Madinat Al Irfane: Is Smart Mobility Feasible?

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Assessing Feasibility of Incorporating Smart Mobility Implementations within Madinat Al Irfane

An Interactive Qualifying Project Report submitted to the Faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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Abstract

The goal of this project was to assess the feasibility of incorporating smart technologies into the current transportation systems within Madinat Al Irfane in Rabat, Morocco. Our team worked in collaboration with Dean Essaidi, of *l'Ecole Nationale Supérieure d'Informatique et d'Analyse des Systèmes* (ENSIAS) to accomplish this goal. Through research, site assessments, surveys, and interviews, our team gauged the public's discontent with the current bus service. After completing our assessment of the existing transportation systems in Madinat Al Irfane, we concluded it is not feasible to implement smart mobility initiatives. In hopes to alleviate prevalent issues the team found in the transit systems, we developed a preliminary design review for a sensor based tracking system for the buses.

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Executive Summary

A minority of Rabat, Morocco's population report having a driving license or access to a private vehicle while "94.5% of urban users [in Rabat, Morocco] are 'captive' to public transport modes" (INECO, 2007, p. 232). Non-private car owners tend to rely on public transportation, aside from walking, in order to get to their destinations within Rabat. Our project focuses on assessing the available public transit systems in a specific district of Rabat, Madinat Al Irfane. There are three types of public transportation available in Madinat Al Irfane: tramway, taxis, and buses. Through research and data analysis, this investigation determined that the latter is in the most need of attention. Our project sponsor, Mohammed Essaaidi, Dean of the *l'Ecole Nationale Supérieure d'Informatique et d'Analyse des Systèmes* provided his assistance, guidance and facilitated our assessment of Madinat Al Irfane's transportation system. The team developed a feasible plan to address current issues with the bus system in Madinat Al Irfane by recommending ENSIAS develop a system to tell customers when their bus should arrive. The project report also explores possible solutions for addressing other mobility problems noted throughout our stay in Rabat.

A variety of transportation methods serve Rabat for commuters and visitors to get around the city. These transportation systems include the tramway, taxi and bus. Recently open to the public in 2011, the tramway serves as the main public transportation in Rabat, and accommodates an expected 180,000 people every day (Jeffreys, 2012). Residents and commuters who do not use the tramway, have taxis and bus services at their disposal. There are approximately 3,800 taxis that roam around Rabat and a fleet of 540 buses that cover Rabat's streets (Ramadan & Delatte, 2016). Our team focuses specifically on transit within Madinat Al Irfane. The area of Madinat Al Irfane encompasses universities, hospitals, as well as residences. The team worked within this area in order to assess the viability of smart city implementations. A smart city is a fusion between technology and social interest. Smart cities cannot rely solely on technology-focused approaches; developers must place citizens' needs at the center of smart initiative designs in order improve quality of life. Smart cities range from different perspectives including technological or social approaches but ultimately these two approaches aim to improve the citizens' quality of life. Figure 1 illustrates how a smart city is comprised of different categories such as health, energy, mobility, governance, social, and education (Ng et al., 2010).

Figure 1: Six Pillars of a Smart City

Our project concentrated on the mobility category, which aims to decrease pollution, traffic, street congestion, and crosswalk crowding (Dameri, 2017). The goal of this project is to assess the feasibility of incorporating smart technologies into the transportation systems within Madinat Al Irfane. Madinat Al Irfane has the potential to act as a test bed for smart city initiatives at a smaller scale in order to assess their feasibility before applying the initiative to a larger system. In order to accomplish this goal, our team established three objectives in this process: to understand the factors that make a successful transportation system, to assess the current state of mobility in Madinat Al Irfane, and to use public opinion to develop a preliminary design review for a smart mobility initiative. In objective one, we laid the groundwork for the rest of our project. We determined the components of a successful public transportation system through our comparative analysis and development and application of our rubric. In objective two, the team collected data which included our site assessment, heat mapping, surveys, and interviews. Objective three entailed the analysis of all the collected data and the production of our deliverable, a preliminary design review of a smart mobility initiative.

Our data collection methods included surveys, interviews, site assessment, and heat mapping. At first the team analyzed peer-reviewed publications on the most successful transit systems and determined common factors among the systems to understand why each was a successful transportation system. These metrics derived from the comparative case study analysis formed the basis of the team's weighted rubric used to evaluate any transportation system. As part of the site assessment, team members used Global Positioning System (GPS) watches and created an in-depth heatmap. This map highlighted points of congestion and walkability issues in a given area. The team administered household self-completion surveys and intercept surveys to students of ENSIAS through an online survey tool, Qualtrics. Additionally, we distributed the same household self-completion surveys to students of *Institute National D'aménagement Et D'urbanisme'* (INAU) and *Ecole Nationale d'Architecture* (ENA) through an email alias. The team also conducted semi-standardized interviews with three of our four major stakeholders. Semi standardized interviews allowed our group to deviate from the original set of pre-written questions to gain a better understanding of the expert's opinion.

A major component of our project was the site assessment of Madinat Al Irfane. In order to properly evaluate the various available transportation methods, the team created and used a weighted rubric, based on a comparative case study analysis of the best transportation systems around the world. Three major categories comprise this rubric: people, planet and profit. The people section of our rubric pertains to the comfort of the system, the various services it offers, and how difficult it is for the user to understand and use the system. The planet section evaluates the environmental impacts of the transportation system and the profit section assesses the economic viability of the system. The WPI team established an overall score for each system based on the average of the team members' individual ranked scores. Based on an existing transportation rubric, the team calculated a passing score for a transportation system according to the WPI Smart Cities Rubric (SCR) as a 51%.

To evaluate transportation within Madinat Al Irfane, the team rode the tramway, bus, and taxi during the morning and afternoon rush hours. While riding the systems, the present team members evaluated and filled out the rubric based on numerous observable metrics. Based on the team's responses, the tramways people, planet, and profit sections received scores of 63, 65, and 71 out of 100 respectively. The tramways overall score of 66.33% passes the established passing grade of 51%. The team deemed the tramway as fairly reliable, clean and easy to use. However, the tram had poor coverage within the city, offering only two lines.. The team gave the bus scores

of 50, 63, and 55 for the people, planet and profit scores, granting it an overall score of 56%. Although the overall score meets the established passing score, the team found many problems with the current bus system. The bus company, Stareo, does not provide proper maintenance for the buses, resulting in outdated and unreliable system. Additionally, the bus stops did not have information about arrival time or available bus routes. Four team members in total rode and gave the taxi system scores of 63.5, 49, and 64.5 for the people, profit, and planet section of the rubric. The team granted the taxi an overall score of 59%, passing the established score of 51%. We gave the taxi a poor overall score due to the high levels of pollution, poor coverage and steep fare prices. Finally, the team made a heat map to assess walkability in the area. The heat map exhibits no major congestion points but drew attention to the lack of defined sidewalks and stop signs.

In addition to the site assessment, the team distributed household self-competition surveys, which yielded a total of 65 responses, 68% of which were students from various universities within Madinat Al Irfane. This survey collected information regarding the respondent's choice of transportation to Madinat Al Irfane, commute time and price, as well as free responses dealing with the current state of the transportation system. Figure 2 displays the respondents' use of each transportation system broken down by percentages. The team predicted the bus would have the most ridership given its low cost of four Dirhams per ticket. However, this was not the case; our results showed that the bus accounts for only 3% of ridership among our survey respondents.

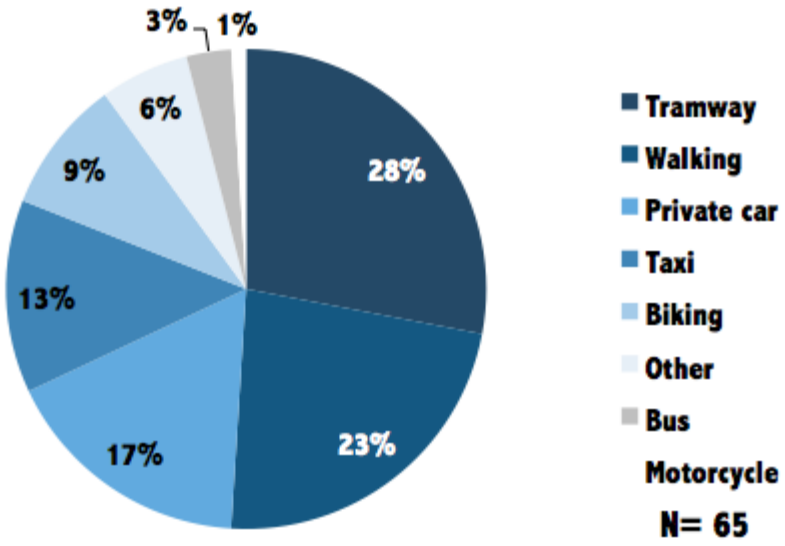

Figure 2: Usage of transportation options within Madinat Al Irfane

The site assessment revealed both positive and negative aspects of the bus system in Madinat Al Irfane. While the coverage of the bus is adequate, and the cost is the lowest of all the evaluated systems, the shortcomings of the bus outweigh these positives. The bus system is unreliable, as it often runs late and stops at undesignated areas. Additionally, the maintenance of the bus is poor. Question ten of our survey asked respondents what "[they] [felt] [was] the biggest transportation problem facing Madinat Al Irfane," and a common theme identified through coding was availability. Shortcomings in the availability for a transit system include an inadequate number

of vehicles, limited schedules, and limited coverage. The team then asked the respondents to provide suggestions to address their identified problem. Figure 3 below exhibits the results for this question; 36% of the respondents to this question identified the bus as the area in most need of improvement. The poor state of the availability and quality of the bus resulted in only 3% of the survey respondents indicating that they ride the bus. Improvements to the system, including smart city technology implementations could potentially improve ridership for the citizens.

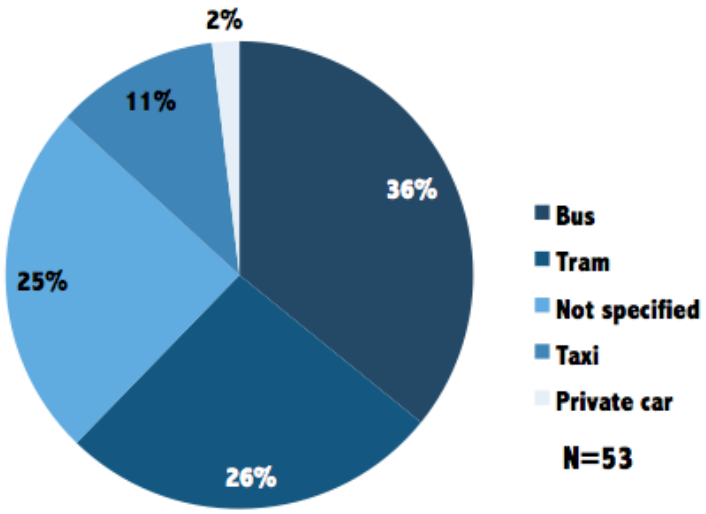

Figure 3: Percentage of References of Transit Systems for Suggestions

The team conducted three semi-standardized interviews. There was a minimum of two team members in addition to a translator present at each interview. For our first interview, we spoke with the student body president of *Ecole Nationale Supérieure d'Informatique et d'Analyse des Systèmes* (ENSIAS), Mohammed Amine. Through this interview, the team gained insight into how the general student body population feels about the transportation system around Madinat Al Irfane. Second, we interviewed the Assistant Director for Studies of the *Institute National D'aménagement Et D'urbanisme*' (INAU). The goal of this interview was to attain an expert opinion on smart initiatives pertaining to Madinat Al Irfane. In our final interview, we spoke with a panel of professors at the School of Architecture, with the goal of learning about the current state of smart mobility projects in Rabat. After the collection of each of these interviews, the team transcribed them for further analysis. We used a technique, coding, to analyze the interview transcripts and separate out the main ideas and takeaways from each interview.

Each of the interviews we conducted proved to be valuable as the key findings were relevant to, and granted insight into the direction of our project. In our interview with Mohammed Amine, the student body president of ENSIAS, we learned that students receive a triannual 2000 dirham stipend from the government. This determined how expensive each form of transportation was for the average student. From the interview with the Assistant Director for Studies at INAU we learned that the Rabat government is investing in private sector transportation improvements such as roads instead of public sector transportation such as the bus system. Our interview with

the panel of professors at the School of Architecture shed light on the current developments in smart city technologies in Morocco and how they frequently fail to meet their goals. The interview also strongly suggested that the transportation system is the most critical system in need of improvement from a smart city application. Specifically, the bus faces the biggest challenges.

Our team proposes that ENSIAS develops a Bus Time Prediction System (BTPS) to provide residents with live information about the buses in their area. This system would utilize sensors to track the location of the bus and a dynamic model would estimate the time of arrival of the bus based on the collected data. This project covers many areas of research that ENSIAS is currently pursuing from wireless technology to databases. The BTPS could be an application of their current research. By providing real time bus arrival times, riders would be able to plan out their days and ideally reduce their commute time. This smart mobility initiative has the potential to improve the efficiency, ridership, and reliability of the bus system. The bus company would be able to analyze the collected data and determine which bus routes consistently fall behind schedule and at what points along the route they stop.

The team interviewed multiple professors at *Ecole Nationale d'Architecture* and gained invaluable insight into smart cities initiatives within Morocco. We encourage future teams to speak with the university, as they provided extremely useful information about their research, problems facing smart cities in Morocco and the state of transportation within Morocco. The team learned that in Casablanca, the local government implemented a smart cities initiative to identify and respond to crime and safety issues through a series of cameras. Our team recommends future groups investigate this smart city initiative and use it as a case study. Additionally, the WPI team recommends future teams conduct a cost benefit analysis for our proposed preliminary design review. A cost benefit analysis would assess the economic viability of developing and bringing the prototype to Madinat Al Irfane. The addition of a cost benefit analysis to the recommendations section will help support the recommendations the team makes.

The goal of this project was to assess the feasibility of implementing a smart mobility initiative in Madinat Al Irfane. By evaluating the current transportation system of the area using a comprehensive rubric created through a best practice comparative analysis, heat mapping, surveying the public, and interviewing experts, the team gathered a better understanding about pressing issues in the current system. The results highlighted the public's discontent with the current bus service. The team generated a preliminary design review for a bus time prediction system that will allow users to get real time updates on the estimated time of arrival of the bus on their phone, laptop and at the bus stop. This system will enhance the current system in place by increasing reliability to the users, therefore, growing the ridership of the system.

Executive Summary Bibliography

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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 (Statista, 2016). This travel time does not include the commute home, nor does it include any other personal transportation-related activities. People spend an appreciable amount of time commuting whether it be by car, train, bus, walking, or bicycle. Consequently, developing efficient, low cost, transportation systems is a worthwhile venture that can have many positive effects, especially in crowded urban areas where commute times can be long due to population density or poor to non-existent urban planning.

Public transportation can allow residents and visitors to travel around cities with ease depending on the quality of the system. In the United States, from 1995 to 2005, commuters took 9.7 billion trips on public transportation (Public transportation, 2007). There are many options to get around in a variety of urban areas, including ride sharing services such as Uber and Lyft, subway systems, buses, trains, monorails, walking, and cycling. In sustainability-minded countries like the Netherlands, walking or cycling make up more than half of all daily trips for residents (Buehler, Pucher, 2017). Easy access to good transportation systems increases the livability of the area. The Economic Development Research Group, a research and consulting firm, determined that in the United States, proximity to public transit stations is a good predictor of property value in several large cities (Forkenbrock et. al., 2001). When deciding on a place to live, a major factor that prospective residents look for is the availability and quality of transportation systems within the surrounding community.

Most cities build modern transportation systems to address the needs of exponentially growing populations. By the year 2030 a predicted 66% of the world's population will live in cities with populations of 10 million or more (Griffiths, 2016; United Nations, 2014). The downside of this demographic shift is that more people are moving into cities from the suburbs, making transit more congested and increasing the need for efficient transportation. Some cities like Hong Kong, ranked first in the world for its transportation system are able to handle this large influx of people. Other cities, such as Bangkok which ARCADIS' Mobility Index ranks 94th in the world, face major transportation challenges. (Batten, 2017). Morocco closely follows this trend with 61.2% of the country's population currently living in cities and an annual city growth rate of 1.92% (CIA, 2017). Rabat is one of the top cities by population density and population in Morocco (CIA, 2017).

The city's transportation system may not be able to accommodate the current population, much less the growth that the aforementioned statistics predict. Therefore, researchers should assess Rabat's transportation system. In Rabat, the public transportation network includes intercity rail, a tramway that spans 19.5 km, 35 bus lines, and approximately 3,800 taxis (Ramadan & Delatte, 2016). These transportation systems are not perfect and each come with their own set of problems.

Smart city initiatives can potentially address problematic transportation systems. A smart city is "an integrated system in which human and social capital interact, using technology-based solutions" (Monzon, 2015, p.3). This definition highlights the importance of balancing the technological and social aspects of a smart city. There are six major pillars of a smart city including mobility, health, education, social, governance, and energy. This project focuses on the smart mobility pillar. This pillar advances transportation systems that work towards reducing both customers' and providers' costs, noise pollution, and congestion, while increasing speed and safety (Dameri, 2017). Achieving these goals can assist with decreasing commute times and improving the transportation experience of the everyday user.

Initially, urban planners should implement smart city initiatives at a smaller scale in order to assess their feasibility before applying the initiative to a larger system. Our project investigates a specific area in eastern Rabat called Madinat Al Irfane. This is an area that encompasses a cluster of universities, hospitals, and residential living areas. There are several universities within Madinat Al Irfane. The largest university, Mohammed V University, which has 19 college campuses located within the area. This district of Rabat, with many residents, shops, and different modes of transportation is a good test bed to research the viability of smart city initiatives and to assess the commuters, visitors, and residents acceptance of new technology.

The goal of this project is to assess the feasibility of incorporating a smart mobility initiative within Madinat Al Irfane. Our team worked in collaboration with our sponsor, *École Nationale Supérieure d'Informatique et d'Analyse des Systèmes* (ENSIAS), within Mohammed V University to complete our project. Working with students from Mohammed V University, we engaged with the public through our site assessment, surveys, and expert interviews to understand the problems that commuters, residents, and visitors face. A common issue shown through our data collection is the unreliability of the bus system. Our team proposes that ENSIAS develop a Bus Time Prediction System (BTPS) to provide residents with live information about the buses in

their area. This system would let customers know when their bus should arrive based on sensor data and ideally will help improve the efficiency and reliability of the bus system.

Chapter 2. Background

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

2.1 Site Description

Rabat, the capital of Morocco has a population of 1.6 million and is responsible for 16.4% of the country's Gross Domestic Product (GDP) (Morocco World News, 2017). There are a variety of transportation methods 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 public transportation services including the tramway, petite taxis, and buses. There are 540 buses and 3,800 taxis in Rabat which make up 14% and 6%, respectively of the total public transportation choice by the population (Ramadan & Delatte, 2016). Opened to the public in 2011, the Rabat - Sale tramway, seen in Figure 4, serves as one of the main methods of public transportation in Rabat. Every day it serves an expected 180,000 people, about 14% of total public transportation choice (Jeffreys, 2012).

Figure 4: Rabat-Sale Tramway Network Map (Transdev, 2012).

Our project site, Madinat Al Irfane seen in Figure 5, is a cluster of universities, hospitals, and residences located in Rabat. According to a Mohammed V University student with first- hand experience, the preferred mode of transportation for students within this area is walking (M. Salhi, Google Hangout Interview, December 1, 2017). Madinat Al Irfane is the first stop on line one of the tramway when boarding on the south of the city, and the last stop when boarding at Hay Karima in the north, making this a convenient mode of transportation for commuters, residents, and visitors of this area. Many students, who make up a large portion of the population of the project site, do not own private vehicles and prefer public transportation and walking (M. Salhi, Google Hangout Interview, December 1, 2017). The team used available transportation statistics of Rabat to represent Madinat Al Irfane because there are no available statistics for Madinat Al Irfane.

Figure 5: Satellite map of Madinat Al Irfane in Rabat, Morocco (Google, 2018).

The Bouregreg Agency, a public agency tasked with the urbanization of the Bouregreg valley area, built the tramway in partnership with Society of Rabat Sale Tramway (STRS) to accommodate transportation demand with the rising population and to improve the connectivity between the two cities of Rabat and Sale; a city located in northwest Morocco opposite of Rabat. The tramway has 31 stations, each strategically located in close proximity to major facilities and urban areas, spanning 19.5 km over two lines. On weekdays, the tramway runs every eight minutes (Sadmi, 2010). A single ride on the tram costs six dirhams, however STRS offers passes for more frequent users, ranging from 250 dirhams monthly to a yearly pass costing 2500 dirhams allowing for an unlimited amount of rides. There are approximately 18,000 tramway pass holders, 60% of whom are students, who are eligible for a discount pass of 150 dirhams monthly and 1500 yearly (Sadmi, 2010). The tramway seems to be popular compared to other transportation systems as it is cost effective, runs frequently, and has a mediocre 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). The bus and tram do not span all the popular areas around the city, causing a need for more than one transportation method to reach the desired final destination. As shown in the prior statistics, taxis are the least popular mode of public transportation. Taxis lack certainty, are difficult to locate, and can be expensive for long trips. Hence, aside from walking, residents use the tram and the bus most often as forms of public transportation within Rabat. Taxis fall significantly below the other forms of public transit in terms of ridership.

Within Madinat Al Irfane, the team collaborated with the Ecole Nationale Supérieure d'Informatique et d'Analyse des Systèmes (ENSIAS), the National School of Computer Science and System Analysis, at Mohammed V University. This university contains 19 institutions with a student population of 65,000 students which includes a variety of teaching disciplines such as Medicine, Pharmacy, Engineering, Science and Technology, Education of Sciences, and Human and Social Sciences. The Dean of ENSIAS, Mohammed Essaaidi and Professor Hassan Berbia served as our liaisons and facilitated the team's assessment of the current transportation system. The intent of this assessment was to identify potential areas for improvement using smart mobility concepts in Madinat Al Irfane.

2.2 Stakeholders

Collaboration with our stakeholders is integral to our project, as they have valuable opinions on shaping smart mobility initiatives into beneficial and feasible models. 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 in column two along with the assets they can bring to this project in column three.

Table 1: Stakeholders for Smart Cities project

Stakeholders	Interest	Perspectives	Assets
School of Urban Planning	Innovation/advancement, academia	Development and use of land	Social/infrastructure aspect of our project
School of Architecture	Innovation/advancement, academia, aesthetics, function of city	Design/structure usage	Infrastructure aspect of project
Office of City Planning	Case study for Rabat, cost of proposed project	Resident livability, urbanization, and the government's economic gain and potential loss	Transportation laws /policy and power
Mohammed V University	Better lifestyle around campus	Convenience	Opinions on current transportation systems and relevant ideas

The most important stakeholder of this project is the current users of the transportation system within Madinat Al Irfane. The resident and commuter that use the transportation system have the largest stake in the project, as they depend on these systems every day. To better understand public acceptance of smart initiatives the team interviewed the student body president; gaining insights on the transportation system and accessibility of transportation in Madinat Al Irfane. The student body elected their president to serve a representative for them, and thus he acted as a representative of the entire population of Mohammed V University which encompasses the students, staff, and residents.

Additionally, to supplement public opinion from the population of Mohammed V University, there are a number of stakeholders who provide expert opinion that further our insight into our project. The Office of City Planning works on the infrastructure within Rabat, and can provide insight on the relationship between transportation and urbanization. The School of Urban Planning will complement the information the team receives from the Office of City Planning because they will provide the scholastic approach to the subject, giving information on the process and steps of implementing an urban planning project. Another educational source, the School of Architecture can help provide further academic insight on the regulations and opportunities of smart technologies in correlation with preservation and conservation of the historic architecture of Madinat Al Irfane.

2.3 Definition of a Smart City

As smart cities rapidly emerge across the world, scientific literature has been exploring the concept since the 1980s. First introduced in the late 1990s, the term "smart city", has since garnered a range of definitions (Fernandez-Anez, et al, 2017). In 1997, researchers Stephen Graham and Alessandro Aurigi introduced the term "virtual city", which were "cities based on the World Wide Web and they operated as electronic analogies for the real, material, urban areas that host them" (Anthopoulos, 2017, p.13). The idea of a smart city started as a concept that simulated a virtual city, however it lacked citizens as a tool for feedback. Later on, academics translated the virtual city into a physical concept that integrated technology and citizens. As technology develops, the exact definition of what a smart city is changes. Smart cities range from different perspectives including technological or social approaches but ultimately these two approaches aim to improve the citizens' quality of life. Regardless of the approach, smart city projects fall into different "categories" such as health, energy, mobility, governance, social, and education (Ng et al., 2010).

Governments and organizations around the world implement smart projects within their cities as a tool to address urban challenges and to process and manage real-time data that flows from both digital infrastructures and services (Hoon, Hawken, 2017). Hoon and Hawken's definition focuses on the technological aspect of a smart city and notes there is a purpose to address challenges occurring in urban areas. Another researcher describes a smart city as the integration of Internet of Things (IoT) devices into city infrastructures to solve a diverse set of problems within

the community (Sanchez, 2014). Internet of Things devices transfer and receive data over the Internet through an embedded system. Sanchez's definition emphasizes the importance of having researchers develop IoT technology based on the resident's problems and needs.

In contrast, Caragliu et al. define a city as 'smart' when "investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic growth and a high quality of life" (Caragliu, et al, p.50). Caralgiu's holistic definition emphasizes the importance of investing in human and social capital, which are relationship-based resources within a community, while promoting social and cultural development. Knowledge networks (i.e., the bank of local knowledge within an organization or team that may be specific to a domain), voluntary organizations, crime-free environments and after dark entertainment economies are all examples of investment in human and social capital. These examples are not high-tech driven as their intent is to increase social capital and quality of life (Florida, 2002). Since a technical approach is not sufficient to achieve urban innovation, developers must envision smart cities in terms of cultural and social dimensions in union with technology (Hoon, Hawken., 2017). A smart city is a fusion between technology and social interests, it cannot rely solely on technology-focused approaches; developers must place citizens' needs at the center of smart initiative designs in order improve quality of life.

Many existing definitions divide smart cities into six different categories usually referred to as pillars; they pertain to health, energy, mobility, governance, social, and education. Figure 6 depicts the smart cities pillars (Ng et al., 2010).

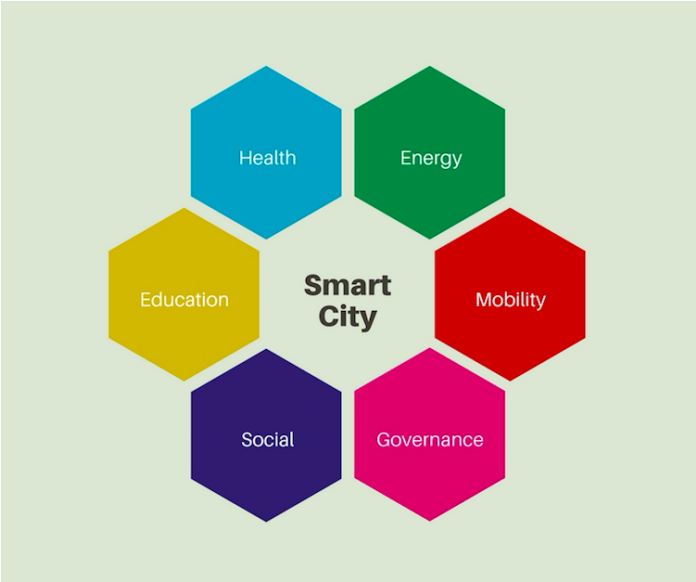


Figure 6: Six Pillars of a Smart City Diagram

2.4 Pillars of a Smart City

Each pillar plays a role in the daily lives of the residents, and the advancement of each one improves both the social capital of the community and livability for its residents. In Table 2, the project team explained 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 indicates an area of focus. To help understand the nature of each pillar, the table indicates the common initiatives and technologies separated by their categories. In major cities around the world, one can spot these initiatives and technologies. A smart city implementation may fall under a single pillar or multiple ones, depending on the city's need and the nature of the project. For example, a bike sharing program would fall under the categories of mobility and health since it promotes health by biking and provides communities with a convenient form of transportation.

