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MONITORING DAILY MOBILITY PATTERNS FOR UNIVERSITYSTUDENTS USING GPS TRACKING: TRIPOLI AS A CASE STUDY

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Abstract

Due to the current rapid growth of cities and technology, younger generations are spending more time in vehicles for their daily trips from home to various destinations, including their educational facilities. It is important to understand how people are using these spaces, and measuring this ‘understanding’ would need to consider a huge number of factors. This paper aims to help understand the pattern of movements in Tripoli city by monitoring Beirut Arab University students for a defined period of time using a GPS tracking method, and then comparing it with the spatial configuration of the city. This preliminary pilot study will raise awareness of the habits and methods of movement among the youth – either their use of mobile vehicles or their walking habits. This awareness is essential information that would help decision-makers in establishing appropriate future socio-health plans for the younger generation. The study shows huge variations in mobility and activity behaviour between genders, in terms of the distances covered, the speed of movements, the time spent in vehicles and the locations. In addition, the pattern of movements shows different degrees of correlation with the spatial configuration of Tripoli city in Lebanon.

Keywords

GPS tracking, mobility patterns, healthy movements, spatial configuration

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ABSTRACT: *Due to the current rapid growth of cities and technology, younger generations are spending more time in vehicles for their daily trips from home to various destinations, including their educational facilities. It is important to understand how people are using these spaces, and measuring this 'understanding' would need to consider a huge number of factors. This paper aims to help understand the pattern of movements in Tripoli city by monitoring Beirut Arab University students for a defined period of time using a GPS tracking method, and then comparing it with the spatial configuration of the city. This preliminary pilot study will raise awareness of the habits and methods of movement among the youth – either their use of mobile vehicles or their walking habits. This awareness is essential information that would help decision-makers in establishing appropriate future socio-health plans for the younger generation.*

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KEYWORDS: *GPS tracking, mobility patterns, healthy movements, spatial configuration*

1. INTRODUCTION

'Streets and their sidewalks, the main public spaces of a city, are its most vital organs.'(Jacobs, 2011). Since they can be considered essential organs, it is important to understand how people are using these spaces – and measuring this 'understanding' would need to consider a huge number of factors. It is worth mentioning that this paper is a preliminary pilot study. It acts as an initial phase of ongoing research, which is why it is limited to movement analysis without including other factors or layers of data, such as environmental conditions, land use distribution, different types of transportation modes, health aspects and other relevant factors. This paper focuses only on movements within the city, with a particular focus on university students as the main actors. It aims to analyse patterns of movements and their relationship with the spatial configuration of the city. This relationship would reveal how students use spaces for their daily trips and could contribute to different aspects of research from the perspectives of both spatial analysis and health and wellbeing.

The initial idea came from trying to answer the fundamental question of 'how much time do people spend on daily movement trips?' Little research in Arab cities has been concerned with this problem, although it has been widely addressed in a number of surveys in various Western countries. For example, six European countries conducted a survey on the driving and parking patterns of European car drivers (Pasaoglu et al., 2012), where Fig. 1 shows that Fridays and Saturdays are the days when more distance is covered in comparison to the other days of the week.

This study aimed to identify drivers' current patterns in order to promote the usage of electric cars in the countries surveyed and enhance their future configurations to match the current movement patterns. This action would decrease the dependency on fossil fuel cars and decrease the emission of CO_2.

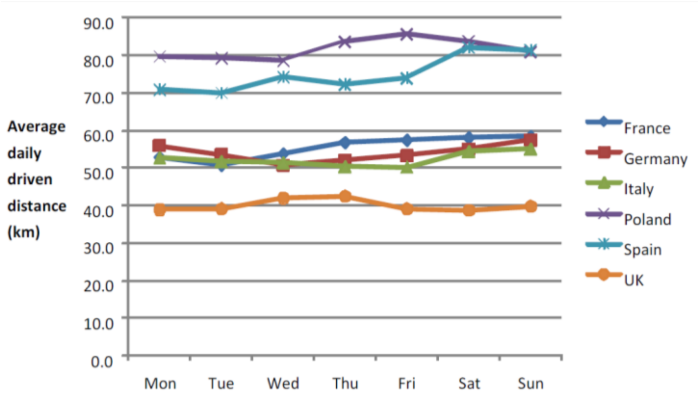

Fig. 1 shows the average daily distances driven (km) for six European countries in a one-week duration. Source: (Pasaoglu et al., 2012)

