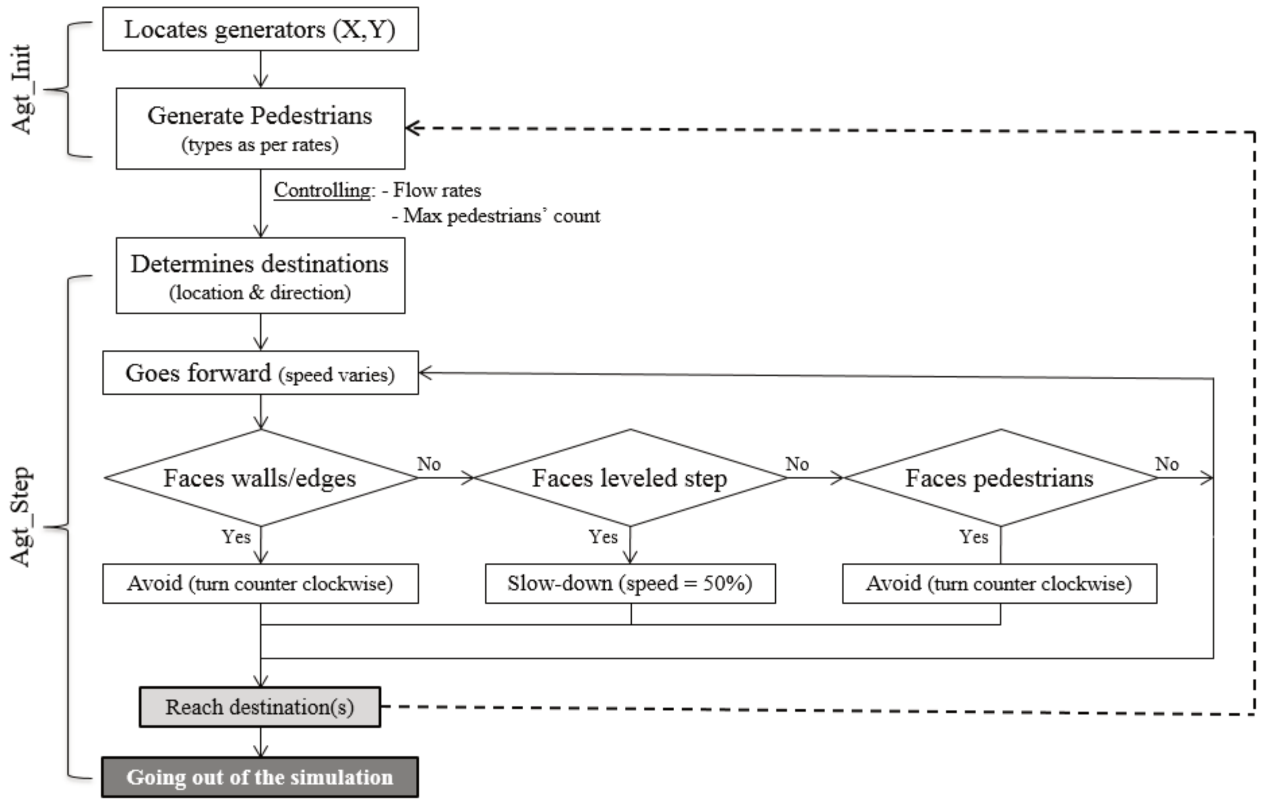

Fig 6: Flow chart of one type of agent's behavior.

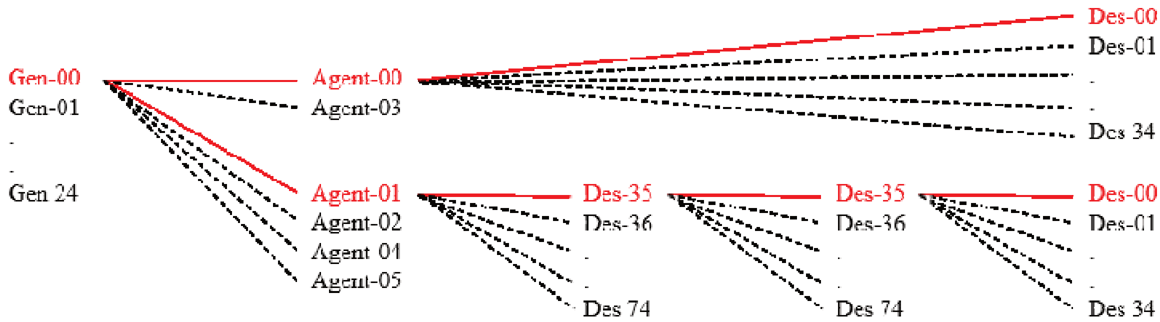

Fig 7: A diagram of agents' routes structure.

