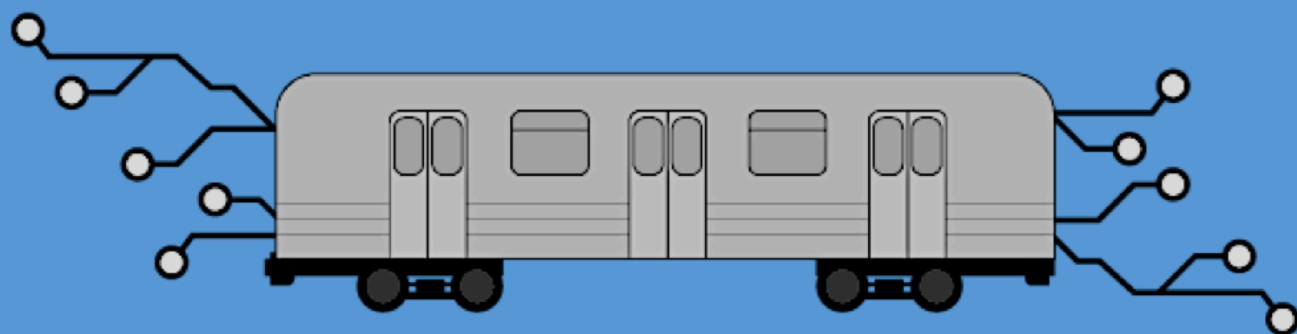
Assessing Smart Mobility In Madinat Al Irfane



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Submitted to:

WPI

ENSIAS

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Glossary

BAS: Building automation system

BLE: Bluetooth low energy

CCTV: Closed-circuit television

ENSIAS: École Nationale Supérieure d'Informatique et d'Analyse des Systèmes

GPS: Global Positioning System

OECD: Organization for Economic Co-Operation and Development

RSS: Radio signal strength

RSSI: Received signal strength indicator

SPM: Smart polygeneration microgrid

Chapter 1. Introduction

Slightly over six days is the average amount of time spent each year commuting to work or school in China, India, and South Africa who are countries part of Organization for Economic Co-Operation and Development (OECD) (Statista, 2016). This does not include the commute home, nor does it include any other transportation-related activities that the average person engages in. Needless to say, as a species, humans spend an appreciable amount of time commuting whether it be by car, train, bus, walking, or bicycle. As such, developing efficient, low cost, transportation systems is a worthwhile venture and can have many positive effects, especially for crowded urban areas where commute times can be especially long due to population density or poor to non-existent urban planning.

Easy access to good transportation systems increases livability of the area. The Economic Development Research Group determined that proximity to public transit station is a good predictor of property value in several large cities (Forkenbrock et. al., 2001). People like living in places where it is easy for them to get around. The spreading of cheap and effective transportation systems has made it easier than ever for people to cross large distances. The downside of this trend is more people moving into cities from the suburbs, making cities more congested and the need for modern transportation even greater. By the year 2030 a predicted 66% of the world's population will live in cities (Griffiths, 2016). Morocco closely follows this trend with 61.2% of the country's population currently living in cities and an annual urbanization rate of 1.92% (CIA, 2017). Rabat specifically is one of the top cities by population density and population in Morocco, making it a good candidate for assessing the state of transportation within the city.

Modern public transportation allows residents and visitors to maneuver around cities with ease. In the United States, from 1995 to 2005, commuters in the U.S. took 9.7 billion trips on public transportation - 15 times the number of trips they took on domestic airlines (Public transportation, 2007). There are many options to get around in cities, including ride sharing such as Uber and Lyft, subway systems, buses, trains, monorails, walking, and cycling. In sustainability-minded countries like the Netherlands, walking or cycling makes up more than half of all daily trips for residents (Buehler, Pucher, 2017). In Rabat, the public transportation network includes intercity rail, a newer tramway that spans 19.5 km, 35 bus lines, and approximately 3,800 taxis (Ramadan & Delatte, 2016). All of these transportation systems, old and new, are not perfect and each come with their own issues.

Smart city initiatives may be a possible solution for problematic transportation lines. A smart city has connected infrastructure that allows the collection and analysis of naturally occurring data to help improve the lives of its citizens (Chourabi, 2012). Smart city projects have six major pillars including mobility, health, education, social, governance, and energy. This project will address the smart mobility pillar which assesses the impact of transportation methods and works to reduce transfer costs, improve transfer speed, reduce noise pollution, reduce congestion, and increase safety (Dameri, 2017). City planners must implement smart city initiatives at a smaller scale first in order to assess their feasibility before they apply the initiative to a larger system.

Our project will focus on a specific area in eastern Rabat. The Madinat Al Irfane district includes clusters of universities, hospitals, and residential living. There are six university campuses within Madinat Al Irfane: Mohammed V University, University City Souissi I, International University, Veterinary Institute Hassan II, Faculty of Dentistry, and Regional Center for Education. Each university campus consists of different disciplinary schools. There are two major hospitals located in Madinat Al Irfane: Children’s Hospital and Mohammed V Military Hospital. This sub-community of Rabat, Madinat Al Irfane, makes for a perfect test bed to research the viability of smart city initiatives and the commuters’ and visitors’ acceptance of new technology.

The goal of this project is to assess the feasibility of incorporating smart technologies into the transportation system within Madinat Al Irfane. The team will work alongside 20 students from the Mohammed V University in order to assess current modes of transportation in Madinat Al Irfane. The team will engage with the public to understand the problems the commuters and visitors face, and contribute to assessments for smart mobility initiatives to the sponsor, ENSIAS (École Nationale Supérieure d'Informatique et d'Analyse des systèmes) within the Mohammed V University.

Chapter 2. Literature Review

This chapter outlines the historical context of Morocco's transportation system to assist in understanding and assessing the impact of implementing a smart city project. The team defines a smart city and discusses the different pillars that comprise it. Section 2.5 compares and contrasts case studies, and considers the challenges faced with smart city initiatives.

2.1 Site Description

Rabat, the capital of Morocco maintains a population of 1.6 million and is responsible for 16.4% of the country's GDP (Morocco World News, 2017; Rabat, 2016). There are a variety of options for commuters and visitors to get around the city. The most popular mode of transportation is walking, which accounts for approximately 66% of transit throughout Rabat (Ramadan & Delatte, 2016). Residents who do not walk, have the option of other transportation services. However, there are only 540 buses and 3,800 taxis in Rabat and they make up 14% and 6%, respectively of the total transportation choice by population (Ramadan & Delatte, 2016). Rabat's ancient city has to adapt to the modernization of transportation seen worldwide, as many of the alleyways are narrow and prevent the passing of buses and taxis and are only accessible through walking.

