MONITORING SOME SMART CITY GEOGRAPHICAL CHARACTERISTICS OF MEDINA IN SAUDI ARABIA

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Key-words: smart city; Medina; GIS; quality of life.

Abstract. "Smart City" has grown as an important field of study, that relates especially to the future sustainable development of cities. There was a large number of attempts to formulate a more comprehensive and accurate concept to the smart city during the past years, focusing on the development of both place and people. Nevertheless, studies still lack in similar topics on Medina city. This paper aims mainly at exposing and analyzing some smart city geographical characteristics of Medina (a famous city in Saudi Arabia) with its important reputation of religious tourism in the Middle East and the Islamic world as a whole. It begins with the standpoint of reviewing some definitions of "Smart City" and its main axes to assess some of its geographical properties measurable or observable. Then, it demonstrates elements that ait as defects to the city development towards smartness. With the increasing role of the Geographical Information System (GIS), as an inelegant tool, helps in surveying, understanding, managing and monitoring complicated geospatial issues related to the smart cities' main aspects. The study applied ARC GIS 10.3 software, and depending on the data collected from official authorities and field-work led to the perception of some negative aspects that should be rehabilitated.

1. INTRODUCTION

The 21st century has brought a new trend of sustainable urban development, adding new dimensions to urbanization with a view to updating old cities by the integration of new strategies with new technologies and ways of life. Despite the prevalence of recent studies of smart cities, there is a lack of studies that treat Medina opportunities to be considered as a smart city.

This paper makes a review of the multiple definitions and characteristics of smart city found in the literature, then proposes a set of indicators that are essential for understanding the initiatives of Medina. Consequently, to evaluate what is the situation of Medina among smart cities by measuring components (governance, infrastructures and services, mobility, living and people) which are essential for the further elaboration of the smart city and are studied and evaluated in Medina from many perspectives. ARC GIS software is found to be a powerful tool in several study stages.

During the past few decades, Medina (an alternative name is Madinat Al-Nabi Mohammed) has become a city with half a million population in 1990, and recording 1,100,093 inhabitants in 2010; this was followed by urban growth and pressure on all its facilities and services. It has an important reputation in religious tourism, being visited by hundreds of thousands of people during some 10 months of the year (the Umrah season with the Ramadan and Hajj feasts) and even more. Visitors are concentrated in the central area around the Holy Mosque, where there are global hotels and residential homes. Accordingly, there are challenges of extra-pressure on facilities and services. So, the city is expected to offer better services in terms of infrastructure and facilities, to be more responsive to the citizens' and visitors' needs.

To make the city more efficient to accommodate the growing and evolving needs of its population, simultaneously preserving its resources and environment for future generations, it is

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necessary to follow developed methods in accordance to global technological advances. These methods are often affected by top-down factors (government policies and plans) and down-up factors (population characteristics and attitudes towards technologies). Thus, the idea of evaluating the geographical properties of Medina comes up to perceive its strengths and weaknesses to be a smart city. Furthermore, this paper checks the hypothesis of the importance of collaboration between citizens and government to develop Medina towards smartness.

The study depends mainly upon data collected from official authorities and field-work. GIS software applications (ARC GIS 10.3) are used in surveying, understanding, managing and monitoring the complicated geospatial issues of this study.

2. SMART CITY CONCEPT

As the smart city is a fast-growing field of research, its concept has been confused for several years' time. Some have mixed the fuzzy "Smart City"-term and certain terms which were simultaneous and consecutive (such as: Digital City; Wired City; Green City; Information City). Annalisa Cocchia attempts to compare different definitions of the city linked to the label "Smart City and to list them according to the literature review" (Cocchia, 2014). Furthermore, in previous years it was approached from different perspectives. In the same vein, Berardi reviewed some definitions proposed in this literature providing varied concepts regarding it (Berardi, 2015).

It can be safely said that "Smart City" focuses on the city now more than ever before. "It becomes wider to include aspects of applying the benefits of modern technologies for true development of the city elements in alignment with technical transformation" (Stratigea Anastasia, 2015). However, with the beginnings of the emergence of the term "Smart Cities", the focus was on the word "Smart", so some mentioned that a major difficulty in identifying the smart city definition is the confusion of meanings attributed to the word "Smart" and to the label "Smart City". Furthermore, the faith that the "Smart City" resembles the terms of "Digital City", "Wired City", "Knowledge City" and "Green City", which link technological informational transformations with economic, political and socio-cultural change (Hollands, 2008).

In-between the previous varied concepts, researchers attempted to draw up a comprehensive concept of Smart Cities, which can be summarized as follows:

– "The smart city is where the use of smart computing technologies makes the critical infrastructure components and services of a city more intelligent, interconnected, and efficient" (Washburn, 2010).

– "The smart city concept implies a community-driven reaction to solve traffic congestion, school overcrowding, air pollution, loss of open space and skyrocketing public facilities cost" (Pardo, 2011).

– "The smart cities, emerged as a solution of people's strong inclination to concentrate in cities, generated both positive and negative effects, such as traffic jam, carbon dioxide, greenhouse gases emissions and waste disposal with consequences on health conditions" (Caragliu, 2011).

– "The smart strategy is ICT, considered that the main issue is to meet the needs of the market, rather than the intelligence which is required for cities to be smart" (Dameri, 2013).

– "The smart city related to the concepts of smart community, sustainable city and green city, including the economic component, environmental component and social component" (Sylvie, 2013).

Finally, it must be said that the *smart city* is an extensive concept which describes cities with smart communication, urban governance, environment and people and produces smart living. Also, it can be said that the city could not be a smart one when there is shortage or surplus of its components (such as energy, water, services production or property).

3. SMART CITY AXES

According to the reiterative shared features of the city suggested to meet the future needs over the coming decades, there were studies drawing up the main axes of the smart city. Researchers of the future cities laboratory at the *Singapore-ETH Center* for Global Environmental Sustainability have explored the characteristics of the future city. They reached seven main pivots, considering the city as an urban metabolism. So they used the concepts of "Stocks and Flows" to describe its status and dynamics by studying material, energy, water, people's positions, finance, information, density and space on three different scale levels: "S (small)-scale": the individual building, "M (medium)-scale": the urban part and "L (large)-scale": the territory (ETH, 2015). This scales are similar to Hafedh's previous classification (Hafedh, 2012). After filtering, Pardo *et al.* (Pardo *op. cit*.) reduced these dimensions to three which have implied all dimensions as follows:

a) The "Technology dimension based on the use of infrastructures (especially information and communication technologies, ICT) to improve and transform life and work within a city in a relevant way. This dimension includes the concepts of Digital City, Virtual City, Information City, Wired City, Ubiquitous City and Intelligent City".

b) The "Human dimension based on people, education, learning and knowledge, because they are key-drivers for the smart city. This dimension includes the concepts of Learning City and Knowledge City".

c) The "Institutional dimension based on governance and policy, because the co-operation between stakeholders and institutional governments is very important to design and implement smart city initiatives". "Recently, main city smart axes come as smart governance, energy, environment, transportation, IT, communications and smart buildings" (Exhibitions, 2015).

4. GEOGRAPHICAL INFORMATION SYSTEM (GIS) AND SMART CITY

The Geographical Information System (GIS) environment is considered as an adequate spatial data platform for a lot of the smart city pivots such as mobility, energy, communication, population and others (Joseph, 2014).

The importance of applying *GIS* in smart cities comes basically from identifying location-based services. It facilitates geographical data storing, updating, analysis and visualization that help decision-makers without wasting time. Furthermore, "it introduces powerful tools that allow both city mangers and citizens to create interactive spatial queries, analyze, get maps , reports and results" (ISO.ORG, 2014).