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 raising awareness about 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, trust, and goodwill, 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 City Case Studies

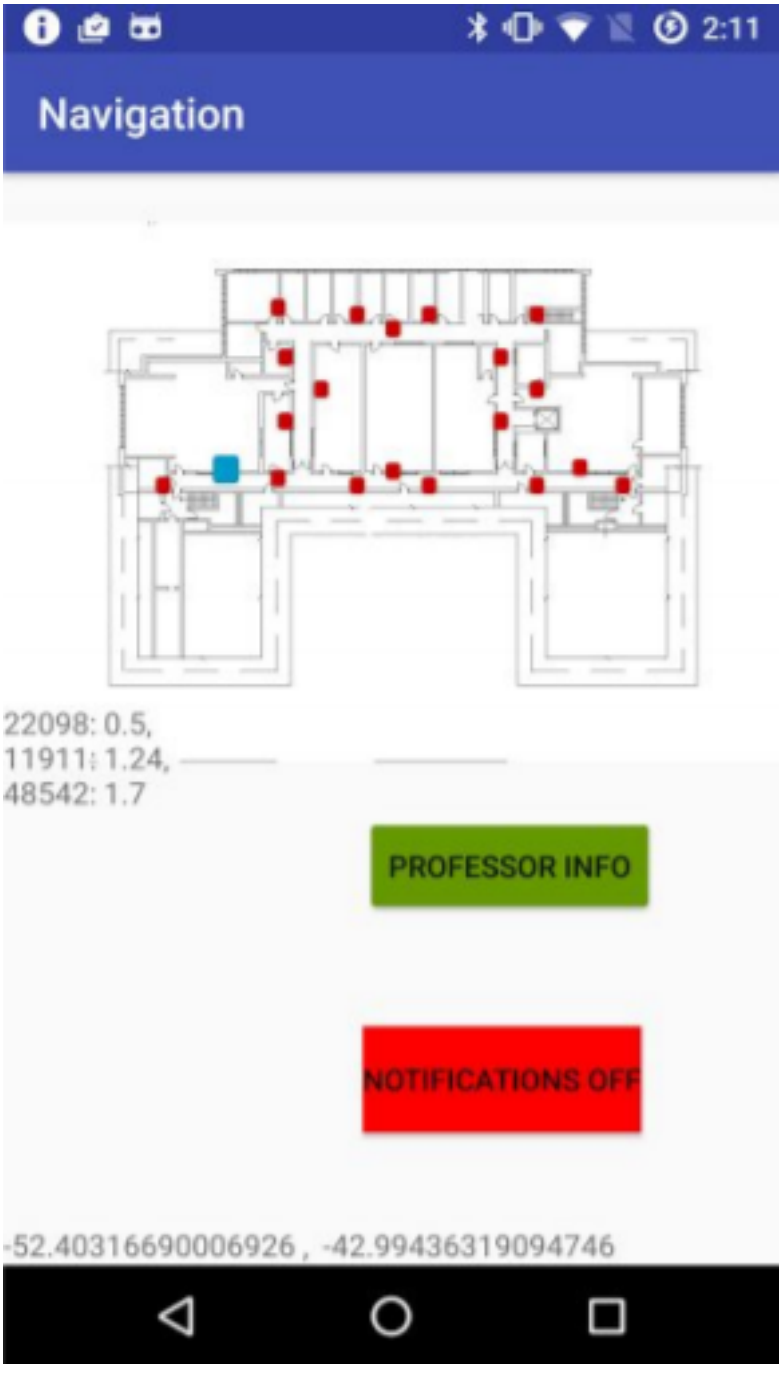
In order to assess the feasibility of a smart city initiative, it is important to analyze similar projects undertaken by others. This section reviews two case studies pertaining to the smart mobility pillar, the technology involved, any challenges faced and its relevance to smart cities in Morocco.

2.5.1 Beacon Localization

Google does not typically map college campuses on Google Maps, making navigation for visitors difficult. In 2017, a team of students at Worcester Polytechnic Institute (WPI), developed a smartphone application, displayed in Figure 7, 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 researchers deployed the project in the electrical engineering building, Atwater Kent, on WPI's campus. 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 signal 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. Figure 8 depicts this triangulation method. The team's application calculates the shortest route to the desired location and displays it.

Figure 7: Android Application (Alhumoud et al).



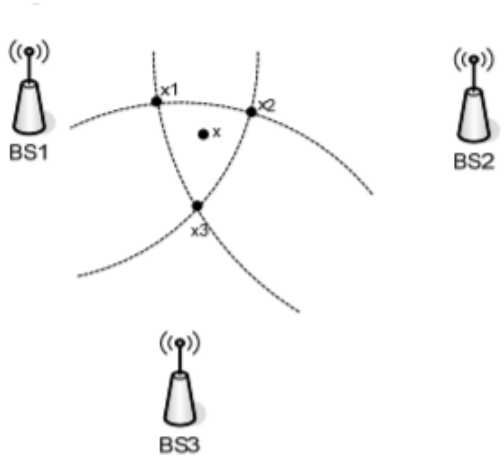


Figure 8: Position estimate using triangulation (Yapeng et al., 2013).

The WPI team ran into difficulties while implementing their beacon project on campus. The most pressing complication 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 usefulness 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 the engineers need to conduct more research to refine its accuracy and usability.

Sometimes, route navigation with Google maps will not work when the user is under bridges, indoors, or in a complex network of alleys due to the lack of Global Positioning Signal (GPS) (Ojeda, 2007). This is the case in many cities around Morocco, where newcomers attempting to navigate the labyrinthine streets and alleys in medinas discover their phones will not help. A smart beacon initiative, like the iBeacon project conducted at WPI, would be able to guide them through the alleys and find their desired destinations with ease. However, implementing a smart beacon localization project in a Moroccan city would face a series of unique challenges. In terms of installation, the engineers would have to strategically place the beacons to ensure the application covers the entire area. They would have to mount them high enough so no one steals

them, and retrofit them with existing infrastructure. Additionally, since the system guides users through the city through a smartphone application, it would only help newcomers with smartphones. A smart beacon localization initiative has the potential to improve mobility and navigation in cities in Morocco, but the initiative also has to address a series of social and technology challenges prior to its implementation.

2.5.2- Monitoring Urban Accessibility in Smart Cities

Researchers in the field of Information and Communication Technology (ICT) are discovering new advancements that have the potential to improve the efficiency and quality of life for citizens. The ICT field focuses on incorporating telecommunication technologies into existing infrastructure and systems. Cities are beginning to incorporate sensors, software, and the field of ICT to make their transportation systems better by reducing congestion, air pollution, and increasing the reliability of systems. When developing smart cities, developers should ensure that mobility and transportation are accessible to all of its citizens. Accessibility is a crucial element in cities that allows individuals to be independent, functioning actors in modern society (Mora et al., 2017). A major issue cities face is the lack of accessibility for people with disability. Although there are regulations in most cities to ensure areas are handicapped-accessible, in practice many locations have insufficient facilities for the handicapped. Researchers studying urban accessibility note the many obstructions that can inhibit movement of a citizen with a disability: “pedestrian crossings with curb ramps on only one end, excessively narrow sidewalks and those occupied by street furniture, [and] unsuitable slopes” (Mora et al., 2017, p.2). Professors and researchers at the University of Alicante developed a system to track and record users through their daily travels and accessibility issues in urban environments through self-reporting and data inference algorithms. All of the reported issues by users are available on a phone application within a database. This allows handicapped users access to the application and makes them aware of any obstacles within their planned route, and helps other citizens and public administration to understand and address any accessibility issues.

In order to record issues of accessibility throughout the routes traveled by citizens, the system must know their location while traveling. To determine their position, the application uses a combination of Global Positioning System (GPS) and Radio Frequency IDentification (RFID). The researchers decided to use GPS for localization when the user is outside because it is reliable,

accurate, and found in almost all smartphones. Since GPS devices cannot receive signals indoors, researchers used RFID transmitters and receivers to locate the user while they are indoors (Mora et al., 2017). The team of researchers developed a cell phone application to track their position, view obstructions previously reported and make researchers aware of new issues. The application tracks their route from the obtained GPS information and if the user encounters any issues such as a ramp being too steep, they can take a photo and self-report the issue. The self-reporting process records the location of the issue, and updates the database with the specified problem and respective information. In addition, the system's software infers accessibility issues that occur from the route information using two algorithms.

The first algorithm compares two possible routes from point A to point B seen in Figure 9. The system can detect that one of these routes is longer than the other. If multiple handicapped users utilize the longer green path seen in Figure 9 instead of the shorter red path that is most commonly used by non-handicapped citizens the system can infer that the red path is not handicapped accessible. Usually people with disabilities have to take longer paths to get to their destination due to obstacles in the shortest routes such as stairs.

Figure 9: Longer route, in green, for handicapped users due to physical obstructions (Mora et al., 2017).

The second algorithm looks at user frequency of traveled paths. Some paths labeled handicapped-accessible may be equal to the length of other paths that users can take to the same final destination. In Figure 10, the red and green path are the same distance. However the university designed the red path so transit for those with mobility impairments is easy. The system tracks the frequency of path usage by handicapped users; if sensors notice that people avoid using the red,

handicapped-specific path, the system can infer an accessibility issue. Lack of accessibility may be due to unpaved roads, curbs, or other physical constraints that are not an issue in the alternative green path. This frequency algorithm brings the need for path upkeep needed to attention, enhancing the lives of the handicapped citizens living within the urban area.

Figure 10: Frequency algorithm detecting an accessibility issue with handicapped user taking non-handicapped path (Mora et al., 2017).

This application stores all issues within a cloud system, both self-reported by users and inferred by the system. If enough users report the same issue, the system updates the information in the database to show priority of a recurring issue. This database is available to the public, and shows the need for certain urban construction projects to increase the accessibility in the area. The mobile phone application, in Figure 11, makes it easy for handicapped users to voice their difficulties, and for the public to understand and gain respect for these access issues.

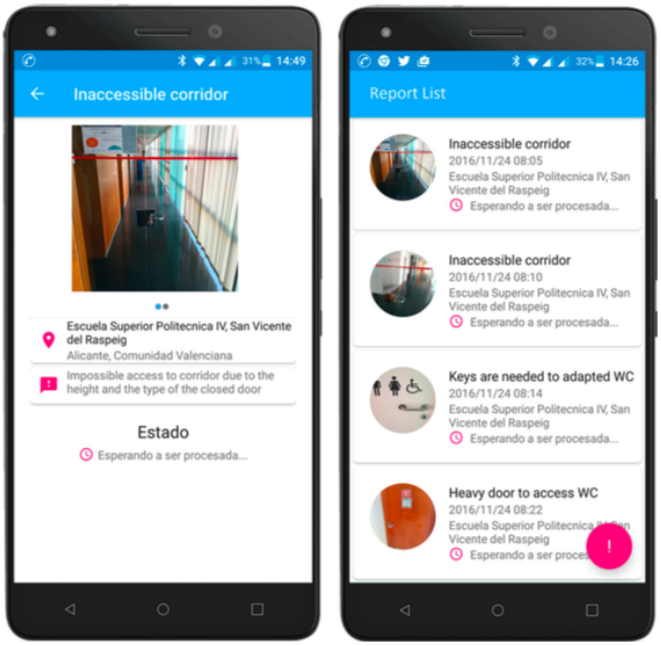


Figure 11: Visual of mobile application for self-reporting incidentals (Mora et al., 2017).

Scientists piloted the designed technology on the campus of the University of Alicante in Spain to discover how the system works in a variety of scenarios. Additionally, this test run allows researchers to adjust to any flaws noted during this testing period. The campus served as a model for a small city because it contained a diverse set of facilities such as rooms, labs, restaurants, and outdoor space. Researchers focused the data collection on evaluating the accessibility of the daily paths both inside and outside of the college buildings to get to lectures, meetings, sports, and lunch.

After one week of operation, the system inferred many incidents and application users filed claims. The reported incidents included trouble accessing toilets, getting to professors' offices, and entering classroom buildings. All these issues were due to physical constraints such as curbs, handicapped ramps being too steep or long, unpaved paths, and heavy doors that force the handicapped citizen to seek an alternative route. The alternative route may be longer, an inconvenience, or nonexistent. The system successfully identified and processed the collected data

with an output of accessibility issues within the designated area; key stakeholders of the university can review the data and prioritize changes to make the area handicapped-accessible. If handicapped issues are apparent in Madinat Al Irfane, this case study demonstrates a successful tool that allows for a future where accessibility is not a limiting factor in transportation and citizens have direct contact with the government to voice any mobility issues. Implementation of this smart mobility initiative allows for a change in urban accessibility.

2.5.3- Case Study Comparison

The iBeacon localization project and urban accessibility project both address mobility issues using sensors, algorithms, and user-input. The WPI team working on beacon localization, had a good concept: create a device that would help guide newcomers around in an unfamiliar building. The major problems were that their final prototype was inaccurate, contained too many bugs for it to be useful, and did not take into account the technological abilities of its users. Additionally, the students deployed the project within an electrical engineering building and the students testing it were engineering students. There is an inherent bias when it comes to usability of a prototype when the students testing it fully understand the technology and develop it. Smart mobility projects must take into account the technological abilities of all target users and the researchers must thoroughly test it to ensure the system works properly and everyone understands how to use it.

The Monitoring Urban Accessibility project addresses an important problem facing major cities: transportation accessibility for people with disabilities. The researchers designed a system that incorporated cutting edge technology: GPS, RFID, algorithms, and cloud computing and integrated these technologies with the issues of the users to address the accessibility problem. The prototype system had a few problems. The first problem was that the system needed RFID technology so the application could track users indoors. The problem with using RFID is that the engineers would have to place transmitters throughout the city and users must wear a small RFID tag. This may pose a problem because the researchers would have to make the user wear an RFID tag around while using the system. The second problem is that the system collected and tracked the location data of its users. The researchers said their software would encrypt the data, keeping their information private, but they did not specify which encryption method they would use. Nevertheless, the system allows the users with disabilities to directly report and civically engage

with the urban planning process through the self-reporting method. This notion of using the power of technology, coupled with citizen involvement to address an issue is the essence of a smart city.

2.6 Challenges of Smart City Implementations

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, one should consider the drawbacks and common pitfalls, such as the social and technological challenges. Technological challenges include infrastructure failure with a building automation system, manipulation of smart grids by malicious individuals, and privacy breaches with IoT devices. Social challenges include developing solutions around people-centric problems, and the issue of needing to retrofit existing structures with the required equipment to implement a smart project.

2.6.1- Building Automation Systems Vulnerabilities

Building automation systems (BAS) are crucial to smart buildings and contribute greatly to smart cities. These systems control elevators, access control, closed-circuit television (CCTV), water and energy systems, as well as other services. BAS's use sensors and actuators to control different devices and manage entire building operations automatically (Baig et al., 2017). Most management systems control building automation systems remotely, exposing the services to wireless attacks, which if successful allow a malicious individual to interfere with critical building functions in a potentially harmful manner. In a case study by the Institute of Electrical and Electronic Engineers (IEEE), Thomas Mundt and Peter Wickboldt identify a list potential risks to a building. This list includes destroying mechanical components, destroying electrical components, changing temperature in temperature sensitive areas, shutting off lighting, and manipulating air ventilation systems. An attacker could manipulate ventilation systems to cause breathing problems or to radiate harmful chemicals instead of expelling them (Mundt, 2010). This study shows that the potential for harm with the misuse of a BAS is extremely high. Furthermore, the same case study also determined that it is easy to exploit these systems. Researchers found that they could control the entire BAS through several different methods. This can be as simple as removing a light switch or plugging a USB drive into an exposed USB port intended for maintenance; Figure 12 shows one of these USB access ports. Additionally, once researchers

gained access to the network, there was no encryption or authentication required. Hence, they could arbitrarily read and send commands to the entire system (Mundt, 2010).

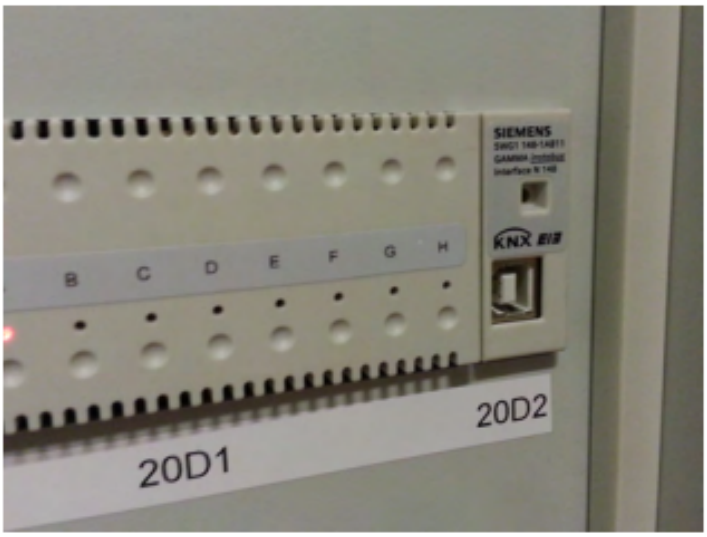


Figure 12: USB Gateway Installed for Ease of Maintenance (Mundt, 2010, p.5)

The study also found that none of the analyzed buildings had an individual or group of individuals specializing or in charge of security for the system (Mundt, 2010). In order to prevent such security vulnerabilities, projects should employ professionals to manage the security of the system during development and operation. This means providing security at all levels including encrypting traffic on the network, requiring authentication such as a username and password on the network, and having physical access points in secure places where only authorized employees can access them.

2.6.2- Smart Grid Vulnerabilities

Another commonly implemented part of smart initiatives is smart grids. Smart grids use modern communication techniques to perform power-flow control, provide energy reliability, and measure and provide consumption data (Yan et. al, 2012). Many of these systems 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 exposes 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 denial of service attacks. 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. Additionally, attackers can cause significant physical damage to transmission, distribution, and generation infrastructure through misuse of the power distribution system (Yan et. al, 2012).

Accordingly, when implementing the smart grid portion of a smart project, the designer must take appropriate steps to ensure the security of the system against various attacks. This requires the use of state of the art security technologies including, "public key infrastructure technology, trusted computing elements, [and] authentication mechanisms based on industry standards" (Yan et. al, 2012, p. 1007). The National Institute of Science and Technology (NIST) developed a set of standards that developers should follow in the creation of smart grid applications (Yan et. al, 2012). By following these standards, smart city applications can experience the benefits of a smart grid system while minimizing the risks of malicious individuals or groups destroying important infrastructure.

2.6.3- Internet of Things Vulnerabilities

Internet of Things (IoT) sensors are technologies that protect communication but are still prone to data and privacy compromises caused by security breaches. Two recurring issues are the accessing and exposing of 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). The risks and mitigation techniques for IoT sensors are nearly identical to that of Smart Grids and Building Automation Systems; the main difference is the scope of the risk factors. For example, if connections are not secure, this can lead to eavesdropping, and the interruption and manipulation of communications, as opposed to manipulation of physical systems or damaging of electrical grids (Mukundan et al., 2014). Unauthorized users breaching privacy could lead to criminals using sensitive information for malicious purposes. Additionally, IoT devices tend to be

simpler than Smart Grid systems and as such are easier to secure and have less severe consequences if they are hacked than a system which controls power grids.

2.6.4- Addressing People-Centric Problems

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 stem from a people-centric mindset. This means that the implementation should address problems that people are having and tailor technological solutions to meet their needs rather than beginning with a technology and trying to fit the users' needs to the implementation (Boykova et al., 2016). To improve livability, smart initiatives should address their residents' engagement, social challenges, infrastructure of the existing city, and possible technological challenges.

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). Jane Jacobs, an urban theorist, echoes this sentiment that technology researchers working in conjunction with social science specialists must address urban issues from the point of view of the people as opposed to forcing a solution upon people that might not improve their situation accessibility (Jacobs, 2012). When assessing the public's needs, the developer should consider of technology in the community. It is much harder to implement smart city initiatives if a city's population cannot engage and does not have access to the proposed technologies. It is important that this project does not widen social gaps, by catering to the needs of a certain social class, but instead addresses the issues of the community as a whole. 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 (Statista, 2016). When developing a smart city initiative, it is important that the project is beneficial to the entire population, and not just the people who have mobile phones with Internet connection. Additionally, it is important to investigate the social attitude towards a project that could inherently collect information from people as they go about their daily lives. Making the initiative both accessible to people who are

not technologically savvy or may not have access to certain technologies, as well as marketing the initiative well to avoid distrust of data collection from the public are both important to implementing a successful smart city project.

2.6.5- Retrofitting Infrastructure

When implementing a smart city initiative, ideally the planner would build a city from scratch rather than introducing new technology to a pre-existing city infrastructure. The challenge here is not "creating" a smart city, rather it is merging new technology with old infrastructure. Cities with pre-existing infrastructure introduce obstacles to retrofitting (Bélissent. 2010). Retrofitting is "work required to upgrade an aged or deteriorated building" (Nicolae; George-Vlad, 2015, p.77). For example, ʿAbd al-Muʾmin founded the stronghold of Rabat in the 12th century as a military fortress. Later, during the 17th century, the Moriscos, a group of people who the king expelled from Spain immigrated to Rabat spurring its growth into a major city. Today, Rabat is a world heritage site and the majority of the structures in the city, especially in the Rabat Medina date back as far as the 17th with a few buildings dating as far back as the 12th century from its days as a fortress (Abu-Lughod, 1980). Many of these structures are world heritage sites, meaning that the Unesco World Heritage Centre protects them from destruction (Unesco World Heritage Centre, 2018). Not only are these sites old and outdated in terms of technology, but they have historical significance preventing a contractor from ripping open a wall to place in the necessary electrical components. Retrofitting determines a contractor's approach to modernizing a building in order to integrate the type of technology that the service requires and ensure its success (Boykova et al., 2016). These restrictions can make the act of retrofitting protected areas challenging.

The Department of Energy, Information Engineering and Mathematical Models (DEIM) is an Italian organization that does work with energy conservation efforts. The Department of Civil Engineering and Architecture (DICAR) is an Italian organization that works with preserving historic architecture in Italy. Researchers at DEIM and DICAR conducted a study on techniques for retrofitting historic buildings in Italy with energy upgrades. These efforts faced similar issues to those in Rabat in that the infrastructure is old and requires preservation for cultural reasons. Researchers at these two organizations utilized several advanced techniques that allow for the addition of new infrastructure on old structures without damaging the original building. Some of

these techniques include internal and external wall insulation, roof, and window insulation, HVAC installation, and installation of Intelligent Control systems (Galatioto et. al, 2016). Figure 13 below shows an example of a retrofitted HVAC system with a centralized control system. This system contains the entire unit for controlling the HVAC system within the package enabling a user to attach it to a wall without needing to run cabling to a central control system. The Galatioto study details all the specifics of implementing these upgrades, and serves as an excellent resource for proceeding with any smart city implementation that might deal with old infrastructure in Rabat. These findings have the potential to allow for the implementation of smart city projects in Rabat without destroying historically significant buildings, leading to more legally and socially viable projects.

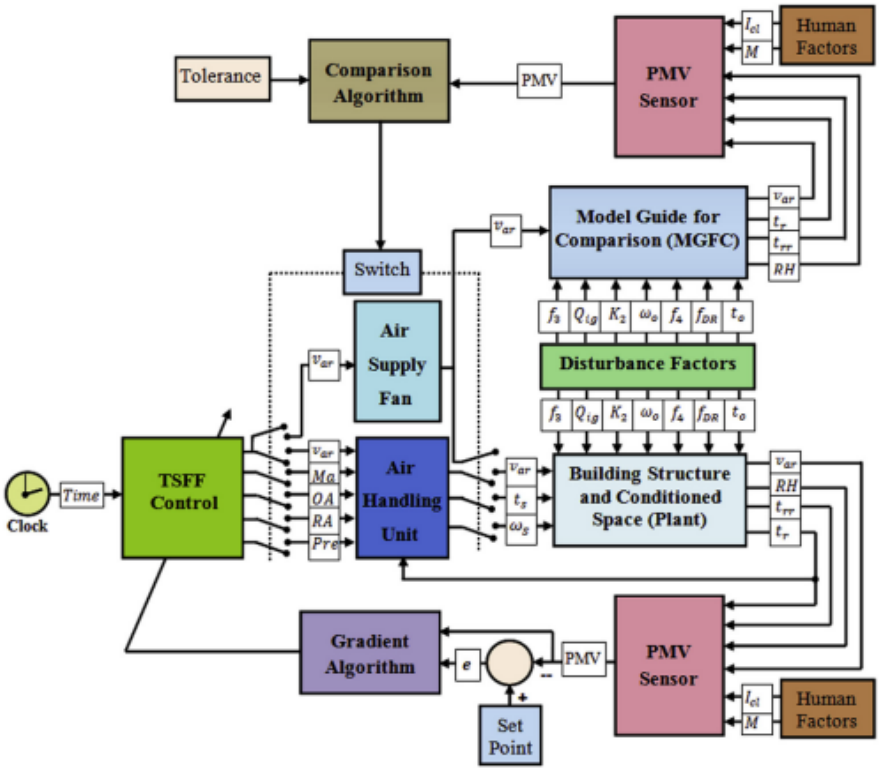


Figure 13: HVAC Block Diagram for retrofitting (Homod et. al, 2014, p. 664)

2.6.6- Discussion

While there are several challenges in implementing smart projects, this section outlines solutions to many of the common problems. Engineers and system designers should consider all these factors when planning for a smart implementation. 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, researchers can anticipate the advantages and limitations of the proposed improvement. By considering both the technological and social impacts and challenges of our proposed project in this manner, the team can design a feasible smart city project for ENSIAS to implement.

2.7 Summary

This chapter assesses a subset of the available literature surrounding transportation culture in Madinat Al Irfane, the definition of a smart city and its constituent pillars, smart mobility case studies, and the challenges faced when trying to implement a smart city into an existing location. Understanding the current mobility of our site and stakeholder's expert opinions play a vital role in the shaping of our smart city project. Smart city innovations encompass technological and social approaches; they are not mutually exclusive, and both aim to improve the citizens' quality of life. Analysis of two smart mobility case studies led to a better understanding about the process of implementation of a smart project, the importance of thoroughly testing the prototypes and involving the users' input. Despite the various technological and social challenges surrounding the implementation of smart technologies in cities, there are many good available solutions. The team used these key findings to formulate our methodology.

Chapter 3. Methodology

The goal of this project is to assess the feasibility of incorporating smart technologies into the transportation systems within Madinat Al Irfane in Rabat, 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 to develop a preliminary design review for a smart mobility initiative

Figure 14 below shows the flow chart of the sequence of our aforementioned objectives. This project's deliverable is a designed implementation plan of a smart mobility initiative in Madinat Al Irfane based on public opinion. Our project deals mainly with improving public transportation, which in the context of Madinat Al Irfane we define as the tramway system, the bus system, and taxis. Although walking does not fall into the category of public transportation, we include walking as part of the transportation system because it is a common mode of transportation in Madinat Al Irfane. In objective one we laid the groundwork for the rest of our project in determining the components of a good public transportation system through our comparative analysis and developing a rubric. In objective two, the team collected data which included our site assessment, heat mapping, surveys, and interviews. Objective three entailed the analysis of all the collected data and the production of our deliverables including a preliminary design review and a cost benefit analysis.