Our project site, Madinat Al Irfane, is a cluster of universities, hospitals, and residential living. People in Madinat Al Irfane follow the same movement trends as seen in the Rabat community, with the preferred mode of transportation as walking. Other options for travelling around Madinat Al Irfane include cycling, or taking buses, and tramway. The tramway runs every eight minutes on weekdays throughout Madinat Al Irfane and Rabat. Opened to the public in 2011, the Rabat - Sale tramway, seen in Figure 1, serves as one of the main methods of public transportation in Rabat. Every day it serves an expected 180,000 people (Jeffreys, 2012).

Figure 1: Rabat-Sale Tramway Network Map (Transdev, 2012).

According to the Bouregreg Valley Agency the tramway monthly passes costs 150 dirhams and a yearly pass costs 1500 dirhams. There are approximately 18,000 tramway pass holders, 60% of whom are students, who are eligible for discount passes. The tramway has 31 stations and spans 19.5 km (Harvey, 2010). This explains its popularity compared to other transportation systems as it runs frequently and has a wide reach throughout the city. The bus system, in comparison runs less frequently, and there are only 35 bus lines in all of Rabat (Ramadan & Delatte, 2016). Many students, who make up a large population of Madinat Al Irfane, don't own private vehicles making walking and the tramway the most used transportation option.

Within Madinat Al Irfane, the team will collaborate with ENSIAS, the National School of Computer Science and System Analysis, at Mohammed V University. This university has 19 institutions with a student population of 65,000 and includes a variety of teaching disciplines such as Medicine, Pharmacy, Engineering, Science and Technology, Education of Sciences, and Human and Social Sciences. The liaison of this project is Dean Mohamed Essaaidi, who will guide the team to assess the current transport systems and potential areas for improvements using smart mobility concepts. ENSIAS and Professor Essaaidi plan to use the results from our project to determine how to improve the efficiency, cost, and reliability of the current transportation system within Madinat Al Irfane.

2.2 Stakeholders

An important part for the success of the project is to collaborate with our stakeholders' prototyping to help shape a smart mobility initiative into a beneficial and feasible model. Table 1 lists our key stakeholders along with their interests, perspectives, and assets. The interest column states each stakeholder's relationship as a contributor to this project. Stakeholder perspectives on smart city implementations are stated in column two along with the assets they can bring to this project in column three.

Table 1: Stakeholders for our project

Stakeholders	Interest	Perspectives	Assets
School of Urban Planning	Innovation/advancement, academia	Development and use of land	Social/infrastructure aspect of project
School of Architecture	Innovation/advancement, academia	Design/structure usage	Infrastructure aspect of project
City Hall	Case study for Rabat	Resident livability, urbanization, and economic gain	Laws/policy and power
Population of Mohammed V University	Better lifestyle on campus	Convenience	Input to project and relevant ideas

2.3 Definition of Smart Applications

The goal of the project is to assess the feasibility of a smart city initiative in Madinat Al Irfane. A "smart city" or "smart campus" has many definitions but both work towards the same goal of enhancing the efficiency, cost, and reliability of all aspects in major urban areas. It is necessary to clarify the two key terms definitions to suggest potential advancements for the different transportation systems within Madinat Al Irfane.

The only difference between a smart city and smart campus is location of the implemented smart technologies. As the names suggest, a smart city refers to an entire city of "smart projects" whereas a smart campus encompasses a specific district. There is not an agreed upon definition of a smart city, it is constantly changing and adapting as smart city technology develops. Researchers help develop these concepts at conferences focused on urbanization and sustainable energy. The 2012 *Annual Hawaii International Conference on System Science*, for example, defined a smart city as "a city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage collective intelligence of the city" (Chourabi, 2012, p. 29). This definition breaks down a smart city into its collaborative constituent elements, which is helpful when it comes to the planning and implementation.

Another researcher describes a smart city and its usage of the Internet of Things devices as a concept to solve a diverse set of problems for a community (Sanchez, 2014). This definition emphasizes the importance of the physical electronic devices in the creation of a smart city, however it also highlights the importance of focusing the devices on addressing the prevalent issues of the inhabitants based on the users' needs. Both definitions break down a smart city into major components. Separating a smart city or campus into its component parts or "pillars" is a popular method of structuring projects within this domain.

Figure 2 depicts the smart cities core components called pillars (Ng et al., 2010). Each pillar plays a role in the everyday community, and the advancement of each one could enhance the lives of the citizens by cutting costs, increasing reliability and efficiency. Some smart city initiatives can encompass a few pillars, while others focus on just one.

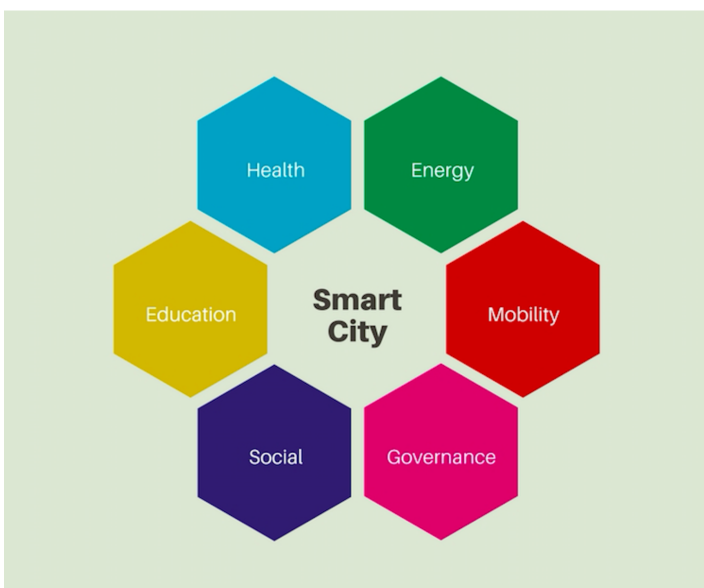

Figure 2: Six Pillars of a Smart City Diagram

2.4 Pillars of a Smart City

In Table 2, the team defined each pillar stating the main focus and problems each component individually addresses. Each pillar does not have a specific definition in the literature but rather a repetitive area of focus. To help understand the nature of each pillar, the table indicates the common initiatives and technologies separated by their categories. These initiatives and technologies appear in major cities around the world.