Some researchers have addressed the interaction between *GIS* capabilities, cloud computing, geo-visualization, and human-computer under the term of "Interdisciplinary Urban *GIS* science" in order to transform the cities' managements to a more efficient level, "especially in the fields of transportation, risk management, urban planning, noise mapping and solar energy" (Li, 2013). Besides, accurate updated data are very important elements to manage smart cities, by increasing the importance of real-time measurement and data transfer techniques. The raw data no longer worth the same value as they previously had, requires a lot of data analysis to take rapid decisions to help manage the crisis. These decisions always have spatial dimensions, such as problems of traffic and transportation, water, sanitation, etc., maximizing the value of *GIS* in all of the smart city components.

Modelling and simulation are the most important *GIS* applications concerned with the smart city geo-spatial management, they act as a platform which can serve many topics, such as;

- Monitoring urban growth and Change detection.
- Managing networks (water, electricity, and sanitation lines).
- Planning roads, locations, and services (selecting the smart locations).
- Interpolation of digital surface models (DSM).
- Setting up GIS with 3D capabilities (3D city model from satellite images).
- Handling the dynamic and semantic aspects of city modelling and simulation.

- Producing intelligent maps and implementing them online through WebGIS.
- GIS excessive capability in representing visible and invisible phenomena of the city
- Crime prevention (using data-collected through GPS and intelligent map).

Finally, it can be said that applying GIS technology to smart cities emerged as a complete package referring to a number of modern technologies and advanced processes of expanding knowledge of urbanization and connections among people to manage and deliver spatial data by geographical location. It illustrates the problem of location, its surrounding context, different scenarios in a dynamic environment and suggested solutions.

5. STUDY-AREA SMART SITE AND LOCATION

Medina is the capital city of Al Medina Province which is located in the Western part of Saudi Arabia (Fig. 1) at the intersection of 39° 36' E long. with 24° 28' N lat. The city is situated on the Arabian shield composed of metamorphic rocks dating to the first geological period of the Paleozoic Era. It seems to be in harmony with nature, and is surrounded by mountains from all destinations that can be seen particularly from the North and the South. The mounts of "Ohod" and "Thor" are seen in the North, "Eyr" in the South and "Dalee Al Bary" in the West.

It has a distinctively hot desert climate. Summer is very hot, but Winter is milder, with very little rainfall sometimes. It rains almost entirely between November and May.

The city gained its importance as the second most important Islamic city in Saudi Arabia after Mecca, which is visited by thousands of Islamic visitors. Also its nodal site at the intersection of a number of highways that connect it to some important cities in Saudi Arabia supported its smart site. It connects to: Riyadh, Yanbu, haiel, Jeddah, Mecca and Tabuk (Fig. 2). Its location had the same importance in the past because it lay on the old caravan route which linked the South of The Arabian Peninsula with the Levant (Sham) in the North.

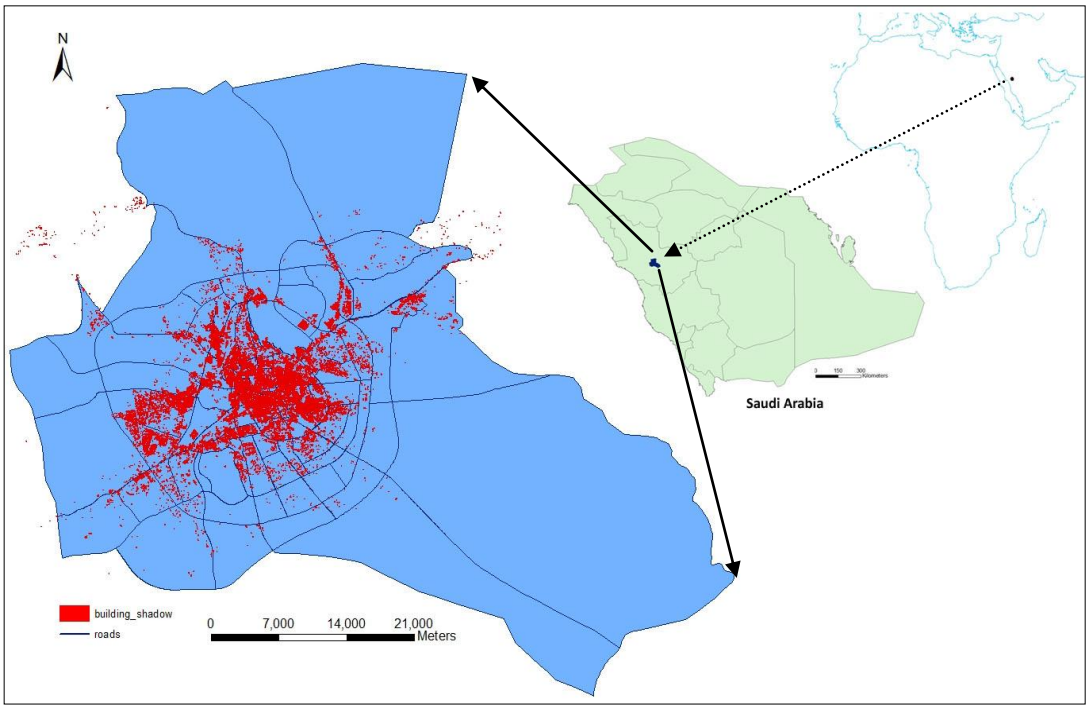

Fig. 1 – Medina (Al madinah Almunawwarah). Location.

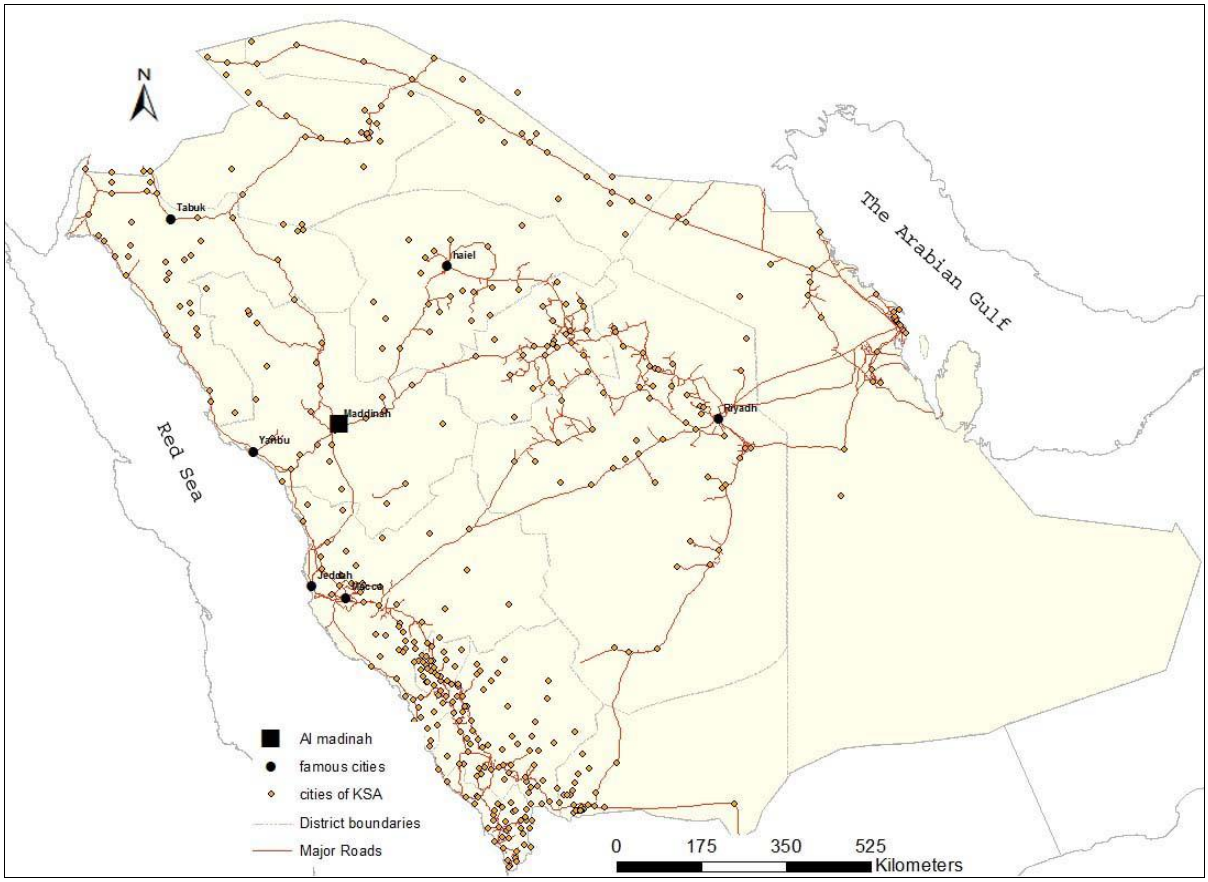

Fig. 2 – The nodal site of Medina Location
at the intersection of highways.

