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The Effect of Smart Mobility Implementations in Increasing the Level of Road Traffic Safety in Riyadh City (Abi Bakr Assiddiq and Al Urubah Roads as a Case Study)

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Abstract: Over the past century, there has been rapid increasing in urbanization everywhere worldwide. People and vehicles movement have always been critical to the quality of life around the world. This development causes some challenges in several main aspects of cities, including mobility systemsThis study mentions the current smart implementations in Riyadh city, Saudi Arabia, focusing on its effectiveness in raising the level of traffic safety by reducing traffic accidents. The statistical data of traffic accidents was used in different spots through two main roads: Abi Bakr Assiddiq and Al Urubah roads during two different years (2016 and 2018). Comparing the accidents data shows a significant decrease in the number of traffic accidents that occurred in the selected study areas. Accordingly, most of the study sites indicate that smart applications in urban cities have positive effects on the level of traffic safety by reducing road traffic accidents.

Keywords: Riyadh City, Smart Mobility Implementations, Urban Growth, Traffic Accidents, smart implementations.

1. Introduction

Over the past decades, population in urban cities has grown rapidly throughout the world, caused by birth or migration. By 2050, about 70% of the population will live in cities (Benevolo et al., 2016) compared with 30% in 1950 (Virtudes et al., 2017). The urban growth in population density plays major social, economic, and environmental roles in cities (Virtudes et al., 2017). It also causes some challenges in cities quality such as pollution, energy consumption, waste obstacles, and traffic congestion.

In parallel with this rapid growth in population, there has been a technological development in the recent centuries that created new patterns of lives that rely on digital technologies instead of traditional patterns (Sadeq & Safor, 2013). This revolution would help to reveal smart solutions in smart cities to overcome the density growth in urban cities and reduce the potential negative impacts on people's lives.

Smart cities is a recent subject that has rapidly increased to cope with urban issues including traffic problems (Benevolo et al., 2016) and provides solutions to the urban obstacles.

According on several scientific papers, smart cities have many definitions that have existed with several conceptual frameworks. They consecrate on connecting the physical, the IT infrastructure, the social, and the business infrastructure to leverage the collective intelligence of the city (Harrison et al., 2010). Giffinger et al., (2007) defined the smart city as "a city well performing in a forward-

looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of activities of self-decisive, independent and aware citizens". It has six main dimensions that smart cities look forward to; smart economy, smart living, smart environment, smart people, smart governance, and smart mobility, According to The Center of Regional Science at the Vienna University of Technology (Giffinger et al., 2007).

Traffic problems in mobility system is one of the main aspects that affects people quality of life by making them dependent on mobility transit in their daily movements. Urban mobility is considered one of the most important aspects of urban cities (Benevolo et al., 2016) as it plays a major role in mobility quality and the quality-of-life in cities. In major cities with a high density of population, people daily movements cause some traffic problems such as congestions and traffic accidents where a positive causality of congestion on the number of accidents. The consequences of congestion include more accidents and damage to the quality of life (Bull, 2003) where they have a positive relation (González et, al. 2021)

In the first sections of this paper, the implementations of smart mobility tools in transport systems were discussed followed by clarification of smart mobility tools spatial distribution in the city through Abu Bakr Assiddiq and Al Urubah roads. Thedata of accidents in these two roads was collected in two years (before and after establishing smart tools) to reveal the percentage of traffic accidents and the effectiveness of smart tools in mobility systems.

2. Literature Review

Smart transit and transportation are considered one of the main subjects that have attracted many researchers' attention in several ecological, economic, and urban planning aspects as well as traffic challenges in mobility. Many research papers have discussed traffic congestion in urban cities because of problems that show up through rapid urbanization and the reliance on transportation in daily life. However, few papers have discussed how the smart mobility aspect in urban smart cities could affect the quality of people's life as well as how could it reduces the number of accidents in urban cities.

Benevolo et al., (2016) showed that there are some initiatives related to smart cities transit analyzing prospective that have been discussed. Furthermore, the Information and Communication Technology (ICT) is playing a major role in supporting smart transit procedures and could reflect on people's quality of life. Smart cities seek to offer strategies using technologies to improve life quality, including improving the quality of the surrounding environment and providing the best services to citizens in urban cities. Therefore, the study provides a deep anlysis that concentrates on the main aspect of smart cities, smart mobility, and its classification considering the ICT aspect and its objectives and assessing the ability of each factor to improve the quality of citizens' life. The study found that smart mobility has a main role in achieving smart cities goals such as limiting the city's ecological footprint and improving citizen's life. Moreover, ICT is not a necessary technology to apply smart mobility strategies and many of smart transit rely on other technologies such as the fuel vehicles, people behavior and their understanding of the importance of using public transportation and bikes instead of private cars. Benevolo et al., (2016) believe that people are the main factor in applying sustainable smart mobility implementations and they should get involved in shared smart goals achievements.

Sadeq and Safor (2013) pointed out that smart cities terms and characteristics contain, in general, three main elements: technology, social, and environmental, that are in the place where the virtual and the real-world meet. They also indicated the dimensions and applications of smart cities that focus on the concept, objectives, and basic components of intelligent transportation systems. Then, Sadeq and Safor (2013) reviewed the technical components in smart cities as they play an important role in solving urban cities problems, especially traffic obstacles and improving city development by monitoring current and future traffic problems. This represented an analytical study of Arab and international experiences to frame smart mobility strategies to find out some solutions through analyzing the smart mobility in Damascus as a case study. The study found that using smart cities applications, especially smart mobility, helps positively in finding solutions to urban problems and achieving a balanced urban environment that contributes to solving some traffic problems, and avoiding the need to construct or expand new roads in the city by making optimal use of the capacity of

the current roads. It recommended plans that can be used in emergency situations as well as being shared with the public to encourage them to use public transportation and bike transportation to achieve integration in Damascus transportation.