Table 2: Smart City Pillars Description

Pillar	Concept	Initiatives & Technology
Mobility	Mastering efficiency of the transport of vehicles and people. Main focus is to reduce pollution, traffic, street congestion, and crosswalk crowding*.	● Autonomous cars and shuttles ● Sensors providing traffic updates ● Personalized GPS
Energy	Reduces the carbon footprint by bringing awareness of the negative impact current systems have on the environment and decreasing the amount of emissions of greenhouse gases**.	● Sensors monitoring air pollution ● Smart grids & buildings ● Green/renewable energies ● Waste & water management***
Health	Allows all patients and health care providers to have access to check their health statistics at their own convenience, along with patient information under strong privacy limitations****.	● Personalized health monitoring ● Wearable (Ex: Fitbit) ● Early epidemic warning systems ● Disease interventions**

Education	Incorporates technology into the classroom to give "content-on-demand"*** to the learners along with teaching in the individual's preferred learning style***.	- Collaborative student care system - Real-time remote distance learning - Analysis of student learning pathways - Ebooks & Eresources**
Social	Spreads knowledge about the city in an effective way through social interactions***.	- Information sharing - Work collaboration - Social localization - Pattern analysis - Interest grouping**
Governance	Digitalizes the government to better manage and support the evolving city*****.	- Sharing governments documents and procedures*** - Collaboration - Data exchange - Service integration*****

*- (Dameri, 2017).
**- (Ng et al., 2010)
***- (Neirotti et al., 2014)
****- (Solanas et al., 2014)
*****- (Chourabi et al.,2012)

2.5 Smart Campus Case Studies

In order to assess the feasibility of a smart campus, it is important to analyze similar projects undertaken by others. This section reviews two case studies pertaining to the smart mobility and energy pillars which determine factors that enable a project to be successful, outlines the technical aspects and shows the challenges that smart city implementers face.

2.5.1- Beacon Localization

College campuses are typically not mapped on Google Maps, making navigation for visitors difficult. In 2017, a team of students at Worcester Polytechnic Institute developed a smartphone application to guide newcomers and students to a requested location on their college campus. Their capstone project, "Using iBeacon for Navigation and Proximity Awareness in Smart Buildings", implemented Bluetooth low energy (BLE) proximity sensors to determine the location of the user's phone, and then displayed the route to their goal on an Android application that they developed. The main sensors used in this project were Bluetooth beacons built by Estimote, which "allows an embedded device to broadcast telemetry to various Bluetooth-enabled devices, specifically smartphones" (Alhumoud et al., 2017, p. 8). The beacon projects a Bluetooth signal, and as long as the smartphone is within the range, the built in Bluetooth chip is able to connect to the device. The received signal on the smartphone, known as the radio signal strength (RSS), has a filter applied to eliminate noise and to estimate the position of the phone relative to the beacon (Yapeng et al., 2013). The WPI team used three distance estimates relative to different beacons to triangulate the position of the phone in the hallway. The team had the application calculate the shortest route to the desired location and display it.

The team ran into issues while implementing their beacon project on campus. The most pressing issue that the team uncovered was that the distance estimate from the beacons had an "average error [of] 8.78 meters with a standard deviation error of 7.72 meters" (Alhumoud et al., 2017, p. 56). They attributed this large error to noisy and inaccurate received signal strength indicator (RSSI) readings. This issue diminished the overall functionality of the app and made it impractical to implement. Another problem with the project was the lack of user testing. For any smart campus project, it is pertinent to take into account the user's needs and technological abilities to ensure the prototype's successful implementation. This beacon localization project demonstrated that the concept of indoor navigation is feasible, but more work must be done to refine its accuracy and usability.

2.5.2- Smart Microgrid at Genoa University

Researchers are developing smart grids to reduce energy consumption, ensure reliable energy, save money and improve the environment. The smart energy pillar incorporates these components with one of the solutions being a smart microgrid. Smart microgrids are "a sustainable and efficient urban centre that provides a high quality of life to its inhabitants through optimal management of its resources" (Brenna et al., 2016, p. 1). Smart microgrids manage energy consumption efficiently, incorporating different types of energy. Researchers at the Savona campus of the Genoa University developed and implemented a smart polygeneration microgrid (SPM), Figure 3, to reduce its dependence on traditional electric grids, integrate renewable energy and minimize the campus carbon footprint. Prior to this project, the campus received all of its energy through traditional power grids. This smart microgrid interfaced renewable energy such as wind and solar panels, along with thermal production to intelligently switch between traditional means of electricity grids and renewable energy.

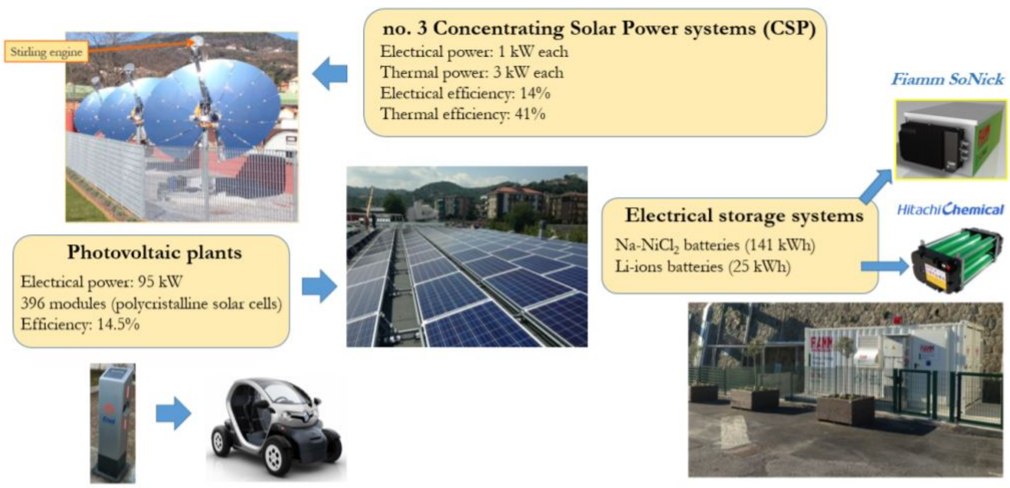

Figure 3: Smart Polygeneration Microgrid at Genoa University (Brenna et al., 2016).