6. MEDINA SMART CITY DOMAINS

Although nowadays a smart city is a critical issue in the literature, yet there are few design methods and architectures of smart cities. The event-driven approach to the smart city design is unclear, too. On the other hand, there are many recently published studies that deal with smart cities and their architectures which may help drawing up the main elements for Medina to be a smart city.

With respect to such studies previously discussed, the smart city components are governance, information, mobility, economy, environment, services and people. The current study-framework includes five characteristics (Fig. 3) as a targeting the further elaboration of the smart city which examined and evaluated Medina from many such perspectives.

It should be noted that each of the following characteristics is therefore defined by a number of factors. Then, each factor is described by a number of indicators which are derived from public and freely available data. The study always takes into account the overall target. These five characteristics are as follows;

– smart governance.
– smart mobility.
– smart people.
– smart infrastructures and services.
– smart living (Quality of life).

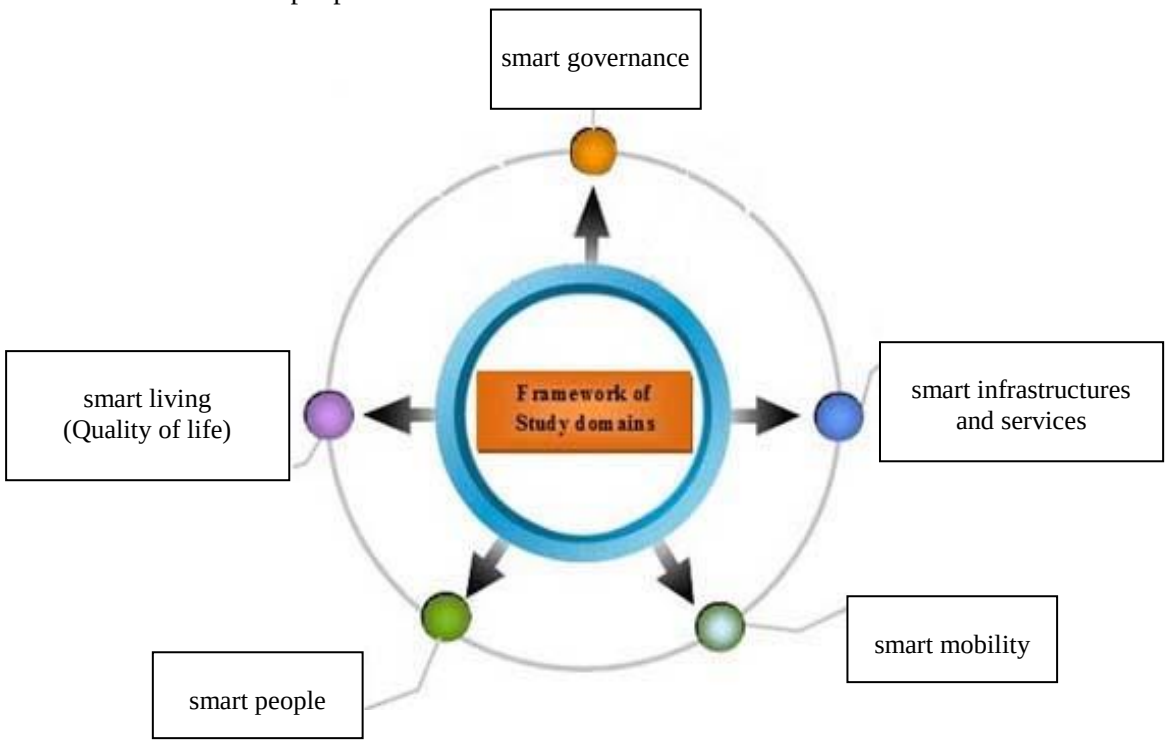

Fig. 3 – Framework of study domains.

6.1. Smart Governance

Governance is the exercise of the political, economic and administrative authority to manage a nation's affairs. It is a complex of mechanisms, processes and institutions through which citizens and groups articulate their interests, exercise their legal rights and obligations, and mediate their differences (Somayya Madakam, 2014). Medina *leadership and governance* comes basically from its regional municipality. On the other hand, the "Al Madinah Al Munawarah Development Authority" participates, together with the municipality, in planning fields.

Since *smart governance* depends on the implementation of a smart governance infrastructure that should be "accountable, responsive and transparent" (Mooij, 2003), a field survey with a preset questionnaire form was conducted for monitoring and evaluating the smart governance maturity level of Medina city. The questionnaire included inquiries about the main objectives of smart governance which achieve greater efficiency (e.g. strategies, visions and plans) in addition to the technological tools and facilities that support decision-making.

Depending on the selected measurement factors shown in Table 1, the top-down smart city strategy is simply absent, no leadership engagement related to it and the vision towards smart is exhibited on a case-by-case basis in a decentralized way. Most departments have documented clear roles, but no dedicated teams for the smart city were formed.

City governance basically applies technology (fax, tel. and internet) to facilitate and support better planning and decision-making. It introduces electronic services in several sectors (to be addressed in detail later), but continuous improvement of services through innovation is absent in all

the departments. It is worth mentioning that *GIS* is used merely as a portfolio of spatial data, as well as some on screen analysis. On the other hand, failure to activate "Cloud Computing" technology reduces the benefits of this GIS technique.

Although, the smart governance concept must comprise performance measurement tools, in which feedback registration is an important factor, yet it is ignored in the city.

Table 1

List of the main objectives evaluated according to the field survey used to assess the smart governance maturity level of Medina city.

Objective		**Regional Municipality (Departments) :**	Follow-up and control	Reconstruction and projects	Coordination of project implementation	Municipal Affairs	Services	Administrative and Financial Affairs	information technology	Municipal investments	Info. Media	Regional development, Planning & Quality	Legal Affairs	Human resources	Land and the landowner	Public relations	**Development Authority (Departments) :**	Urban development	Information Technology & GIS	Planning	Administrative & Financial Affairs	Legal Affairs	Transaction systems	E-competitions	Tender announcement
1 – Strategy			×	×	×		×	×	×	×		×			×			×	×	×			×		
2 – Vision						×	×	×	×		×	×						×	×	×			×		
3 – Clear role			×	×	×	×	×	×		×			×		×			×			×	×	×	×	×
4 – Dedicated Team work			×				×		×									×	×	×					
5 – Partnership																								×	×
6 – Innovated civil services																									
7 – Applying Technologies	Tel.		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	Fax							×	×		×			×		×		×	×				×		×
	Internet		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	Cloud computing																								
8 – Applying GIS							×												×						
9 – Electronic Services	business sector						×														×		×	×	×
	governmental sector						×														×		×	×	×
	individual sector						×																×		
10 – Feedback regist. & Performance Measurement																									

6.2. Smart infrastructures and services

Although, the effective networks of infrastructures and services are important for sustainable cities, the smart city idea depends mainly upon applying articulated soft infrastructures, i.e. mobile applications, social networks and the communities' cultural systems, and various forms of *ICT* which improve the performance of such hard infrastructures and services.