Alghadi (1999) reviewed the main subjects of smart mobility systems and its areas and functions, which are advanced traffic management systems, advanced mobility information systems, commercial vehicle operations systems, advanced public transportation systems, and advanced vehicle control and safety systems. It discussed each area of these and how they fit into the reality of Saudi Arabia with its own conditions. The study also illustrated the smart mobility requirements in Saudi Arabia and the importance of a local structure for intelligent transportation systems by adopting one of the good structural maps (such as the American structural map) with modification and adaptation to suit the local needs and conditions in the Kingdom. Moreover, it found out some benefits of structural map for smart transit systems in the Kingdom by providing three available options that could improve smart mobility in the country. Furthermore, the study recommended the need to establish the entities that are responsible for all smart mobility systems aspect starting with the governmental, private, and academic sectors. These entities have the responsibilities to implement the main tasks of smart mobility in the Kingdom, including developing or preparing a national structural map for intelligent transportation systems. Therefore, the research topic will be a continuation of the previous researchers' efforts in the field smart cities mobility of Riyadh, the Kingdom of Saudi Arabia.

3. Study Area

Saudi Arabia is a country that occupies around 80% of the Arabian Peninsula (Al Shaye et al., 2019). Riyadh is the capital city of Saudi Arabia and is located in the central part of the country. It is considered one of the Middle East cities that is growing very fast in the last few decades (Altwaijri et al., 2012).

During the middle of the past century, Riyadh started as a village with about 8 square kilometers, and home to around 60,000 inhabitants (Riyadh Municipality, 2015). Nowadays, it has more than 6.5 million people with a total developed area of about 2395 km2 in 2014 (Fig:1 a and b) (Altuwaijri et al., 2019) with an expectation to be about 2500 km2 in 2028 (The Royal Commission for Riyadh City). This rapid increase causes some problems as the population is growing rapidly and it puts pressure on the infrastructure of the city.

Main streets and roads cover most of Riyadh city areas as it is one of the prominent aspects in urban cities. It occupied approximately 37% of the city' area by about 16.000 km (Almogarry, 2015).

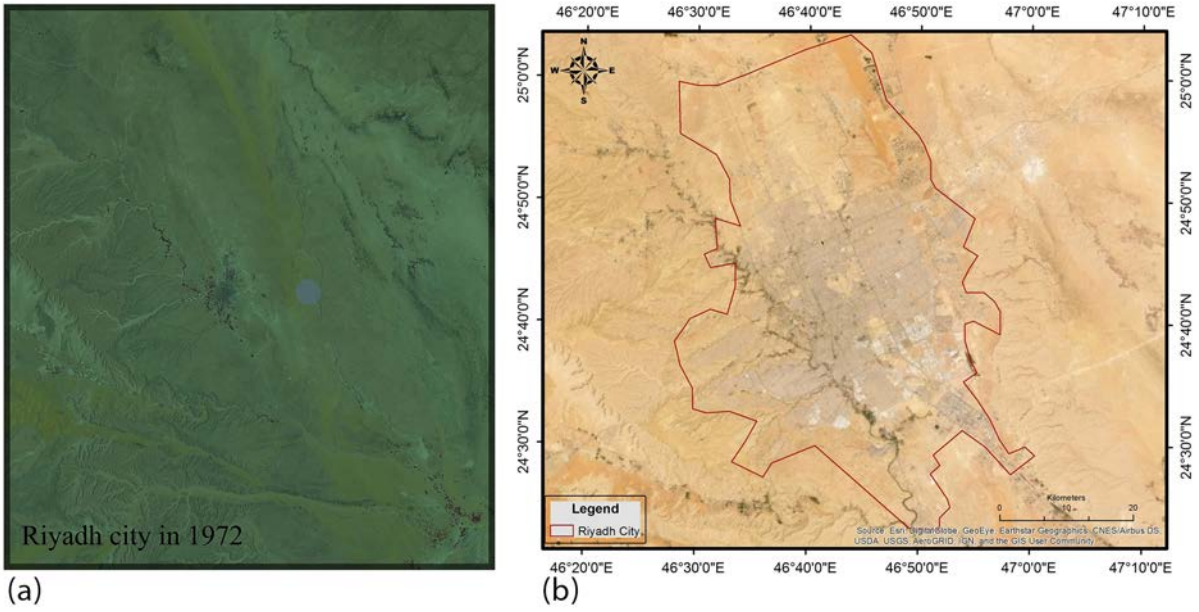


Figure (1). Riyadh City in 1972 (a) and in 2019 (b). (Source: Google Earth and Imagery in ArcGIS 10.4)