The smart polygeneration microgrid (SPM) is comprised of an electrical grid, thermal grid and software managing system. Within the electrical grid, solar and thermal energy feed into the system. The electricity output of the system provides power for two electric vehicle charging stations, the control room for the SPM, a laboratory, and all of the power plant auxiliaries (Brenna et al., 2016). As seen in Figure 3, the sources of energy for the electrical grid are a photovoltaic plant, three concentrating solar power systems, three high-efficiency cogeneration microturbines, and two electric storage systems. The photovoltaic plant is a large array of traditional solar panels, whereas the concentrating solar power systems uses mirrors or lens to concentrate a large area of sunlight and a stirling engine converts the solar power to heat (Boerema et al., 2013). Three cogeneration microturbines and two traditional boilers fed by natural gas produce the thermal grid's energy. During the winter time the thermal grid provides heating to the campus. The SPM's energy system combines the electrical grid from renewable energy, thermal grid and traditional electricity from a power grid. The SPM uses software provided by Siemens called Decentralized Energy Management System to adequately manage the system. The system uses an optimization algorithm specifically for technology being deployed with the ultimate goal of minimizing daily operating costs. The university uses this advanced software to manage their SPM to reduce energy consumption and incorporate renewable energy.

The SPM project, funded by the Italian Ministry for Education and University of Research, serves as a case study for energy supply systems as well as a model for the city of Savona, Italy. The project started on February 12, 2014 and remains fully operational today. The main goal of this project was to increase its use of renewable energy, reduce its carbon footprint and yearly total operating costs. After careful data collection and analysis, researchers were able to reduce their yearly operating costs for energy by 33% and have calculated that their efforts will reduce CO_2 emissions by a total of 120 metric tons per year (Brenna et. al, 2016). The project was successful in implementing a smart grid on a campus level and has proven to be a model for larger scale smart cities.

2.5.3- Case Study Comparison

The beacon localization project and smart microgrid project both addressed issues on their respective campuses through technology. The WPI team working on beacon localizationindiv had a very good concept, create a device that would help guide newcomers around an unfamiliar campus. The major problem was their final product was inaccurate, contained too many bugs for it to be useful and didn't take into account the social aspects of the users. In contrast, the smart polygeneration microgrid at the University of Genoa was able to develop a microgrid that took advantage of new energy sources and proved its success through data collection and analysis. This project used the university as a test bed for the city of Savona, Italy. There is very little information published on the social implications of smart city projects. When designing a smart city project, it is pertinent to consider the social factors of the users to ensure that it addresses the needs of the users.

2.6 Vulnerabilities of Smart City Implementations

Current smart city initiatives tend to rely on technological approaches that suggest that technology alone will solve urban problems and improve resident's quality of life (Boykova et al., 2016). However, implementations "should be based on a people-centric approach rather than on a 'technological one'. The order of priorities and accountability should be adhered to: living standards [to] state of the urban environment [to] technological solutions" (Boykova et al., 2016, p.68). In order to improve livability, smart initiatives should address their resident's engagement, social vulnerabilities, the infrastructure of the existing city and possible technological vulnerabilities.

When planning a successful smart city initiative, "user-centric" approaches are essential. User-centric approaches "consider urban issues from the perspective of [its] citizen's needs" (Monzon, 2015, p.3). When assessing the public's needs, one must consider the accessibility of technology in the community. It is much harder to implement smart city initiatives if a city's population cannot engage with the proposed technologies and do not have access to appropriate technology. This becomes a challenge when planning initiatives that include the usage of smartphones or information and communications technology (Monzon, 2015). According to statistics about the population subscribing to mobile services in the Middle East and North Africa, Moroccan residents who are not mobile phone subscribers make up 33% of the population. Users that have access to phone call and text services, make up 18% of the population and the remaining 49% of the Middle East and North Africa residents do have access to mobile internet (Statista, 2016). When developing a smart city initiative, it is important that the project be beneficial to the entire population, and not just the people who have mobile phones with internet connection.

Besides taking into account the resident needs, the infrastructure for a city that categorizes as existing rather than new, will encounter obstacles such as retrofitting (Bélissen, 2010). Retrofitting is "work required to upgrade an aged or deteriorated building" (Nicolae; George-Vlad, 2015, p.77). This technique has many uncertainties such as service changes and human behavior changes. These uncertainties determine how a contractor retrofits a building in order to integrate the type of technology and ensure its success (Boykova et al., 2016). In contrast to an existing city, a new city does not face the same issues. The advantages of a new city are the availability to start from "scratch" and not have previous city infrastructures to limit the implementation of smart initiatives, yet it is important to consider financial burdens that come from starting a city from the ground up (Boykova et al., 2016).

Smart city projects have the opportunity to improve the lives of residents, as researchers design and implement smart cities, they need to make sure the negative effects from the project do not surpass the positive impacts (Monzon, 2015). Before implementing smart solutions, it is important to consider the offsets, such as the social and technological vulnerabilities. Social vulnerabilities within technology encompass privacy issues, hacking as well as tracking and monitoring of individuals. Technology vulnerability includes infrastructure failure with a building automation system, manipulation of smart grids, privacy breaches with IoT devices.

Building automation system (BAS) are crucial to smart buildings and contribute greatly to smart cities. BAS's controls elevators, access control, closed-circuit television (CCTV), water and energy systems, as well as other services. BAS uses sensors and actuators to control different devices and manage entire building operations automatically (Baig et al., 2017). Most building automation systems are managed from remote locations, exposing the services to unauthorized wireless attacks.

Smart grids collect and store energy consumption data in a household with an installed smart meter. Some of these meters use cloud computing to process the data and send it to their utility provider (Baig et al., 2017). Since smart grid devices and the cloud maintain a two-way communication, this creates "numerous entry points for an adversary to penetrate the smart grid, and also expose smart grid data stored in the cloud to various security threats" (Baig et al., 2017, p.4). Cyber security threats can expose sensitive information and can render devices useless through a denial of service attack. Unauthorized users can use smart grid data to collect information on the number of people living in a household and consumer data that could reveal the user's personal information (Jokar et al., 2016). Denial of service attacks affect interconnected devices "through generation of legitimate but useless traffic thereby delaying the delivery of legitimate messages and also through launching jamming attacks in wireless power networks" (Baig et al., 2017, p.5). By delaying messages, devices will not work properly thus affecting the efficiency of the city. Smart grids are able to improve energy consumption, but it is important to consider the dangers they bring with their implementation.

Internet of Things sensors are mostly encrypted technologies that protect communication but they are still prone to data and privacy compromises caused by security breaches. One recurring issue is the accessing and exposing data by unauthorized users that could potentially identify users of the system (Mukundan et al., 2014; Ziegeldorf et al., 2014; Pardeshi and Borade, 2015; Mantelero and Vaciago, 2015). If connections are not secure, this can lead to eavesdropping and communications being interrupted and manipulated (Mukundan et al., 2014). Unauthorized users breaching privacy could lead to criminals using sensitive information against residents and compromising their role in society.