6.2.1. Electronic (E)- Government

E-Government is the term coined to describe this soft real time infrastructures and services. It depends on providing access of needy citizens to government information and services (regardless of their cultural and technical level of access to information and communication technologies). Services are provided through some government centers, private centers and smart phones. *E-Government* includes many services supplied by various ministries and other government agencies for citizens, thus shortening time and distance since geographical factors play an important role in service assessment. Decree No. 7/b/16,838, issued in 2001, established the national plan that regulates the stages towards e-applications in Saudi Arabia in general, and in Al Medina (mcit., 2015). The city has moved to implement *E-Government* in most government departments. The government services percentage converted electronically increased from 29.4% in 2009 to 31.6% in 2013 (Observatory, 2013).

Accordingly, some *E-Government* services centers have been distributed in several parts of the city, supplied with computers connected to the internet to provide and conduct electronic transactions. These services were applied first at post-offices, then at private centers in response to the increasing needs of users for electronic transactions. After that, the opportunity of logging in this applications became available on smart mobiles. Figure 4 demonstrates that there are 80 *E-Government* services centers in Medina, their distribution pattern being seemingly clustered within the second round road, but they are also dispersed in the other parts of the city, too.

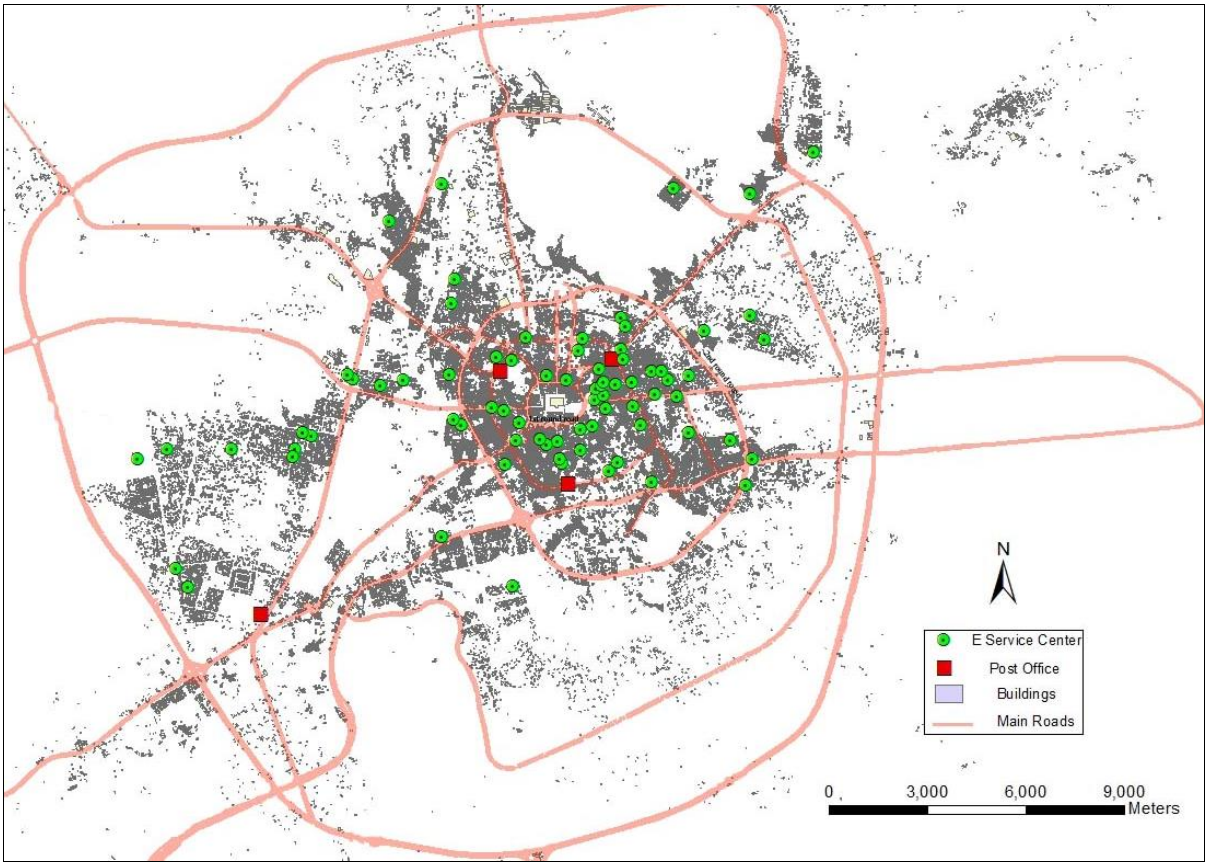

Fig. 4 – E. Government Services distribution pattern in Medina.

(ARC GIS 10.3 is applied to calculate the nearest neighbour index using the equation: Nearest neighbour index (R) = observed distance / expected distance)

6.2.2. Accessibility of services data (Open Data)

The data quality and *open data* platform strategy meet the demand for citizens who would like to access their services easily at home, or at work via the web, or on their mobile devices. This confirms the deep-going concept of smart cities that allows data sharing and transparency.

Data openness does not mean only the opening up of data by government authorities, but also making data available for privately-owned companies and individual citizens to use and share them.

In such a context, a questionnaire (of 300 form) was applied to some firms, authorities and individuals aiming at measuring the availability of several sectors to obtain the data. Figure 5 shows the results of applying this questionnaire, indicating the availability of the open-data platform as follows:

a) It is clear that the public authorities have distinctive access to open-data movement compared to private companies and individuals.

b) Education, administration and finance data represent major open domains for all the sectors.

c) Individuals offer open data in certain areas (e.g. Education, Health & Public Safety).

d) Sport, transportation and environment represent minor open domains for all.

It is important to note that data sharing will raise concerns about information security, privacy and data protection. So, controls may be necessary to identify what type of data can be processed (as open) and in which sector.

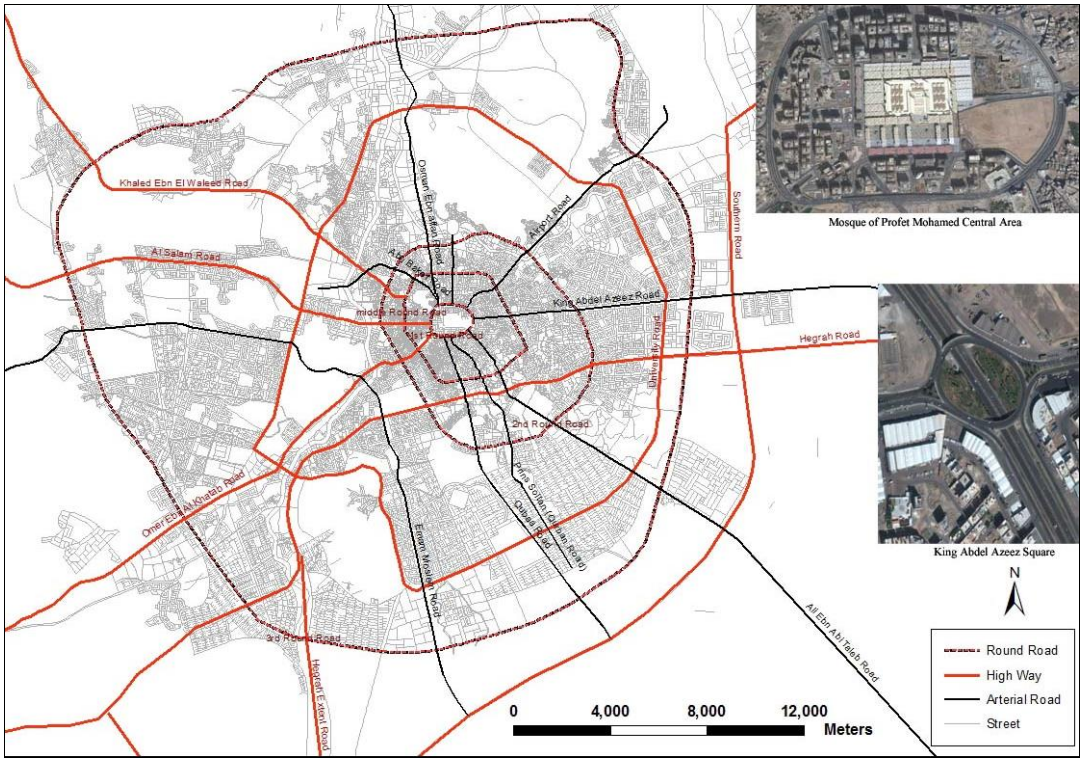

Fig. 5 – Open-data availability by categories in Medina.