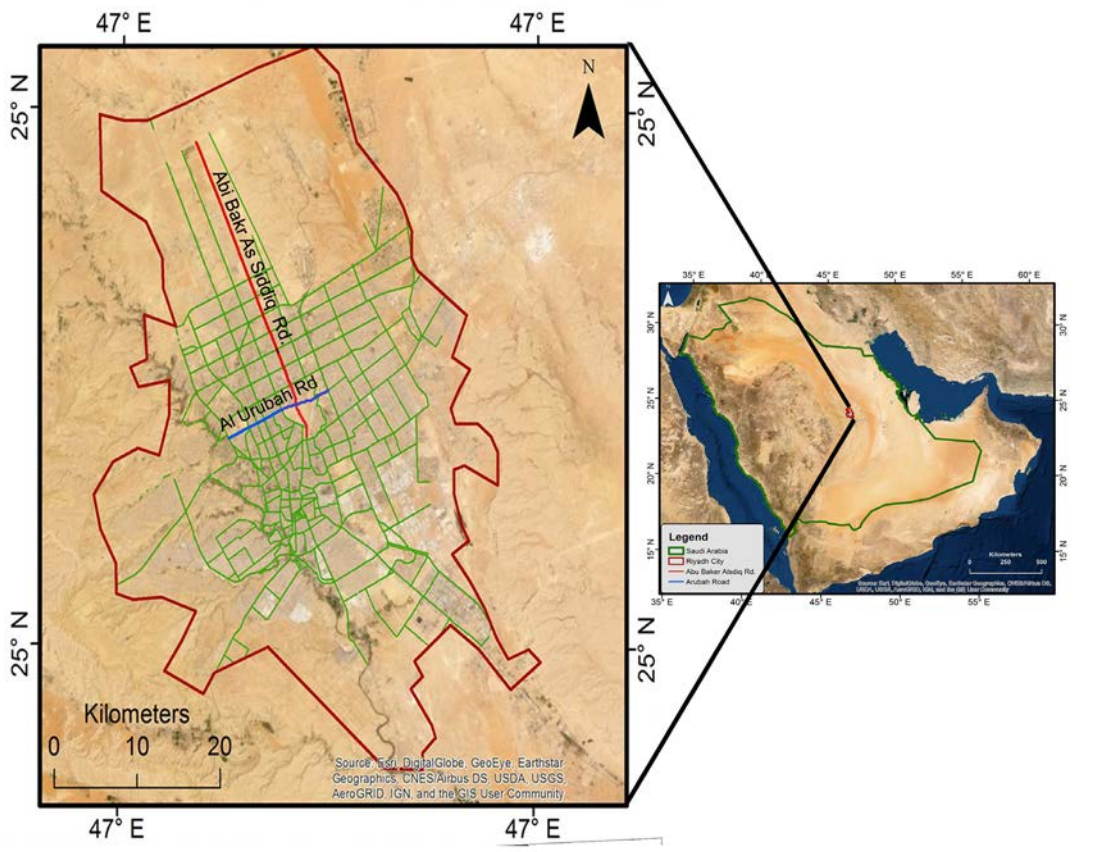


Figure (2). Riyadh City and the study area. (source: the authors)

It also indicates that private cars are the main way for most city individuals to their day, traveling with a percentage of about 97% compared with other cities such as Chicago, London, and Tokyo by percentages of 61%, 39%, and 10% respectively.

According to a survey prepared by The Royal Commission for Riyadh City (RCRC), the flow of cars on roads around the city is about 958,000 cars per day and 90% of them are private cars with an average of 1.6 cars per family (Al-Majhad et al., 2018). The average trips in Riyadh have reached up to 9 million trips per day with an expectation to reach 12 million trips by 2050 (Riyadh Development Authority, 2018). Moreover, the rapid development in the city has increasesd the traffic vehicles activities around it leading to congestion and accidents that can be seen every day. However, good transit planning and implementations are an effective way to reduce crashes injuries and deaths rates, leads to an increase of safety levels in the city of Riyadh (Altwaijri et al., 2012).

4. Smart mobility dimensions and its current implementations in Riyadh City

The efficient transport system's implementations can provide solutions to congestion problems; however, smart mobility aims to be one step further (Alonso et al., 2016). There are four dimensions that smart mobility focuses on to define its scope; vehicle technology, Intelligent Transport Systems (ITS), data, and new mobility services (Jeekel, 2017). They aim to provide smart solutions to the challenges of city transit systems for every individual in cities by concentrating on five goals (Alghadi, 1999):

- Increasing operational efficiency, including increasing the use of public transportation.
- Improving the level of people's movements.
- Improving traffic safety level, including reducing car accidents number
- Decreasing energy consumption.
- Improving economic productivity

In Saudi Arabia, there are many projects and initiatives that have been established or under establishment to build or develop a smart city that rely on six dimensions and the smart mobility is one of these main dimensions (Aina, 2017). Some new cities have implemented smart city systems and infrastructure from the beginning to be a smart city including smart mobility systems. Neom City and King Abdullah Economic City are examples of the new cities that have smart infrastructure and e-services. On the other hand, Riyadh, Yanbu, Jubail, Jeddah, Makkah, Dammam, and Madinah, are cities that could be developed and/or under development to be smart as these cities have implemented smart systems including smart mobility and digital traffic control and management (Aina et al., 2019).

Riyadh city has continued to exert efforts to develop the city' mobility to be smart, including smart mobility. On the public level, there is in Riyadh one of the most important and largest existing projects and is still under construction in the city. It is established by RCRC and aims to cover the city and its public mobility system by means of a network that offer both train network (Riyadh Metro) and buses network (Riyadh Buses). Reducing both road congestions and accidents; and raising traffic safety; and reducing the human, social and economic losses are the main goals of King Abdul Aziz Public Transport Project (Almogarry, 2015).