In another detailed analysis of driving time and average daily trips (2014–2015/2016) in the USA, it was revealed that the average number of daily driving trips per driver was 2.09, the average daily time spent driving per driver was 48.4 minutes, and the average daily distance driven per driver was 47.96 km. On average, men reported driving 24 per cent more kilometres than women per year and spent 18 per cent more time behind the wheel. The length of trips on any given weekday were significantly greater than on weekend days, and the mean number of daily trips was correspondingly greater on weekdays than on the weekend. The average daily number of driving trips was the smallest on Sundays and the largest on Fridays (Triplett, Santos, Rosenbloom, & Tefft, 2016). Table 1 shows detailed data based on gender and age.

Table 1 is the annual estimated average number of driving trips, kilometres driven and hours spent driving in the USA. Source: data extracted from (Triplett et al., 2016)

		Annual average Trips	**kilometres**	**Hours**
Age (years)	**16-19**	646	12152.1	208
	20-29	748	18183.9	311
Gender	**Male**	730	19333.1	319
	Female	798	15609	269

The above analyses used questionnaires, surveys and travel diaries as the main data sources for their seven-day analysis. They monitored daily mobility patterns relying only on the memories of their participants and their estimations of distances and durations. This method alone provides a general overview of the mass population; however, it is not precise enough to understand daily habits such as eating, walking, selecting specific routes for day trips, shopping and other daily related activities, as it does not geo-reference their exact locations. The emergence of such mobility data brings new opportunities to integrate more information in decision-making. However, the complexity of the data also increases with the dimensions of its contents, which imply complex dependence and higher-order interactions between space, time and individual social-demographic attributes. It becomes challenging to retrieve important information due to the increasing volumes and complexity of datasets (Lijun Sun 2016). As a result, other methods should be considered (Kimijima & Nagai, 2017).

The datasets of mobility patterns are used in number of research studies concerning health and wellbeing and targeting different age groups or genders. For example, some research has focused on understanding walkability within different neighbourhoods and its reflection on total physical activities for youths (Carlson et al., 2015), for older adults (Hirsch, Winters, Ashe, Clarke, & Mckay, 2016) and even for children (McCrorie, Fenton, & Ellaway, 2014).

The following sections address various methods of analysis and the selected method for this paper, in addition to the case study analysis. The students of Beirut Arab University (BAU) at Tripoli Campus in the north of Lebanon have been selected to participate in this pilot study.

2. Methods of analysing pattern of movements

Mobility patterns are one of the main concerns in a variety of behavioural analysis fields. Different studies have previously been conducted to derive a mobility model for each individual from their location information (SONG, 2016). The individual mobility model for a person can be built using different methods. The newer methods use positioning devices such as GPS receivers, which exist in all current smartphones, from which the raw positioning data of human mobile traces can be obtained (Dong Yup Kim, 2017). The traditional methods that depend on the manual monitoring of individual activities, such as the one used by William H. Whyte (Whyte, 2001) or Jan Gehl (Gehl, 2010) are not effective in a large-scale analysis when considering the size of the places covered and the number of observers, as they are time- and money-consumers and require a large team and various resources.

There are two methods for analysing the mobility patterns of pedestrians or vehicle travel. The first is by monitoring real movements, whether live tracking to capture instant actual movements or by retrieving previous recorded movements that happened at a definite date and time. The second method is forecasting potential movement trips to places or routes that people might use as a source or destination for their movements.

2.1 Monitoring real movements

Selecting the appropriate method for real movement tracking is governed by a number of factors. The first is the duration of the experiment. One week (seven days) as a test period is widely accepted in the literature (Ekblom-Bak et al., 2015; Hirsch et al., 2016; Ryder, Longstaff, Reddy, & Estrin, 2009); however, in some research, a longer duration is necessary due to the nature of the study, the participants or the effect of other factors. Secondly, with regard to the sample size, it should be randomly selected and represent the type of population that the study is focusing on, also considering the gender balance of the selected participants. Finally, with respect to the method used, this factor is greatly affected by the available budget and the duration of the project, in addition to the location of the experiment. Some technologies are limited to distances, indoor/outdoor positioning, the morphology of the space, and other related factors. The following technologies and methods are commonly used in the relevant types of research.