Technological solutions are essential to implement smart initiatives, yet these alone will not necessarily improve quality of life. By focusing on a holistic approach that includes technology and input from the local community, we can anticipate the advantages and limitations of the proposed improvement. Using this approach, this project can achieve a successful smart city project.

2.7 Summary

This chapter assesses a subset of the available literature surrounding the history of transportation in Madinat Al Irfane, the definition of a smart city and its constituent pillars, smart technology implementation case studies, and the vulnerabilities that surround them. Defining smart cities facilitates understanding of what constitutes a smart city project and will guide the type of implementations the team looks into. The team discovered that smart cities encompass several categories known as pillars that define a sub-domain of the smart city. Overlapping project spaces interconnect these pillars. By analyzing two case studies, the team learned some key nuances about the requirements of a quality smart city implementation. For example, the data collection from the Smart Micro grid project showed that it has a track record of success, and takes into account the technological aptitude of users and addresses their needs. Assessing vulnerabilities of a system helps avoid common points of failure when adapting smart city solutions. The team will use these key findings to help formulate our methodology.

Chapter 3. Methodology

The goal of this project is to assess the feasibility of incorporating smart technologies into the transportation system within Madinat Al Irfane, Morocco. The three objectives for achieving this goal are:

1. Understand the factors that make a successful transportation system
2. Assess the current state of mobility in Madinat Al Irfane
3. Use public opinion as a resource to propose smart mobility initiatives.

Figure 4 below shows a flow chart diagram of the sequence of our aforementioned objectives. It starts at number one with our first objective and follows through our last objective, and in the center our deliverable can be found. The deliverable of this project is a set of recommendations to improve Madinat Al Irfane's transportation system.

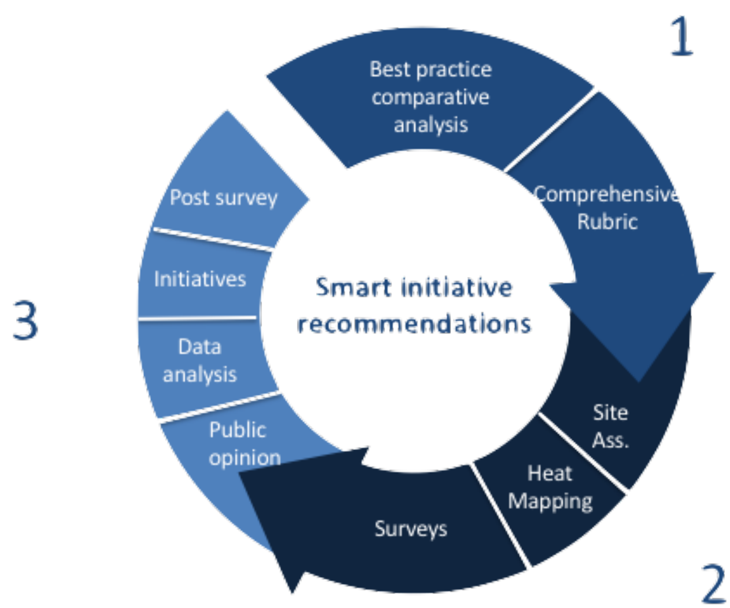

Figure 4: Flowchart of Methodology

3.1: Understand the factors that make a successful transportation system

In order to assess the feasibility of incorporating smart technology into the transportation systems in Madinat Al Irfane, the team will conduct research into transportation systems around the world. Since there are many types of transportations systems, we are going to focus on the tramway and bus systems because they are in Madinat Al Irfane. The team will read and analyze publications that review the costs, safety, accessibility and efficiency of these systems in major cities. In addition, the team will conduct a best practices comparative analysis on a successful system and the current transportation system in Madinat Al Irfane. A best practices comparative analysis is a means of analyzing the casual contributions of different conditions to an outcome of interest (Berg, 2012). While conducting this analysis, it is understood there are cultural and logistical differences between cities which prevent a linear mapping between one transportation system in a city to another.

Through this research, the team will synthesize factors that lead a system to success or failure, along with identifying the different modes of transportation in major cities. These established factors along with pre-determined metrics including efficiency, low costs, and reliability, will help us create a comprehensive rubric in the form of a checklist. This checklist will serve as a tool to evaluate the performance of a transportation system which we will use in Madinat Al Irfane.

3.2- Assess current state of mobility in Madinat Al Irfane

Site Assessment Mapping

We will conduct a site assessment to build upon the information about Madinat Al Irfane in our background chapter. Our first task will be to create an in-depth map of this area by utilizing the outline Open Street Map provides in Figure 5. This map will include foot, motor vehicles, and public transportation paths within the college campuses and hospitals, that are currently lacking. This will allow for a better understanding of possible mobility routes throughout the area as a whole. See Appendix A for a list of locations of particular focus for mapping within Madinat Al Irfane.

Figure 5: Madinat Al Irfane Map (OSMF, 2017).

Using this new map of Madinat Al Irfane along with GPS watches and their mobile applications (Nike+ and Garmin), we will track random commuters throughout this area to ascertain their commuting path. To understand Madinat Al Irfane accessibility, we will use random sampling starting at tram stations and bus stops during rush hours of 7-8 A.M., 12-2 P.M., and 6-7 P.M. to select our observant. The team will select the 5th person off the tramway or bus to avoid bias towards a specific traveler and to discreetly collect a diverse set of final locations. The observer will follow the observant from a distance of 10 meters, and the sampling event will end when the observant leaves the boundaries of Madinat Al Irfane, seen in Figure 5, or when they enter a building. The observer will take notes about the route information with the observation matrix in Appendix B using the Google Excel application on their mobile phone. The observation matrix will collect data about the starting and ending location of the observant path along with the respective times. In addition, the GPS watch will give information about the route traveled, the pace, and the total route time. Compiling all this raw data, the team will create a heat map. A heat map, seen in Figure 6, is a visual to understand complex data surrounding mobility. The team will analyze the congestion experienced when walking around the college campuses, hospitals, and residential living areas. For example, in the Beverly Hills heat map in Figure 6, the route outlined in red shows the most congested path, dark blue represents the next lower congestion level in biking paths. After overlaying all raw data points from random sampling using the observation matrix and GPS watch applications, this map will identify the areas of congestion and the most popular walking routes within Madinat Al Irfane. By assessing the most congested areas within the area, we are able to address these locations to improve efficiency of the mobility for the commuters and visitors of Madinat Al Irfane.