6.3. Smart Mobility

Medina is growing, and so is the number of trips taken within the city. In the *mobility* concept, attention is paid to ensure sufficiency, as well as efficiency. Smart mobility generally aims at local accessibility, (inter-) national accessibility, sustainable, innovative and safe-transport systems that can

be described by traffic management, reduction of time and energy and facilitate travel and payment of tolls, all aiming at the citizen's satisfaction.

Somayya determined the smart mobility framework emphasizing travel choices, healthy, lovable communities, reliable travel times for people and freight and safety for all users (Somayya *op. cit.*).

To analyze the mobility performance of the city, the following factors will be included;

- Road classification.
- Transportation means.
- Use of non-motorized traffic.

6.3.1. Road classification

Medina has a good network of roads and streets, both within the city limits and beyond them. It can be said that the important location of the Mosque of Prophet Mohammad has clearly reflected in these radial network of roads that ends up in Medina. Figure 6 illustrates a detailed profile of the three road classes in Medina, based on their type, condition, width and designated speed, as follows:

The first type (Round Roads) consists of four closed ways of circular rings that surround the Mosque of Prophet Mohammad. They are between 60 m and 100 m wide. The designated speed on these round roads is 110 kilometers per hour, except for the first round road where speed is of 80 kilometers per hour. These round roads represent the main framework of traffic adjustment and most of the movement within the city, especially of the large number of vehicles around the Mosque.

The second group includes those highways that function is fast-going traffic to and from the city centre towards the peripheries and beyond them. They are about 100 m wide, speed allowed at 120 kilometers per hour.

The third group consists of arterial roads, no more than 65 m wide, which help the functions of highways speed: only 60:80 km/hour. In-between, there is a good network of paved streets that connect the above-mentioned types of roads.

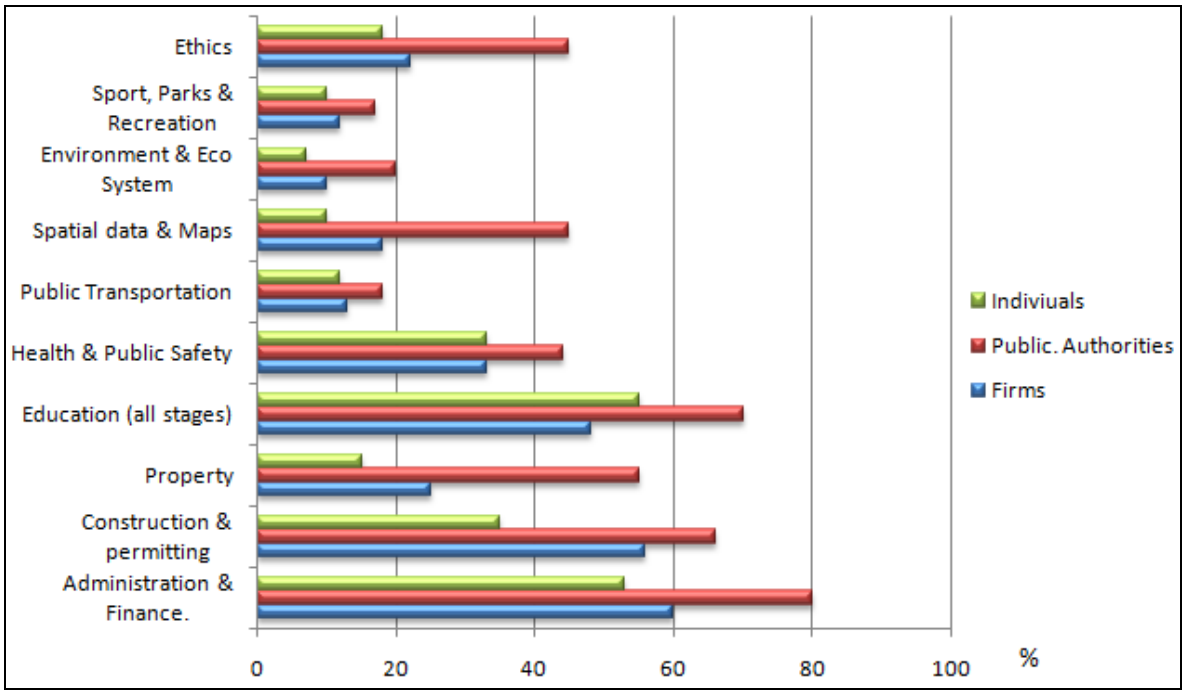

Fig. 6 – Medina network of roads and streets.

6.3.2. Transportation means

Transportation means in Medina are of two kinds: for goods and for passengers; transport is private and public.

According to the reports of Medina traffic department (Department of Licensing), in 2014 there were 49,350 cars in Medina area (data on the city numbers are unavailable) that is by 8,630 more to than in 1994 (40,720 cars). Private cars represent 48.4% while other types vehicles account for 51.6% of the total number of licensed cars. It should be noted that private cars are used for the transport of passengers within the city, either by their owners, or by taxi services, where the law allows it.

Public transport is the second type of movement in Medina, the Saudi Public Transport Company *SAPTCO* operates a comprehensive network of high-quality bus services across the Kingdom of Saudi Arabia. They link all major cities, towns and villages.

There are ten bus lines departing from Medina to the surrounding cities (Jeddah – Al Mahd – Mecca – Yanbu – Tabuk by desert road – Tabuk by coastal road – Riyadh – Dammam – ELola – haiel), covering the passengers' needs. The main lines, operated by the company for the Medina area, run between Medina, Mecca and Jeddah. In 2014, there were 4,016 trips from Medina to Makkah and 4,989 in the opposite direction, transporting nearly 131,000 passengers (SAPTCO, 2014). On the other hand, the Medina–Jeddah line registered 4,658 trips from Medina to Jeddah, and 4,124 trips in the opposite direction. Data on trips, ticket reservation and payment methods can be easily obtained on the internet.

As for international transport, the city depends on two ports in the adjacent Yanbu city, namely King Fahd industrial port and the commercial port, besides the two airports: Prince Mohammed bin Abdul Azeez Airport within the city and Yanbu Airport. As the region has an old railway-line (the *Hijaz* line), which is out of service now, there is an ongoing project to build a new railway-line between Medina and Mecca.

There is no doubt that modern transport technologies, logistics and new transport systems improve the inhabitants' mobility. So, traffic management is an essential element of the cities towards development and smartness. In this context, the Medina Government has planned traffic management inside the city and beyond it as follows:

As regards traffic management on roads outside the city, the K.S.A. Ministry of Transport has been measuring the traffic volume on the regional roads since the beginning of 1992; this is done by a number of permanent stations including one in Madinah (Station No. 104) located on the Medina/ hanakiyah road. They count traffic per hour on the track direction by vehicle type, an annual report presenting data for each station. On the other hand, the Hajj Research Center makes permanent reports on the traffic volume at the four main entrances to Medina. The processed data have been converted on tables. The other component that supports traffic management on roads from-and-into the city is the Police unit for road security that oversees roads traffic and has accurate statistical data on road accidents in terms of location and degree of injury.