The Riyadh Metro consists of six lines with a total length of 176 km, 85 metro stations, and 25 parking lots Park & Ride (Fig. 3A). The operating system on the metro will be automatic and without drivers and each one contains digital screens of line information, audio and video systems, a safety and monitoring system with three service classes. The number of trains is about 190 trains and could have a capacity of 338 trains in the future. The passenger's capacity in the beginning will be about 1,160,000 passengers per day with a maximum capacity of 3,600,000 passengers per day (RCRC).

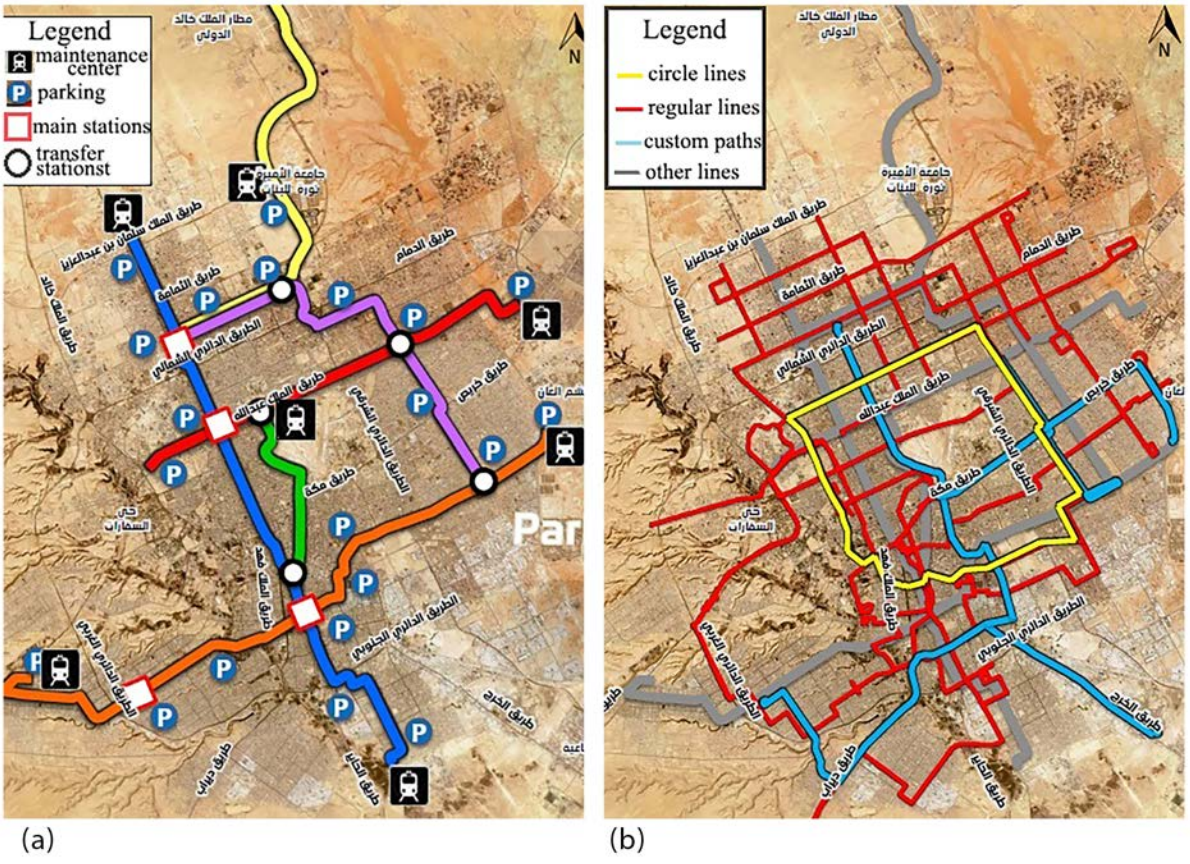


Figure (3). Riyadh Metro (a-left) and Riyadh Bus (b-right) networks and lines. (Source: The Royal Commission for the Development of Riyadh City)

On the other hand, the buses network (Riyadh Buses) consists of 24 lines (Fig. 3B) with a total's length of 1083 km (Almogarry, 2015) It has about 6700 parks and waiting stations and 956 buses with a maximum capacity of 900,000 passengers per day (High Commission for the Development of Riyadh City). There is an application for smart phones that has been launched by RCRC under the name "Delilat Arriyadh" that gives information and directions to passengers about the trains and buses networks in the city.

On the safety level, the effective management of smart control systems plays an important role in reducing traffic congestion in urban cities (Alonso et al., 2016). There are other smart implementations in the city that the government sectors work on. Saher for speed limits, automatic monitoring cameras that include crossing the red signal, using mobiles while driving and speed limits (Saher) are some examples of smart implementations in the city of Riyadh. Saher monitoring systems for speed have positive effects in improving the level of traffic safety in Riyadh roads by reducing the number of traffic accidents between 2010 to 2015 by about 41% (AL- mutair & AL-Rasheedi, 2017). To measure the effectiveness of the current smart implementations, two main roads of the city were focused on this study. The first is Abu Bakr Assiddiq Road with a total length of 12 km and width of 60 m., with north- south direction. The second is Al Urubah Road that starts from King Khalid Road in the west to the Eastern Ring Road in the east passing through The Riyadh Air Force Base and intersects with Abu Bakr Assiddiq in the middle (RCRC, 2019). The Royal Commission for Riyadh City is responsible for these two roads development. It has started to develop and repair them by improving roads and installing smart tools to raise the public safety and achieve the Commission's goals.