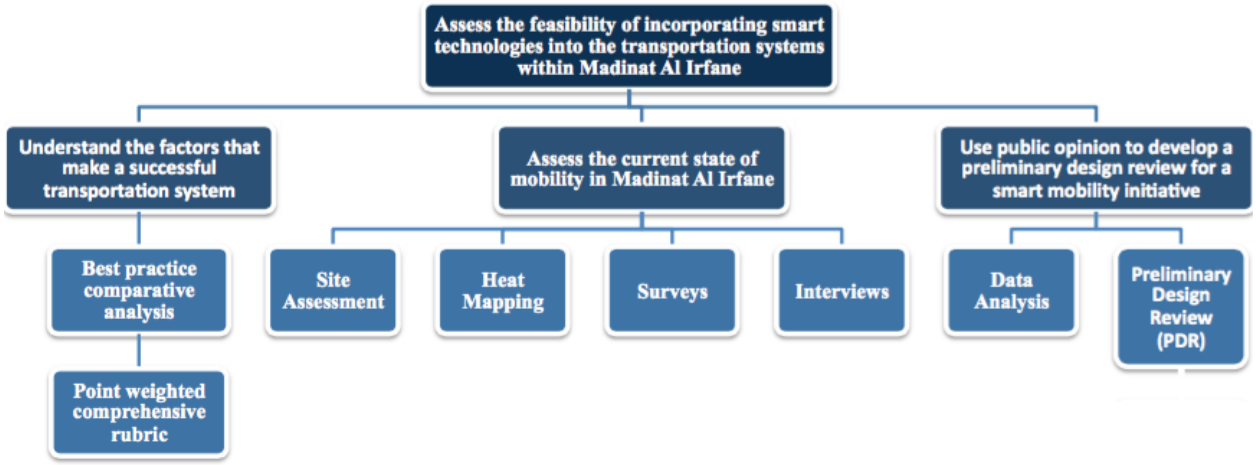


Figure 14: Flowchart of Methodology

3.1 Understand the factors that make a successful transportation system

The first step of our project was understanding the factors that make a successful transportation system. In order to determine improvements to the transportation system in Madinat Al Irfane, we needed to understand what makes the best systems successful. The group conducted a comparative case study on the top systems in the world to deduce their common metrics. From these common metrics and an existing, available rubric, the team created its own weighted rubric to evaluate any transportation system.

A comparative case study "cover[s] two or more cases in a way that produces more generalizable knowledge about casual questions - how and why particular programmes or policies work or fail to work" (Goodrick, Rodgers, 2014). A comparative case study involves the analysis and synthesis of the similarities and differences across two or more cases that share a common goal. The team conducted a comparative case study on three of the top-ranked transportation systems in the world that all share the common goal of transporting residents and travelers within their city.

The first step of our comparative case study analysis was to establish what would constitute a case. The team established that a case would be a city's transportation system that experts consider to be successful. The group began with researching the top transportation systems around the world from a broad search of transit systems. Initially, we utilized Google, various news

organizations and a research firm, ARCADIS, to determine the top systems. ARCADIS, an international design and consultancy firm, evaluated the performance of mobility systems in 100 cities around the world through an index based on 23 individual indicators, "each reflecting a component of urban mobility, from infrastructure spending commitment to affordability of public transport" (Batten, 2017, p. 1). As seen in Figure 15, we were able to use their evaluation to establish three cities that they consider to have successful systems.

The second step of our comparative case study was to find literature for each case. The team searched Google Scholar, academic journals, and databases looking for peer-reviewed publications that explain why each of the three cities' transportation systems is successful. We looked for papers that discussed the metrics of the transit system. The group defined metrics as the major qualities and specific components of the system that the team can measure and that consider the system triumphant.

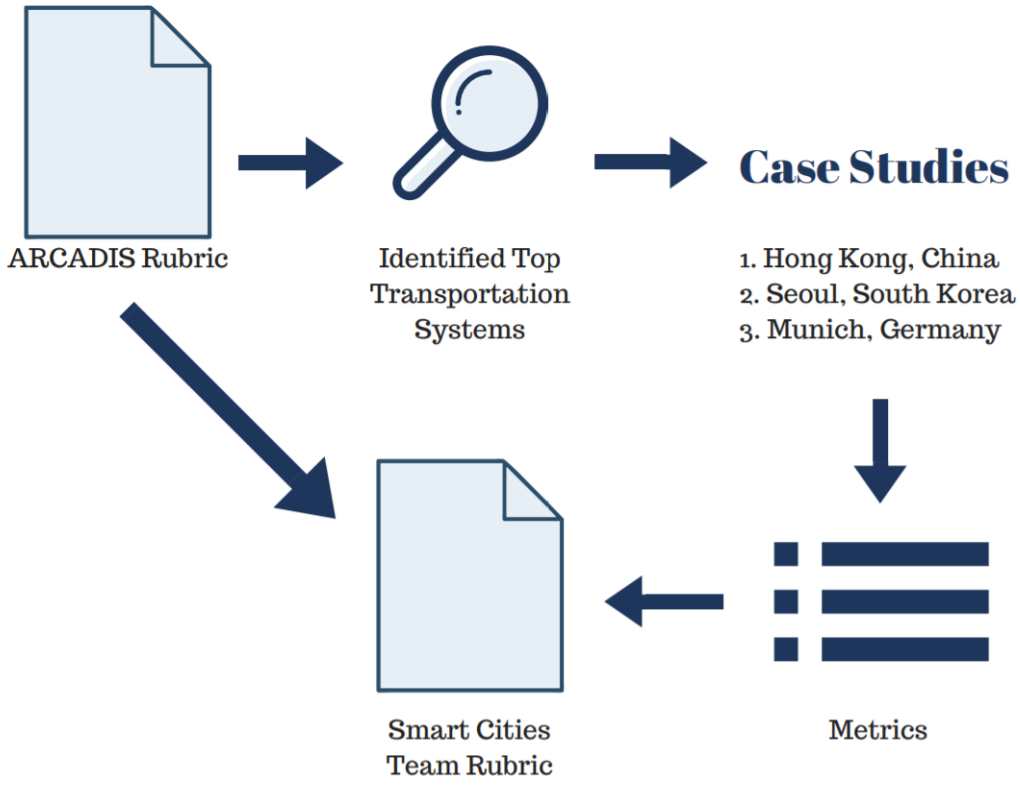


Figure 15: Smart Cities Rubric creation process

After finding adequate literature to evaluate each case, the group read and analyzed all of the publications. A team member read each paper and took extensive notes (see Appendix A) about the system, its major components and metrics. Once the researcher compiled the notes for the case, they read through the notes and bolded metrics that they felt made the system successful. The team then repeated this method for the two other cases. The group then looked at all bolded terms across the three case studies and determined the common metrics and major components for each system. These common metrics from the comparative case study formed the basis of the SCR.

While researching successful transportation systems the team discovered ARCADIS's 2017 Mobility Index, an extensive rubric used to evaluate the performance of mobility systems. The Mobility Index is comprised of 23 individual indicators to score a transportation system that are based on information from various publications, databases, government requests and subsidiary research firms (Batten, 2017). Our group used the metrics that we synthesized from the comparative case study analysis to form the basis for our rubric. Additionally, we used some of the weights from the ARCADIS Mobility Index, seen in Figure 16, to weigh the factors in our rubric. The SCR is a result of the research from the comparative case study analysis and some aspects of the ARCADIS Mobility Index.

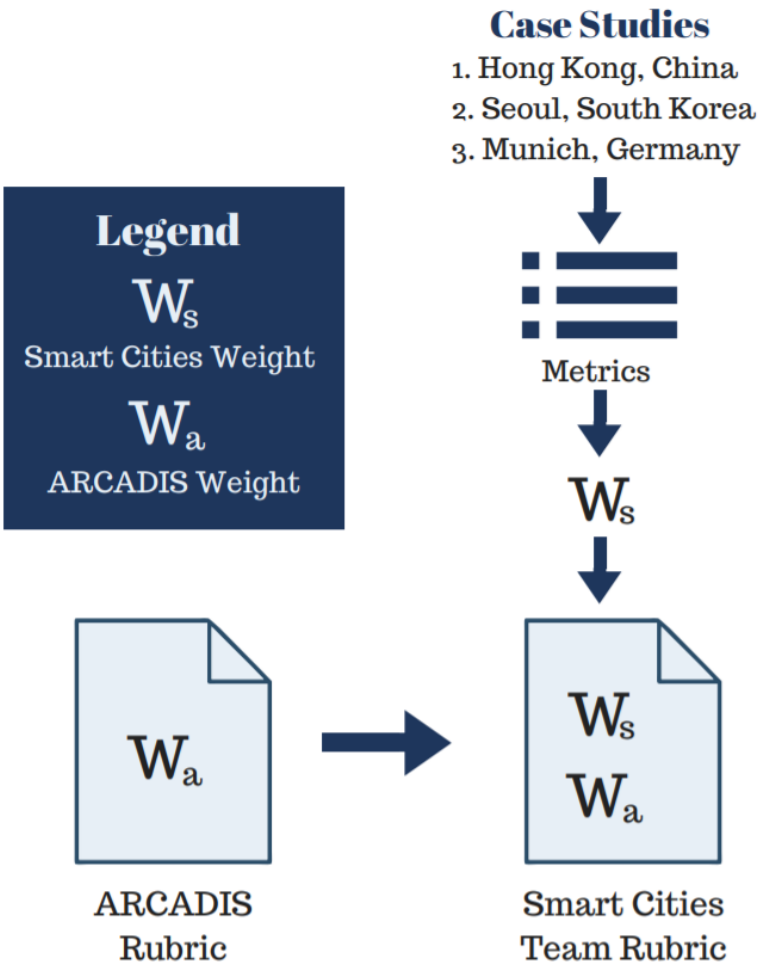


Figure 16: Smart Cities Rubric based off ARCADIS Rubric and determined metrics

3.2 Assess current state of mobility in Madinat Al Irfane

Site Assessment Mapping

There are many available maps of Madinat Al Irfane from Open Street Map (Figure 17), Google Maps (Figure 18), and the map acquired from City Hall (Appendix B) but all of them differ and contain different features. When comparing the two figures below, there is a noticeable difference in the marked roads. Google Maps, Figure 18, displays more possible routes in white than Open Street Maps. Whereas, Open Street Maps exhibits better building details.

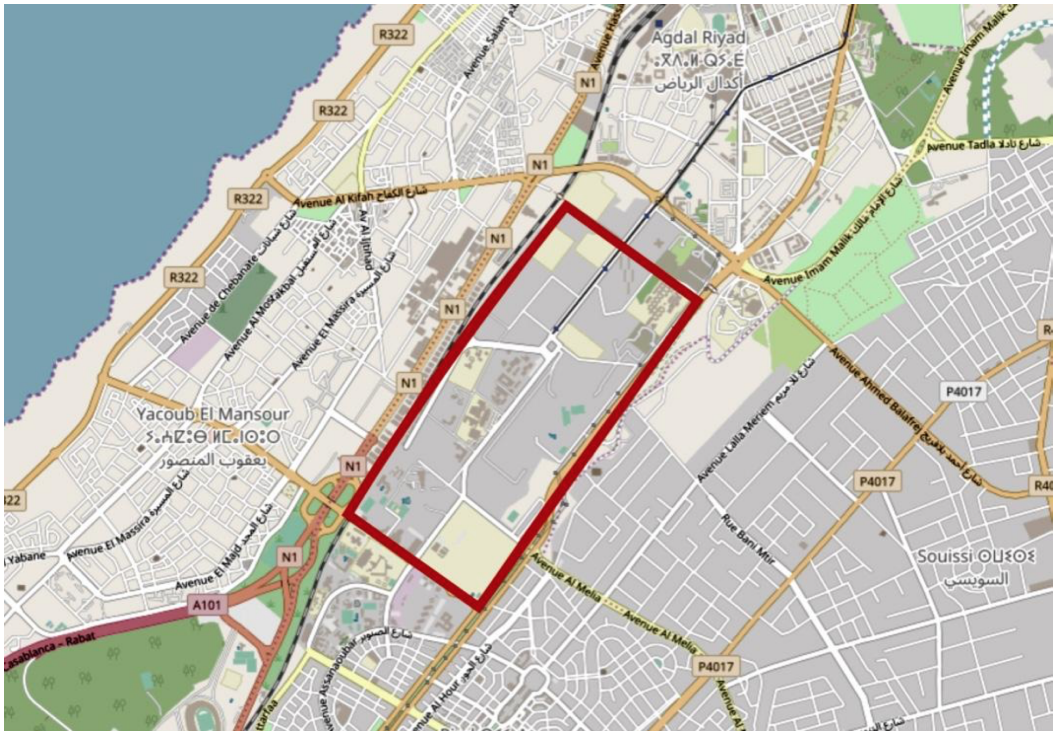


Figure 17: Madinat Al Irfane, Open Street Map (OSMF, 2017).

Figure 18: Madinat Al Irfane, Google Maps with Live Traffic (Google, 2018).

Studying all three maps lead to a better understanding of all possible mobility routes throughout the area. Figure 18 above from Google Maps provides live traffic updates. The live update provides varying shades of red and orange to indicate how severe traffic congestion is in certain areas. This information is helpful in understanding the congestion faced in private vehicle transportation. The team is not able to use a meshed model of all three maps and chose to utilize Google Maps for the rest of the project. The Google Maps version of Madinat Al Irfane has more mobility routes than Open Street Maps but the City Hall map has the most. Unfortunately, there is no possible mechanism for the team to edit the map acquired by City Hall and therefore the team cannot use it for our data collection in this objective. Out of the three options, Google Maps had the best components for the methods in this objective.

The team used both Google Maps and the map acquired by City Hall to navigate the area and evaluate all possible public transportation options with the comprehensive rubric created in objective 3.1. The team determined a number grade for each mode of public transportation using the weighted rubric by riding all public transportation systems in Madinat Al Irfane from different locations at peak hours in the morning, 7:00 A.M.- 9:00 A.M., and evening, 4:00P.M.- 6:00 P.M. Each available team member for assessment that day completed the rubric separately on the Google Sheets mobile application. This allowed for individual outlooks on each mode of transportation. In addition to the rubric, the team took notes and pictures during the period of travel to show personal experiences and to document any visible issues such as congestion or technical difficulties.

While completing the site assessment, the team noted any congested walking paths and the exact times to begin assessing the walkability of the area. The team noted these paths on the map as areas of focus. Additionally, the team spoke to randomly selected university students who experience this congestion first hand every day; we added all information received about congested paths and specific time frames from these conversations to our identified areas of focus in Madinat Al Irfane. In this method we took random samples from a subgroup of a population, the students from Madinat Al Irfane, a process known as stratified sampling (Berg, 2012).

At the recorded times, we used Global Positioning System (GPS) watches and their mobile applications (Nike+ and Garmin) to understand the human traffic patterns for commuting paths inside the boundaries of Madinat Al Irfane. The observers throughout the route of the area must assess the walkability within the exact areas of focus, determined in the process explained above, that the team labeled on the map that Google Maps provided. The two observers with GPS watches took notes about the route information using the observation table in Appendix C on the Google Sheets mobile application. The observation table collects data about the starting and ending location of the path along with the respective times and the control pace. Since everyone walks at different speeds, the team used the average pace for walking as stated by the Center for Disease Control and Prevention, which is 20 minutes per mile (CDC, 2018). The GPS watch helps regulate the control pace throughout the entire route by beeping when the observers walked faster than the set pace. In addition, the GPS watch gave information about the route traveled and the total route time.

After compiling this raw data, the team created a heat map using the online software Graph My Run. Graph My Run takes in the gpx files that the GPS watches outputs, and overlays the route the observers walked and the respective paces on Google Maps. A heat map, seen in Figure 19, is a visual to understand complex data surrounding mobility. In the heat map sample below, researchers in Beverly Hills executed this technique for biking routes in the area. The routes outlined in red show the most congested biking path and dark blue represents the next lower congestion level. By overlaying all raw data points collected using the observation matrix and GPS watch applications, the Madinat Al Irfane heat map indicates the areas of congestion and the most popular walking routes within the Madinat Al Irfane area. By identifying the bottlenecks, the team's goal was to improve the efficiency of mobility for the commuters and visitors of Madinat Al Irfane.

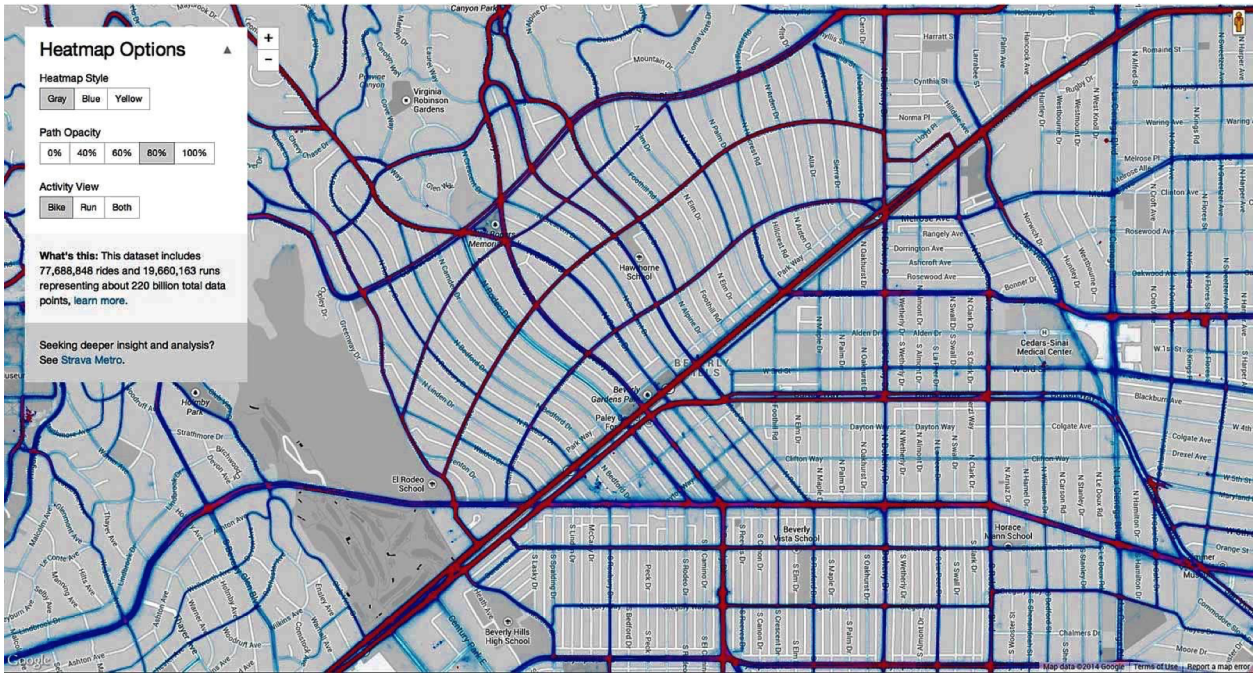


Figure 19: Example Heat Map of Beverly Hills (Elliot, 2014).

Surveys

Our team administered an anonymous survey utilizing two different distribution methods: household self-completion and intercept surveys found in Appendix D (Richardson, et al., 1995). In the household self-completion survey, the surveyee completes a survey without assistance; they "read and understand the question, mentally formulate an answer, and transcribe this answer onto the questionnaire form itself" (Richardson, et al., 1995). It differs from an in person survey in which the surveyor is in charge of reading and making sure the interviewee understands the questions. After the surveyee formulates their answer, the surveyor would transcribe it. An intercept survey differs in its method of administration. The team conducted the surveys while a subject was in the process of their daily activities (Richardson, et al., 1995). Surveys were available in both English and Arabic, to commuters, residents, and visitors of Madinat Al Irfane. The team obtained the translated survey in Arabic from our translator Mohammed Salhi, a student at ENSIAS. The team later analyzed and code the surveys once the respondents had submitted them. Coding refers to the process of labeling and compiling data in order to conduct a qualitative analysis.

The team designed the household self-completion survey in an application called Qualtrics, an online survey tool. In the household self-completion survey, the surveyee fills out the form without any assistance and can complete the survey at their own pace (Richardson, et al., 1995). Aiming to avoid any misunderstanding, our method included assessing the survey's effectiveness by pre-testing the questions with our classmates. We timed the pre-test survey in order to gauge the time needed to take the survey to inform our survey respondents. This pre-test enabled us to gather feedback on the questions asked in order to adjust the survey and eliminate any ambiguity.

The team emailed the online survey through a designated email alias provided by our sponsor; this email targeted ENSIAS students, faculty, and staff within Mohammed V University. Furthermore, Mohammed Salhi, a student at ENSIAS provided the team with contact information for several club presidents who agreed to share the surveys with their respective club members as well as their peers though social media. In order to not restrict our results to just engineering students, the team sent the online survey link to students of the I*nstitute National D'aménagement Et D'urbanism* (INAU), the Moroccan Institute, and *Ecole Nationale d'Architecture* (ECA), the national architecture school. The Dean of ENSIAS, our sponsor, introduced our team to these

universities. Additionally, the team coincidentally met a student at INAU who was eager to distribute the online survey link to the school's private Facebook groups.

In order to carry our intercept survey, we interacted with a random sample of students at Mohammed V University. If they had not already taken our survey, which we determined by asking them, then we distributed our intercept survey that contained the same questions on paper as the household self-completion survey, found in Appendix D. Mohammed Salhi from ENSIAS at Mohammed V University served as our translator while students completed the survey. In order to keep a complete electronic log of our collected data, we transcribed the intercept surveys into Qualtrics. In order to have a extensive data set, the intercept surveys aided in gathering a cluster sample which is a naturally occurring sample group within Mohammed V University campus. From that sample group we selected random students or faculty to participate in our survey (Teddlie, et al., 2007). In these densely populated areas within Mohammed V University, our team divided into pairs and rotated turns in interviewing, always having one female and one male so the surveyee was comfortable. In order to conduct the intercept surveys, Mohammed Salhi served as a translator in order to approach any subject on site. Our team introduced ourselves, asked if the subject had taken the survey before to avoid resampling of the population, explained the purpose of our survey and gave the subject the option to participate or decline the survey.

The survey includes twelve questions; seven are selection-based and four are open response. The surveyees had the option to include their email if the project's results interested them. Additionally, our team prevented the subjects from taking the survey more than once by enabling an option in Qualtrics that placed a "a cookie on their browser when they submit a response. The next time the respondent clicks on the survey link, Qualtrics will see this cookie and not permit them to take the survey" (Qualtrics, 2018). This does not take into account surveyees responding to the survey on another device, but the odds of a surveyee re-taking the survey are negligible. Our team collected the participants' demographic information in question one of the survey by asking their role within Madinat Al Irfane; we used this information to categorize and separate group responses. This survey gathered information about the movement of residents, commuters, and visitors around Madinat Al Irfane. Additionally, the survey questions addressed the current transportation system, how people travel to Madinat Al Irfane, their transportation cost, and their destination.

Interviews

After ascertaining the factors that make a successful transportation system from objective one, the team further investigated our key stakeholders' opinions regarding the public transit system. Our key stakeholders are: the School of Urban Planning, the School of Architecture, City Hall, and Mohammed V University. Due to time constraints, the team was not able to interview a representative from the City Hall as we planned. The project team chose to conduct in person semi-standardized interviews (see Appendices E-G). This technique allowed delving into more topics based upon the order of set questions, to better understand their valuable opinions (Berg, 2012). Since many of our stakeholders are specialists within a variety of fields, we received a diverse data collection within the pillars of smart city technologies.

We formed sub-teams of two or three group members. Each sub team contained a common member for two of the interviews; this allowed for our team to have a rough overview of the similarities amongst interviews prior to data analysis. The first interview occurred on February 6, 2018 at 5pm, with student body president and Treasurer Mohammed Amine of Mohammed V University. The interviews at INAU and ENA both occurred on February, 16, 2018 at 10 am, causing the team to deviate from the original plan. Two members attended the interview of Professor Mohamed Hanzaz, from INAU. The other three team members attended the ENA and had the opportunity to interview Professors Reddad Erging, Khalid El Harrouni, and Hansour Majid. Having many parties present during this interview, it quickly turned into an open discussion. These interviews provided some understanding of all of our stakeholder views pertaining to smart technologies, the current transportation systems, acceptability of smart transportation systems, and possible obstacles. We tailored every question the team asked within the interview for the specific interviewee. The team had a different translator for each interview; this was due to the availability of different translators at the interview times. Mohammed Salhi a student from Mohammed V University served as the translator for the interview of student body members. Professor Kharmich Hassan, an English professor from ENA, served as the translator for the ENA interview, and Professor Idrissi, an Economics professor from INAU served as a translator for the INAU interview. Translators attended the interview along with the group members, and if necessary facilitated the conversation between interviewer and interviewee. Each member served a role within the interview, either questioning, note taking or recording. We asked the questions in order of importance to respect the interviewees' time.

Once put into contact with our stakeholders by our sponsor, our team emailed them and found a time to meet. Prior to conducting the interview, the sub-team members requested permission to record the interview. The recording allowed the team to capture exactly what the interviewee stated, and assisted in the process of the transcription of the interview. The interview began with the team members introducing themselves and explaining the project. This semi-structured communication between interviewee and the interviewer was standard for every interview.

3.3 Use public opinion to develop a preliminary design review for a smart mobility initiative

After completing all planned data collection from the public, the team processed all raw data for analysis. The team entered any paper intercept surveys into Qualtrics to make data analysis easier and transcribed all interviews into a separate Excel file.

The data collected from the intercept and household self-completion surveys captured both quantitative and qualitative answers. Qualtrics automatically analyzed most quantitative data. After this took place, the team then exported the data to a Comma Separated Values (CSV) file to further analyze and make charts in Excel. On some questions, the team had to do further analysis like finding the mean, median, and mode and determining out of the three, the best form to use for the purpose of each analysis. The team converted all qualitative data into a quantitative format to allow ease of analysis. The team used the technique of coding to achieve this format. One team member exported the raw data from Qualtrics into a single Excel spreadsheet and broke up every response into cohesive thoughts or sentences for coding. This spreadsheet set up is a systematic filing system, and allowed the team to easily see any overlap in responses and determine any other categories to sort the data into (Berg, 2012). Team members performed all the coding by hand in Excel by separating the data into distinct categories that captured the themes of the qualitative data (Basit, 2003).

The process of coding begins on the first raw data entry in the CSV file where the researcher can deduce a theme from the response. For example, our first response for question ten of our survey which asks the surveyee what in their opinion is the biggest challenge for the transportation system was “Not enough bus lines”. A city not having enough bus lines fall under the theme of availability. The team member then put Availability into the coding legend, given the code A and the color green. The researcher repeated this process for every response creating a

coding legend with nine different themes. Figure 20 below displays the coding legend to determine the theme of the response.

Theme	Color	Code
Congestion		J
Speed		D
Management		M
Price		P
Availability		A
Safety		S
No problem		NP
Coverage		C
New system		NW

Figure 20: Theme of the Response Coding Legend Used for Qualitative Survey Analysis

The team noticed many responses had two halves, both a focus about a certain aspect of the system and the certain system of complaint. We created another coding legend that allowed for responses to not just have a team assigned a code on the aspect of the system but also the system itself. Having this second coding technique allowed the team to divide the responses up by the system the respondent discussed the most and helped indicate which system the respondents felt warranted the most attention first. In the same example above: “Not enough bus lines”, the team would highlight the phrase ‘not enough’ in green and code one would receive an A, and the team would color ‘buses’ in magenta and code two would receive a B. Figure 21 showcases the second coding legend below for determining transportation systems of attention.

Theme	Color	Code
Tram		T
Bus		B
Taxi		X
Private car		C
Not specified		NS

Figure 21: Second Coding Legend for Determine Transportation Systems of Attention

Code 1:		
Theme	**Color**	**Code**
Congestion		J
Speed		D
Management		M
Price		P
Availability		A
Frequency		F
Safety		S
No problem		NP
Coverage		C
New system		NW
Problem in Rabat		PR
Solution		SO
Expected Smart City Outcome		E
Actual Smart City Outcome		AC
Social Impact		SI
Growth		G
		Sum

Figure 22: Coding legend for the interviews

In order to develop this legend, the team transcribed each interview and read through it. Figure 22 above displays the legend. Many of the themes found in the survey coding were applicable and seen throughout our interviews. The team manually coded the interviews using Excel, which can be found in Appendices N-P. As we analyzed the interviews, the team extracted pertinent excerpts which we felt the most relevant. However as different themes started to appear in the interview transcripts, the team added a new set of codes to the list. The codes represented common viewpoints that each stakeholder could share, pertaining to smart city initiatives and the transportation system within Rabat. For example a respondent mentioned the idea of problems with implementing smart city projects in Rabat, so we created the "Problems in Rabat" category, gave it the pink color shown below and the code PR. Any time a respondent mentioned the idea of 'problems with implementing smart city projects in Rabat', we highlighted the section the same pink color and labeled it with the code PR. As well, the team assigned color for each transportation mode assessed. Figure 23 shows the coding legend of the urban transports. When the team finished

data analysis, we collected and organized public opinion into themes allowing the team to draw conclusions about a recurrent problem and address it in the Preliminary Design Review (PDR).