The empirical data for pedestrian mobility analyses is obtained from pedestrian monitoring. Two major scales are distinguished and provide different sensor technologies (Liebig, 2013). First, microscopic monitoring technologies return detailed individual movement data. These include trajectories and their attributes, speed or movement direction. Possible technologies include video surveillance systems or global satellite positioning systems (GPS). Second, macroscopic monitoring technologies focus more on groups – for example, quantity, density or average number of direction changes. Possible sensor technologies include digital quantity counting or Bluetooth tracking.

The video surveillance is developed to extract trajectories and flow counts (Bertozzi, Broggi, Fascioli, & Tibaldi, 2004) from video observations. Based on visual features such as contour, texture or colour, pedestrians are identified and recognized in a camera image (frame). The global positioning system (GPS) was developed mainly for military usage in 1988, opening up for civil usage in 1995. The system consists of 30 satellites circling around the earth in six orbits. Per orbit there are four active satellites and one redundant one, to compensate for any malfunctions. There are also other GPS systems developed by different countries, such as the Russian GLONASS, the European Galileo, and others. The Bluetooth scanners, transceivers or beacons are capable of monitoring people's locations using most popular digital gadgets: mobile phones and intercoms. There are strong privacy objections to the analysis of mobile network GSM (Global System for Mobile Communications) log files, which has limited the scope of its usage.

Due to the nature of this pilot study, the budget limitation and the sample size of the participants, the paper uses the GPS method located in the participants' mobile phones.

2.2 Forecasting potential movements

Space syntax, as both a theory and a set of tools, originated in the early 1970s from research by Bill Hillier and colleagues at the Bartlett School of Architecture, University College London (UCL). The theory attempts to understand why, from a spatial point of view, the built environment takes its shape in relation to corresponding socio-cultural activities (Hillier & Hanson, 1997). The relationship between the spatial and the social is a two-way interaction. Consequently, there is a fundamental link between the structures and functions of cities, as the configuration of the network is the primary shaper of the pattern of movement.

Space syntax is a quantitative method that describes patterns of spatial layouts, showing the effect of an urban grid configuration on existing movements. The more integrated the street, the higher the pedestrian flow rates are recognized, and this in turn attracts specific land uses to take advantage of the movement flows. These land uses act as a multiplier effect, through time, on the original flows (Hillier & Vaughan, 2007). One of the main measurements in space syntax is integration, which refers to accessibility. This describes the average depth of a space in relation to all other spaces in the systems. It indicates the preferable potential places that people will go to as a destination or 'to-movement' (Hillier, Turner, Yang, & Park, 2007). The outcome maps can be ranked graphically from the most integrated (red lines/plots or thick, dark lines in a greyscale ranking) to the most segregated (blue lines/plots or thin, grey lines) (Hillier & Iida, 2005).

This theory of space syntax and set of methods is used in the main case study in order to forecast the potential existence of movements along the main route of Tripoli city. The result is compared with the real movements tracked from the GPS data collected from the participants of the experiment, as discussed in the next section.

3. Daily patterns of BAU university students

The experimental project began by inviting 24 students of different levels and genders attending the BAU university campus in Tripoli. Since this is experimental research with a very low budget, the students were asked to use their mobile phones as GPS tracking devices, using the same tracking software that operates on both Android and Apple operating systems. This tracking software recorded their mobility activities and exported them in the form of a *.GPX file. This type of file was used in a geographic information system (GIS) environment to monitor the students' collective movement per day. The typical standard duration of such experiments, according to the literature, is one week (seven days), as highlighted in the literature review.

Operating such an experiment turned out to be a very difficult task because of the following points. First, using a personal mobile as a GPS tracking device consumes the mobile battery very fast. For some students, this represented a problem in continuing to use it for the entire day; as a result, some data was lost. Second, some students were not able to consistently remember to activate their GPS location each day during the experiment. Third, in order to collect the data, there was no simple and automatic method that did not cost any extra money for sending the files to the operator, which meant that some data was either lost or was not sent on time. Finally, not all the students had the same new mobile devices or updated software; some old models of specific brands operated with less efficiency than other, newer brands. This issue caused some misleading GPS data, which necessitated a longer time in refining the data and making sure of its accuracy.