There are several types of smart tools to control the traffic safety and traffic congestions and the public safety in the two roads. There are five types of smart implementations that support mobility systems (Fig.4). The figure, also shows

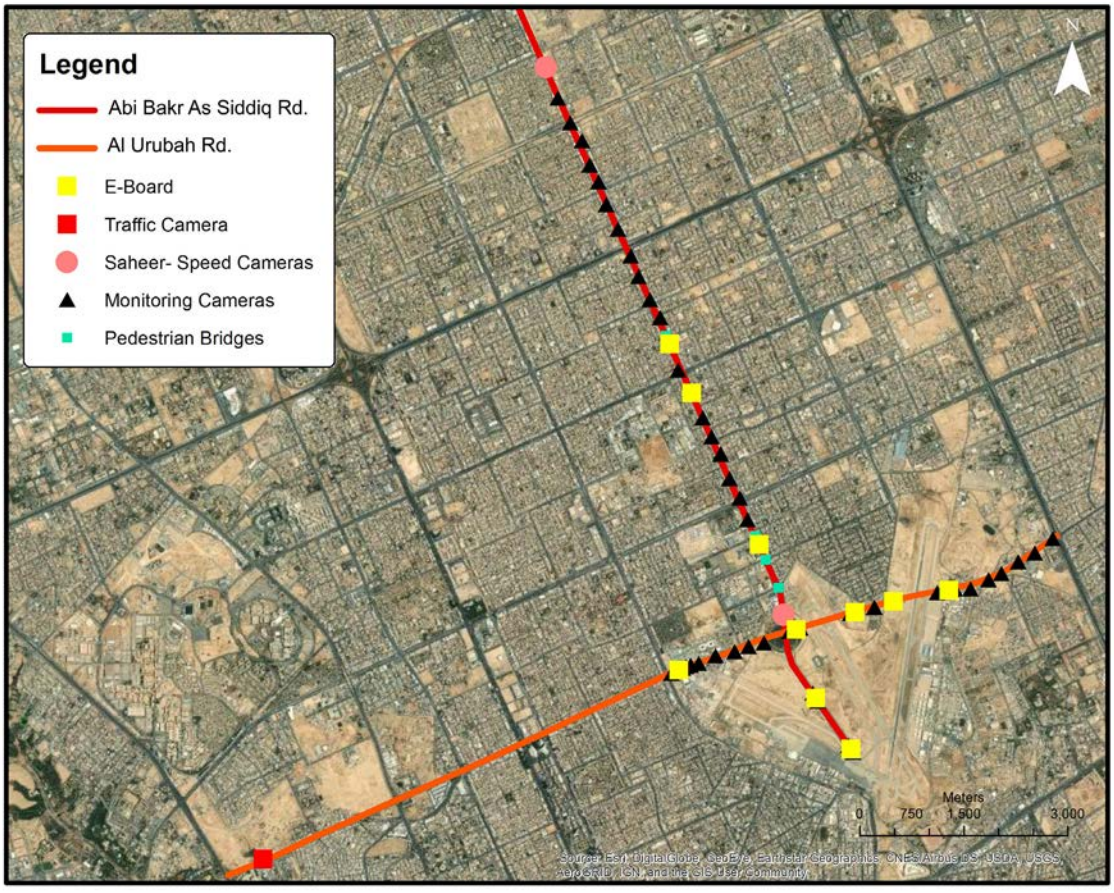


Figure (4). Smart tools and monitoring systems' spatial distribution in the two roads

a. Electronic sign boards (E-board)

b. Electronic sign for each lane

c. Saher and monitoring cameras

d. pedestrian bridge and elctronic speed signs

Figure (5). The road smart implimentations and monitoring systems

the spatial distribution of these smart tools on the roads. There are a lot of monitoring cameras on streetlights that are located in every three lighting poles.

There are many electronic sign boards that direct drivers to the right way and give information about the rest of the road and weather information (Fig. 5a & b). There is a recording tickets machine (Saher) in the west of Al Urubah road for exceeding the speed limit, using cell phones while driving, or crossing the red signals (Fig. 5c-left) as well as monitoring road cameras along both roads (Fig. 5c-right). The roads also have many other electronic boards that give the speed limit of the roads (Fig. 5d). There are some other smart implementations in the city that support smart mobility systems such as smart parking and electronic boards that have QR barcodes with street information, however, this study focuses on the current smart implementations on Abu Bakr Assiddiq and Al Urubah roads.

5. Methodology

The development of both roads, Abu Bakr Assiddiq and Al Urubah roads, is one of the main RCRC projects that were announced in 2013 by RCRC. These two roads were chosen because they had the priorities of the first five-year plan road network for the city of Riyadh (RCRC). To measure the level of road traffic safety, the accidents data covered years of 2016 and 2018 which are during and the end of the project years, respectively. The accidents data of the roads was collected from Najm Company(1) who works with General Directorate of Traffic, which is responsible for recording the city accidents. ArcMap 10.4 has been used to transfer Excel data into the software then extract accident data for only Abu Bakr Assiddiq and Al Urubah roads. All the smart implementation spots through the roads were identified to extract the accidents that occurred around them in about 200 meters distance. 12 different locations were spotted in the study (Fig.6). The abbreviations of "L" in the map followed by numbers are the study's locations that will be used in this study to compare data accidents between the two years. The figure also shows the spatial distributions of all types of smart implementations that have been installed in the two roads. The spatial distributions of smart implementations were collected by field surveys along the two roads and imported - into the ArcGIS 10.4 software.