Within the city, there is an automatic Traffic System of connected control centers, in terms of Traffic Laws, street marking and cameras. The city's traffic plan includes the following objectives (Ministry of Transport, unpublished report):

- Reducing traffic congestion especially in the central area.
- Securing compliance to traffic laws and rules.
- Optimizing traffic flows within the city.
- Reducing accidents in the city.

Noteworthy, Medina has witnessed a phenomenal growth of vehicles. As a result, many of the arterial roads and intersections capacity is exceeded and average journey speeds on some roads at peak hours are low. Also, the time required by citizens for everyday mobility and the number of trips taken are subject only to minimal variations.

6.3.3. Use of non-motorized traffic

It can be said that if the traffic situation in the city depends mainly on individual motor vehicles, the higher population growth rate will result in more car trips, energy consumption, emissions of pollutants and the intensive use of urban space in the city. This will affect a high quality of life for its dwellers.

Although measuring non-motorized movement on sidewalks, bikes, etc. is difficult because official data and tools are missing, yet researchers did use two distinct methods to monitor this type of traffic: "(1) short (1– or 2–hour) manual counts, and (2) continuous measurements using automated instruments" (Papanikolopoulos, 2010). Others have used aerial photography for the same purpose (Behnam, 1977).

In Medina, there are no bicycle facilities or pedestrian lanes such as painted bike lanes, except for only one off-street for pedestrians and cyclists, including sidewalks and trails. So, applying GIS is effective to classify streets and determine every street's general function according to various land uses. Classifications include main roads (round roads and highways), arterial roads and local streets. A student-team conducted the field count. They measured traffic volumes for pedestrians and cyclists at 30 locations (selected for their characteristics of special interest) and calculated the hourly traffic volumes (Fig. 7). Most counts have been made in October and November at two peak-hours. The general trends in volumes at the selected locations proved traffic variations (pedestrians and cyclists) in relation to location characteristics and land use. The observation showed the increase of pedestrians in the central area and commercial streets compared to other parts of the city, while the number of cyclists in the city was the lowest.

It should be noted that these results cannot be broadly generalized to the city because the location and timing of these observations were not random. So, they are nothing more than just indicators for the study.

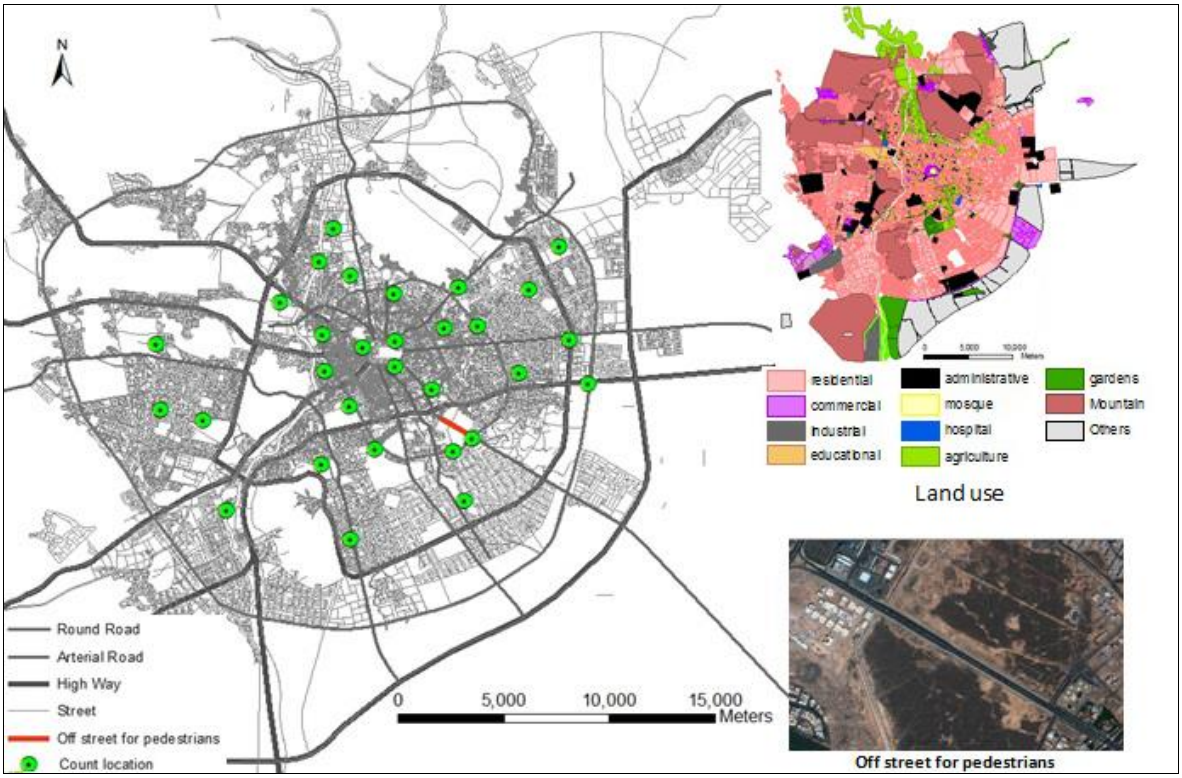

Fig. 7 – Locations of non-motorized traffic counts and land use.

6.4. Smart Living (Quality of Life)

Due to the final report of a research project on Smart cities Ranking of European medium-sized cities (Ljubljana, 2007), "smart living comprises various aspects of the quality of life. The most important of these aspects is housing, health, education, environment and tourism". They will be studied in Medina in the following.

6.4.1. Smart housing

According to the socio-economic survey of the *Urban Observatory Center of Medina*, average per capita housing 2012 was 34.9 square meters in Medina (Observatory, 2012), while the rate of overcrowding reached 1.6 individual / room. These rates are acceptable according to international standards. Moreover, dwellings that meet health requirements in construction (with building permits) represented 85.4% of the total number of dwellings in the city (2012), while 14.6% of them had no building permit, being located in the slums.

Besides, the city has 8,113 vacant housing units, which represent 3.7% of the total number of housing units in the city (non-allocated for the accommodation of pilgrims) (Electricity, 2014). Most of these high-value units are beyond the purchasing power of a large number of people.

6.4.2. Smart health

Smart health can be described by the rate of hospital *beds per inhabitants*, *doctors per inhabitants* and the quality of service. There are a number of public and private hospitals in Medina, with an average of *21.6 beds per 10,000* inhabitants (Health, 2014). This is a good rate compared with the rate of beds in Saudi Arabia in general (*20.1 beds per 10,000 inhabitants* in 2014).

In 2014, Medina had *18.1 doctors per 10,000 inhabitants*, whereas Saudi Arabia had *19.8 doctors per 10,000 inhabitants*. Therefore, that same year, the mortality rate was *10.6 per 100,000* live births, and it was *12 per 100,000* live births in Saudi Arabia.

6.4.3. Smart basic education

The smart basic education indicator could be derived from some elements, such as number of *students per inhabitants*, *educational quality* and *satisfaction with access to the educational system*.

In brief, it can be stated that there is a wide variety of male and female education enrolment rates in Medina. In 2013, male enrolment rate in primary, preparatory (Intermediate) and secondary schools was 77%, 79%, 76% (Educational, 2013), while the female enrolment rate was 71.4%, 71.3%, 72%. Figure 8 A illustrates the absence of female rates in comparison with males, because of conventions that underestimate female education.

On the other hand, the quality of education can be evaluated by classroom density. It is from *28.0 to 29.5 pupils per class* in primary and preparatory schools, and between *36 and 38.9 students per class* in secondary schools. These numbers are better than those in Saudi Arabia generally, but in regard of the structural condition of schools, reports indicate that only 23.4% of them meet quality requirements and this is a big drawback for school buildings in the city.