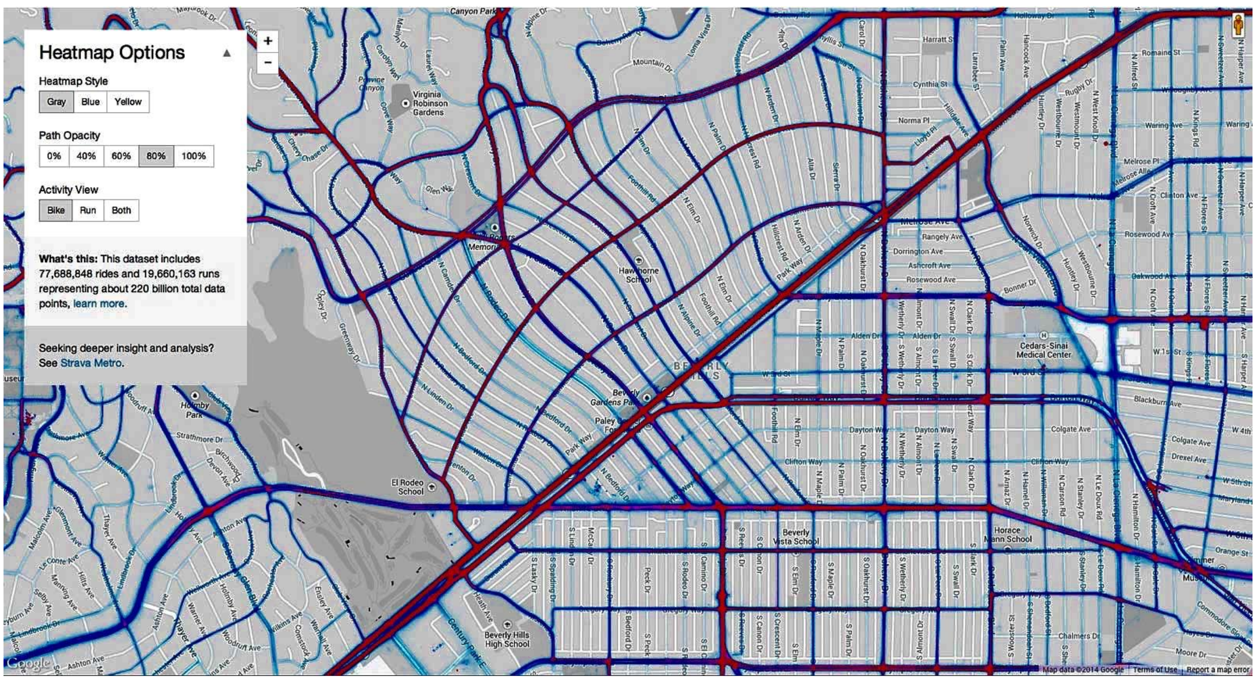

Figure 6: Example Heat Map of Beverly Hills (Elliot, 2014).

Surveys

Our team will administer two anonymous surveys in English, Arabic and French to the residents of Madinat Al Irfane, seen in Appendices C and E. The students we are working alongside from ENSIAS at Mohammed V University will serve as our translators, if necessary. These surveys will include one household self-completion survey and one intercept survey (Richardson, et al., 1995). Potential respondents will receive household self-completion surveys via Qualtrics, an online survey tool. The team will email the online survey through designated email aliases targeted toward Mohammed V University students and faculty. In the survey, the respondent will fill out the form without any assistance and allow for completion of the survey at their own pace (Richardson, et al., 1995). Aiming to avoid any misunderstanding, we will assess the survey's effectiveness by pre-testing the survey with our classmates. We will time the pre-test survey in order to gauge the time allotted to take the survey to inform our respondent. This will also allow us gather feedback on the questions asked in order to adjust the survey and eliminate any ambiguity.

We will also interact with Madinat Al Irfane commuters and visitors through an intercept survey found in Appendix C and E. Intercept surveys take place while subjects are in the context of the site activities (Richardson, et al., 1995). In order to have a comprehensive data set, the intercept surveys will gather a cluster sample which is a naturally occurring sample groups outside of the Mohammed V University (Teddlie, et al., 2007). The intercept points will include high concentration areas such as other college campuses, hospital property, and Campus Al Irfane. Campus Al Irfane, located in the center of Madinat Al Irfane, contains a food court and the main tramway station. In these densely populated areas in Madinat Al Irfane, our team will divide in sets of two's and three's, always having one female and a male so the respondent is not uncomfortable. In order to conduct the intercept survey we will invite the ENSIAS students to serve as translators in order to approach any subject on site as they are conducting their daily activities without a language barrier. The team will gather in the aforementioned areas within Madinat Al Irfane in order to conduct our research through a convenience sample, where we will distribute the intercept survey by approaching the most accessible subjects (Marshall, 1996). Our team will introduce ourselves, explain the purpose of our survey and give the target subject the option to participate in or decline the survey.

The survey includes ten questions, four selection-based and six open response. Our team will collect the participants' demographic information related to their role within Madinat Al Irfane in order to categorize and separate group responses. This survey will measure movement of residents, commuters and visitors around Madinat Al Irfane. The survey questions gather information about the current transportation system, how people travel to and from Madinat Al Irfane, their transportation cost, and their destination. This data will assess the current state of mobility in the region and determine mobility trends (See Appendix B).

Interviews

After understanding the factors that make a successful transportation system from objective one, the team can further investigate the stakeholders' opinions on the performance of the current transportation systems in Rabat through interviews. The project team will conduct interviews with key stakeholders of our project, which include respondents from the School of Urban Planning, School of Architecture, and the City Hall. In person semi standardized interviews organized with our stakeholders, provided in Appendix D, allows us to digress from the main order of set questions as needed to better understand their personal experiences (Berg, 2012). To avoid overwhelming our stakeholders, we will form sub-teams consisting of three group members with one common member for every interview. Each member will serve a role within the interview, either questioning, note taking, or recording. In each interview, the team or translator if necessary, asks the stakeholder questions about their views of the current transportation systems, acceptability of smart transportation systems, and possible obstacles.

Once put in contact with our stakeholders through our sponsor, the team will reach out to the interviewee to find a mutually convenient time. Prior to conducting the interview, the team members present will request permission to record the interview, and will have translators present if necessary. The translators for this project are collaborative students from the Mohammed V University. The interview begins with the team members introducing themselves and explaining the project, followed by the first question. Once our stakeholder gives a response, the translator, if present, will relay the English translation to the interviewing team. This allows our team to understand the answered question, and ask any follow up questions. Utilizing this process will lead to more accurate, detailed, and unbiased responses than a post translation of a recording. This structured communication between interviewee and the interviewer will stay the same for every interview.