As a result, from the above limitations, only 13 students were able to complete the task and provide full, detailed data throughout the seven days (as shown as Fig. 2). They were nine females and four males. This task was operated in the fall semester of the academic year 2017–2018, and the weather conditions were moderate without any rain or strong winds that might affect the students' movements. The students were asked to use their mobile GPS to record their movement activities, using their normal travelling modes throughout the experiment – meaning that if at the weekends they did not normally go outside their home, this should be recorded as an activity.

Since this experiment was conducted with university students, it is easy to spot the location of the university and other main sources of movement, such as the students' homes (as shown as Fig. 2).

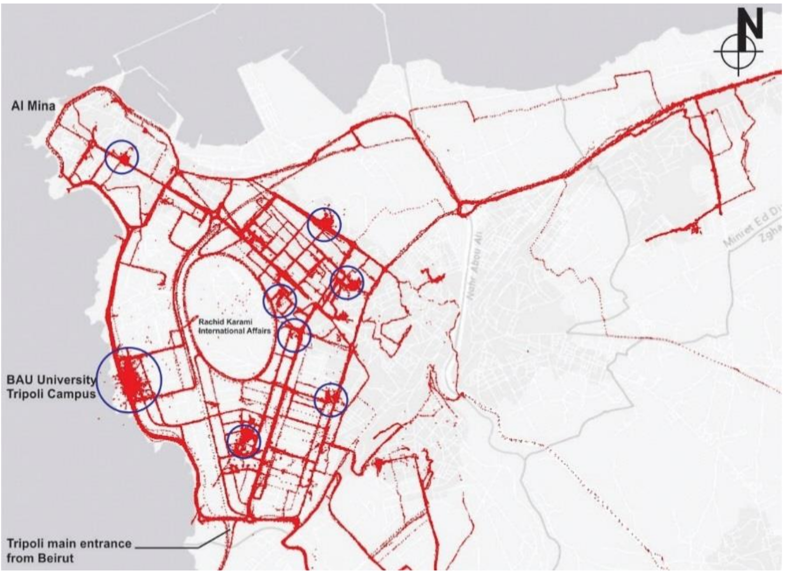

Fig. 2 shows the collective movements (red dots) of the 13 students throughout one week of tracking movements; thicker lines (dots) mean more density of movements, while the circles mean major source/destination stops

3.1 Tracking daily movements

The tracking outcome is divided into three monitoring categories: the typical mid-week days (see Fig. 3); the start and the end of the week (see Fig. 4 (A)); and the weekend days (see Fig. 4 (B)). The logic behind these categories is the nature of the work of the participants, since they are related directly to the university as a main destination for all the participants on the working days; thus the working days represent a major influence on the pattern of movements. Fig. 2 represents a collective pattern of movements that shows the spread of movements throughout Tripoli cities. Although the university is located within the city's main waterfront, walking to/from the university is rarely considered as an option because of the type of land use surrounding the campus and the nature of transportation modes available in Tripoli. The new part of Tripoli's waterfront is unused, with more than 85 per cent of it empty land, and it is isolated by a highway that separates the waterfront from the main city fabric. Hence, there is no potential destination that might attract walking movements to/from the city fabric. In addition, public transportation in general in Tripoli is not very active, except private taxis or buses on a contract basis.

Participants use almost the same routes on the typical mid-week days, except there are apparent variations within the selection of city centre routes (see Fig. 3). These variations appear in the evening pattern of movements. The start and the end of the week represent different mobility patterns. More density of movements is recorded from the participants; they use more routes within the city centre from the afternoon until late evening (see Fig. 4 (A)), with an increase in the number of trips and the duration of mobility. On the other hand, weekends (Saturday and Sunday) have a complexity of different mobility patterns in comparison to all the weekdays. This is understandable due to the shift of destination interest (the university no longer acts as a destination attractor). Further, the interest in route selection shifts towards the city centre. Sundays have a slightly higher number of trips than Saturdays.