Code 2:		
Theme	**Color**	**Code**
Tram		T
Bus		B
Taxi		X
Private car		C
Not specified		NS

Figure 23: Third Coding Legend focusing on Smart Cities

A preliminary design review consists of the four beginning steps of the engineering design process. Experts define the engineering design process as "systematic, intelligent evaluation of specifications whose form and function achieve stated objectives and satisfy specified constraints" (Dym, 2012, p.16). This process is a tool used to strategically plan out the entire engineering project, while also leaving it sufficiently flexible for the incorporation of revisions. Figure 24 depicts the entire engineering design process. Figure 24 displays the preliminary design process on the left, which the project team focused on for this objective. The final step of the PDR is an in-depth conceptual design to prepare for implementation of an engineering project. The PDR contains facilitates effectiveness and feasibility and excludes selecting scheme(s) such as specific technologies, algorithms, and the materials needed (Dym, 2012). The conceptual design of the preliminary design review is open ended, liable to change, and does not specify technical details.

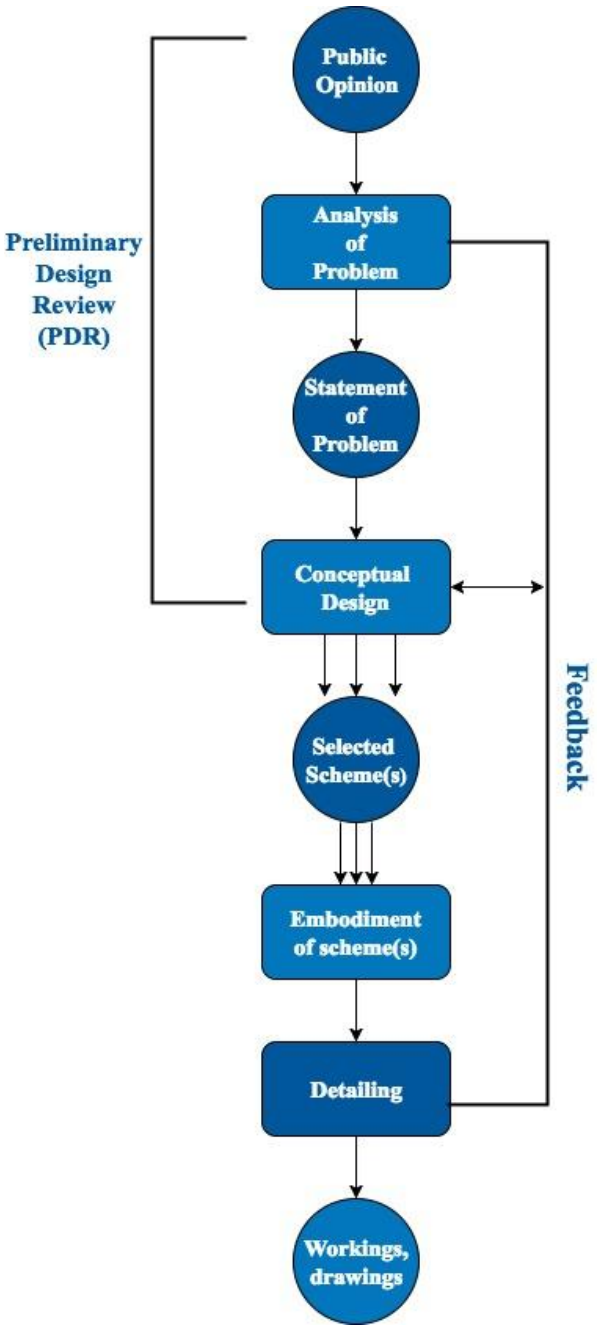


Figure 24: Engineering Design Process Overview

Using the collected data from the public, the team chose a repetitively voiced problem and researched smart mobility initiatives that might possibly improve the identified issue. Moving forward with one of our researched initiatives, we reviewed the necessary changes needed to tailor the project to Madinat Al Irfane. Any preliminary design review should attend to the political, cultural, and social barriers that may vary from country to country because the implementation

process is not universal, but rather context-dependent (Wiley et al, 2013). Every decision made throughout our preliminary design review pertained to preserving Morocco's heritage. Undergoing the process of tailoring the initiative for a specific region of implementation allows for a higher acceptance rate from the public when the researcher completes the entire engineering design process. The team finishes the last step of the PDR, the conceptual design, when the team adapts the smart mobility initiative to meet the public's needs. The conceptual design also demonstrates the project's feasibility.

On completion, the team presented the preliminary design review to ENSIAS with a conceptual design of a feasible smart mobility initiative to ENSIAS that the administration at Madinat Al Irfane could implement. This informed ENSIAS about the feasibility of the proposed project, giving them the option to move forward with a full engineering design process.

3.4 Estimated timeline

The Gantt chart shown in Figure 25 below demonstrates the timeline followed to complete each section of our methodology including researching, gathering raw data analysis of results, suggesting recommendations, weekly presentations, drafts, and final presentation reports.

During the first two weeks, the team conducted research on successful and unsuccessful transportation systems. The site assessment took approximately four weeks, during which the team learned about Madinat Al Irfane by building the heat map of congested walking routes along with evaluating the public transit system using the weighted rubric. In week two during the Mohammed V University break, the team administered household self-completion and intercept surveys to students to increase the amount of responses; this lasted into the fifth week, in addition to surveys administered to INAU and ENA. In the fourth week the team started to interview our key stakeholders.

After the data collection phase, we analyzed the information and completed a preliminary design review demonstrating the feasibility of the smart cities project recommendation. In the final weeks of the project the team created a finalized report and presentation on our findings for our sponsor at ENSIAS.

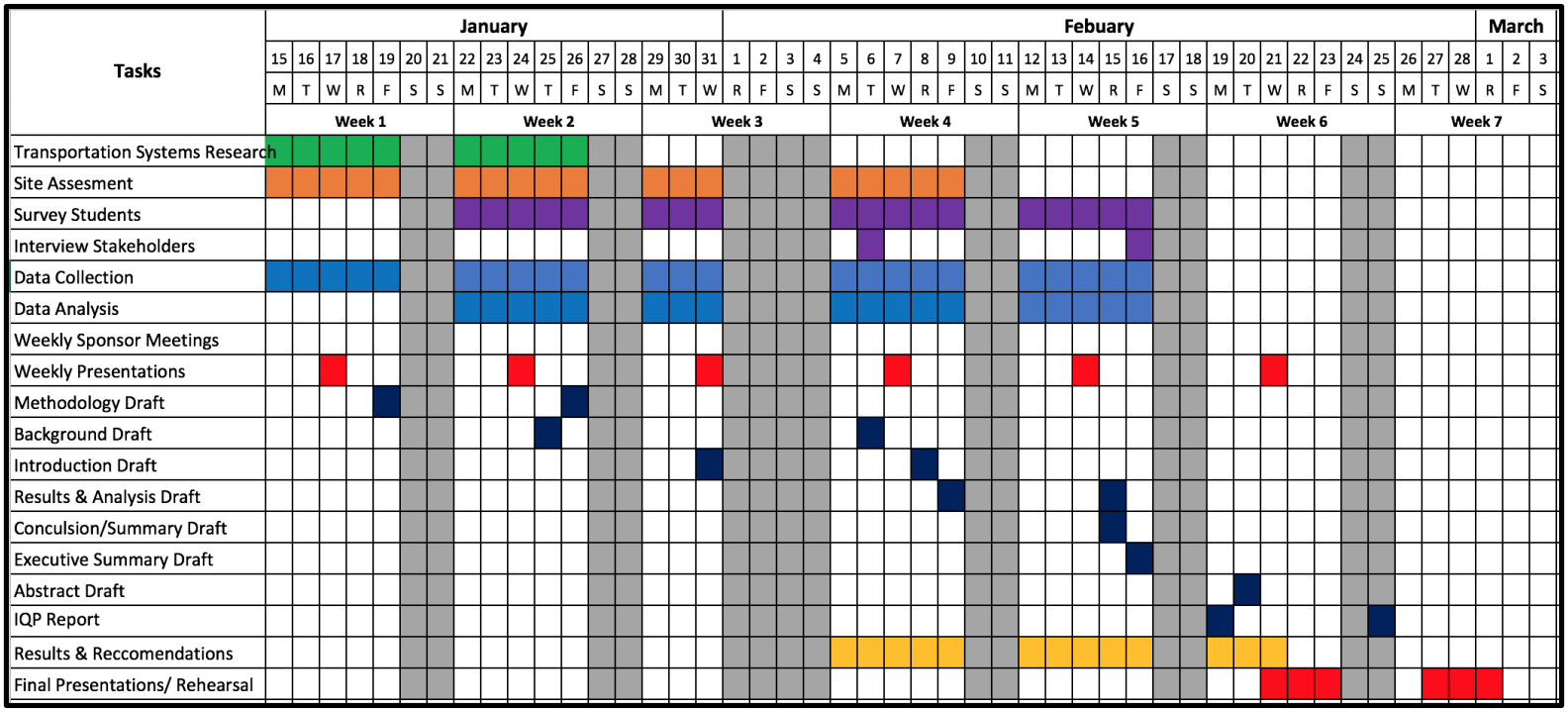


Figure 25: Gantt chart showing timeline while in Rabat, Morocco

Chapter 4. Results & Analysis

This chapter highlights the data our team collected and analyzes these findings in order to propose a set of recommendations for the improvement of the public transportation system in Madinat Al Irfane. Sections 4.1, 4.2, 4.3, 4.4 and 4.5-4.7 present the data collected through site assessments, surveys, and stakeholder interviews. The site assessment incorporates a best practice comparative analysis that aided in the shaping of the rubric used to evaluate public transportation for the commute into Madinat Al Irfane. This chapter also includes an analysis of walkability around Madinat Al Irfane, which the team completed through heat mapping. The following sections of surveys and stakeholder interviews provide an insight into the public transit system through the results of expert and public opinion. The public opinion, collected through surveys, provided qualitative and quantitative data to guide the direction of the recommendations. The interviews provided a better understanding of the implications of smart transportation innovations from an academic viewpoint. Lastly, section 4.7 presents our recommendations using public opinion to develop a preliminary design review for a smart mobility initiative in Madinat Al Irfane.

For the site assessment analysis section, the research team evaluated the transportation systems and walkability in Madinat Al Irfane. Our team sought to understand the metrics that make a successful transportation system and compared and contrasted top transportation systems by performing a best practices comparative analysis. The metrics found in the aforementioned analysis aided in the creation of an evaluative rubric that aimed for maximum objectivity and that measured the current public transportation systems in Madinat Al Irfane against the top transportation around the world. Alongside the transportation evaluation, this section assesses walkability through heat mapping. The team used a GPS watch to create a heat map that tracked the different routes taken and the recorder's walking pace. The goal of this walkability exercise was to pinpoint areas of congestion in Madinat Al Irfane.

4.1 Best Practice Comparative Analysis

The first objective of this project is understanding the factors that make a successful transportation system. The team conducted research into transportation systems, and analyzed the established top transportation systems in the world. Using these systems as examples the team performed a best practices comparative analysis, and created a weighted rubric to evaluate the different transportation systems in Madinat Al Irfane. The SCR does not take into account the

location of the city or the cultural aspects, but rather is intended to be an objective tool to evaluate any given system based upon peer-reviewed research. We developed the rubric shown in Appendix I, to assess the different transportation systems in Madinat Al Irfane. The team rode the tramway, bus and taxis in order to individually fill out the SCR.

The team's rubric has three main sections: people, planet, and profit (Batten, 2017). We adopted these three sections from the ARCADIS rubric. The people category attempts to rate the quality of life for a city's commuters, the planet category evaluates how the transportation systems impacts the environment and the profit category looks at the costs of the system for the rider and determines if the costs create a financial gain for the company. The team rode the tramway, bus, and taxi system and used the SCR to evaluate the systems and give each component system an average overall score.

This investigation began by doing a broad search in transportation systems around the world through a standard Google search. After learning which cities researchers ranked as the best transportation systems, the next step was to search peer-reviewed journals and publications that outlined details of these transportation systems. The top three transit systems the team identified are Hong Kong located in China, Seoul, South Korea, and Munich, Germany. In our best practices comparative analysis, each of these cities serve as a case study to understand the metrics that make a successful transportation system.

We researched existing weighted rubrics for transportation systems and discovered the 2017 Sustainable Cities Mobility Index created by ARCADIS, a global design company. The firm developed a "framework to evaluate the social and human implications of urban transport, as well as the environmental impacts and aims of a city's mobility system" (Batten, 2017, p. 3). The company used this framework to evaluate transportation systems around the world according to three main sections: people, planet and profit. A city receives a score for each category based on a series of sub factors and a city's overall transportation score is equal to the average of their score in the three pillars. For example, Copenhagen, Denmark, has scores of 58.4% for the people section, 74.9% for the planet section and 49.8% for the profit section. The average of these three values is 61% which gives the city an overall score of 61%. ARCADIS evaluated major transportation systems around the world using this mobility index and determined Hong Kong, China has the highest overall score with 65.3% which ranks it first in the world. Closely behind,

ARCADIS gave Seoul, South Korea a score of 64.4% putting it in fourth place and Munich, Germany 14th place with a score of 59.5%.

4.1.1 Hong Kong, China

Hong Kong's public transportation system services an estimated 12.6 million passengers every day. The Mass Transit Railway, along with ARCADIS global research firm, recognized it as the top transit system in the world (Loo, et. al, 2010). On a daily basis, 90% of all trips made by residents, commuters, and visitors are on the public transit system (Loo, et. al, 2010). There are multiple modes of transportation within their model system including: railways, buses, minibuses, taxis, ferries, trams, and private vehicles. ARCADIS gives Hong Kong an overall score of 65.3%, which is an average of its score awarded for the people, planet, and profit section: 80.5%, 55.5%, and 60% respectively. The profitability score is for the MTR organization that runs the transit system in Hong Kong. In 1999, Hong Kong legislation demanded that the railway increase usage by 50% by the year 2016 (Tang, Lo, 2008). At the same time they passed laws enforcing freedom of choice for transportation, incentivizing the creation of competitive transportation systems. In order to stop the competition from getting out of control they also passed laws to regulate the addition of routes and vehicles by companies. Through these regulations and subsidies, the government was able to unite the transportation systems under the MTR Corporation and the Ministry of Railways. This unity allowed for the connection of services, increase in efficiency, the creation of a unified payment system, and smart information systems that keep users informed about critical information such as estimated time of arrival and service announcements (Tang, Lo, 2008).

To maximize efficiency and minimize transfer time, the Department of Civil Engineering at the University of Hong Kong and the University of Singapore conducted a study to create a mathematical model of the bus system. From the mathematical model, the researchers learned that the problem is a "mixed integer nonlinear programming problem and a heuristic method is required to solve the problem efficiently" (Szeto, Wu, 2011, p. 153). This means that there are several non-linear factors that they use to get a good approximation of the optimal solution because the actual optimal solution is implausible to find. Through their mathematical analysis of the problem Szeto and Wu were able to make recommendations for the frequency of the stops, the route paths, and the location of the stations to maximize traffic flow and minimize distance and time between

transfers. Hong Kong's Mass Transit Railway Corporation (MTRC) used these findings in the planning of their transit system.

In order to improve rider experience and make information more easily accessible, MTRC hired the ROCTEC Technology Ltd. to implement a live information system. The live information system uses liquid crystal display (LCD) screens, which are in buses, trains, and trams and are visible in transit stations. The LCDs on the various forms of public transportation are versatile, and display upcoming destinations as well as important notifications. The LCDs in the stations display the live estimated time of arrival for the next bus, train or tram in addition to issues that might arise in the transit system.

Since the Hong Kong legislation was responsible for the planning of the tramway and heavily subsidized the bus system, this served to unite both of these forms of transit in terms of policy decision. This allowed for the government to easily enact a universal payment method that worked among all the forms of public transit under their control. This payment method is the Octopus Card. The card, shown in Figure 26, is reusable so users can recharge in many physical locations as well as online and the same card can pay for several forms of public transportation including the tram, the bus, and the taxi system. Additionally, several convenience stores accept the Octopus Card as a valid form of payment (Chau, Poon, 2003). The Octopus card makes the purchase and validation of tickets easier for users. There is no need to carry exact change since the card readers simply adjust the balance upon reading the Octopus card. Having this centralized form of payment speeds up payment. Namely, users can just tap their card to the contactless readers to both pay and receive a virtual ticket.

Figure 26: Octopus Card (Left) and its scanner on the bus (middle) and at a convenience store (right) (Mass Transit Rail Corporation, 2018; Hong Kong, 2016; The Travelling Trini, 2013)

Hong Kong's transportation system excels in prioritizing the user, yet fails at not taking into account the impact of transportation on the environment. ARCADIS gave Hong Kong a score of 56% in the planet category. Hong Kong is actively trying to implement electric vehicles and buses yet faces many hurdles in the process. ARCADIS scored Hong Kong at 50% for electric vehicles incentives. The Environmental Protection Department (EPD) in Hong Kong recognizes that the air quality is an issue. The EPD reports, "Motor vehicles, especially diesel vehicles, are the main sources of these pollutants at street level in Hong Kong" (Hong Kong EPD, 2018), justifying Hong Kong's score of 65% for air pollution. These pollutants have a direct impact on the user's health, but the reduction is not a high priority for the government. Hong Kong is making efforts to decrease these emissions as seen by the EPD initiative to promote green technology on their website.

Overseeing the largest number of passengers per day on their public transit system, 12.6 million users, Hong Kong's systems have many factors which promote ridership (Loo, et. al, 2010). As their transit system is very affordable for the average citizen, Hong Kong merited 70% for this category. Affordability is a key factor in the popularity of the system. The affordability factor supports the 100% ranking of economic opportunity for this system by ARCADIS because the system is very financially sustainable. With an average score of 60% in the profit category, there is room for improvement in categories such as utilization of the transport system and efficiency of road networks.

4.1.2 Seoul, South Korea

Seoul, South Korea, has an advanced public transportation system that serves approximately eight million passengers a day (Pucher, J., & Kurth, S., 1995). The Mobility Index gave Seoul an overall score of 64.4% with its people, planet and profit sections scoring 69.6%, 74%, and 51.3% respectively. In early 2000, the majority of Seoul's public transportation systems consisted of a series of bus systems all operated and controlled by private companies who determined the routes and did not coordinate with any other bus systems. This was a major pitfall of the system because riders would have to wait long periods to transfer between different bus companies and have to pay separate fares. In 2004, Seoul Metropolitan Government completely revamped public transportation with a reform to the system in attempts to reduce congestion, pollution, and improve the quality of services. The reform brought all of the private services under

one ownership, allowing the government to coordinate all bus systems. Today, Seoul's public transportation consists of 327.1 km of subways, 7,485 buses and 72,181 taxis. The system ranks highly in the world because of its connectivity, efficiency, simple payment system and clear presentation of information.

Seoul's public transportation system coordinates and connects all of its services so riders can seamlessly transfer between the subways, buses, and taxis. In public transportation, connectivity is "the schedule, speed, operational capacity, urban form characteristics, and is an influential element of the image of any transit network" (Sabyasachee et. al, 2012). Seoul's transportation system incorporates a connected layout, with the main goal of bringing all of its public transit services together for convenience to the rider. The government strategically built bus transfer centers, seen in Figure 27, at key locations around the city, allowing riders to switch between different types of buses with ease. The different types of buses can be easily distinguished by the rider because of the color coordination the bus system utilizes. The bus company painted the buses specific colors to correspond to the distance the bus travels. The blue buses are for long distances and connect outlying suburbs, whereas the red buses are express long distance allowing for quick commutes. The green buses are for local services, and yellow buses travel within the city itself (Song et. al, 2015). To enhance the efficiency of all these buses there is a median bus lane. Figure 27 depicts the median lane in red, which allows for buses to get from point A to point B in a quick manner without experiencing any private vehicle congestion. The high connectivity of the system leads Seoul to earn a 100% for rider connectivity on the ARCADIS rubric contributing to its overall score in the people category.

Figure 27: Bus Transfer Centers in Seoul, South Korea (Seoul Public Transportation, 2014).

The Transport Operation and Information Service (TOPIS), was able to reduce transfer time between services from 12 minutes to 3 minutes and the new layout reduced average transfer distances from 300 meters to 50 meters (Seoul Public Transportation, 2014). Seoul Metropolitan Government made commuting easier by reducing the wait time and minimizing the distances they have to walk between services. People commuting to work and school want to do so in the shortest time possible. Connecting the services and reducing wait time frees up rider time and improves their quality of life. Seoul's synchronization of services contributes to its high score of 69.6% for its people pillar.

In 2004 with the redesign of the system, Seoul introduced a new integrated transit card that allows riders to pay for the various services with one smart card. Most systems around the world have payment systems where commuters have to pay individually for each trip and each type of transit service. Seoul's integrated system removes these complications by providing users with a single card, T-money, based on the total travel distance. Figure 28 below shows that the single T-money card works as a payment method for the subway, bus and taxi. This convenient payment system yielded the city a score of 100% for Modal split, the total trips taken by public transport, which is a major factor for the systems success.

Figure 28: The subway, bus, and taxi all accept the T-money card for payment (Seoul Public Transportation, 2014)

Seoul's government presents live information to users through TOPIS. The system, seen in Figure 29, is an "integrated transportation management center that collects information from and provides information to the city's Road Traffic Management System, Bus Operation Management System, Unmanned Enforcement Systems, Traffic Broadcasting System and Seoul Metropolitan Police Agency and exerts comprehensive control and management of traffic situations in Seoul" (Seoul Public Transportation, 2014, p. 24). TOPIS tracks and coordinates all services to facilitate connectivity. The system collects information regarding bus locations, traffic congestion, accidents and then presents the data in an easy to understand format to users. For example, TOPIS provides bus passengers with a wealth of information, such as the predicted bus arrival time, congestion due to accidents and the predicted time of arrival of the nearest subway (Lee, 2015). Providing live information in an easy to understand format to users is a crucial component of a successful transportation system. Passengers want to know when their transit vehicle is going to arrive. By providing this information in near real time, TOPIS makes the most up to date information available to its riders. ARCADIS gave Seoul a score of 63.2% for transport applications and digital capabilities, which pertains to accessibility of information.

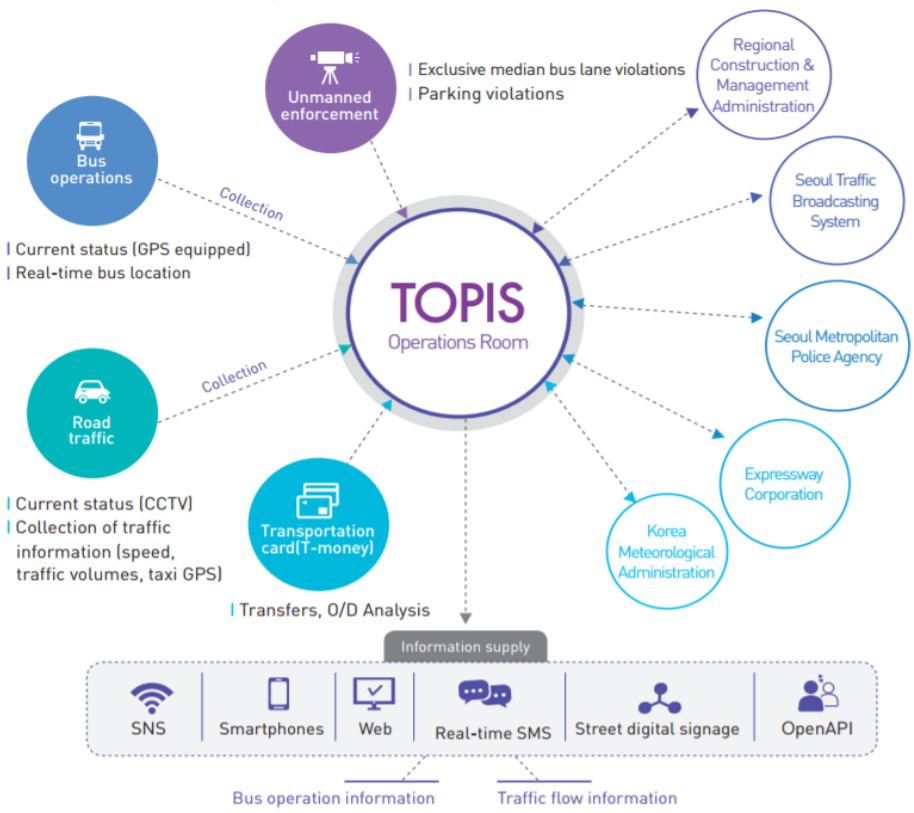


Figure 29: TOPIS system monitors and controls the transportation system in Seoul, South Korea (Seoul Public Transportation, 2014)

In 2004, the city purchased a fleet of new bus models. These buses are either electric or run on compressed natural gas (CNG), both are free of exhaust and reduce noise (Song et. al, 2015). These new buses helped increase air quality for citizens by reducing the pollution from buses. ARCADIS ranks Seoul's planet section 11th in the world, with a planet score of 74%. The city scored a 68% for air pollution on ARCADIS and a 91% for greenhouse gas emissions, with the high scores indicating a lack of air pollution and greenhouse gas emissions. Seoul also received a 100% within the category of electric vehicle incentives due to this bus reform. The work Seoul has put into their transportation system to incorporate green technologies to reduce the pollution has a direct impact on its citizens' quality of life.

A lot went into the reform for Seoul's transportation system, including a large sum of money from the government, which led to the system being ranked fourth in the world. In 2005,

one year after the reform, the city was 6 billion dollars in debt. About 80% of this debt came from the transportation reform (Pucher et al, 2005). This is the main reason for Seoul receiving a score of 36.5% in public finance along with a score of 67% for affordability in the profit section.
In order to pay off this large debt, ticket prices are now higher. With the efficiency and high technological design of the system the future looks bright for economic opportunity, receiving a score of 70% from ARCADIS. Overall, Seoul received a score of 51% in the profit section. The reform required a large investment from the city, however their efficient system will attract more ridership and eventually pay off its remaining debt.

Seoul's public transportation system is one of the largest in the world, carrying approximately 8.4 million passengers a day, which is twice the volume of New York City's subway system (Song et. al, 2015). This system is able to serve so many passengers daily because a central system connects their services; it is very efficient in terms of wait time, has an easy payment method that works across services and presents live information about the status of the services. These key metrics demonstrate why there are so many people riding their transit system. The ARCADIS Mobility Index confirms this notion, giving the city an overall score of 64.4% and ranking it the fourth best system in the world.

4.1.3 Munich, Germany

Munich, Germany has been ahead of the curve with its state of the art transportation system which serves approximately 365,000 commuters each day (Sanderson, 2017). In 2017, ARCADIS rated Munich's overall system a score of 59.5% with people, planet and profit receiving 56.7%, 78.9% and 42.8% respectively. The government formed the Hamburger Verkehrsverbund (HVV) in 1967, bringing all private and public transportation systems under one umbrella. Today, Munich has four transit types, including U-Bahn, subway, S-Bahn, and the bus. Many passengers use this system because of its connectivity, efficiency, and payment methods.

The Hamburger Verkehrsverbund organization coordinated all services through careful planning and scheduling. One system synchronizes the integrated bus stops, the U-Bahn (metro system), and the S-Bahn (suburban railroad) (Pucher, 1995). Commuters that live outside the city can ride the suburban railroad, Figure 30, from their home on the S-Bahn and then easily transfer to the U-Bahn to get around the city and go to work. The coordination of the services allows a rider to transfer to another system without having to wait long periods of time. In Munich, the

average waiting time at a stop or station for a tram, subway, S-Bahn, and bus line on a weekday is 10 minutes (MooveIT, 2017). ARCADIS Mobility Index gave Munich a score of 54.7% for rider connectivity because the system has a synchronized transfer time. However it is not perfect or even at the same level of the other two cities. The diverse options for transportation, coupled with its good connectivity of services is a key factor for its success.