3.3- Using public opinion as a resource to propose smart mobility initiatives

Once we complete data collection and research to effectively understand what constitutes an effective transportation system, we must then analyze this data. This will entail recording the rich data in a spreadsheet where we will separate the answers into categories. This coding method will allow for separation of the data into distinct categories that capture the themes of the qualitative data (Basit, 2003). Capturing the data like this makes searching the data for common themes and drawing conclusions easier (Grbich, 2007). This spreadsheet is a form of a systematic filing system, which allows us to easily see the overlap in responses (Berg, 2012). Once the data is in this format, we can narrow down the results to a few transportation related problems that the team can address.

Next, with this extracted set of problems, we can conduct research on effective smart transportation initiatives to help develop options for each of these problems. Once we have a reasonable set of options, we will give a post-survey to determine the opinion of the respondents on each of our proposed options. Appendix E contains a sample of the post-survey. Similar to the first survey, the post survey can be categorized as intercept and household self-completion surveys (Richardson, et al., 1995). The post survey is a simple rating system for each option. The participants will rate each option on a scale from one to seven, seven being the best. At the end of the survey, there will be a section for auxiliary comments for each one. We will read these comments and record them into our coding system. Finally, our team will collect demographic information about the participants identical to the collection method in the first survey. This will allow us to ensure we thoroughly sample each demographic category within Madinat Al Irfane. After collecting the data from the post survey, we will analyze the results to find options with the highest average scores, and then deliver a report on the feasibility of the project.

3.4- Data Management and Translation

The data collected from both our surveys and interviews could be in three different languages: English, Arabic, and French. The team of 20 students at Mohammed V University are available to assist with translation in this project for both surveys and interviews. The five WPI students and the ENSIAS student that serve as the translator will review the goal of the project, any necessary background information, and the expected results of the interviews and surveys to calibrate and ensure clarity about the subject to the respondent or interviewee. The team's preference in the structure of the interview is that the translator takes notes during each question and then relay the information after completion of every question. This technique gives the team an opportunity to have input and ask follow up questions while avoiding inaccurate and biased data collection by the translator. If the interviewee provides consent, the interviewers will record the interview for future reference.

3.5- Estimated timeline

The Gantt chart shown in Figure 7 below serves as a timeline for the completion of each of the sections of our methodology including gathering raw data, analysis of results, suggesting recommendations and the final write up.

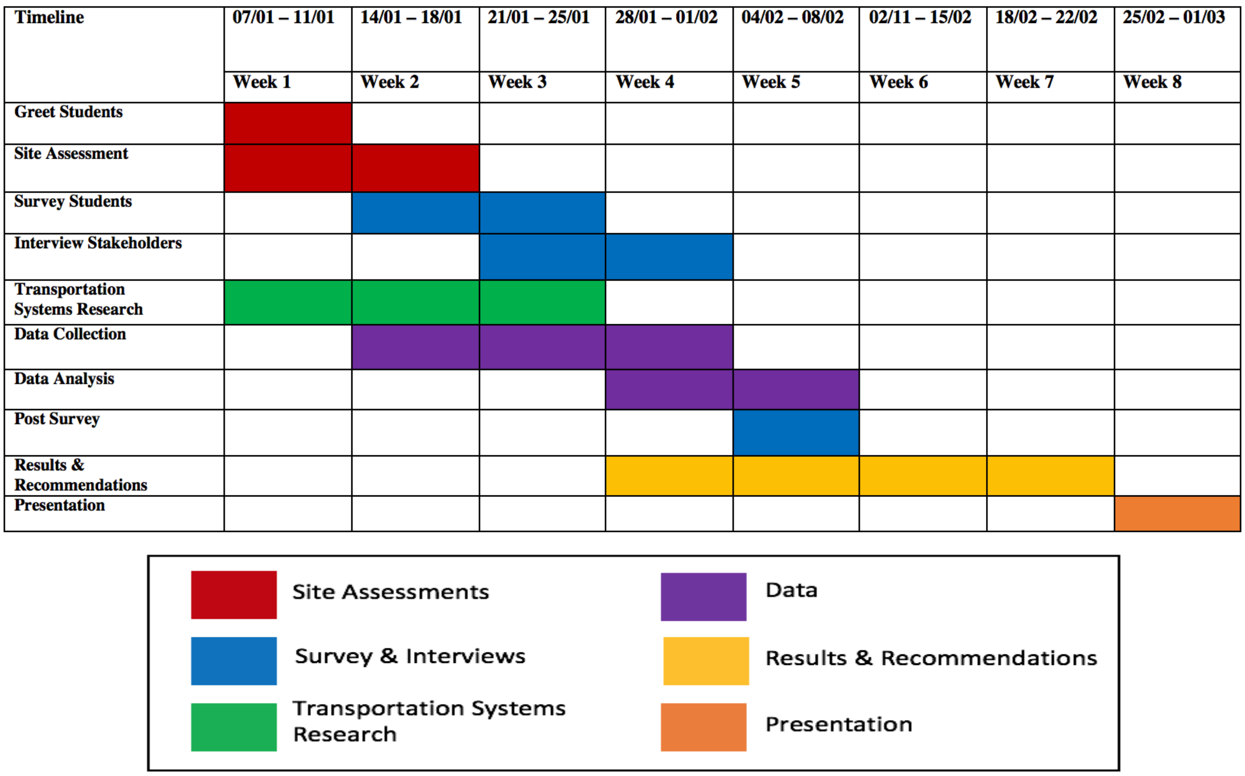

Figure 7: Gantt chart showing expected timeline while in Rabat, Morocco

During the first week our team will acclimate ourselves with Rabat and Madinat Al Irfane, meet the 20 students that we will be working with and begin our site assessment. The site assessment, will take approximately two weeks, where the team will be learning about Madinat Al Irfane by building our heat map of congested areas. Starting in week two, we will administer surveys with students, residents and visitors and in the third week we will conduct interviews with our stakeholders. Throughout the first three weeks the group will be simultaneously researching transportation systems as outlined by objective one in our methodology section. After the data collection, we will analyze the information to determine a common set of problems with the current transportation system. Based on our research and analyzed data we will formulate recommendations to try and address the problems determined from the first survey and interviews performed in week two. Then, the team will resurvey the population to determine their opinion on the various options. In the final weeks of our project, we will finalize our recommendations and present them to ENSIAS.