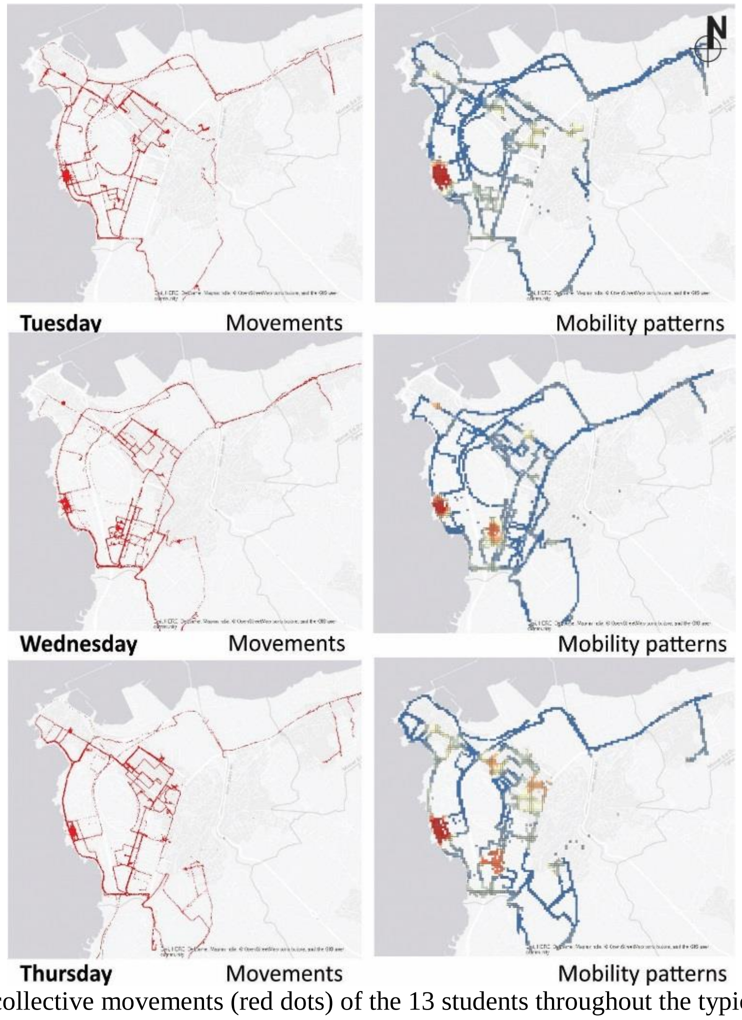

Fig. 3 shows the collective movements (red dots) of the 13 students throughout the typical mid-week days of tracking movements; thicker lines (dots) mean more density of movement, while the mobility patterns refer to densities, where red dots have higher densities than the blue ones