Figure 30: Munich, Germany S-Bahn (Retrieved from Portal München Betriebs-GmbH & Co, 2018)

Munich's transportation system is very efficient and environmentally friendly due to its reserved bus lanes, centralized computer network, and use of green technology. The city has reserved lanes that only the bus can use. Additionally, a computerized traffic system controls traffic lights and gives trams and buses priority access to intersections shared with cars and trucks. These technological controls enable "90% of trams to adhere perfectly to their timetable" (Pucher, 1995, p. 284). For the profit section, ARCADIS's Mobility Index gave Munich's system a score of 66.7% for its commuting travel times. Since commute time is shorter, it encourages more riders to use public transit system, improving profit margins for the companies. Transit systems that help reduce carbon emissions are a vital component to improve air quality for its inhabitants. In 2017, Munich, Germany introduced new buses into its transit systems that are "100% electric zero emission EBUSCO 2.1 busses" (EBUSCO, 2017). Munich's green energy technology resulted in a score of 78.1% for greenhouse gas emissions metric under the planet section of the ARCADIS

mobility index. Dedicated bus lanes, central computerized traffic system, and clean technology contribute to the efficiency and success of Munich's transportation system.

Munich's transit system has a simple ticket service which enables riders to transfer between services with ease. After the HVV conducted an analysis, they determined that "a simpler and cheaper fare structure would attract more riders" (Pucher, 1995, p. 286). Instead of a complicated ticket system, they revamped it so there are ticket options for target audiences such as daily commuters, students, and the elderly. Riders can purchase a ticket online, by phone application or in person. Figure 31 below shows a ticket system in Germany where users can easily purchase tickets in different languages.

Figure 31: Multilingual ticket machines making it easy to purchase tickets (Flippo, Hype (Photographer). (2015). Retrieved from www.german-way.com).

Munich, Germany has an efficient transportation system that allows riders to commute from the suburbs to the middle of the city quickly and easily. A central computerized network along with reserved lanes allow buses to reach their destination in a timely manner. Munich demonstrates its commitment to green technology through its electric buses, improving the air quality and livability for its commuters. A simple payment method allows users to purchase and use single tickets across multiple modes of transportation in the city. Munich, Germany has a successful transit system because it has aspects that adequately address the people, planet and profit sections. These special attributes warrant it a score of 59.5% from ARCADIS and which ranks it as one of the top transit systems in the world.

4.1.4 Comparative Analysis

Hong Kong, Seoul, and Munich all share similar attributes that contribute to the success of their respective transportation systems. Each of three cities transportations systems have a central organization regulated by the government, a computerized management system, methods for improving efficiency, good interface with the users through presentation of information and payment systems, and incorporation of green technology. By analyzing these shared factors, this project was able to draw conclusions about the factors that make a transportation system successful.

Each city contains a central organization controlled by the government that oversees all transportation for the city. In Hong Kong, the MTR Corporation and the Ministry of Railways coordinate the extensive railway network. In Seoul, the Seoul Metropolitan Government privatized all transportation companies and brought it under one organization's control. In 1967, Munich, recognizing the need to synchronize the city's transit systems created the Hamburger Verkehrsverbund (HVV) which brought all private and public services under one group. Seoul is the only city of the three that completely privatized the industry, whereas Hong Kong and Munich allow private and public organizations to operate concurrently. Governmental control over all modes of transportation is a key element in these three successful transportation systems, enabling them to coordinate and synchronize services.

Additionally, each of the three cities control all of the various technological systems to monitor and coordinate all of the transportation systems in their city. Hong Kong's system uses a mathematical model to determine bus locations, routes and times. Seoul has the Transport Operation and Information Service (TOPIS) which synchronizes the various transportation services, updates commuters with live information and reports accidents. Similarly, Munich has a centralized computer network that is responsible for monitoring traffic lights, ensuring that tram and buses get priority access in intersections. Each of the cities employ a technological system to monitor and track all modes of transportation, allowing efficient transfer times and fast commutes.

To improve the time efficiency of the bus systems, Seoul and Munich developed dedicated bus lanes. These bus lanes run through the middle of the city and are only for the buses, improving their likelihood of accurately achieving their estimated arrival times. Additionally, both cities employed distinct transit systems for differing distances. For example, Seoul has multiple buses each with different colors indicating the distances they travel. Similarly, Munich has a S-Bahn for

longer distance commutes and U-bahn for inner city travel. Seoul and Munich are able to have efficient systems that span large areas of their city and surrounding area through the use of distance specific transit systems and a dedicated bus lane.

All three cities have advanced systems that present useful information, and a simplistic payment system to make the commuters experience better. Hong Kong has LCD systems at each stop and onboard the trains to present users with live route information and current estimated time of arrivals. Similar to Hong Kong, Munich has live information presented at stations and on the vehicles. Of the three cities, Seoul has the best presentation of information with its TOPIS system. The system presents all of the information that it collects in near real time and offers users multiple communication media, including text messages, social media updates and standard LCD screens. In terms of payment options, all three cities provide a single ticket or card for all modes of public transportation. Munich does not have a single card, however riders can purchase a ticket and use it for all systems.

Many transportation systems are implementing or working towards the incorporation of green technology. Munich and Seoul both have entire fleets of buses that are completely electric and don't emit carbon monoxide. Hong Kong has been attempting to implement electric buses since 2010 but has experienced multiple recalls due to technical issues (Lo, 2016). Hong Kong, Seoul and Munich have all recognized the significance of using green technology and are all carefully planning for the future.

Hong Kong, Seoul and Munich all share attributes that make them successful. The governments of these three cities control the transportation systems and have a central network to coordinate all modes of transportation. Their services are reliable and on time due to the central network and dedicated bus lanes. Public transportation in each city spans large distances with specific modes of transit dedicated for specific distances. In Hong Kong and Seoul, users can easily maneuver the transit system with a single card and check when their system will arrive through the use of live signage or their smartphone. The three cities have planned for the future by already incorporating and expanding the use of green technology. From these main attributes we deduced that reliability, efficiency, comfort, ease of payment, and accessibility, are major metrics that make a city's transportation systems successful.

4.2 Rubric Development

After determining key metrics from our comparative case study analysis, our project developed a weighted Smart Cities Rubric. The team developed this rubric, which can be seen in Appendix I, to evaluate any transportation system based on the top transportation systems around the world. As seen in Figure 32, the group utilized ARCADIS Mobility Index for its overall structure and some of its weights. Our team liked this division because it takes into account the user, environmental factors and economics of a transportation system. We then grouped the key metrics outlined in our comparative case study and categorized them into either the people, planet, or profit section. Within each of the main sections, we further divided the metrics into subcategories. Doing so allows us to evaluate the transportation system based on observations. Appendix H provides an explanation of each metric and what criteria the group used to score it.

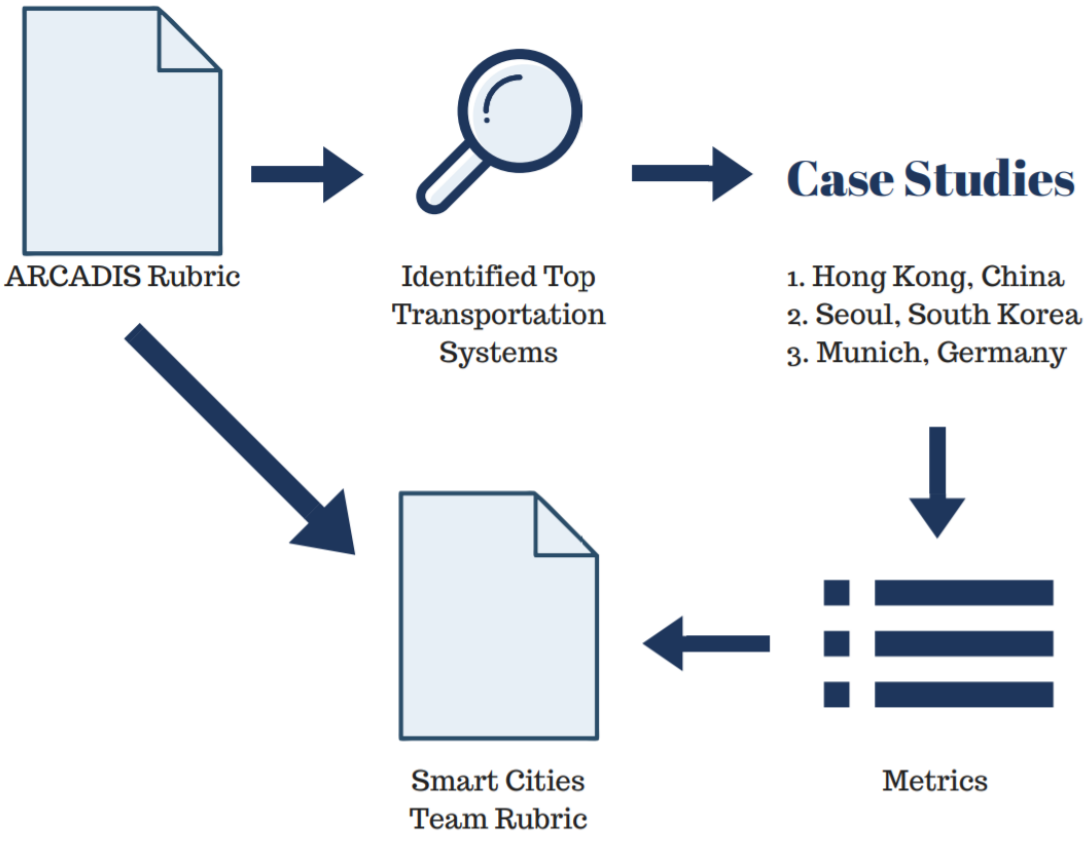


Figure 32: Smart Cities Rubric creation process

The team based all of the weights on either the ARCADIS Index Rubric or research they conducted. Each metric of our rubric has a calculated weight that contributes to the overall score of each section. As seen in Figure 33, the Smart Cities Rubric contains weights derived from our own research, denoted by Ws, and ARCADIS's weights, denoted by Wa. Researchers at ARCADIS based the weights from the Mobility Index on information from various publications, databases, government requests and subsidiary research firms (Batten, 2017). We factored in additional elements because not all of the metrics from our best practice comparative analysis were properly represented in the index.

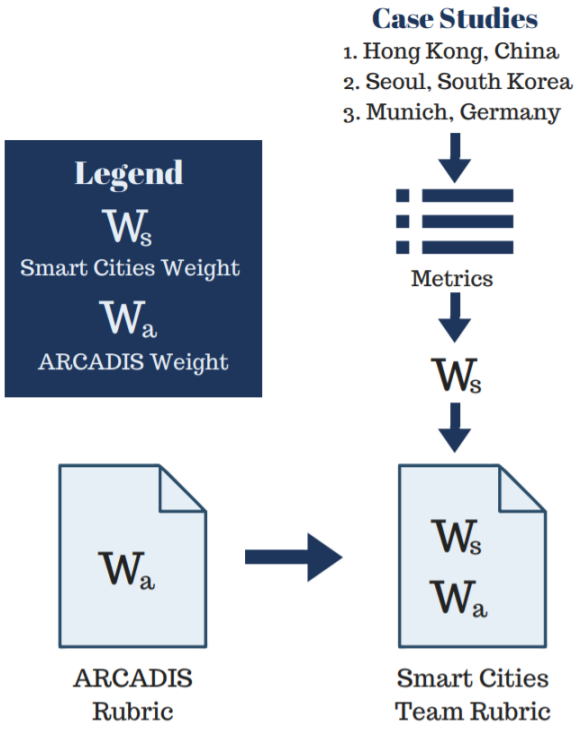


Figure 33: Smart Cities Rubric based off ARCADIS Rubric and determined metrics

In the proceeding figures, the ARCADIS Index weight is under the column labeled ARCADIS and the final determined weight for our rubric is under the Smart Cities column. The metrics' weight is highlighted red if the team used the ARCADIS Index's. Figure 34 is a key outlining when we based a weight on ARCADIS versus when we changed the weight based on our research. The ARCADIS weight was either diluted, split into smaller weights, or established depending on the metric.

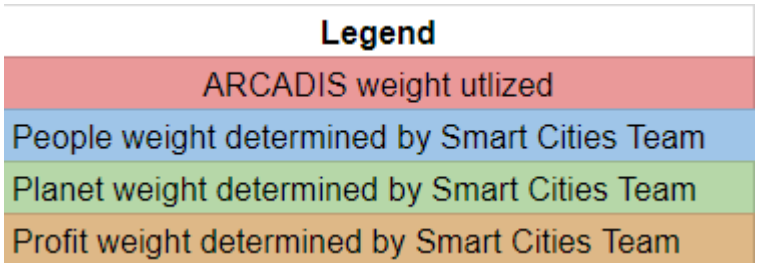


Figure 34: Legend for the weights of the Smart Cities Rubric

In several cases we found it necessary to incorporate key factors from our research in the rubric. This means that our rubric contains more factors than the ARCADIS rubric. In order to accommodate the new factors and make sure each section sums to 100%, the original weights of the ARCADIS factors must be reduced. When a factor is reduced in weight for this reason, we label it as "diluted". An example of this dilution process is shown in Figure 35, where a subsection in ARCADIS is comprised of three factors with a weight of 15%. In order to accommodate the five factors in the same subsection in the Smart Cities Rubric, the weights are diluted so each factor weighs 3%.

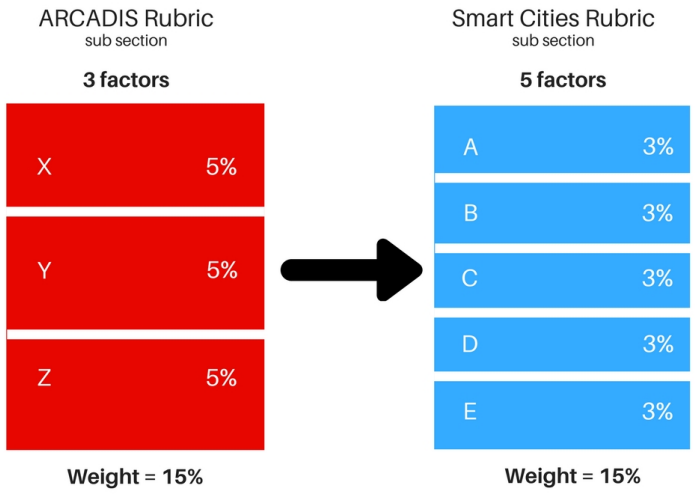


Figure 35: Smart Cities Rubric dilution of weights

An ARCADIS weight is split, Figure 36, when there is a larger, more encompassing metric from the Index that can be split into smaller metrics that came from our case study. For example, in ARCADIS there is a weight for amenities with a weight of 11%. Since we had three metrics breaking down amenities: Wi-Fi, Cell Service, and AC, we divided the 11% by three and assigned the 3.67% for each sub metric in the Smart Cities Rubric. Lastly, a weight is established when the metric was not in ARCADIS. In this instance, the team made an educated guess on the weight. The creation of the Smart Cities weights were determined partially by ARCADIS's weights and the researcher's intuition.

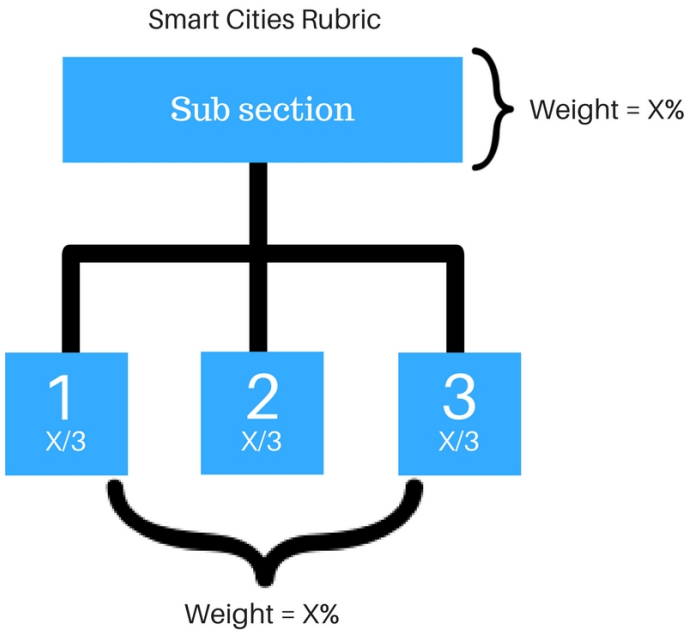


Figure 36: Smart Cities Rubric Splitting a weight

4.2.1 People Section

The first category of both rubrics is the people section. The people section of our rubric pertains to the comfort of the system, the various services it offers, and how difficult it is for the user to understand and use the system. This section is broken down into six sections: Rider Quality, Amenities, Presentation of Information, Purchasing a ticket, Garage Area/Parking, and Land use of Surrounding Area.

The Rider Quality subsection, Figure 37, is made up of five metrics and tries to address the physical system and evaluate how nice it is for the rider. Within the rubric shown, the metric is on the left side and the maximum score that the researcher can give it is in parentheses next to it. For example, the Comfort of Seating metric is scored out of 10. Within this section, the most important metric is the availability of seating, weighted at 20/100 of the combined Ride Quality and Amenities section. The group adjusted the ARCADIS weight because we felt having a seat is an important aspect of rider quality. The Amenities section is broken up into three metrics: Wi-Fi, Cell Service and Heat/AC System. Since the amenities fall under the ride quality sub category, their overall weight on the people category is one third of their listed weight within the sub category. For example, while Wi-Fi accounts for 11% of the ride quality sub category, it accounts for 3.67% of the people category. Under the amenities section, the factors sum to 11% of the overall people section because the ARCADIS Index has a single metric, Amenities that is weighed at 11%.

	ARCADIS	Smart Cities
	Ride Quality	
Comfort of Seating (10)	N/A	3.33%
Avalibility of seating (20)	13.00%	6.67%
Handicap accessibility (10)	5.00%	3.33%
Ease of authorization (ticket) (10)	N/A	3.33%
Maintence (17)	8.00%	5.67%
	Amenities	
Wifi (11)	11.00%	3.67%
Cell Service (11)	11.00%	3.67%
Heating/ AC system (11)	11.00%	3.67%

Figure 37: People category with subsection Ride Quality and Amenities

Another subcategory of the people section is live information. Figure 38 illustrates the breakdown of this section. Within this subcategory there are four metrics. The two heaviest weighted values within this section are the quality of static map and ease of navigation, weighted both at 5.00% of the overall people score. These metrics are weighted heavily because the team believed understanding the layout of the map and being able to navigate the system are important factors that comprise the people section (note - the colors illustrate that quality of map is a category

we added while navigation is an existing ARCADIS weight). The fourth subcategory of the people section is purchasing a ticket. The weights for all of these metrics were determined by the WPI team. The group decided to weigh the payment method at 5.00% because ease of payment was a main attribute found in our comparative case study analysis. This is an example of an attribute added from our comparative analysis process.

	ARCADIS	Smart Cities	Reasoning if Different
Presentation of Information			
Live Information			
Quality of static map at stop (15)	N/A	5.00%	-
Ease of navigation (15)	9.00%	5.00%	Split - 3
On board route visualization (10)	9.00%	3.33%	Split - 3
Live location (5)	9.00%	1.67%	Split - 3
Purchasing a ticket			
Payment method (15)	N/A	5.00%	-
Cost calculation (10)	N/A	3.33%	-
Cost (20)	N/A	6.67%	-
Versatility of ticket (10)	N/A	3.33%	-

Figure 38: People category with subsection Presentation of Information

The fifth subcategory of the people section is the station layout/location which can be seen in Figure 38. This subcategory is comprised of designated parking area and availability of parking both weighed at 8.33%. The sixth subcategory of the people section is land use of surrounding area. The overall People category score is the average of all subsections. All of the weights in both of these section were determined by the WPI team because these attributes were derived directly from the comparative case study and were not a part of the ARCADIS Mobility Index.

	ARCADIS	Smart Cities	Reasoning if Different
Station Layout/Location			
Garage Area/ Parking			
Designated Parking Area (25)	N/A	8.33%	-
Availability of parking (25)	N/A	8.33%	-
Land Use of Surrounding Area			
Commercial use (15)	N/A	5.00%	-
Residential use (15)	N/A	5.00%	-
Industrial use (10)	N/A	3.33%	-
Educational use (10)	N/A	3.33%	-

Figure 39: People category with subsection Garage Area/Parking and Land Use of Surrounding Area

4.2.2 Planet Section

The second major section of the Smart Cities Rubric is the planet section. This section, Figure 40, tries to evaluate the environmental impacts of the transportation system based on five identified metrics: incorporation of green technologies, promotion of green energy, display of environmental impact, coverage, and pollution. Three of the five metrics were not within the ARCADIS Index but rather derived from the comparative case study analysis. The most important factor within the planet section is coverage, with a weight of 50%. The WPI team deemed this metric important and therefore weighing heavily because our research showed that coverage of a transit system is a crucial factor to a systems success.

	ARCADIS	Smart Cities	Reasoning if Different
Incorporation of green technologies (10)	16.00%	3.33%	Distilled
Promotion of green energy (5)	N/A	5.00%	-
Display of environmental impact (5)	N/A	5.00%	-
Coverage (50)	N/A	50.00%	-
Pollution (30)	12.00%	30.00%	Reaffirmed

Figure 40: Planet category of Smart Cities Rubric

4.2.3 Profit Section

The final section of the Smart Cities Rubric is profit. This section tries to evaluate the efficiency, reliability, and economic viability of the transportation system. The profit section is

comprised of five subcategories: price, government, frequency, reliability, and connectivity. Within the Price category, Figure 41, the most important metric is the economic viability for consumers, with a weight of 15%. This value is distilled from ARCADIS' weight of 25% based off the team's opinion. The government category of the profit section aims at evaluating the role the government plays in the transportation system. All of these weights were determined by the WPI team, with the highest emphasis put on the Subsidy and Regulatory hurdles for companies, both weighed at 10/100. The WPI team learned from Seoul's successful transportation system that large government investment into transportation systems can help establish new, efficient systems. Therefore, the team decided to weigh the Subsidy metric at 10%.

	ARCADIS	Smart Cities	Reasoning if Different
Price			
Card options (5)	N/A	2.50%	-
Discounts (10)	N/A	5.00%	-
Economic Viability for consumer (30)	25.00%	15.00%	Distilled
Government			
Subsidy (20)	N/A	10.00%	-
Incentive (tax break etc.) (15)	N/A	7.50%	-
Regulatory hurdles for companies (20)	N/A	10.00%	-

Figure 41: Profit category with subsection Price and Government

Another subcategory within this section is frequency, **(**see Figure 42**),** which gauges how often the system runs. All three metrics within this subcategory are split from the ARCADIS Mobility Index and adapted to fit the score of the section. Frequency is the highest weighted metric in this subcategory, at 10%, which evaluates how often the mode of transportation runs. The next subcategory, reliability, is comprised of three metrics that make up 22.5% of the overall score. The most important metrics within this subcategory are arrival time and breakdowns, both weighed at 10% of the overall score. The WPI team determined reliability is an important attribute of successful systems and that this metric can be observed through the arrival time and breakdown of the transportation system. The final subcategory of the profit section is connectivity. All three cities from the comparative case study had systems with very efficient connectivity between transit systems. The group determined that ease of transfer between the different modes of public

transportation system is important, therefore weighing it 5% of the overall section score. The profit section evaluates the affordability, reliability and economic viability of transportation system.

	ARCADIS	Smart Cities	Reasoning if Different
Travel Time			
Frequency			
Frequency (20)	14.00%	10.00%	Split - 5
Adjustment for ridership traffic (5)	14.00%	2.50%	Split -5
Express options (10)	14.00%	5.00%	Split - 5
Reliability			
Arrive on time (20)	14.00%	10.00%	Split - 5
Live ETA (5)	N/A	2.50%	-
Breakdowns (20)	N/A	10.00%	-
Connectivity			
Ease of transfer (10)	N/A	5.00%	-
Distance to transfer (5)	N/A	2.50%	-
Time between transfers(3)	14.00%	1.50%	Split - 5
Live updates about transfers (2)	N/A	1.00%	-

Figure 42: Profit category with subsection Frequency, Reliability and Connectivity

4.3 Application of Rubric in Madinat Al Irfane

Using the rubric discussed in section 4.2 the team evaluated three different forms of transportation as methods of travelling into Madinat Al Irfane. The three forms of transit we evaluated are the tramway, buses, and taxis. This section goes into detail about the assessment of each of these three forms of transportation, discussing the scores that the team gave each one in the rubric and the reasons for the scoring. Additionally, at the end of this section we compare these three forms of transportation with the goal of choosing one to focus on for the Preliminary Design Review in section 4.8.

4.3.1 Tramway Assessment

In order to assess the tramway, all five of our team members rode the tramway from the start of line 1 at Hay Karima to the end at Madinat Al Irfane. We made the trip as a group of five in order to get as many data points as possible. This allowed for the elimination of some of each

members' individual biases. The team made the decision to focus only on line 1 given our available resources in order to get more detailed data as opposed to less thorough data with more line coverage. We made this trip twice, once during morning rush hour at eight o'clock on January 29th, 2018, and once during the evening rush hour at five o'clock on January 26th, 2018 in order to assess any differences that timing might create. During these rides we used the Smart Cities Rubric to evaluate the tramway. Figure 43 below shows the breakdown of the average rubric scores into the three main categories: people, profit, and planet as well as the overall score for both the morning and the evening rides. Both the planet and profit scores remained relatively static across the morning and evening trips, however, the people score changed drastically between these time periods. This is because the quality of a ride can change throughout the course of a day whereas the environmental and economic factors of a transportation system do not fluctuate much, if at all within a given day.

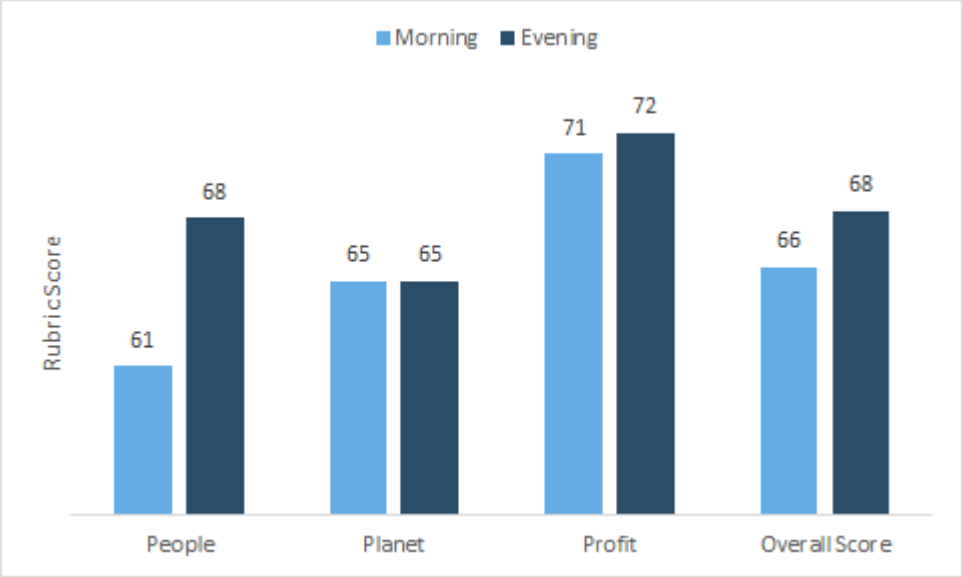


Figure 43: Average Rubric Scores for Morning and Evening Rabat Tramway Rides

The people category for the tramway received an average score of 63 out of 100. Looking at the individual factors, this difference was in large part due to the unavailability of seating on the morning ride. The morning ride towards Madinat Al Irfane was significantly more crowded than the evening ride leaving little room to stand, and nowhere to sit. As a result our team gave the seating availability an average score of 10 out of 20 for the morning whereas we gave it an average

score of 15 out of 20 for the evening. The over-crowdedness of the tramway during morning rush hours is further supported by our observations in which we noticed that on several occasions during the test rides, waiting passengers who had already purchased a ticket could not board the tramway because it was already too full. The amount of space available on a given tramway during peak hours was too low to accommodate the volume of traffic properly. Consequently, rideability was more difficult as people were unable to find seats or standing room on board the tramway.