In parallel, we have created the field (space) where the simulation would run. Our space has been expressed by a GIF format image that presented a plan of the area of study showing: the sidewalk, the asphalt road the mid-island, and the retails colored as per categories.

Now, the simulation is ready to run, and each agent has been coded with needed behavior at the area of our case of study. But, we have coded other controlling panels to make the simulation more flexible for any change in further surveys, and also to be computable with other similar case(s). These additional controlling panels were basically for calculating pedestrians flow rates and pedestrians total count who come from each generator point. By running the simulation, agents appeared walking in different colors (to identify the user type) following the pre-coded behavior at the field of study, Fig 8.

As per mentioned above, we have created a control panel to control the pedestrians' flow rates and number of pedestrians. Besides that, we have developed a measurement method to calculate the densities along the sidewalk while the simulation runs. We can explain these two analytical steps in the following:

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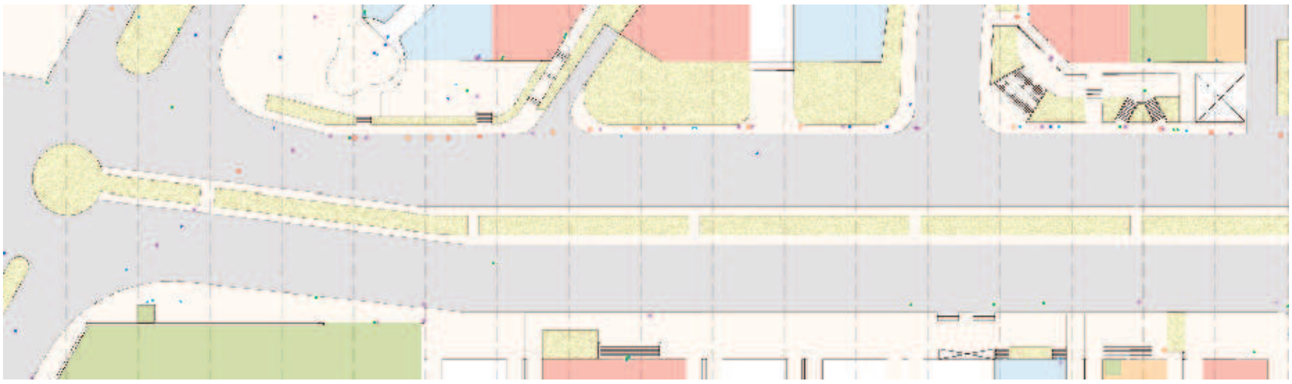

Fig 8: Simulation preview with: street, uses, and walking pedestrians (dots).

4.8 Control panels

Two control panels has been created to control the flow rate and the maximum number of pedestrians’ count for each generator point. This means that our model can control the whole simulation with 25 flow rates controllers and additional 25 pedestrians’ count controllers. These control panels can control the simulation before or while running. They make the model more flexible if we want to expand or shrink the field of study. Also if we get new data from another survey(s).

4.9 Densities calculations

Measuring densities and their relation with the type of use is our main goal of study. So, we have developed a way to measure the density at many points considering the change of uses. First, we divided the street length (360 m) into 36 zones equally (every 10 m). Secondly, we have counted the area where pedestrians walk at each zone using AutoCAD. Then, we have recoded the model to count the number of pedestrians found at each time length (120 steps, two minutes) and to calculate the density at each zone, then, to extract all data in a CSV format sheet, read by MS. Excel. Finally, we run the simulation again, with the new measurement method, for 14400 steps (equals two hours in real). Accordingly, we could got the results of the simulation by two ways, in parallel. The first way was by checking a dynamic bar-graph preview which was counting densities while the simulation running, and the second one was after finishing the simulation by getting data from a CSV format sheet.

4.10 Simulation results

The results we got were the values of pedestrians’ densities each two minutes at 36 zones along the street on both sides. We extracted the down shown graphs from the data sheet, Fig 9 to Fig 12. Then, we calculated the average value of density at each zone in order to specify the standard deviation of values, Fig 13. Then, we put preferred not to count the first and the last zone which were mostly high because they contain many generator and destination points.