Other Maps in Fig.7 have been used to extract total number of accidents in these spots for both years, 2016 and 2018. Google Earth has been used to get a temporal framework of the smart tools in the two roads as well as getting information on traffic control and monitoring systems from Tahakom Company(2) that is responsible for building and maintaining security control systems in Saudi Arabia.

(1) Najm: is an insurance company that is responsible for recording traffic accidents in the city including information on accidents' location, reasons.

(2) Tahakom: is a Saudi Company owned by the Saudi government that is responsible for achieving safety and security goals in the country through building a digital system.

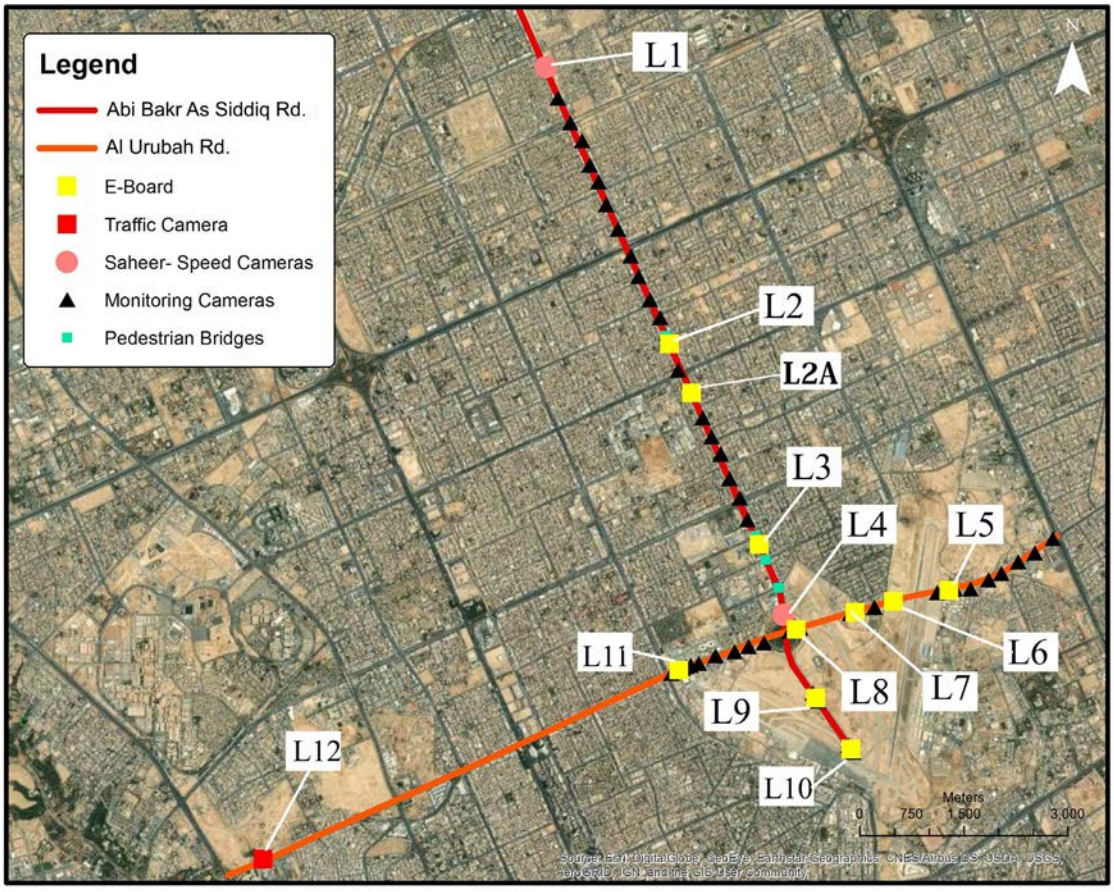


Figure (6). Traffic control tools and monitoring systems in the two roads including study locations (L#)

6. Discussion and Results

The preliminary statistical data for the total number of all types of accidents in the city of Riyadh are shown in Table 1 by Najm. It can be clearly noticed that there was a remarkable decrease in the total number of all city road accidents from 2016 to 2018 by about 11.3 %. In addition to that, the table shows the total number of accidents on both Abu Bakr Assiddiq and Al Urubah Roads.

In Abu Bakr Assiddiq road, there was a slight increase from 2016 (3030 accidents) to 2018 (3202 accidents) by about 180 accidents with a percentage of 5.7 %. However, this total number of accidents includes all the accidents that ocurred in the whole road and not only in the spots of the study that have smart implementations, this is on one hand. On the other hand, Al Urubah road had a significant decrease by about 610 accidents from 2016 to 2018.