Figure 44: Two Forms of Ticket Purchasing Available for Tramway

Another reason the low score in the people categories was the morning tramway has a limited nature of the ticketing options. Figure 44 illustrates the two methods available for purchasing tickets at the Rabat-Sale tramway stops. The picture on the left is a booth where an employee of the tramway company sells tram tickets. The right picture captures a self-service ticket machine which offers instructions in French, Arabic and English and accepts coins and up to 100 dirham bills depending on the number of tickets you are purchasing. The self-service machine takes too much time to use and frequently builds up a line. On the other hand, the human-run kiosk allows people to purchase a ticket slightly faster than the self-service station. The kiosk hours of operation are from 7:30 A.M. to 8:00 P.M. on weekdays and 10:00 A.M. to 8:00 P.M. on weekends. These hours are good since they cover the rush hours during the week. However, the kiosk and the ticketing machine are insufficient to handle the demand during peak hour traffic. During our rush hour observations in the morning, we noticed that several people missed the tramway because they were unable to purchase a ticket in time. This set of observation yielded an average score of 9 out of 15 for the tramway's payment methods factor.

Another significant shortcoming of Rabat's people category is the lack of handicapped accessibility both getting on and off the tramway. As mentioned above, during rush hour traffic it can be difficult to get onto the tramway due to the congestion; this is especially true for handicapped people as the significant congestion makes it so there is often not a clear path onto the tramway. Additionally, the doors do not have a mechanism that detects if something is obstructing their ability to close. Thus, the doors will close on anyone who is in their path when the timer runs out. This can be harmful, in particular for someone with a disability or who is frail as the force of the door closing could easily knock them over and cause an injury. While there is a button on the inside of the tramway with the universal handicap symbol on it, pressing the button had no effect.

Despite these flaws the team still noted several positive factors contributing to the tramway's people category. During our observed times, the signage for the tramway is good; it is easy to plan your route and there is live location information. Additionally, the signage indicates the tramway's final destination and which line it belongs to as shown in Figure 45 below. For these reasons our team gave both the ease of navigation and quality of static map factors average scores of 13 out of 15.

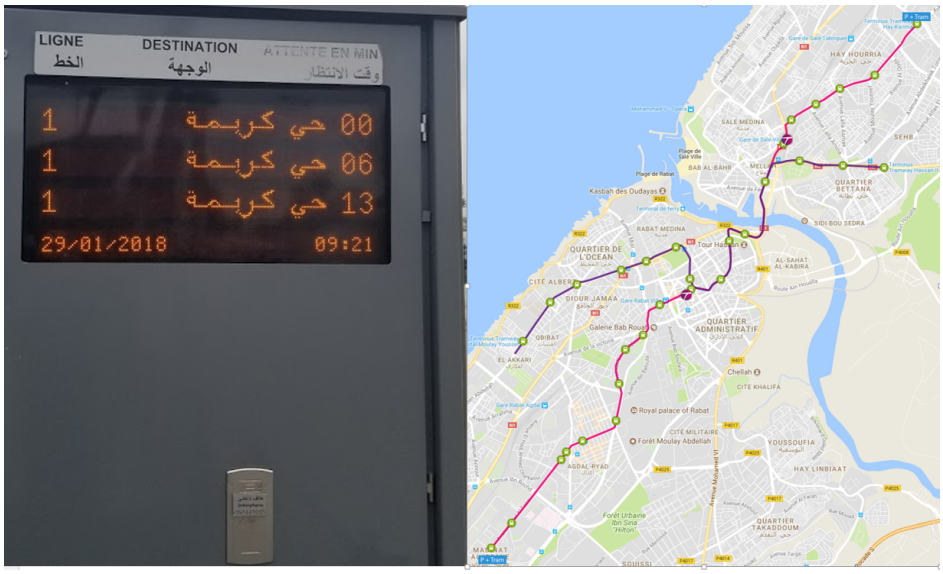


Figure 45: Tramway Live ETA system (Left) and Static Map (Right) (Carte interactive, n.d.)

The average of all the observers' people scores for the tramway came out at 63, the lowest of the three subcategories. As discussed above this is largely due to the shortcomings in handicapped accessibility and how overcrowded the tramway can become during peak operating hours.

The planet score for the tramway scored 65 out of 100. The tramway is relatively environmentally friendly in that it is all electric, and electric systems are more efficient and environmentally friendly than their fossil fuel burning counterparts. As such, it scored well on certain factors use of green technology and pollution, earning an average score of 10 out of 10 for incorporation of green technology and 29 out of 30 for pollution. However, the tramway company does nothing to advertise the environmental benefits of using the tram, thereby missing an opportunity to promote the use of green technologies. The Rabat tramway's weakest factor in the planet category was the coverage. While the tramway is a fairly good form of transportation, the area of the city it covers is limited as there are only two lines and does not go to key areas such as Al Qamra. Even though the lines are fairly centrally located geographically speaking, there are many areas of the city that the tramway does not reach. For example, any neighborhoods of Rabat that do not run directly down the center of the city have trouble reaching the tramway. For this reason the coverage section received an average score of 30 out of 50.

The team gave the profit subcategory the highest average score from the team's site assessment. This is in large part because the government gave a large subsidy of 16% to help with the construction of the tramway allowing for the fare to be relatively low for the quality of service that it provides. Additionally, during the observed times, the tramway is significantly more reliable than other forms of transportation in that the live Estimated Times of Arrival (ETAs) on the boards are quite accurate and during peak hours there is a tramway available every eight minutes. Due to its reliability, the tram received an average score of 16 out of 20 for the arriving on time factor. Additionally, during our observation windows, the system in place makes it easy to transfer between line 1 and line 2, with the automated PA system also announcing the names of the stops in French and Arabic, and when there are interchange stations between line 1 and line 2. The team found room for improvement in the profit subsection in that during our observation periods, the service does not adjust for ridership at all. This means that at peak ridership like the morning and evening rush hours, the tramway runs just as frequently as it otherwise would. This increased volume of traffic with the fixed amount of tramway carts causes an increase in congestion.

Additionally, there are no express options, so if a rider needs to get from the Sale station to Madinat Al Irfane, they must stop at every station along the way taking 48 minutes. Because of this, the tram received a mode score of 0 for both express options and adjustment for ridership traffic.

Finally, the tramway is rather expensive at six dirhams per trip, making it 50% more expensive than the bus system at four dirhams per trip. For someone who commutes on the tramway every day, this can add up to a significant financial difference. As number shows, 15.1% of the cost of living in Rabat goes to transportation (Cost of Living in Rabat, 2018). While this problem is partially addressed by the availability of a tramway card that riders can purchase, there are still several problems the card leaves unsolved. The card is available in monthly, tri-yearly, bi-yearly, and annual increments. Figure 46 below depicts the prices for tramway cards for general riders and students. A one month card costs 250 Dirhams or 150 Dirhams for students, and the one year card costs 2500 Dirhams or 1500 Dirhams for students. This cost makes purchasing a tramway card financially infeasible for some riders. For students on a government stipend, 150 dirhams a month is 22.5% of their 2000 dirham tri-annual income (M. Salhi, personal communication, February 5, 2018). Additionally, a rider would have to incur the six dirham ride cost 42 times in a month before purchasing the card becomes an economically attractive choice. Therefore, the team gave the tram an average economic viability for consumer score of 25 out of 30.

General

Fees

	Price (Dhs)
Monthly	250
Trianually	700
Bianually	1350
Anually	2500

Students

Fees

	Price (Dhs)
Monthly	150
Trianually	420
Bianually	810
Anually	1500

Figure 46: Cost of Tramway Cards for General Riders and Students (Abonnements, n.d.)

The team assigned the tramway an overall average score of 66, an average of the three main categories. Using the Smart Cities Rubric, we are comparing this system to the best transportation systems in the world as researched in our best practice comparative analysis. While

the tramway scored fairly well on our rubric, there are still problems it faces. The key problems the tramway faces are the high cost, congestion at peak hours, inaccessibility to handicapped people, and its coverage.

4.3.2 Bus Assessment

In order to evaluate the bus system, three out of five of the teammates rode the bus operated by the private company Stareo going into Madinat Al Irfane during the morning and evening rush hours. Our team rode the number four bus on Tuesday February 6th, 2018 at nine o'clock in the morning as well as five o'clock in the evening. Starting at the Bab El Had stop going to Madinat Al Irfane, both rides took an average of 38 minutes, with a five minute difference between each. During the assessments, the team kept a common member in both evaluations while two team members rotated between observational rides. The team members individually filled out the rubric after the rides, the same rubric used to assess the tramway, in order to accomplish an assessment of the bus system. The rubric can be found in Appendix I. In order to determine the bus overall score, the group averaged the three scores from each commute. Figure 47 presents the average scores of the three rubric categories, as well as an overall score of the morning and the evening commutes on Rabat's bus number four. The team acknowledges the sample size of the rides along with the team's limited bus routes taken, but we believe it does provide a snapshot of the current state of this system. The team divides the following section into three categories: people, planet and profit, which report the averaged rubric scores from the morning and evening commute, as well as the team's observations which justify the scores assigned.

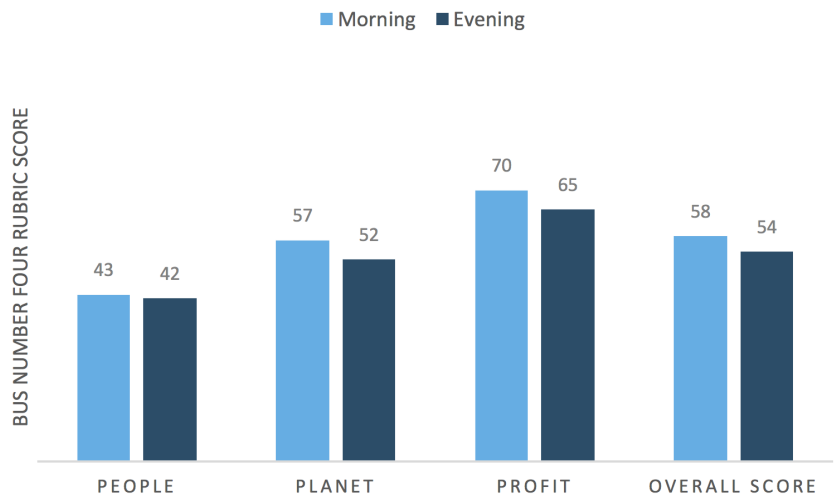


Figure 47: Average Rubric Scores for Morning and Evening Bus Rides

The observational ratings in the People category resulted in the lowest score out of the three categories. The average morning and evening scores were 43 and 42 respectively with an average grade of 42. The team reviewed the specific factors that affected this section score such as maintenance, presentation of information, and handicapped accessibility, all of which are subcategories in the rubric.

Figure 48 displays the current state of the exterior and interior of some of the observed circulating buses in Madinat Al Irfane. The deteriorated state of the exterior of the buses was quite visible. Hence, the apparent poor condition of the buses heavily influenced the bus's low people score. As pictured, the exteriors of a number of buses in circulation are in poor condition including broken windows, rusted and dented exterior, and non-functioning rear or front lights. Apart from noticing the exterior during the bus assessment, the team noted Stareo's, improper interior maintenance of the bus. The team noticed a considerable amount of bus seats covered in graffiti or markings, seen in Figure 47, during the morning and evening assessment. As a result, the aforementioned observations impacted the team's average maintenance score concluding in a 6 out of 17.

Figure 48: Current State of Buses in Madinat Al Irfane

In addition to the poor maintenance of the buses, the team noted the lack of presentation of travel information on the buses and bus stops. Presentation of information refers to the quality of static maps at stops, board route visualization on the bus and ease of access to maps. Figure 49 portrays a bus stop at Madinat Al Irfane that does not have basic maps that inform users of available routes accompanied by a schedule of bus arrival times. The lack of physical availability of route maps as well as schedules, affects the user's ease of navigation. Aside from the maps, the buses do not have an onboard route visualization of the stops. This would facilitate a bus user's commute by allowing them to see upcoming stops and plan where to get off. Because of the lack of basic maps and onboard route visualization the average scores given were zero out of 15 and zero out of 10 respectively, thus impacting the score fairly strongly.

Figure 49: Lack of static maps at Madinat Al Irfane stop

After the bus assessment, the team looked into the availability of Stareo bus maps online. Through a vast online search we found a pdf of the available bus routes, not easily available to the public that Stareo provides to the city of Rabat. Figure 50 below provides the map of the bus lines available for users. For the bus assessment, the team was only able to ride bus line number four due to lack of maps available, which limited our bus line samples leading to Madinat Al Irfane. The team later discovered the availability of other bus numbers that allow users to commute to Madinat Al Irfane. The team found the map to be overwhelming and confusing, which makes presentation of information challenging and not user friendly.

Figure 50: Map of bus lines available within the city of Rabat (Nouha, 2013).

One of the other people factors includes handicapped accessibility. The buses going into Madinat Al Irfane do not have the necessary accommodations for a handicapped person. The buses lacked an easily and readily available ramp for a person with a wheelchair to get on or off and as well as clearly assigned spaces for them, limiting the possibility of handicapped usage of transportation. The average scores for handicap accessibility was two out of ten. In addition to looking at the rider quality, our team analyzed metrics pertaining to the planet.

The average score for the planet category are 57 and 52 for the morning and the evening respectively producing a total average of 55. The planet category breaks down into different sections, some of them being promotion of green energy, coverage, and pollution. The team failed to observe any promotion of green technologies to the public, such as advertising environmental advantages of using the bus, which cause the score for promotion of green technology to receive a zero out of ten. Aside from this subcategory, bus route coverage received an average score of 40 out of 50 which indicates availability of lines leading into Madinat Al Irfane as well as leaving it as seen in Figure 49. Coverage is important to users because it allows mobility to desired destinations and decreases in need of other transportation systems. Aside from these categories, the team was concerned with the pollution emissions of the buses since we noticed clouds of black smoke coming out of the bus exhaust pipe. The smoke emitted decreases air quality, therefore

reducing residents' quality life. The team researched the technical specifications of the bus and discovered it runs on diesel fuel and an engine that complies with the European Standards of Euro III Emission (Nouha, 2013). Diesel usage impacts environment pollution strongly through the emission of pollutants that contribute to a decrease in air quality and increase in environmental and health problems (Reşitoğlu et al, 2015). The Euro III refers to the engine of the bus, a diesel engine, which follows the regulation for heavy-duty vehicle emissions created by the European Commission (Posada, Lowell, 2009). The European Commission standard applied to truck engines and urban buses, in order to regulate and limit the amount of pollution emitted. The European Commission updates this standard every few years; the latest update was Euro VI in 2013. The bus's outdated Euro III engine highlights the lack of environmental friendly features as well as a bus fleet that fails to meet updated and current emission standards. Because of the pollution emitted by the bus, the score given for this section was an average of 16 out of 30. Additionally, our team looked into the profitability of the bus system through the profit section of rubric.

The profit category was the bus's highest score, resulting in 70 and 65 for the morning and evening. The profit category had many factors that influenced the score, some of these were economic viability for consumer, card options, frequency, live estimate of arrivals, and breakdowns. Figure 51 illustrates the bus ticket affordable price of four MAD. Ticket price is important to the economic viability for consumers because affordability of a public transit system is critical. While it is convenient that the bus ticket is affordable, the quality of the system is not necessarily the best. The bus users also have the opportunity of acquiring a bus pass that allows them to use the card multiple times for a month, and grants access to three lines for a monthly price of 100 MAD. On the buses, there were posters with the information about the different pass options. However, the poster was difficult to read because it was washed out and torn. The average scores for economic viability factor resulted in 27 out of 30 as well as two out of five for the card option factors, which made the prices of the tickets and bus passes affordable.

Figure 51: Bus Ticket

During our assessment, the team noticed the arrival frequency of the buses was a prevailing issue. Rabat's buses appear not to follow any arrival schedule; rather they seem to arrive at any time. The team noticed that whenever a bus arrived at a station, a flock of people rushed the bus because there was no guarantee another one would arrive in a timely manner. Given these observations, the team assigned average scores for the morning and the evening test rides of 7 and 9 out of 20 respectively for the frequency of bus factor. The two scores differed since the frequency of the buses varied between morning and evening.

Additionally, the team looked into estimated bus time of arrival as well as live updates of transfer buses. Both of these sections received a zero since there is no available information on estimated time of arrival (ETA), much less, live updates. These features would be beneficial for users to reduce the likelihood of overcrowded buses as well as to provide bus riders with a tool to plan trips and to attempt to arrive on time at their destination.

The overall bus score from our assessment was 56 out of 100. These low scores reflect the poor quality of the transportation service. It is important to note the overall grades we assigned to each system is in comparison to the best transportation systems in the world from our research in the best practice comparative analysis. The major problems included deterioration of interior and exterior, poor equipment maintenance, lack of static maps, availability of bus frequency, and lack of display of live updates on bus arrivals.

4.3.3 Taxi Assessment

The third and last public transportation system the team evaluated was the taxi. In the city of Rabat there are two types of taxis, grande and petit, the latter being the only available to travel into, out of, or around Madinat Al Irfane. The taxi company within Rabat designated grande taxi for intercity travel. Therefore, grande taxis are not available within Madinat Al Irfane. In order to evaluate the taxi, the team divided into teams of two for the morning commute and three team members for the evening commute. The team divided the taxi evaluations into two days due to the team member's availabilities during rush hours. This resulted in a difference between team numbers assessing the taxi. The team of three completed the first assessment on January 29th, 2018 at five o'clock in the evening, departing from Agdal headed to Madinat Al Irfane. Similarly, on January 31st, 2018 at eight o'clock in the morning, the team of two made the same commute. Both rush hour evaluations had one common member in attendance, in order to maintain fairness between commutes. Both commutes started in Agdal, a residential area approximately 6 kilometers away from Madinat Al Irfane. During the morning commute at eight o'clock, the taxi driver took back roads and side streets to avoid main street traffic, making the trip last a total of 14 minutes. In contrast, the taxi driver on the evening ride drove on the main roads which resulted an 11 minute ride. During both commutes there was heavy congestion at the rotary by Madinat Al Irfane due to traffic. The team is aware the sample size of taxis assessed does not represent the whole taxi system and acknowledges the taxi rides may vary; we believe the evaluation is valid and loosely portrays the current taxi system. Figure 52 displays the overall score as well as the breakdown of the average rubric scores of the three categories: people, planet, and profit. The rest of the section will expand on the justification of each score.

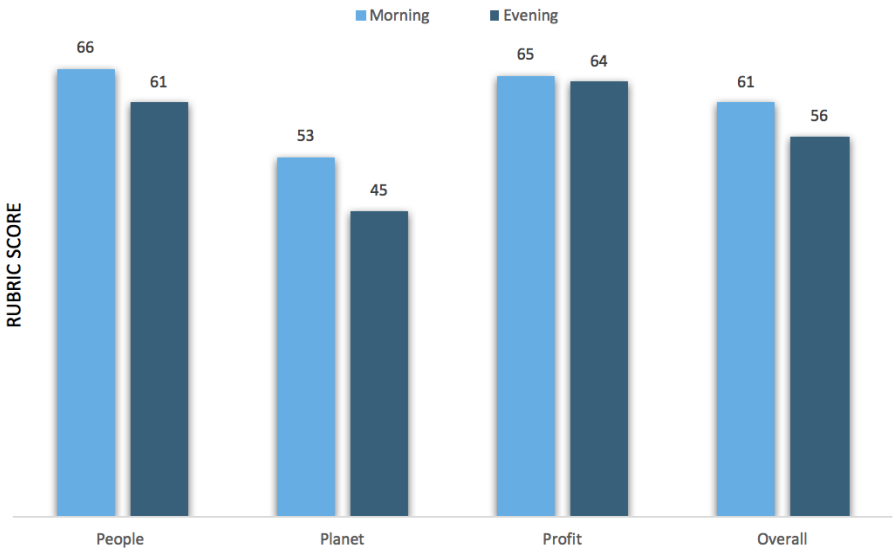


Figure 52: Average rubric score for morning and evening taxi rides

Figure 51 exhibits the scores assigned for the people category. The team assigned a score of 66 and 64 out of 100 for the morning and evening commute, due the limited availability of seating, comfort, and handicapped accessibility. Government law requires petit taxis in Rabat to only seat a maximum of three excluding the driver, although they could seat four people total, excluding the driver. If there are empty seats during a trip, taxi drivers will stop to pick up other passengers who are tentatively seeking a compatible route to maximize their fares per trip. Generally, this will play a factor in the commute time per person. Our comparison of the availability and comfort of seating remains the same from the morning and evening, as there is no change in the availability of seats in a taxi. However, taxis are not handicapped accessible, there are no specialized instructions or guidelines to accommodate people with disabilities. Consequently, the taxi average score for handicapped accessibility was 3 out of 10. We were unable to fully assess the live information updates of a taxi because there aren't any. The team did not penalize taxis for not having the feature of live update on location, giving full scores in this area, as it would be unfair to give the score of zero as live features are not applicable.

There is also no ticket for a taxi, there is just one cash payment at the end of the ride which is given to the taxi driver. Since this is the only mode of payment, it resulted in a score of 11 out of 15. The taxis the team members rode for observation had a meter calculated fare, in comparison to other transportation methods which have preset fares and do not change depending on distance.

This system requires passengers to carry a sufficient amount of cash for the ride, which requires them to estimate the fare prior to entering the taxi. As seen in Figure 53 the meter calculates the fare, which counts the kilometers driven, starting at 1.40 dirhams, and increases based off the distance. The 8 A.M. taxi ride from Agdal to Madinat Al Irfane cost 14 dirhams compared to the 5 P.M. rush taxi ride, which cost 11 dirhams. The team also learned that after 8 P.M. taxi drivers turn off the meter, and charge double the original fare for a taxi, making it very expensive. Additionally, some taxis do not have meters which can result in negotiations over the trip price. These petit taxi rides can be an expensive form of public transportation relative to the tramway and bus, and therefore receive an average cost of 10 out of 20.

Figure 53: Petit taxi meter

Taxis take advantage of the land surrounding them to acquire more business. Most roaming petit taxis, alongside a few taxi stands can be found in main areas such as schools, residences, industries, and other major urban traffic hubs. Pictured in Figure 54, upon arrival to Madinat Al Irfane, there is a congregation of petit taxis. As there is always availability of taxis in these popular areas, this reflects the score given of 50 out of 50, making well use of their surrounding land. The team members gave the score based upon the commute directly into Madinat Al Irfane, however

the team did not have access to data on taxi availability throughout the rest of Rabat. For the evening commute, the three project members gave the taxi an average score of 64.

Figure 54: Availability of taxis at Madinat Al Irfane

The taxi ranked poorly in the planet category receiving an average of 49 because of pollution, coverage issues, and lack of green technologies. Petit taxis do not have any green initiatives in place. Petit taxis (Fiat Uno, Peuegeot 205, and Dacia Logan) operate on diesel fuel and can create pollutants in the air. There are many instances in which taxis are running when they do not have any passengers, but continue to run as opposed to stationed with their motor off. The petit taxis don't display the actual amount of pollution that each one is causing or promote any green technologies. As a result, Rabat's petit taxi system received a score of 11 out of 30 for pollution. Petit taxis travel to any point within a city and do not stop at prescribed locations such as the bus stops or tramway stations. However, they cannot leave the city. The taxi system has mediocre intercity coverage, however this is up to the drivers' willingness to drive to certain locations; drivers can refuse fares or locations. Refusal of fares to drivers may be contingent upon direction and distance. This negatively affected the coverage score, as the team had not noticed this driver bias in past personal experiences.

The planet score category for morning and evening taxi rides had an 8 point difference, 53 versus 45 respectively. The subcategory of coverage mainly impacted the score the planet category received. Students of Madinat Al Irfane informed observers that taxi coverage can go down in the evening due to driver refusals. The team did not face this issue but with many complaints from students about taxi coverage, the team took the possible lack of coverage into account and factored this into the score given.

Profit was the highest scoring category with an average score of 65, pertaining to frequency, reliability, and connectivity of taxis. With 3,800 petit taxis in operation, taxis are frequent and readily available in Rabat. The team hailed a taxi within a few minutes of waiting in the morning, and did not experience any delays during the commute. However, during the evening commute ride testers had trouble locating an empty taxi that could accommodate all three people. This led to the observers assigning a frequency of taxi score of 18 out of 20.

Taxis also seemed reliable to the riders who experienced no breakdowns during transport, arriving in a timely manner, earning them a core of 38 out of 45 possible points in the reliability category. However the area taxis lacked in was reliability. In some areas, there are a plethora of taxis, while in other locations there are few to no taxis. For the average Madinat Al Irfane student, this does not seem like a viable option. Students receiving only a 2000 dirham stipend for 3 months (M. Salhi, Interview, February 6th, 2018), taking a single taxi ride each day for five days per week averaging 13 dirhams for a six kilometer ride, can spend up to 78% of their entire stipend on transportation, resulting in the price subcategory receiving a score of 12 out of 30. This reflects the low economic value for the customer, as the distance traveled in taxi is more expensive in comparison to the bus or tram. Taxis are costly, there are no discounts or incentives for riders so the resulting score we assigned was 0 out of 10 points.

The team was unable to access information on the role of government subsidies for taxis, or any possible tax incentives to attract more drivers. This required the team to take an educated guess, about the extent of the government's role along with any hurdles that companies or individuals might face when applying for taxi ownership in Rabat. The government category received a score of 44 out of 55, because they also set the standard meter costs and minimum prices of a taxi. We believe the government's influence on taxis also affects the price citizens pay per kilometer.

The team assigned the petit taxi service in Rabat an overall average score of 59 which included the averaged observer's scores. Taxis barely passed in comparison to the best practice comparative analysis. Petit taxis are a very convenient and usually a reliable form of public transportation. However, a major issue is the pricing for distance traveled and areas covered, providing little economic value for the price the customer pays.

4.4 Heat Mapping

Independent of the rubric, the team assessed the walkability of the area to have a more comprehensive understanding of area mobility and any issues that commuters face on foot. This section is supplemental to the transportation assessment, but the team believe the assessment must include pedestrian traffic for a holistic analysis of all transportation methods in Madinat Al Irfane. By investigating walkability, the team hoped to discover which mobility option was most in need and could benefit from the implementation of smart technologies.

In order to assess walkability, one or two of the project team members walked through the entire area of Madinat Al Irfane. This region consists of universities, residential living, and hospitals and has a perimeter of about 8.7 km. Studying major routes allowed the detection of congestion and any other walkability issues of the area at morning rush hours, which the team defined as 7:00-9:00 A.M., and at lunchtime, 12:00-2:00 P.M. The team had a target pace of 20 minutes per mile. Given the target pace and the large area to cover within the defined times, data collectors strategically split the heat mapping work. The team separated Madinat Al Irfane into two halves, seen in Figure 55, with the top in green and the bottom in blue, using Campus Al Irfane as a center point. The team then mapped the two areas within the stated two-hour windows.

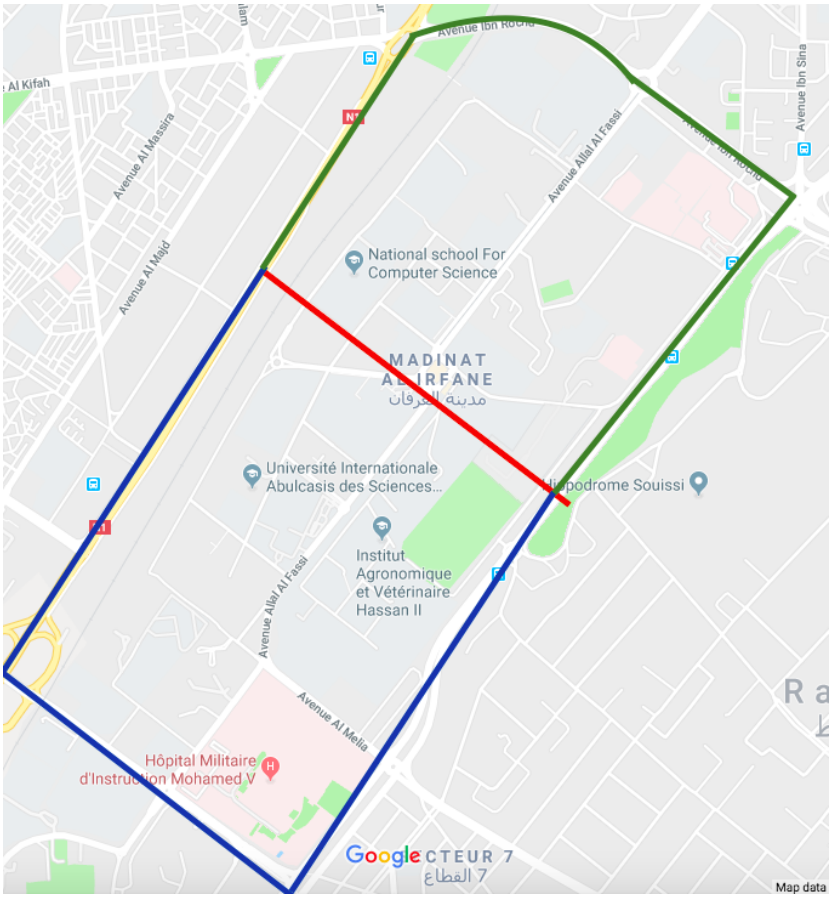


Figure 55: Team's splitting of Madinat Al Irfane into the top (green) and bottom (blue) halves (Google Maps, 2018).