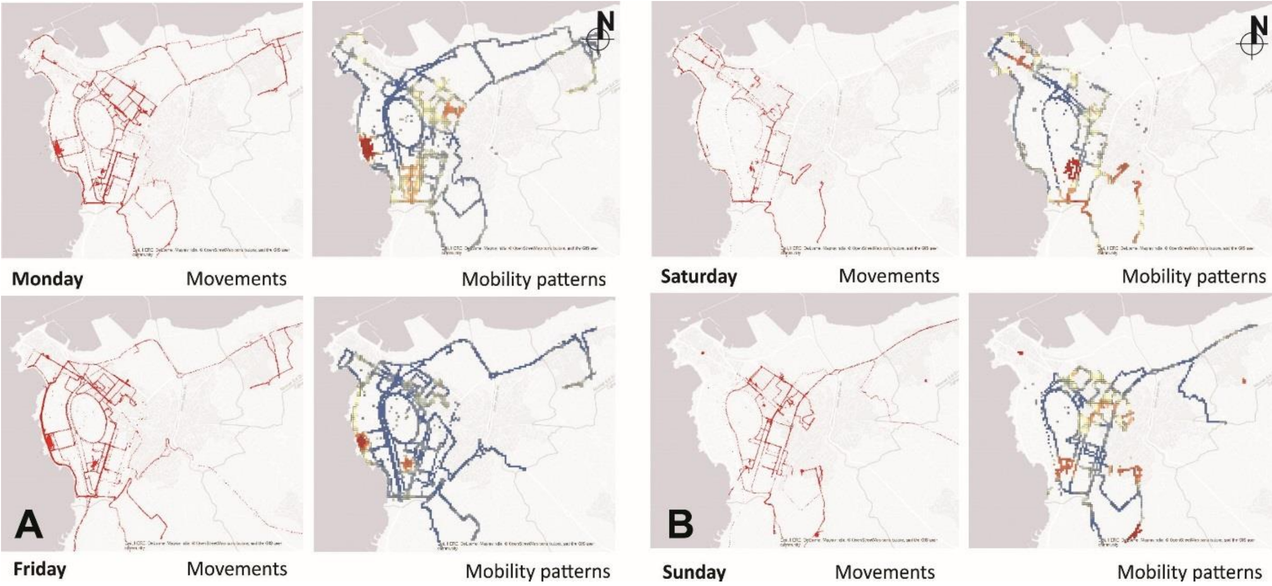

Fig. (4A) shows the movements at the start/end of the week; Fig. 4(B) shows the movements on weekends

The distances covered and the duration of daily trips vary between genders of students throughout the entire week (see Fig. 5). The average highest distance covered by students is on Friday (46 km), particularly for male students (88 km), while the lowest recorded for female students is on Saturday (13 km), as more female students have recorded no activities/trips. The average speed of movement of male students is constantly higher than for female students. The average walking distances recorded for both genders are less than five per cent of the trips conducted in the entire week, which indicates that they do not rely on walking as a mean of movement.

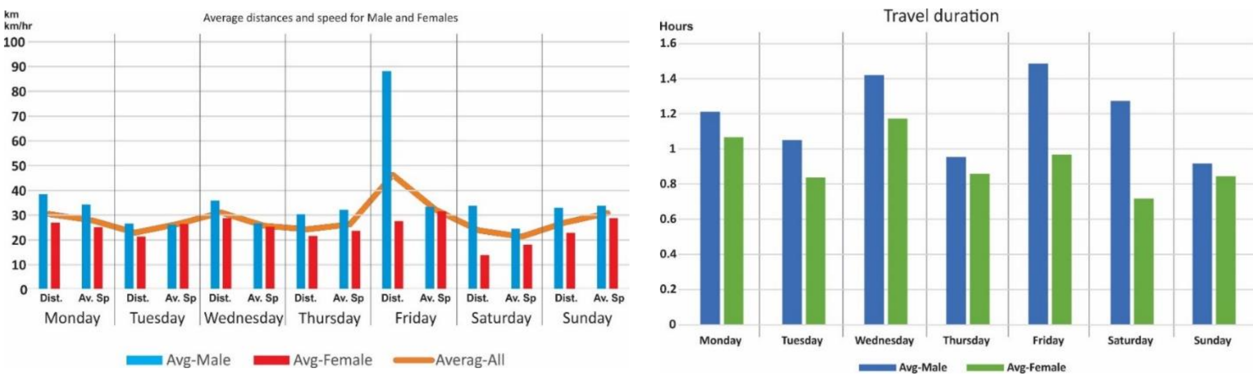

Fig. 5 (left) shows the average distances covered and the speed of trips for both genders; Fig. 5 (right) illustrates the travel duration in hours through the week for both genders

The average day's travel duration for male students during the week is 1.18 hours, 12.4 per cent higher than the female score, which is 0.92 hours (55.38 min) (see Fig. 5 (right)). Friday represents a higher duration in travelling for male students, while Wednesday is the highest for females.

The distances covered in daily trips and the duration of trips for male students are always higher than for female ones, despite the fact that the number of male participants is less than half of the female participants in this experiment. This result could be attributed slightly to the conservative culture of the city, which allows male students more freedom in movement (distance and duration) than female students.

4. Understanding patterns of movement and spatial configuration

It is important to find a relationship between the real movements gathered from the participants' GPS outcomes and the potential movements in specific places extracted from the space syntax analysis. This relationship would provide the ability to understand the current mobility patterns and the spatial relationship between spaces. In addition, the results could be used to forecast movements for future research. The gathered

GPS data for the seven days was processed in Arc-Info GIS software, and two main sources of information were plotted: the densities, which is the sum of the number of dots (movements per participant) recorded in a specific place, and all the other related information for each participant (gender, dates of movements, time and other related information). In addition to the GPS data, the space syntax data was calculated through remote software (Depthmap) and inserted inside the Arc-Info database (see Fig. 6). A previous analysis of the degree of correlation between the spatial configuration of Tripoli city and the monitored real movements indicated 78% of r^2 correlation (Mohareb & Kronenburg, 2012). This correlation was based on manual observations and counting pedestrians and vehicles passing in specific locations at that time.