Chapter 4. Conclusion

To recapitulate, this project will assess the current transportation systems within Madinat Al Irfane as well as the feasibility of incorporating smart mobility initiatives within this area. In order to achieve the goal of the feasibility study in Madinat Al Irfane, it is necessary to understand transportation, study the current mobility systems in the area, and utilize public opinion to cater smart mobility initiatives to the residents and visitors. We will deliver a set of recommendations to ENSIAS designed to improve the efficiency, cost, and reliability of transportation. By recommending improvements, these have the potential to reduce commute time of residents and visitors, giving them more time to focus on other aspects of their lives and may address negative environmental issues. The proposed recommendations could serve ENSIAS students in carrying out future projects in Madinat Al Irfane to use as a test bed. Our deliverable could potentially ignite future research to enhance transportation within Madinat Al Irfane, which could in turn spark smart transportation initiatives in Rabat.

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Appendices

Appendix A: Areas of specific focus for mapping within Madinat Al Irfane

- Regional Center for Education
- Mohammed V University
- International University
- University City Souissi I
- Children's Hospital
- Faculty of Dentistry
- Veterinary Institute Hassan II
- Mohamed V Military Hospital

Appendix B: Observation matrix used for heat mapping

Observation Matrix			
Date	Commuter Gender	Commuter Age	Observers' Intials
	M F	>20 20-30 30-40 50-60 70+	
Route Information			
Mode of transportation			
Start time			
Start location			
End time			
End location			
Duration of route			
Areas of congestion to note on route			

Appendix C: Sample Pre-survey (will also be provided in French and Arabic)

Greetings, you've been invited to participate in a survey to gauge how people get around Madinat Al Irfane. We are a team of American college students from Worcester Polytechnic Institute looking to understand the way that residents and visitors of Madinat Al Irfane get around. We will ask 11 questions that will approximately take about tent minutes.

Your participation is voluntary. If you decide to take the survey and feel uncomfortable at any point and wish to withdraw, you are able to do so. You may skip any questions that make you feel uncomfortable.

Your survey answers will be confidential and are strictly for research purposes. The answers received will never be correlated to the respondent of this survey.

Thanks for your time and support. You can start the survey by answering the questions below.

---

1. Which category best describes you? (Check all that apply)
   - Student
   - Faculty
   - Staff at University
   - Staff at Hospital
   - Doctor/Nurse at Hospital
   - Other __________

2. How do you commute to Madinat Al Irfane? (Check all that apply)
   - Walking _____
   - Bike _____
   - Private car _____
   - Bus _____
   - Tramway _____
   - Taxi _____
   - Other _____ (Please Specify)

3. If you answered private car,
   - How satisfied are you with the availability of parking?
   - How long is your commute (hours)?
   - How much on average do you typically spend on gas in dirhams?
   - Do you travel with others?

4. If you selected any public transport (bus, tramway or taxi)

- How much do you spend on your full commute in dirhams? Please specify if daily, weekly or monthly.
- How would you rate the reliability of public transport? *1 being best and 7 being worst*

  1 2 3 4 5 6 7

5. On what day(s) of the week is it problematic for you to get around Madinat Al Irfane? (Check all that apply)

- Monday _____
- Tuesday _____
- Wednesday_____
- Thursday _____
- Friday _____
- Saturday _____
- Sunday _____

6. What are your primary destinations within Madinat Al Irfane?

7. What is the average length of time your commute to Madinat Al Irfane?

8. Which locations within Madinat Al Irfane are most difficult to reach? Why?

9. What do you feel is the biggest transportation problem facing Madinat Al Irfane?

10. Please list any suggestions to improve transportation services

Please add any additional comments on the back of this page.

Thanks for completing this survey!

Appendix D: Interview Questions for Stakeholders

Hello, we are a team of American college students from Worcester Polytechnic Institute looking to understand the transportation behavior patterns in Madinat Al Irfane. We will use this information to propose some options for smart city transportation projects within the Madinat. Smart transportation is the combination of technology such as sensors with existing transportation methods with the goal of improving the efficiency and convenience of the systems. Some examples of smart mobility projects that have already been implemented in major urban areas are autonomous cars and shuttles, sensors providing traffic updates, and personalized GPS. We will ask 8 questions that will take approximately one hour in total.

May we please record this interview on our smartphones for reflective purposes?
All interview answers will be strictly for research purposes.

1. What is your job title?
2. Are there any projects that you have worked on in the past that relate to transportation systems?
3. What problems do you see with the current transportation system?
    a. Tramway, bus, taxis, private vehicles
4. What challenges are there with smart city implementations within Madinat Al Irfane?
5. What design criteria factors should be considered when implementing smart transportation?
6. Would Madinat Al Irfane commuters and visitors be willing to use a smartphone application to improve their commute?
7. What are the steps taken to implement an urban planning project within Madinat Al Irfane?
8. Do you have any ideas for improvements in the transportation system?

Thanks for your time and support.

Appendix E: Sample Post-Survey

Greetings, you've been invited to participate in a survey to gauge how people get around Madinat Al Irfane. We are a team of American college students from Worcester Polytechnic Institute looking to understand the way that residents and visitors of Madinat Al Irfane get around. We will ask 11 questions that will approximately take about tent minutes.

Your participation is voluntary. If you decide to take the survey and feel uncomfortable at any point and wish to withdraw, you are able to do so. You may skip any questions that make you feel uncomfortable.

Your survey answers will be confidential and are strictly for research purposes. The answers received will never be correlated to the respondent of this survey.

Thanks for your time and support. You can start the survey by answering the questions below.

Which category best describes you?

- Student
- Faculty
- Staff at University
- Staff at Hospital
- Doctor/Nurse at Hospital
- Other __________

Option 1 Description

1. How well do you feel that Option 1 addresses your transportation related issues?

1 being it does not address your transportation related issues at all, 7 meaning that this is a perfect option to your transportation related issues.

1	2	3	4	5	6	7

2. How likely would you be to use option 1?

1 meaning you would never use it, 7 meaning you would definitely use it.

1	2	3	4	5	6	7

3. Additional Comments/Concerns on option 1

Option 2 Description

4. How well do you feel that option 2 addresses your transportation related issues?

1 being it does not address your transportation related issues at all, 7 meaning that this is a perfect option to your transportation related issues.

1	2	3	4	5	6	7

5. How likely would you be to use option 2?

1 meaning you would never use it, 7 meaning you would definitely use it.

1	2	3	4	5	6	7

6. Additional Comments/Concerns on option 2

Please add any additional comments on the back of this page.

Thanks for completing this survey!