Two team members walked the top and bottom areas on the main routes and mapped them at the designated times, additionally recording all relevant information in the designed observation table shown in Appendix B. The researchers used two different GPS sport watches, Garmin and Nike+, in order to improve the accuracy and eliminate any discrepancies in the data. The team compared the data collected by the different watches to indicate any inconsistencies between watches, and if any existed, we averaged the data points before plotting to the heat map. Due to time restraints, and because the heat mapping showed no cause for concern each area at the specific time was only mapped once. This gives a sample size of one for each heat map.

4.4.1 Morning Rush Hours

At 8:03 A.M. on February 6th 2018, the team started at Campus Al Irfane, the central location of the area, and walked north to map the top half of the test area. The top half of Madinat Al Irfane has several hospitals along the perimeter, and many different schools within the center. The team highlighted in red areas of focus during the morning rush hours within the top half of Figure 56. The areas of focus include the hospital traffic along Avenue Ibn Rochd and the bridge that the red line represents on the far left of the map. The route began and ended at Campus Sweet Cafe in Campus Al Irfane, taking approximately 50 minutes to complete.

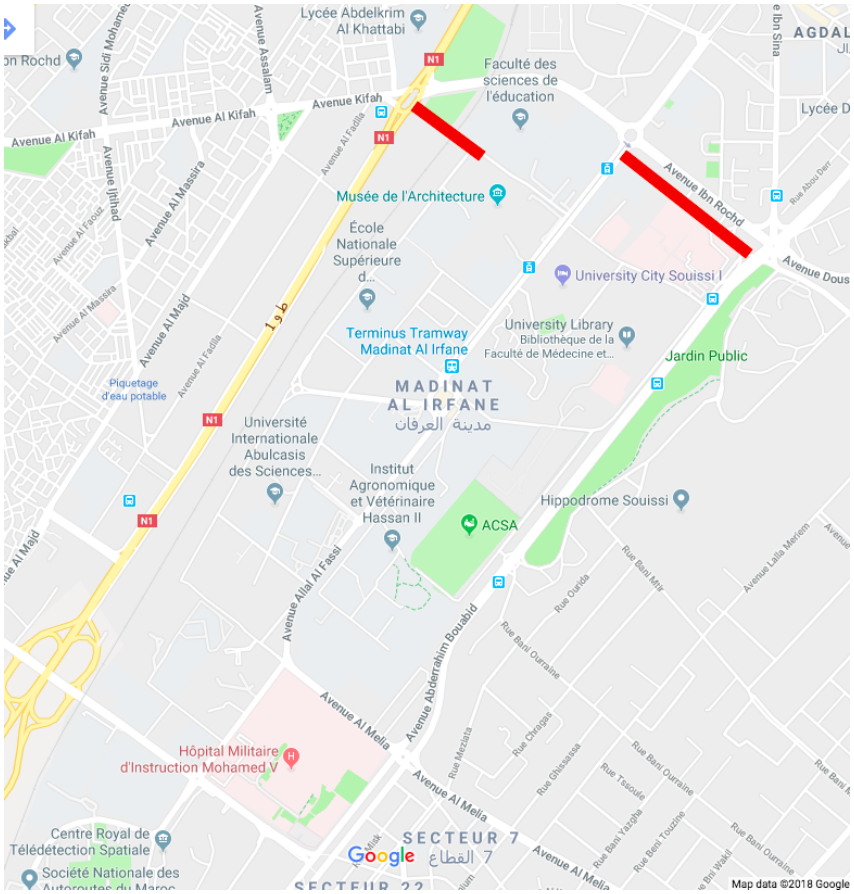
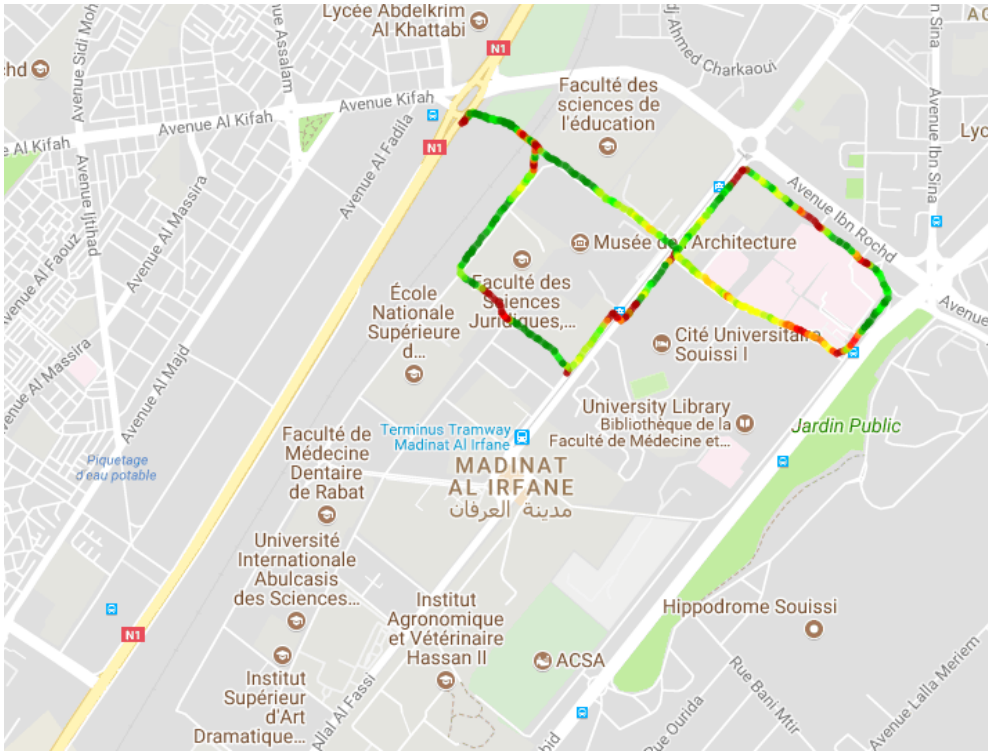


Figure 56: Map of Madinat Al Irfane showing the top areas of focus for morning rush hours (Google Maps, 2018).

A student of ENSIAS reported that during morning rush hour this bridge is usually congested, as many pedestrians cross from their homes to enter Madinat Al Irfane where they go to school or work. As seen on the heat map below in Figure 57, the two areas of focus identified

above have red coloring signifying a necessarily reduced walking pace for the observer due to congestion. Under the heat map is a legend that corresponds to the colors on the map. Each color green, yellow, orange or red, signifies a pace, minutes per mile, shown within the legend. The color red signifies the slowest pace the observer walked during congestion on the route, the color green indicates the fastest pace hit by the observer, and yellow represents the target pace of 20:00 minutes per mile.



23:39 Miles/ min		22:25 Miles/ min		21:11 Miles/ min		19:57 Miles/ min		18:43 Miles/ min		17:29 Miles/ min

Figure 57: Top of Madinat Al Irfane Heat Map from 7-9 A.M (Miller, 2016).

Other areas of the map also show a decrease in pace when crossing main roads within Madinat Al Irfane, such as Avenue Allal Al Fasi, which runs vertically through Madinat Al Irfane and contains the tramway stop. The average pace with congestion and human error is 20:34 minutes per mile and the distribution is seen in Figure 58. Human error consists of the observer

walking faster than the set pace of 20:00 minutes per mile due to natural habits; this raises the overall average to be faster. The red line on the plot signifies the 20 minutes per mile pace, the blue line is the recorded pace of the observer. When the blue line goes above the red line, the observer faced congestion on the walking route. When the blue line goes below the red line, this signifies human error in that the observer exceeded the target pace.

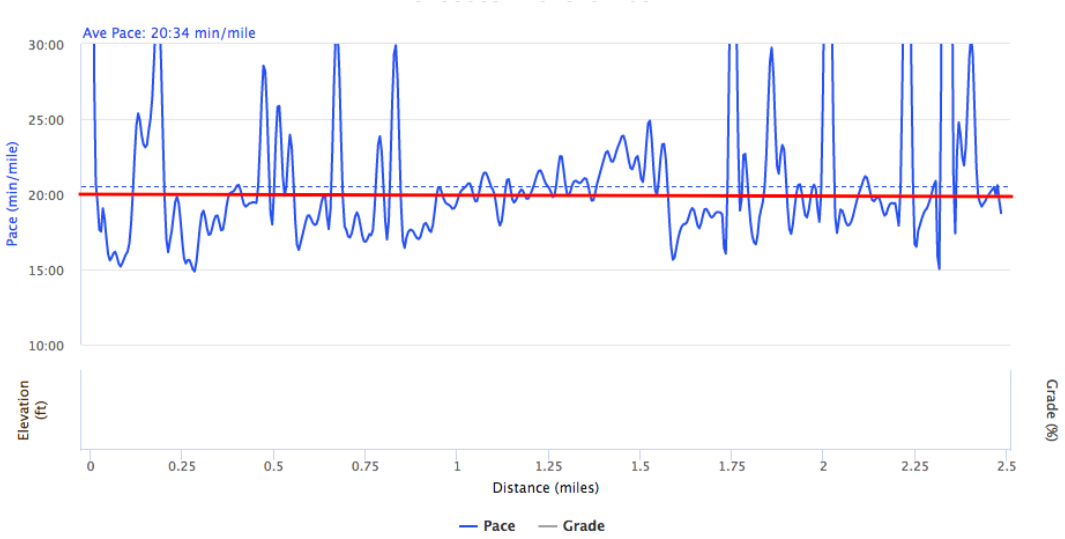


Figure 58: Pace of morning rush hour for top mapping of Madinat Al Irfane (Miller, 2016).

On February 8th 2018 at 8:00 A.M. time, the team of two followed the same protocol for morning rush hours, mapping the bottom half of Madinat Al Irfane (south of Campus Al Irfane). This area contains the same type of landmarks as the top half with hospitals and multiple discipline specific schools. During our site assessment, the team recognized the congestion in front of the hospital within the bottom half and recorded it as an area of focus. The area of interest for predicted congestion is shown in red in Figure 58. The route began at the tramway stop in Madinat Al Irfane and ended at Campus Sweet Cafe, and took approximately one hour to complete.

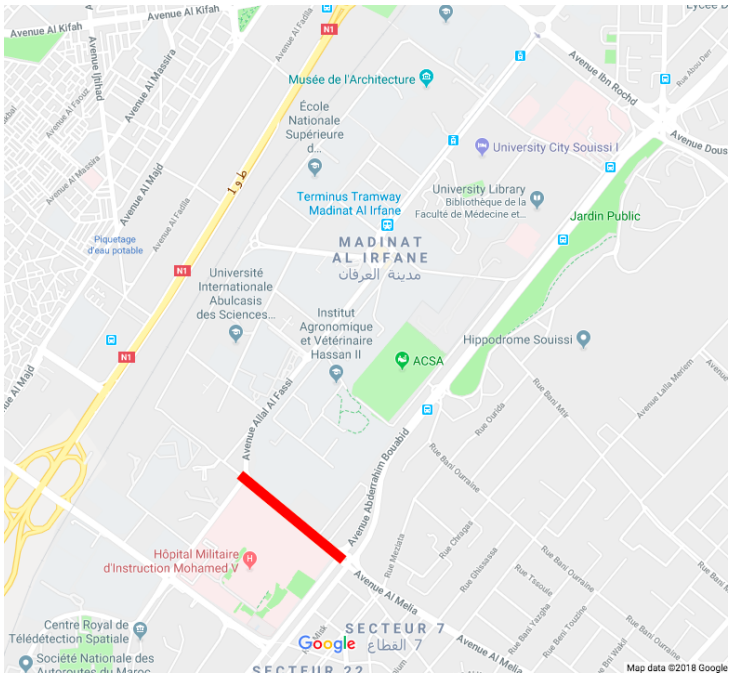


Figure 59: Map of Madinat Al Irfane showing the bottom area of focus for morning rush hours (Google Maps, 2018).

In the morning rush hour heat map of the bottom half of Madinat Al Irfane shown in Figure 59, data collectors recorded congestion outside the hospital. Analyzing the rest of Figure 60 shows that there were no other major areas of congestion in this observation area. The observation area that the team walked was a two-mile loop, represented by the mile markers on the map.

24:30 Miles/ min		23:13 Miles/ min		21:57 Miles/ min		20:40 Miles/ min		19:23 Miles/ min		18:06 Miles/ min

Figure 60: Bottom Half of Madinat Al Irfane Heat Map from 7-9 A.M. (Miller, 2016).

Figure 61 below shows the pace throughout the entire route. The average pace was 21:18 minutes per mile. There are multiple peaks above the red line with various conditions impeding walkability. A bulk of the peaks are within the same area of the graph between 0.75 miles and 1.0 mile, with more at 1.8 miles. In the heat map above, the one-mile marker is on the route of interest, outside the hospital's perimeter, correlating to the slower paces in this area.

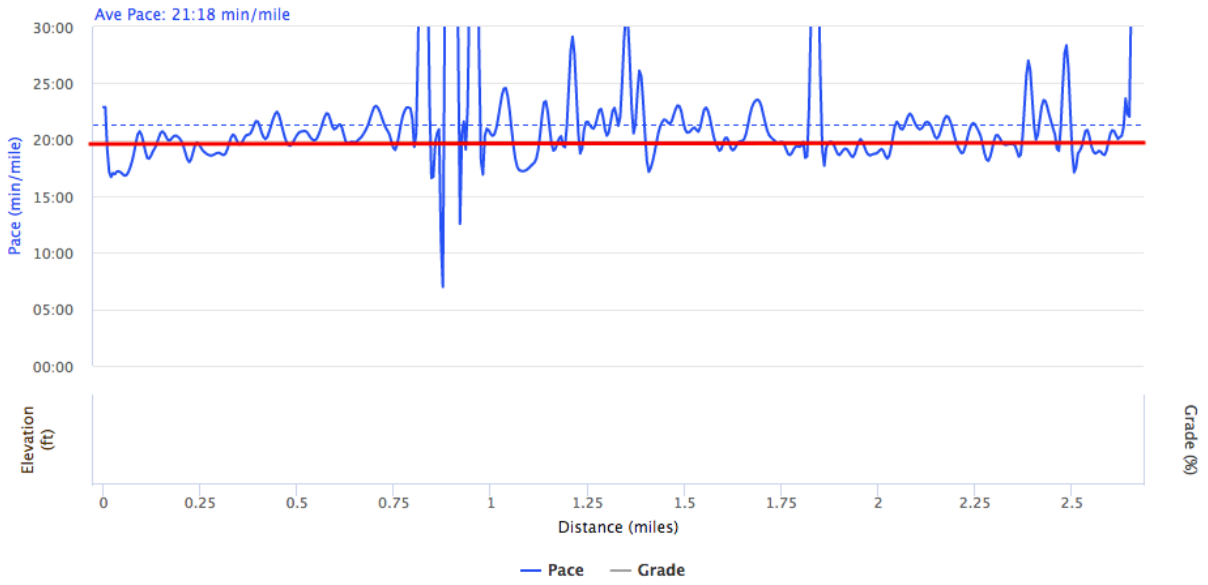


Figure 61: Pace of morning rush hour for bottom mapping of Madinat Al Irfane (Miller, 2016).

4.4.1.1 Morning Rush Hour Analysis

During the morning rush hours reported by students 7:00-9:00 A.M., data collectors assessed walkability using Nike+ and Garmin watches. A compiled heat map of Madinat Al Irfane during these hours is shown below in Figure 62. This complied heat map merges both the top and bottom heat maps shown above. The team completed this heat map by using the application Photoshop. This map allows the team to analyze and address the area as a whole.

24:05 Miles/ min		22:49 Miles/ min		21:34 Miles/ min		20:18 Miles/ min		19:03 Miles/ min		17:48 Miles/ min

Figure 62: Heatmap of Madinat Al Irfane at morning rush hours

The map shows a variety of areas of congestion. There is a low concentration of red zones in Figure 61, which signifies that observers faced no major congestion when mapping at these hours. Many of the congested areas did not cause a large disruption in getting to the final destination. The major areas of congestion in the morning were outside hospitals and on the bridge connecting Al Qamra to Madinat Al Irfane.

One of the major areas of congestion, as shown by the heat mapping is outside the hospital. This in large part due to the fact that there are many families waiting for consultation. People standing make up this congestion, not walking. The hospitals have closed gates that force many patients to wait on the sidewalk making walking through the area difficult. The team members had to weave through citizens sitting on the sidewalk or waiting in line. This phenomenon existed outside of hospitals located both in the northern half of Madinat Al Irfane and the southern half.

In addition, the bridge was a notable issue. Many students live in Al Qamra where there is more affordable housing available. Hence, residents of Al Qamra must cross the bridge to enter Madinat Al Irfane to attend class or go to work. During these morning rush hours, commuters crowded the bridge. With these two areas being the only noticeable problems, the team concluded that walkability within this area between the hours of 7:00-9:00 A.M. is not a major issue. There are multiple alleyways, (see Figure 63) that provide access to and from other destinations, which facilitate the reasonable flow of foot traffic during these rush hours.

Figure 63: Example of an alleyway to avoid sidewalks on main roads

Throughout heating mapping, the team noted in the observation tables, seen in Appendix J, small amounts of congestion along with several other issues that impacted walkability. Some of the congestion found on the heat map was due to crossing roads within Madinat Al Irfane. Whether the road was major or a side street, crosswalks are rare within the area. In an area of Madinat Al Irfane, there is a reflective sign seen in Figure 64, but no crosswalk in sight or lights to assist with a pedestrian crossing.

Figure 64: Crosswalk sign not accompanied by a physical crosswalk or lights

Many citizens chose to jaywalk, walking freely across roads without use of crosswalks. This is unsafe and poses a risk for getting injured by a vehicle. In another part of the observatory region, there is a painted crosswalk across the main road, Avenue Allal Al Fassi. The lights to stop traffic for the pedestrian at the crosswalk were not working, seen in Figure 65, making it dangerous to cross. This is a crucial problem that the team noticed at multiple locations in the observation area. Crossing the street during the rush hours proved to be remarkably difficult and slowed the pace of the observers. The addition of crosswalks, stop signs and lights would help increase the walkability at these morning rush hours.

Figure 65: Physical crosswalk available but with broken pedestrian lights

The morning hours brought to light areas of congestion and many issues outside of the problem of congestion. The team cannot just evaluate walkability based on the morning rush hours. The research team decided to create another heap map at afternoon rush hours and study any changes in congestion between the two.

4.4.2 Afternoon Rush Hours

At 12:00 P.M. on January 30th 2018, the team began heat mapping at Campus Al Irfane and went north to the top half of Madinat Al Irfane; the team used the same technique as the morning rush hour heat map. The team studied the same areas of focus as the morning hours seen in Figure 60 above. The route began at the tramway stop in Madinat Al Irfane and ended at Campus Sweet Cafe. Data collectors spent approximately one hour and thirteen minutes mapping the area; the test walk was approximately 3 miles represented with the 3 mile markers on the map. Figure 66 provides the heat map and indicates the congestion in the area. This map displays some differences from the morning rush hour map. Although the observers faced some congestion around the hospital area, they encountered noticeable pedestrian flow moving in the opposite direction towards Campus Al Irfane. Additionally, observers faced no congestion when walking

across the bridge into Al Qarma. They faced the heaviest congestion on this route outside The Presidency of the University of Mohammed V - Souissi campus, located on the map below in red near the one mile marker. The team noted in the observation table in Appendix J that pedestrian traffic was not the issue at this time but there was severe private vehicle congestion during this period within rotaries and at intersections.

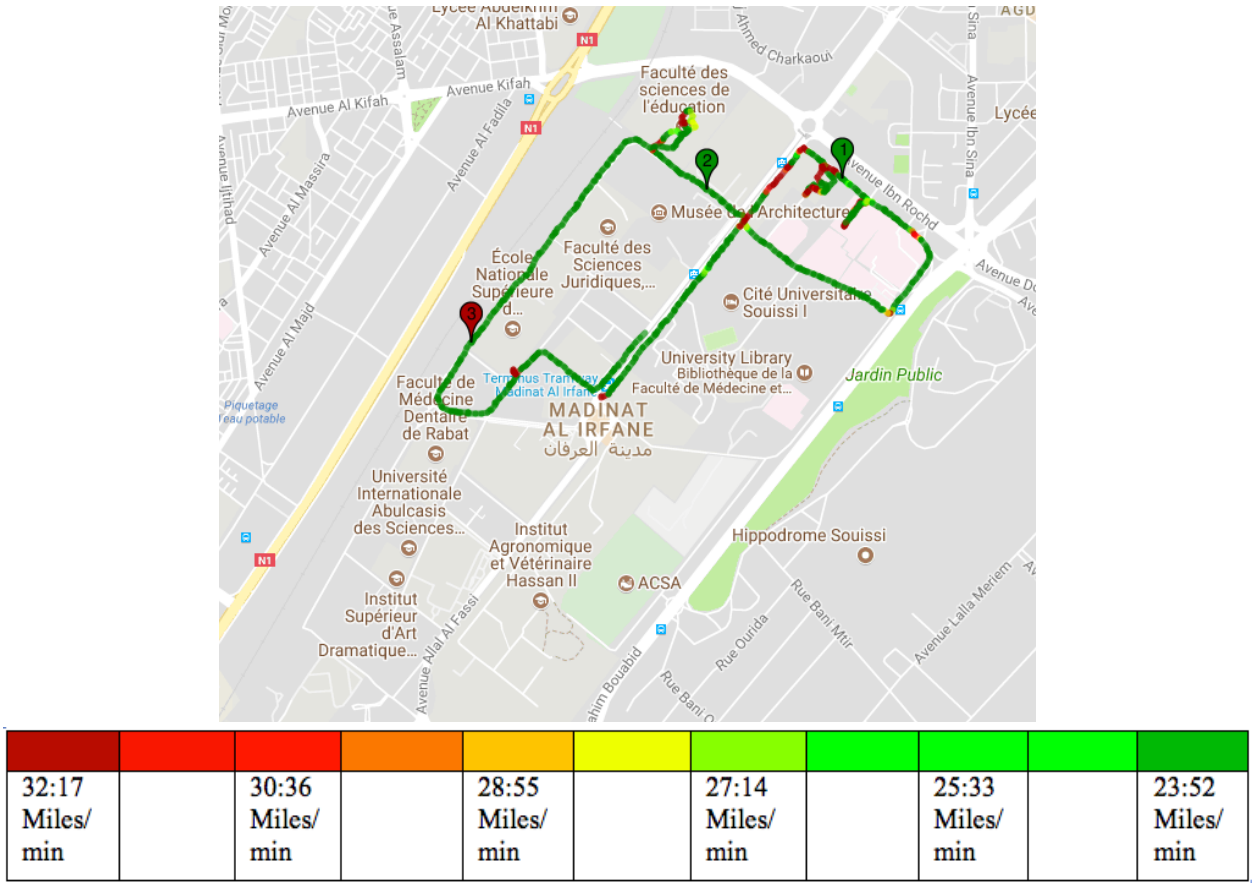


Figure 66: Top half of Madinat Al Irfane heat map from 12-2 P.M.(Miller, 2016).

The pace for this route was much slower than the morning rush hour mapping. The walker's watches recorded the average pace at 28:05 minutes per mile, seen below in Figure 67. A majority of the congestion, peaks seen in the graph below, are all before the mile and a half marker. Looking at the map above this includes congestion faced outside The Presidency of the University of

Mohammed V - Souissi campus and the hospital area. The walkers were consistent with the 20 minute per mile pace during the back half of the route, where they faced little to no congestion.

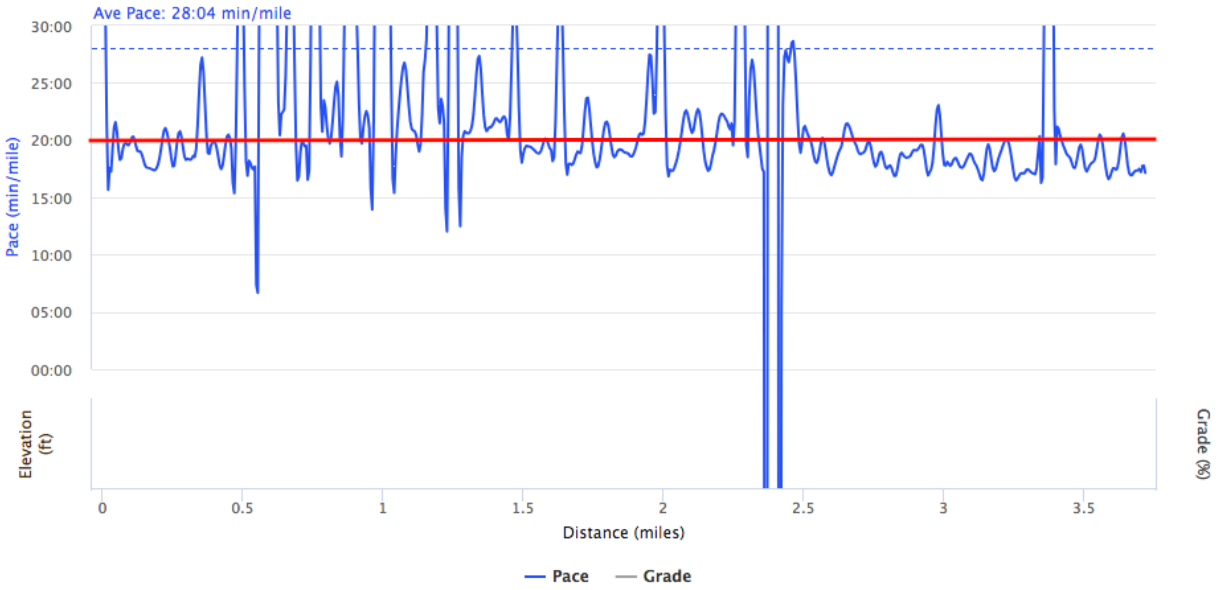


Figure 67: Pace of afternoon rush hours for top mapping of Madinat Al Irfane (Miller, 2016).

On February 6th, the team at 12:00 P.M. heat mapped the southern, bottom half of Madinat Al Irfane. The route started and finished at the tramway stop in Madinat Al Irfane and took approximately one hour. The team added more areas of focus to this heat map from the morning rush hours to accommodate the main food court area, Campus Al Irfane. Figure 68 identifies the areas of focus for the heat mapping in red.