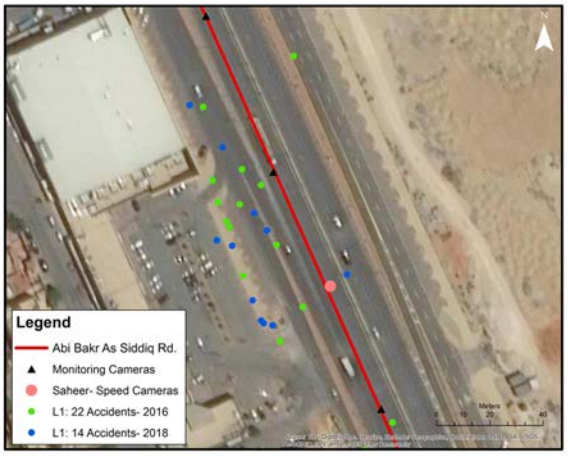
Table (1). All roads of the city accidents and study' roads, Abu Bakr Assiddiq and Al Urubah roads in 2016 and 2018

Year/Road	All Roads accidents	Abi Bakr As Siddiq Road	Al Urubah Road
2016	356,720	3030	2712
2018	316,347	3202	2102

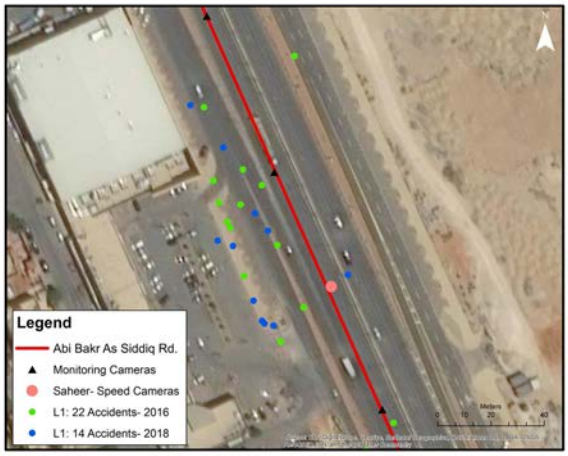
Source: Najm Company

In the roads of this study, there are several different smart and digital tools that have been used to support roads safety. The study has chosen all the locations that have smart implementation on the roads, such as electronic boards (E-boards), traffic cameras, Saher-speed cameras, and monitoring cameras.

The Fig. 7 have 12 maps, starting from location 1 map to location 12, that show all the study's locations separately and have any of the smart implementations in each map. The map results show, in general, that there was a decrease in the total accidents from 2016 to 2018. On the first map (Location 1), there are several monitoring cameras and saher speed cameras to measure car speeds and



Location. 1



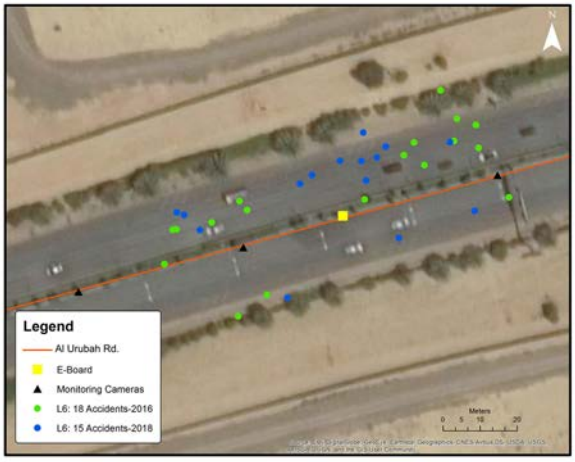
Location. 2

Location. 2A

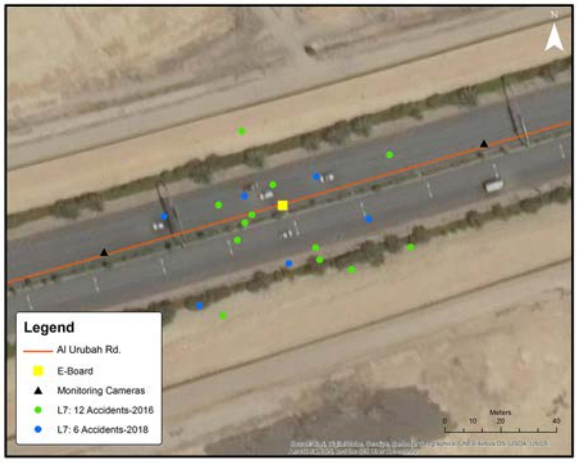
Location. 3

Location. 4

Location. 5



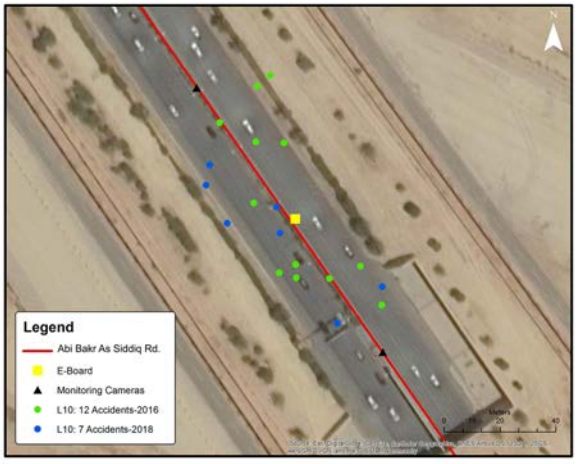
Location. 6



Location. 7

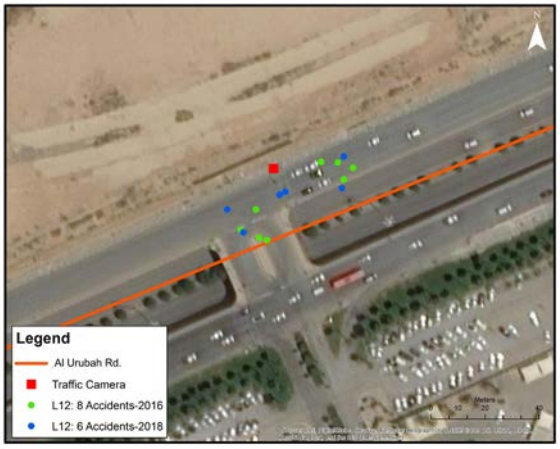
Location. 8

Location. 9



Location. 10

Location. 11



Location. 12

Figure (7). Accidents in study's spots for both 2016 and 2018. (Source: the authors)