The number of students to teachers represents a good indicator to measure the quality of education. Reports in 2013 show 17.6, 14.9 and *16.3 students per teacher* in primary, preparatory and secondary schools in Medina, compared to Saudi Arabia (*11.6, 11.2 and 11.9 students per teacher*) (Fig. 8 B). That means that Medina is in need of additional teachers for all stages of education.

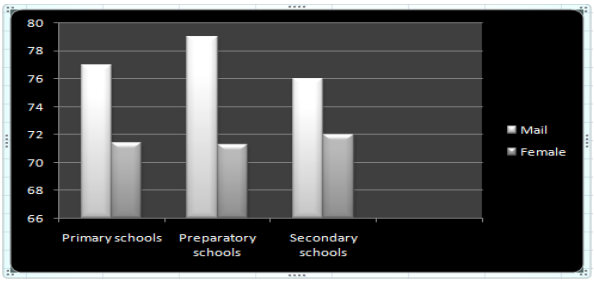

Fig. 8 A – Male and female education enrolment rates in Medina.

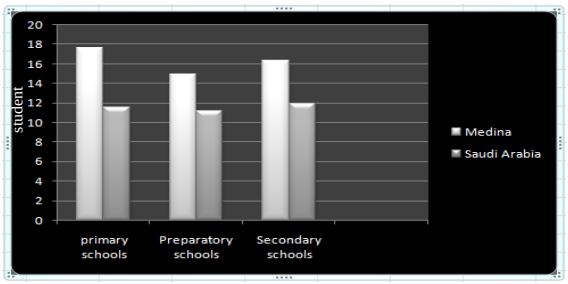

Fig. 8 B – Number of students to teachers in Medina and KSA

6.4.4. Smart Environment and Tourism

The Medina environment can be evaluated by reviewing pollution rates and waste management. Due to the importance of air quality as one of the most significant indicators of the environment, the *Pollution Measurement Laboratory* in Medina municipality reported five types of air pollutants in 2013: Carbon monoxide, Carbon dioxide, Nitrogen monoxide, Nitrogen dioxide and Sulfur dioxide (Municipality, 2014). Although rates were within the allowable range compared to the international standards of air pollution, yet some pollutants, such as Ozone, were not measured.

It should be noted that hydrocarbon compounds, considered to be one of the most dangerous substances for human health, whether they come from the vehicles tailpipe (diesel) or from petrol, have a high density in Medina. Furthermore, a great risk for "Smog" to appear if these hydrocarbons are combined with dust, and smoke, especially in the central area of the city with its tall buildings and high density traffic. Studies (Zollaly, 1998) show the effect of pollutants as a cause of pulmonary edema and other diseases.

Water quality and its efficient use are also important indicators of environment quality. Medina water supply is based mainly on a network of underground pipes (in 84.1% of the buildings) (Water, 2014) which carry water into the tanks under each building, the water being pumped to tanks above the buildings by electric pumps. Danger often lies in this system, because of contaminated reservoirs, both underground or above the buildings, especially when they are not disinfected periodically. Portable tanks on trucks represent the second way of water supply in Medina. They carry clean water for off-grid buildings, and sometimes to buildings connected to the network during outages time.

With regard to water consumption, the amount of water in Medina was of 38,341 thousand liters per day in 2014, with an estimated 307 liters per capita and more in the Hajj and Umrah periods.

On the other hand, the buildings connected to the sewerage network represented up to 56.3% in all (2014) (Observatory, 2014), the majority depending on the underground reservoirs for sanitation: evacuation and transportation to the treatment station may lead to sanitation water leaking into the soil and groundwater.

Waste management is an important component of the environment management system, too. Reports indicate that the amount of solid wastes was 385.3 thousand tons in 2014 (with an increase of 18.2 tons compared to 2006) and an estimated 0.39 tons per capita, which is an accepted rate.

Despite the existence of containers for waste collection in every neighbourhood, permanently emptied periodically and the damaged ones replaced, a lot of these containers are usually filled during the day; so wastes can be seen around them, possibly because waste collection trucks come only twice a day.

Smart tourism can be described by tourist attractivity and tourist housing. Medina has an internationally important rich cultural heritage, with Islamic sites like the Prophet's Mosque and some other mosques of historical interest. Numerous archeological and other important historical sites lie in

the surrounding areas, such as "Saleh cities" in El Ola. There are also many regional monuments, historic cities, urban neighbourhoods, old trade routes and some museums of heritage value. Beaches, unique marine resources appropriate for recreation and natural sites, exist in Medina. Besides, Medina has some central gardens and parks throughout the city and many neighbourhoods of small and medium-sized gardens. According to the reports of the Urban Observatory, in 2014 there were about 5.1 square meters per capita of public gardens and parks in Medina, but studies (Makki, 2011) reported their decrease from 50 in 1988 to 44 in 1994 due to the lack of irrigation water and the change of ownership from public to private.

Applying *ARC GIS 10.3* (Buffer-zone analysis) indicated that 91% of the buildings on the first ring road were located in a 1,000 m buffer-zone gardens, and 67% in a 500 m one; 78% of the buildings on the second ring road lay in a 1,000 m buffer-zone and 55% in a 500 m one; 46% of the buildings on the third ring road were sited in a 1,000 m buffer-zone and 23% in a 500 m zone (Fig. 9).

Tourist housing in Medina falls in three categories: 1-hotels; 2-apartments; 3-guest-houses. There are 66 hotels and 131 other types of tourist housing (S.M.C, 2015). Applying *ARC GIS Mean Center point* application on the distribution of hotels and other types of tourist housing in Medina proves that the *mean center point* of hotels is located in the North-West corner of The Prophet's Mosque, while the *mean center point* of the other types of tourist housing lies in the South-East corner (Fig. 10).

Fig. 9 – Garden buffer zones in Medina.

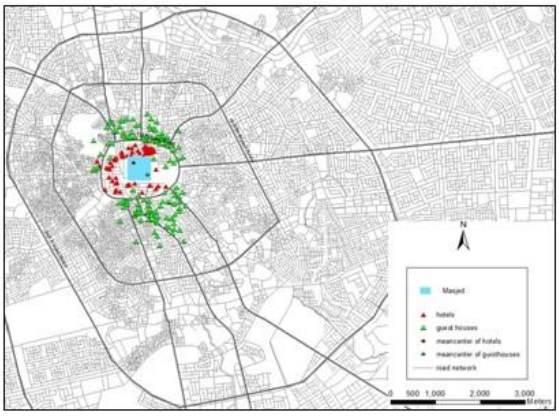

Fig. 10 – Mean Center point of Medina hotels and other types of tourist housing.

6.5. Smart People

People are considered the main factor of urban studies. As there are a variety of definitions to describe smart cities, the conceptual variants that can define who the smart people are varied and mutually connected. In general, *smart people* are described not only by the level of qualification, but also by the elements referring to innovation, social interactions, both public life and openness to the "outer" world.

Studies conceptualize smart people by laying explicit emphasis on learning, training, creativity and knowledge (Coe, 2001), (Campbell, 2009) and (Kanter, 2009). Thus, Smart people can be characterized by the following:

- Higher education and training.
- E-Learning.
- Creativity and knowledge.

6.5.1. Higher education and training

A basic element in the development of cities is having well-educated and trained people. There are two universities in Medina. In 2012, the rate of enrolment in higher education was 34.1% of the city's total population aged 18 and over (Observatory, 2012), compared to 39% in Saudi Arabia. While in 2006 it recorded 33.6% in Medina, it reached up to 38.9% in the entire Kingdom (Fig. 11). This percentage rise in the city may be due to the activation of new educational systems suiting a large class of students who do not attend the university through distance learning and affiliation.