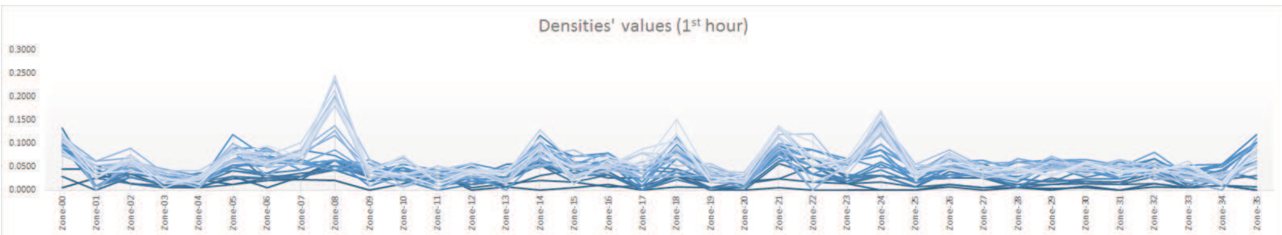

Fig 9: The densities’ values during the first hour.

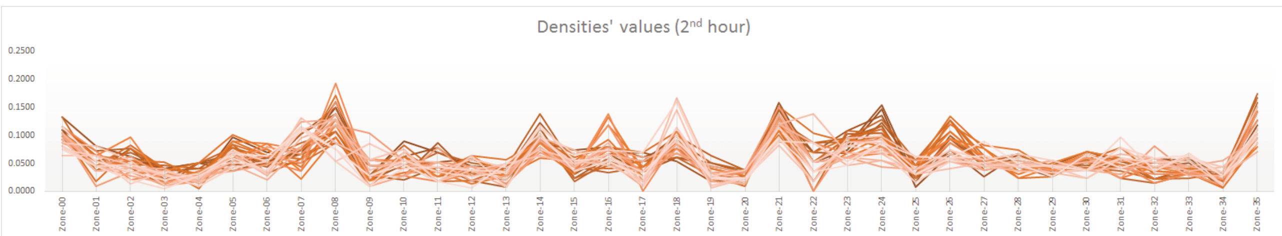

Fig 10: The densities’ values during the second hour.

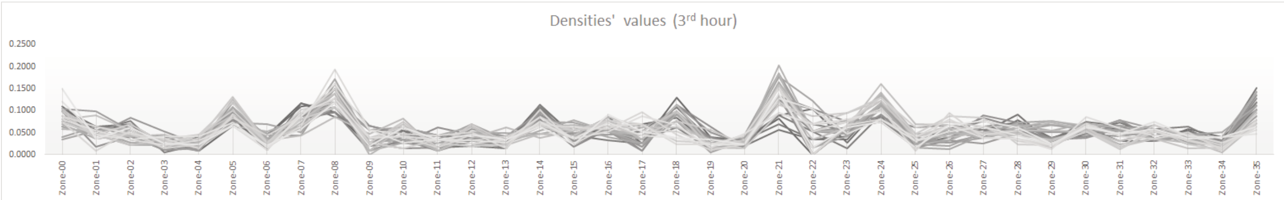

Fig 11: The densities' values during the third hour.

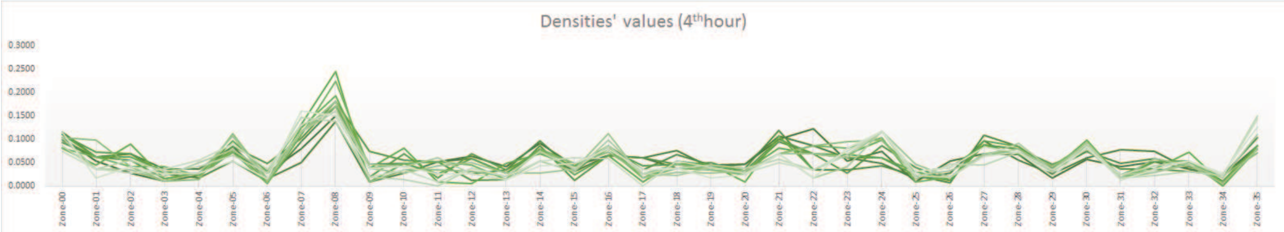

Fig 12: The densities' values during the fourth hour.