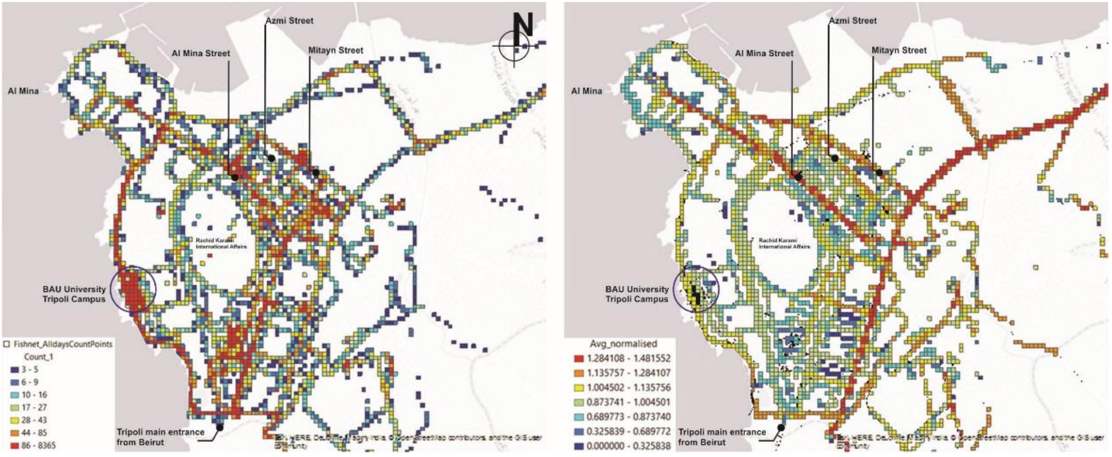

Fig. 6 (left) illustrates the participants' actual total locations (seven days) based on tracking their movements within Tripoli city, where red dots mean more-used routes; Fig. 6 (right) highlights the space syntax map of integration Rn 'to-movement' analysis, which is the potential usage of the spatial configuration of the city

The result of the correlation analysis between the data from real movements and the potential existing in the spatial analysis reveals that the percentage has dropped to 55 per cent as a general average of all days; however, it is changeable if measured by each day or by category (mid-week days, start/end of the week and weekends (the percentage increased at the weekends)). This result could be explained based on two factors: the nature of the selected sample(s) and the dominant land use (source or destination). The sample is from one category (students), and they have one common destination (the BAU University), which means a group action; however, they are free from that destination at the weekends, which means that they act as individual actions. This point of understanding is crucial in comprehending the nature of movements and should be considered in the future next steps of this research.

5. CONCLUSIONS AND DISCUSSIONS

The results of the above experimental study reveal that the average daily distance driven by BAU students in Tripoli is less than the range of outcomes of some European countries and the USA, while the time spent travelling is higher than the Western samples. Males report longer trip durations and cover more distance than the female students, despite their number in this experiment being less than the female participants.

If the participant sample has a common destination target, such as the university location, it affects the students' pattern of movements during working days, and their movements are less correlated with the city's spatial configuration; at the weekends, however, the correlation increases with the city's fabric. This result is due to the fact that the spatial fabric of the waterfront, where the BAU Tripoli Campus is located, is segregated from the city fabric. In addition, at the weekends, mobility patterns are not locked to the same destination; the participants move freely to their other individual sources and destination attractors. Therefore, if the aim is to monitor group mobility patterns, then weekdays are the appropriate time to do so, while individuality mobility patterns are better tested at the weekends.

In general, tracking mobility patterns could be used by decision-makers in research that needs to tailor specific rules or take advantage of the existence of movement flow in a particular place. For indoor applications, service projects such as hospitals and airports could take advantage of people's mobility patterns. For outdoor applications, as discussed earlier, urban spaces could be better understood if we knew how and where people were using them. This experimental pilot study could lead to a number of future research studies considering the following topics: the development of the waterfront of Tripoli city; choosing the appropriate transportation modes within the city; developing a healthy walkability index for the city; or developing appropriate land use within the waterfront sector of the city.

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