A random sample of the city population (4% of Medina's total population) proved that there are variations in peoples' training percentages in terms of their jobs. There are 97% and 49% of the specialists and government employees, respectively who attended training courses, only 9% of students and 6% of other job people. Analyzing the information considered, it follows that the major percentage of government employees, students, and special job people (like professors, doctors, engineers, etc.) were obliged to attend training courses to meet the requirements of their jobs. The study also showed that the majority of the trained population followed local training courses in Medina. Although 41% of the study sample considered that the educational and training offers were suited to the needs of today's market, 59% felt that they were not (Figs. 12 a,b,c,d).

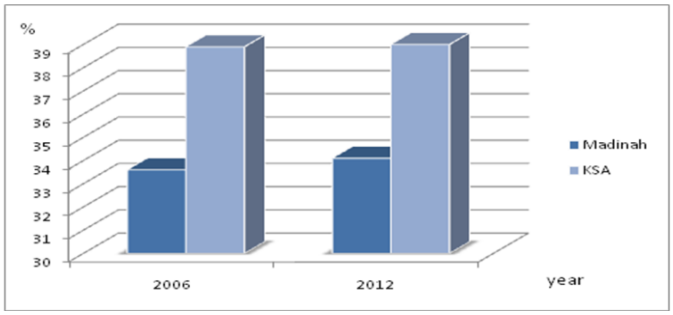

Fig. 11 – Enrolment rates in higher education in Medina and Saudi Arabia in 2006 and 2012.

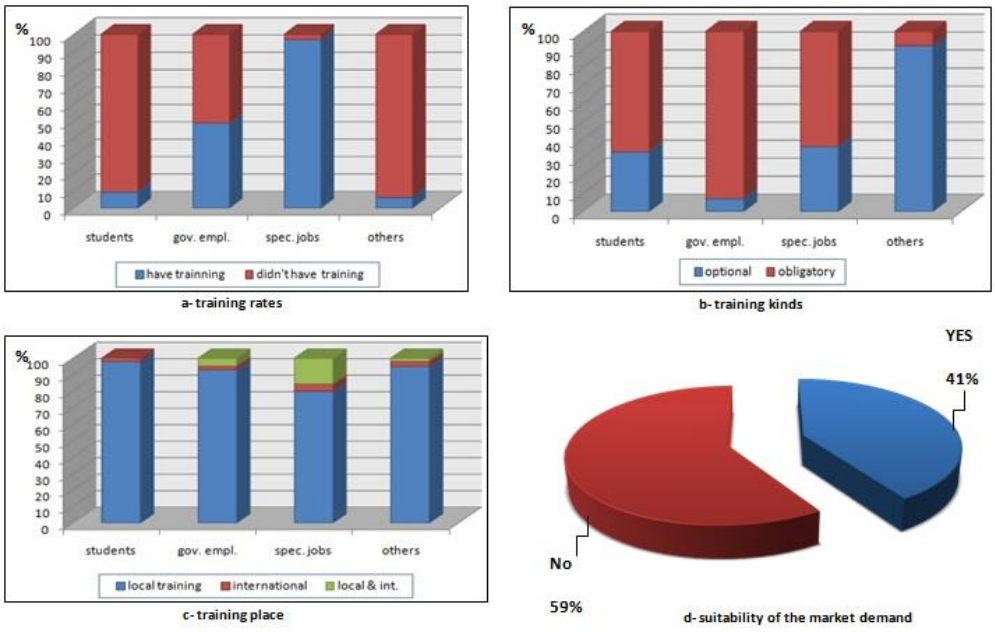

Fig. 12 – Training characteristics of a random sample in Medina.

6.5.2. E-Learning

Plans of digital development implemented by schools and universities in Medina (Medina Ministry of Education, 2015) (259 schools:136 primary schools, 78 medium schools, 45 secondary schools and 2 universities) reflect that there is full digitization, including new methods of ICT (Information and Communications Technology) at the two universities; the majority of the city schools have partial digitization on the way to complete its components according to plans. Also, there are some schools which are in need of these technologies (Fig. 13).

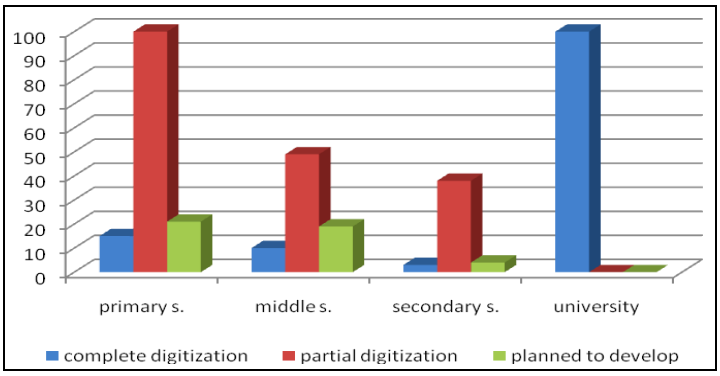

Fig. 13 – Plans of digital development in the schools and universities of Medina 2015.

6.5.3. Creativity and knowledge

Roughly speaking, there was no registered patent in Medina during the last five years (2010 - 2015). The results of field research showed that only 31% of the population sample preferred to read books and 62% were interested in general knowledge. The majority of the subjects did not prefer to connect people outside Saudi Arabia (Fig. 14).

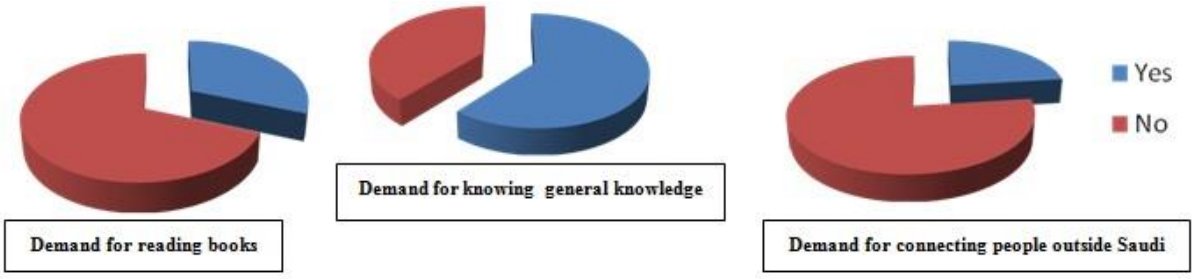

Fig. 14 – The sample population's demand for books, knowledge and connecting people outside KSA.

7. DISCUSSION

Speaking of Medina, the study presented and analyzed some smart city geographical characteristics and demonstrated elements that are a drawback to the city development towards smartness as follows:

- The city governance needs to undertake a clear strategy and have a vision for developments and greater involvement of the private sector in the delivery of services.
- The effective use of GIS, cloud computing and all ICT tools in order to facilitate services and reduce the need for travel.

- Improved access to information through multiple channels – internet, mobile apps, radio, TV and print media.
- Some municipal services, such as water supply and solid waste management should be of very high quality.
- Transport needs a good plan to meet rapid motorization, severe congestion, deteriorating air quality, road accidents and energy waste.
- Citizens of the city are in need of human development training programs because smart citizens build smart cities.

8. CONCLUSIONS

This paper introduces the fundamental concept of smart cities, along with their supporting aspects. It summarizes the *smart cities* characteristics and the distinction between them and other city concepts reported in the literature.

There is a lack of the precise determination of reliable elements for the characterization of smart cities, nor are they given in previous related researches. So, the study proposed a group of characteristics, including factors and indicators derived from public and freely available data and field-work. These characteristics are governance, infrastructures, mobility, quality of life and people. They play the role of Pillars to express the position of Medina and to sharpen its profile from the perspective of transition to a smart city in an non-weighted way.

This study emphasizes the need to incorporate the smart city criteria in Medina which should be taken into consideration.

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