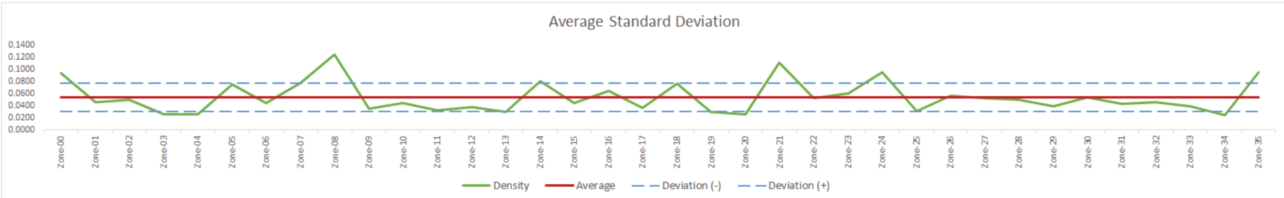

Fig 13: The densities' values average and the standard deviation ranges.

The average density value recorded was 0.054 pedestrian/m2. Also, the results indicated that 9 zones were recorded higher than the average and 7 of them were attached to food facilities. The highest average density recorded was 0.123 pedestrian/m2, at “zone 08”, it is a zone of food facility retail too. The lowest average density recorded was 0.026 pedestrian/m2 at “zone 34”, it is a zone of side street crossing.

The excessively high dense zones, which passed the higher limit of standard deviation, were: 07, 08, 14, 21, and 24 which mostly belongs to the use group “C”(Food Facilities). And, the excessively low dense zones were: 03, 04, 13, 19, 20, and 34 which are mostly areas of either street crossings and parking areas at both sides. The other densities values were closed to the average and roughly equal at 22 zones, these zones are attached to various uses' types including food facilities, parking areas, and crossings too.

5 CONCLUSION

The case we have studied faces basically two main problems: (1) a lack of clear and strict urban regulations and (2) chaotic movement behavior which, basically, emerges in walking outside the sidewalk and non-respecting of the traffic rules, if found. So, in our experiment, we could simulate the pedestrians' movement at the case of study. This simulation could be conducted by identifying, mainly, five items: (1) A video-based site survey, (2) Identifying the pedestrians' actual characteristics that found in the case, (3) Developing a waypoint map by which we could determine the actual movement routes as much realistic as we could, (4) Calculating pedestrians' generating rates at generators and vanishing rates at destinations, and (5) Primarily, categorizing the retail uses using the time which each costumer stays at each of them.

We used these mentioned variables to control the walking speed during the simulation by investigating the influence of each variable on the pedestrian's speed. Also, they enabled us to easily to count pedestrians' densities along the street and to identify their relation with the category of uses. We could find that the food facilities might be an indication of high pedestrians' densities, and that may lead us to taking in consideration a unique and different sidewalk's spatial characteristics at these zones.

6 FURTHER WORK

The case of the study is very complicated, especially that pedestrians cannot walk at sidewalks. In addition, our model was built in a simple way to simulate the actual movement behavior of pedestrians. The results were basically logic, however, we believe that this model has some lacks, such as eliminating 10% of the pedestrians' types in average. Also, it ignored the obstacles influence on walking speed and movement behavior in general. In addition, it was built based on a short-time survey. The model should become more sophisticated by modifying and expanding some features. These features could be considered as our further work as the following:

(1) Conducting a wider survey to get almost 30 hours of video-clips records during eight weeks’ survey, at least, therefore, getting more accurate O/D Matrix, and more accurate probabilities calculations.

(2) Expanding the field of study to add 75m length, at least, from both east and west sides to test the influence of the closest two crossings.

(3) Considering more types of obstacles and update the pedestrians’ behavior accordingly.

(4) Updating the method of generating pedestrians by developing a potential of dynamic generators, and destinations’ frequencies.

(5) Adding a new control panel to control the time of counting the densities, thus, we can control the calculation timing while the simulation runs or make it dynamic second by second.

(6) Adding the ignored pedestrians’ characteristics, such as: children, aged people, pedestrians’ groups, running pedestrians, and bike riders.

7 ACKNOWLEDGEMENT

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All video-clips and photos used in this paper have been taken using a permission given by The General Administration for Relations and Media Office which is followed The Ministry Of Interior (MOI) and with the acceptance of El-Basateen Police Station at south of Cairo. Most of video-clips’ and photos’ records used in this paper have been taken in collaboration with a professional architect photographer: Mr. Obada Nussair.

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