Table (1). All roads of the city accidents and study' roads, Abu Bakr Assiddiq and Al Urubah roads in 2016 and 2018

location/Year	2016	2018
L1	22	14
L2	18	17
L2A	14	13
L3	13	7
L4	8	15
L5	7	6
L6	18	15
L7	12	6
L8	16	17
L9	6	0
L10	12	7
L11	61	47
L12	8	6

Source: the authors

issue tickets for driving over speed limits (90 km) on Abu Bakr Assiddiq. On the western side of the chosen spot, there is an open plaza that has some restaurants, Tamimi supermarket, and other service shops. Moreover, there is a vacant land, which means that it has no buildings on it and it is not being used, on the eastern side of the road. It can be clearly seen that the accidents in the first map (Location 1) were about 22 accidents in 2016 and were reduced up to approximately 85% in 2018 by a total accidents number of 14.

In the second map (Location 2 and 2A), there was a slight decrease in the number of accidents by only one accident, likewise in location 5. In location 2 and 2A, there is a commercial land followed by residential area on both sides of the road.

Other spots had a slight drop in the number of accidents between two to three accidents such

as location 6 and 12 (maps of Location 6 and12). more highly drop in accident were found in location 11, where the accidents dropped from 61 in 2016 to 47 accidents in 2018. However, some of the study spots have a significant decrease by approximately 50% in the total number of accidents such as the 3rd, 7th, 9th, and 10th locations as shown in Fig. 7 (location 3, 7, 9, and 10 respectively).

There were only two locations that had a little increase by about only one accident in location 8 (Location 8). However, in location 4, the total number of accidents rose from 8 accidents in 2016 to 15 accidents in 2018. It was about double the number, but that might be because of Saher cameras are not shown clearly to the drivers on the road in the same manner as monitoring systems, E-boards, and traffic cameras. All the results in all the study locations are gathered in Table 2.

7.Conclusions

Road traffic safety plays an important role in people's quality of life by reducing the rate of car accidents. There are many different smart applications that could enhance the mobility systems in urban cities and facilitate traffic activities.

In Riyadh city, there is a large project that has been established to improve mobility systems in the city and it is still under development. Riyadh Metro and Riyadh Buses are the main goal of the project. There are other several different smart implementations that have been applied to many city roads. Abu Bakr Assiddiq and Al Urubah roads are examples of roads that have been developed recently to enhance smart transport systems in the city. Electronic boards (E-boards), traffic cameras, Saher-speed cameras, and monitoring cameras are digital tools and smart implementations that could be seen in the two roads.

In Abu Bakr Assiddiq and Al Urubah roads, 12 location have been spotted. These locations in the roads have different smart tools. There was a decrease in the majority of the study accidents compared between two years, 2016 and 2018, of the extension project of Abu Bakr As siddiq and Al Urubah roads by RCRC. Each location in the study spots has a different type of smart implementations which could help reduce accidents.

Installing public transit systems and smart tools in urban cities as well as issuing violation tickets could raise public safety and reduce the negative impact of vehicles and pedestrian movement in the long run and reduce accidents. It would also lead to reduced negative impacts on people's lives and property as well as on the government public property.

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أثـر تطبيقـات التنقـل الذكـي في رفـع مسـتوى السـلامة المروريـة عـلى الطـرق في مدينـة الريـاض (طريق أبي بكر الصديق والعروبة كدراسة حالة)

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ملخص البحث. على مدى القرن الماضي، حدث تطور سريع وملحوظ في التحضر في جميع أنحاء العالم، حيث تعتبر حركة الأشخاص والمركبات من الجوانب بالغة الأهمية لجودة الحياة في معظم أنحاء العالم. أدى هذا التطور إلى ظهور بعض التحديات في العديد من الجوانب الرئيسة للمدن، بما في ذلك أنظمة التنقل والحركة. تذكر هذه الدراسة بعض التطبيقات الذكية الحالية في مدينة الرياض بالمملكة العربية السعودية، بالإضافة إلى التركيز على مدى فعالية تطبيقات النقل الذكية في رفع مستوى السلامة المرورية من خلال الحد من الحوادث المرورية. وقد تم استخدام البيانات الإحصائية للحوادث المرورية في عدة أماكن متوزعة بناء على التوزيع المكاني للأنظمة الذكية ووجودها على طريقين رئيسين هما: طريق أبي بكر الصديق، وطريق العروبة، خلال عامين مختلفين (٢٠١٦ و٢٠١٨). وأظهرت مقارنة النتائج الإحصائية وجود انخفاض ملحوظ في عدد الحوادث المرورية التي حدثت في مناطق الدراسة المختارة. وبناءً عليه يشير معظم مواقع الدراسة إلى أن التطبيقات الذكية في المدن الحضرية لها آثار إيجابية على مستوى السلامة المرورية؛ من خلال انخفاض الحوادث المرورية على الطرق.

الكلمات المفتاحية: مدينة الرياض، تطبيقات النقل الذكية، النمو الحضري، الحوادث المرورية، التطبيقات الذكية.