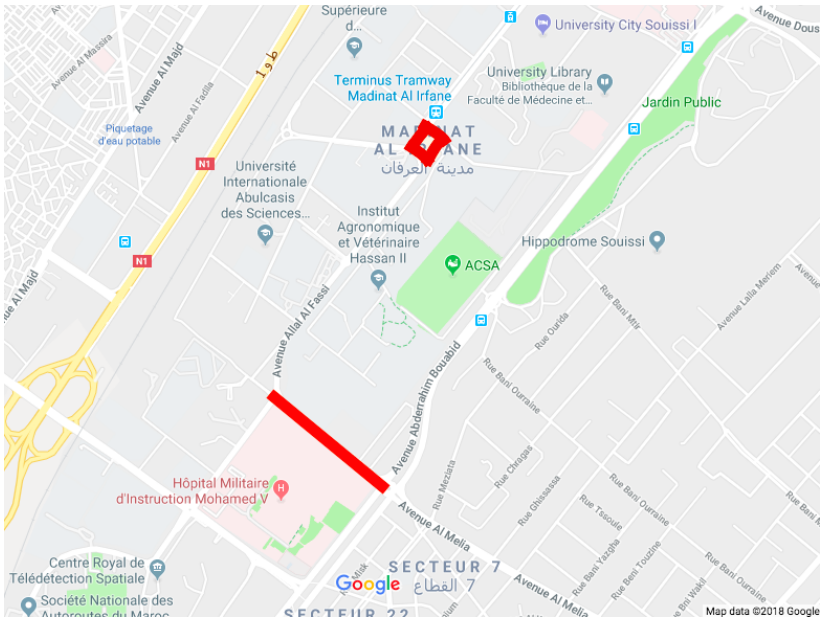
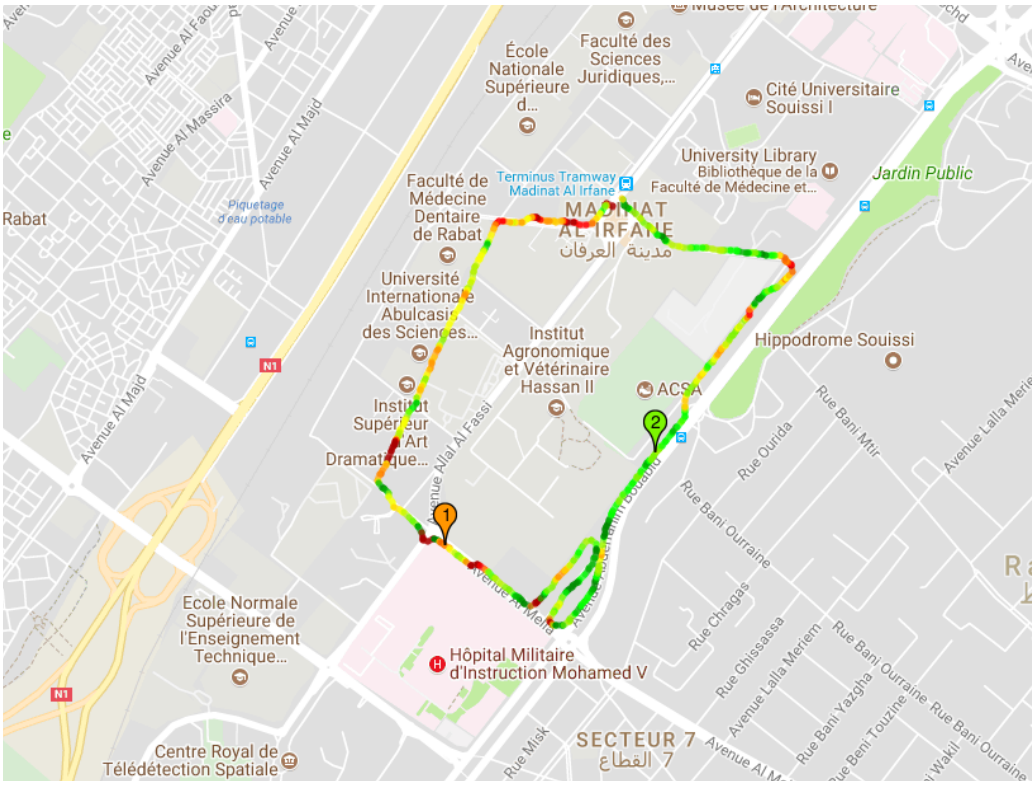


Figure 68: Map of Madinat Al Irfane showing the bottom area of focus for afternoon rush hours (Google Maps, 2018).

The afternoon rush heat map of the bottom half of Madinat Al Irfane, Figure 69, and displays congestion in the focus areas shown on the map above. The numbers on the map represents mile markers to show the walking loop a team member took. Data collectors still recorded congestion around the hospital around lunchtime in addition to congestion around Campus Al Irfane which contains an assortment of outside cafes and convenience shops. The team came to the conclusion that the main reason this area showed congestion around lunch time and not during morning rush hours is because of the availability of food.



23:19 Miles/ min		22:06 Miles/ min		20:53 Miles/ min		19:40 Miles/ min		18:27 Miles/ min		17:14 Miles/ min

Figure 69: Bottom half of Madinat Al Irfane heat map from 12-2 P.M. (Miller, 2016).

The average pace for the southern route during the afternoon was 20:18 minute per mile, almost exactly on the target pace. This indicates a lack of any significant congestion as well as reduced human error. Studying the plot in Figure 70 below, there are not many instances of congestion signified by peaks within the plot.

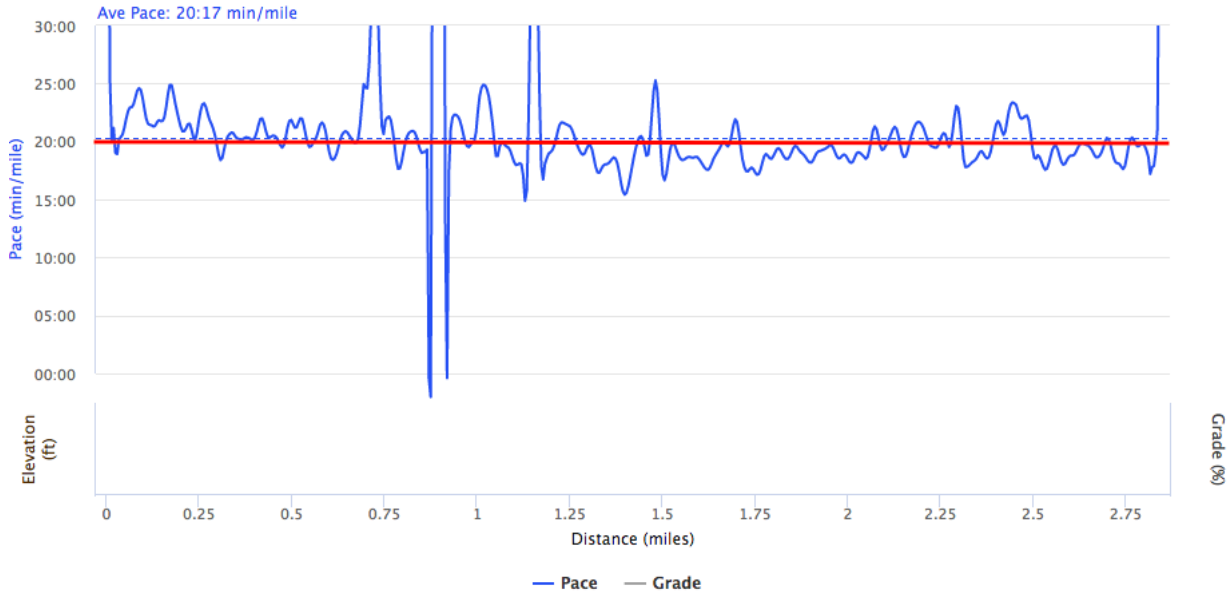
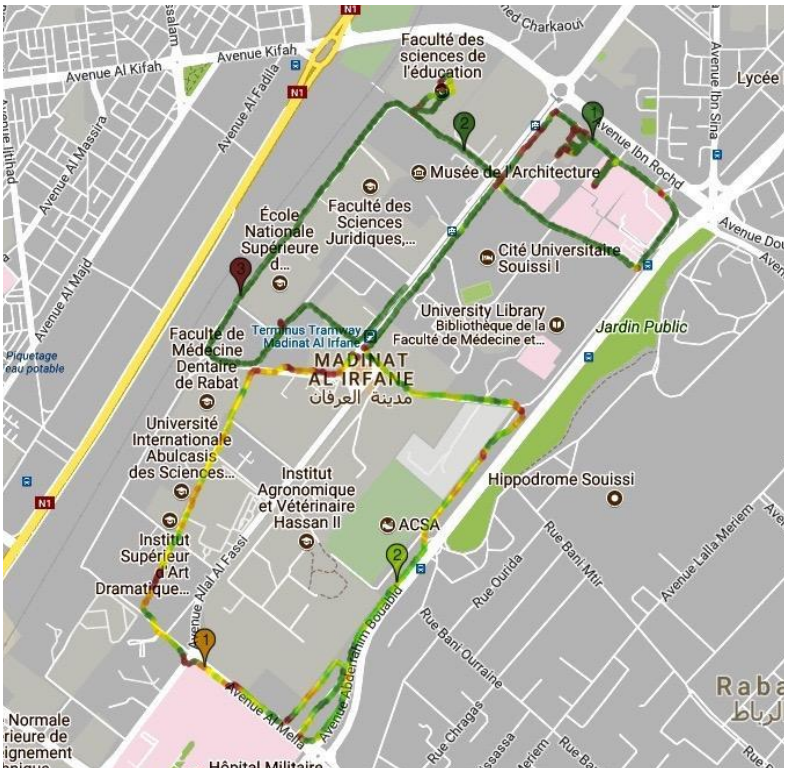


Figure 70: Pace of afternoon rush hour for bottom mapping of Madinat Al Irfane (Miller, 2016).

4.4.2.1 Afternoon Rush Hour Analysis

The team investigated this area of Madinat Al Irfane at lunchtime, 12:00-2:00 P.M., to understand the variability in walkability at different times of day. This produced foot traffic trends more than at just one time of day. Figure 71 offers a cohesive heat map of both the top and bottom halves of Madinat Al Irfane at afternoon rush hours.



28:27 Miles/ min		26:27 Miles/ min		24:54 Miles/ min		23:47 Miles/ min		22:20 Miles/ min		20:33 Miles/ min

Figure 71: Heatmap of Madinat Al Irfane at afternoon rush hours

Similar to the morning rush hour behavior, there are a few cluster areas of congestion that are very independent of the observation area as a whole. These areas of congestion are easy to avoid with the access to multiple paths that pedestrians can take to reach their desired final location. The data did not raise appreciable concerns about walkability of the area. Observations show that the hospital areas had heavy foot traffic in the afternoon as well as the morning hours. This is the only constant data point that the project team found between the two different time periods. The morning versus afternoon heat map had unique congestion points that must be specific to when the research team mapped the area. For example, the congestion faced outside of The Presidency of the University of Mohammed V - Souissi campus during lunch time, may be due to

the end of a class. The heat mapping data points demonstrate little consistency across the time periods and the team can speculate time specific reasons.

Throughout the process of heat mapping, the ease of walkability has been consistent under many conditions. During the lunchtime heat mapping on the bottom area, a rain storm passed over. The rain did not affect the pedestrian flow except for a noticed increase in pace. Since many pedestrians commuters in Madinat Al Irfane are most likely going to school or work on rigid schedules, the rain is less likely to impact the flow of traffic.

Especially within the lunchtime hours, the team recorded high private vehicle congestion within the observation table. This leads to reckless driving which puts pedestrians in danger. The observers encountered the peak private vehicle traffic at the roundabouts both at the top and bottom of Madinat Al Irfane seen in Figure 72. Analyzing the afternoon rush hours, it is clear that no pressing issues exist with walkability but many other associated transportation issues show throughout the miles walked.

Figure 72: Private vehicle congestion seen at roundabout in Madinat Al Irfane

4.4.3- Heatmap Discussion

Overall the heat maps of foot traffic at a variety of times proved to the team that walkability is not a pressing issue within Madinat Al Irfane. There are several different locations within the perimeter that displayed congestion with a decrease in pace, but the decrease in pace was brief and the area was ultimately easy to navigate.

With major construction throughout the region, some areas were worse for pedestrians than others. Some streets completely lacked sidewalks and pedestrians had to walk in the road. The

team noticed this activity even if sidewalks are available; the large width of the street makes it accommodating to both pedestrians and vehicles. This may have led to some discrepancy in our data collection, as not all pedestrians walk on a certain path. In Figure 73 below, you can see an example of the width of a common street within Madinat Al Irfane.

Figure 73: Example of a common street in Madinat Al Irfane with sidewalks available

The major issues discussed in this section are not congestion based, but concern other factors that affect the walkability of Madinat Al Irfane. The city could address many of these factors with sidewalk construction, proper crosswalks, and stop signs. Smart technologies are not the solution to these issues. The areas of congestion that the heat mapping did detect within the morning rush hours consist of the hospital perimeters and crosswalks. In the afternoon rush hours, hospitals, The Presidency of the University of Mohammed V - Souissi campus, and Campus Al Irfane required a slower walking pace due to foot traffic. All data collected and analyzed suggests that congestion when walking in Madinat Al Irfane is prevalent at certain times of the days within exact locations but is not a critical area of focus for this project.

4.5 Surveys

In order to gather a data set regarding the public's opinion on transportation within Madinat Al Irfane, the team emailed the survey through the Qualtrics application to students, staff, and faculty for them to self-complete. The team also distributed the survey in person to a random sample of students and faculty within ENSIAS at Mohammed V University. Through these two distribution methods, the team gathered a total of 65 surveys. The team entered the intercept surveys responses into Qualtrics in order to keep an online record of all our responses, making it easier to process alongside the household self-completion surveys. The data collected by Qualtrics provided qualitative and quantitative data; Qualtrics analyzed the latter automatically. In order to analyze qualitative data, the team converted it into a quantitative format using the technique of coding which separates data, and places it in sub-categories that encompass that theme of the qualitative data (Basit, 2003). In order to visualize any overlapped responses, the team exported the data into an Excel spreadsheet.

The survey collected information regarding respondent demographics, their choice of transportation to Madinat Al Irfane, commute time and price, as well as free responses regarding the current state of the transportation system. The team decided some of the survey questions yielded no surprises or important results. Thus they are not discussed in this section, but relevant graphs can be found in Appendix L.

To better understand the surveyee's background, the survey asked them to pick from a list of options that best described themselves and their role within Madinat Al Irfane. The surveyee had the option to pick more than one if necessary, although no surveyee did. The options were: student, staff at university, staff at hospital, resident, or other. If the surveyee selected other, the team asked them to further specify. Figure 74 displays the demographics of the respondents, with a majority (68%) being students with 47 respondents. The research team distributed the survey to Mohammed V University schools - ENSIAS, INAU, School of Law, and School of Architecture through email. Most of the intercept survey responses were from staff at the university, adding a total of 16 respondents. Only one surveyee fell under the category of staff at the hospital and none of the respondents selected resident or other. The team is aware that these survey results do not represent the entire population of Madinat Al Irfane.

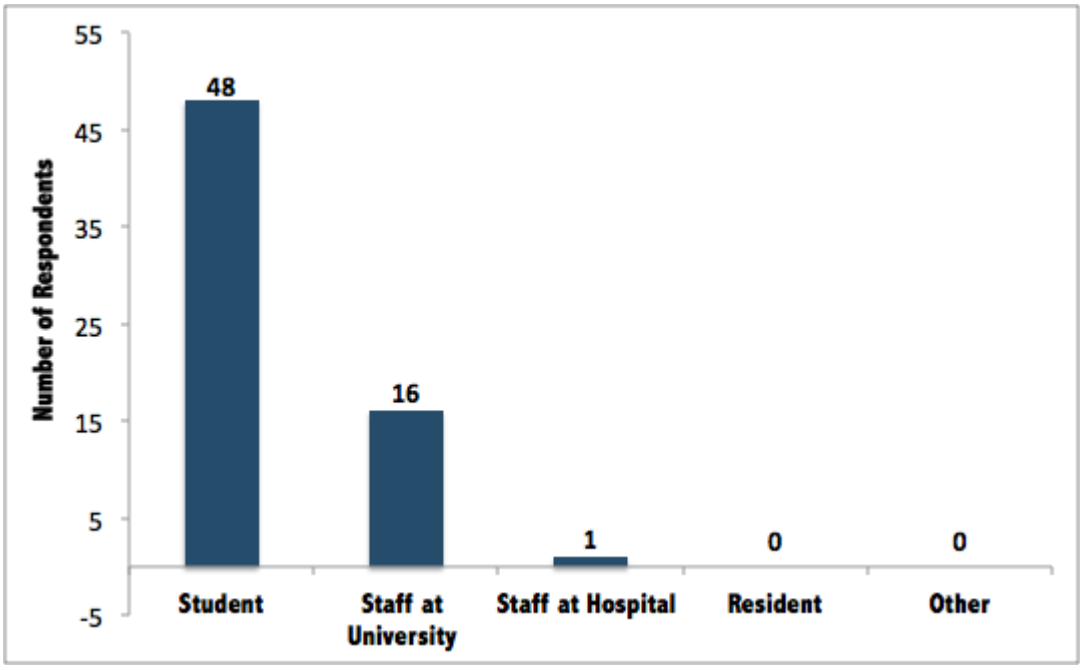


Figure 74: Demographics of Surveyee Pool

Question two addressed the forms of transportation that each respondent takes on their daily commute to Madinat Al Irfane. The team took into consideration that the same person may not take the same type of transport every day. Figure 75 below displays the set up for question two, allowing respondents to pick what percent of the time they take a form of transportation, giving the ability to select more than one. Qualtrics will not allow the surveyee to move to the next question without the sum of percentages equaling 100.

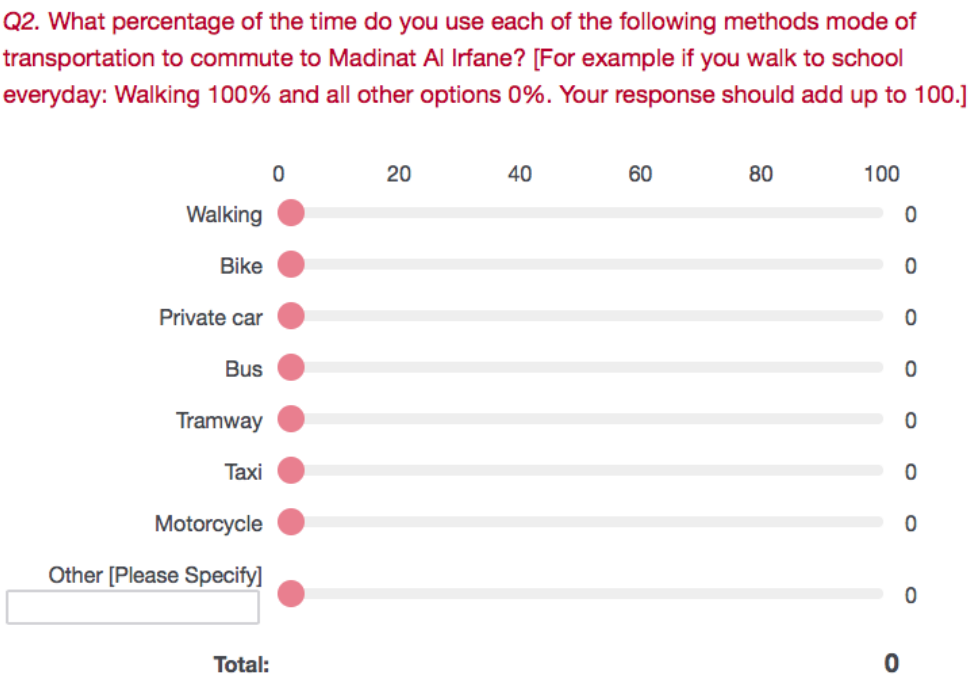


Figure 75: Setup for Question two on Household Self-Completion Survey

The team extracted the raw data from Qualtrics in a Comma Separated Value (CSV) file, and a team member used the programming language Python to format the data into an understandable format. The Python script used can be found in Appendix K. This script opens the raw CSV data file, extracts the percentages from selected columns, formats the extracted data, and then transfers it to a new CSV file. Within the new CSV file, the team took the average of all the percentages for each mode of transit. The team took these percentages and turned them into a pie chart seen in Figure 76. The figure presents the average percentages of usage of each transportation method from the 65 respondents.

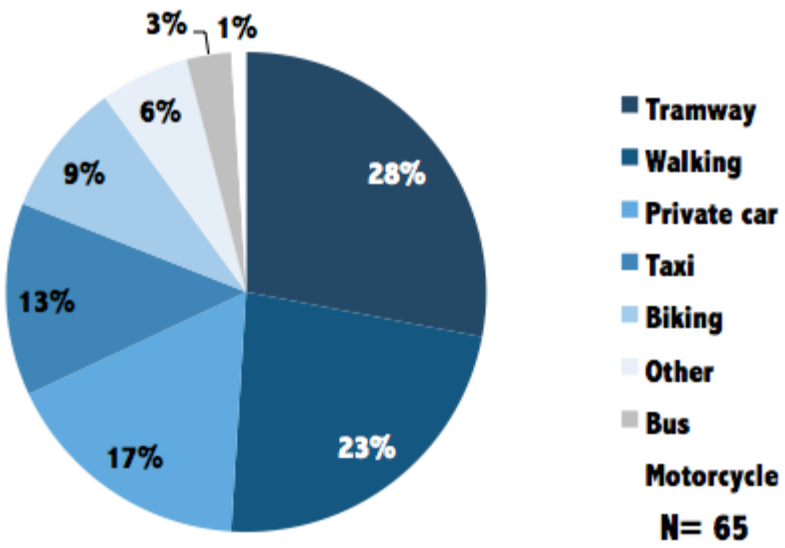


Figure 76: Usage of transportation options within Madinat Al Irfane

The tramway captures the largest number of our respondents, being a mode of transport for 28% of the survey's population. The last stop of line one being Madinat Al Irfane, is a convenient and reliable option. However, the tram is an expensive option for students. A more economically viable option for students, which is a majority of our survey respondents, is walking. Twenty three percent of respondents selected this mean of transport when commuting to Madinat Al Irfane. 30% of the respondents chose private cars and taxis, which are expensive and not popular with our sample students. The majority of the responses for the private car and taxi categories came from faculty of the universities. The "other" category consists of survey respondents who commute via train from further distances and those who are residents in the Madinat Al Irfane and do not commute.

One of the least used modes of transportation displayed by the data in Figure 77 is the bus system. The team concludes that the bus lacks passengers within our survey pool because of its poor quality, lack of reliability, availability, and safety. Throughout our site assessment, the team noticed many problems that were later confirmed through personal anecdotes of the citizens. All these problems led to a poor ridership rate; the bus served only 3% of the 65 respondents. Since the bus has good coverage and is economically viable to the demographics in Madinat Al Irfane, a change to the system could potentially increase ridership. Overall, question two allowed the team

to understand the popular modes of transportation; the next ten questions asked for more in depth information about the transit system and respondents' daily commute.

The survey then gets split into questions based on the method of transportation which the respondent selected in question two. If the surveyee selected taxi, bus, tramway, or walking, Qualtrics automatically directed them to question three to discuss their commute time on public transit and their average spending on the system. Figure 77 below exhibits, the mean, median, and mode for the raw data collected on commute times of public transit of the respondents. Forty two respondents out of the total 65 took public transit as their number one form of transportation.

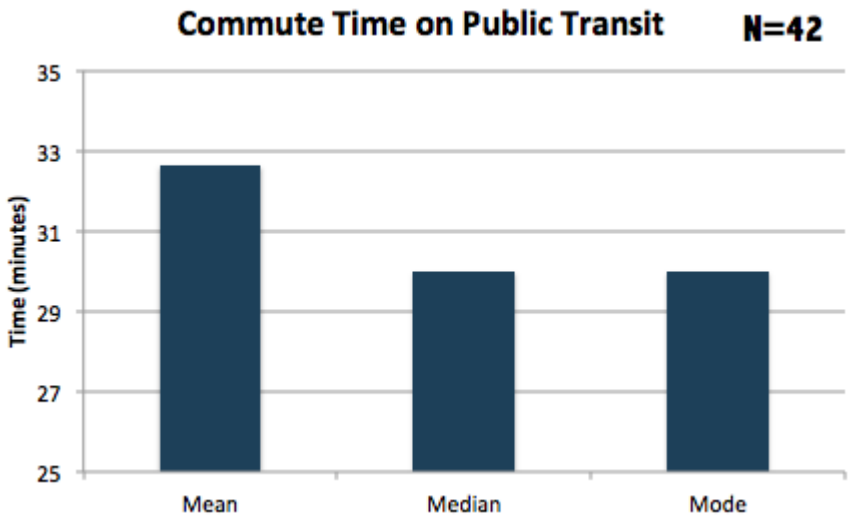


Figure 77: Mean, Median, Mode of Respondents Commute Times on Public Transit

The average commute time is 33 minutes. Since these measures are consistent across the three statistics, we conclude that most commuters live outside of Madinat Al Irfane and commute from the residential areas of the Rabat-Sale complex. The average tramway ride from the beginning of the first line at the Hay Karima stop takes approximately 48 minutes to arrive at the Madinat Al Irfane stop as discovered in the team's site assessment. This is 18 minutes longer than the average commute time, so we infer that most residents don't live far away from Madinat Al Irfane.

In Figure 78 below, the median, mean, and mode for the cost of public transit is shown. The team asked all respondents to specify how much they spend daily, weekly, monthly or yearly,

and the team converted all responses to monthly. The research team based conversions on there being 31 days in a month, 4 weeks in a month, and there are 12 months within a year. Monthly, the average of all 42 respondents was 294 dirhams, which is 94 dirhams higher than the median and the mode.

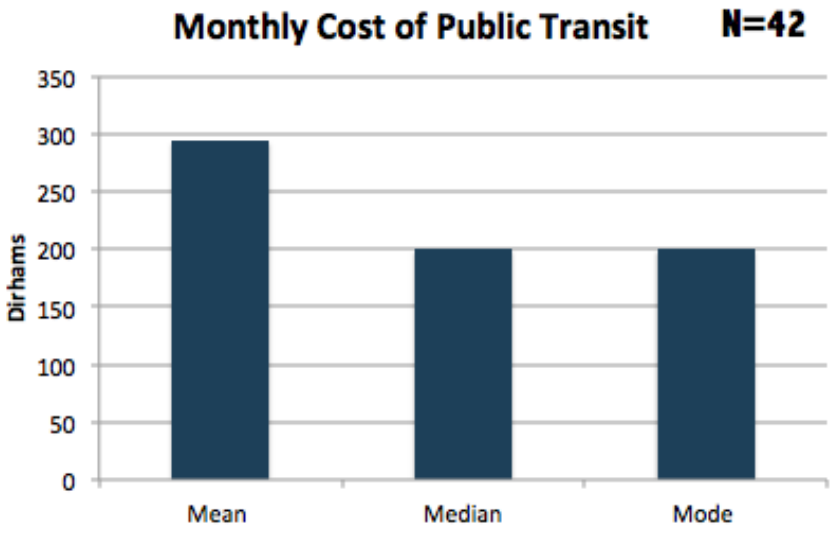


Figure 78: Mean, Median, Mode of Respondents Reported Monthly Public Transit Spending

Some respondents are spending more than others on public transit. Two surveyees with high transit costs answered 40 dirhams daily equaling 1,200 dirhams monthly and another 1,000 dirhams monthly. With these two data points being outliers, the team eliminated them from calculations. The average spending amount decreases to 236 dirhams, which is only 36 dirhams over both the median and the mode. Roughly, commuters spend around 200-300 dirhams monthly on transportation. Looking more into the raw data, those with high spending prices marked taxi on their mode of transportation, which the team has noticed is the most expensive option for Madinat Al Irfane commuters. The average value of 294 gives the most full data analysis including the taxi pricing, whereas, the median and mode eliminate outliers, showing only the pricing for the bus and tramway.

Question four asked the same population of public commuters to rate the reliability of the public transit system with a lower number, one, replying that the transit system is not reliable and a higher number, five, finding it reliable. Figure 79 below conveys the public's opinion. The most respondents, 21 respondents, selected three as a rating. Number four following behind by eight

people with a total of thirteen respondents. The team concluded based on survey data that the public transit system was reliable, with 41% of respondents answering a four or above. Twenty percent of respondents marked the public transit system unreliable with a rank of a two or one. Thirty nine percent of respondents were neutral in the ranking of the public transit system, giving the ranking of a three. This does not, however, correlate to the team's personal experiences on the available public transit options in Madinat Al Irfane. The team would rank the public transit system as unreliable, the opposite of the largest percentage of respondents.

When riding the bus in Madinat Al Irfane, the team found it unreliable, with no schedule followed or updates when the bus would arrive. Teammates waited an hour just trying to take the bus into Madinat Al Irfane to complete our site assessment. In addition, in interviews with students and experts, many expressed frustrations about the bus system specifically. Since only 3% of our respondents take the bus, this lack of reliability was not reflected in our collected data shown below. The data the team collected on reliability mostly represents the more popular public transit modes among our respondents: the tramway, taxis, and walking. To get a better understanding of the public transit system's reliability as a whole, the team would need to collect more data from a heterogeneous respondent pool and ask more concise questions on a specific method of transportation.

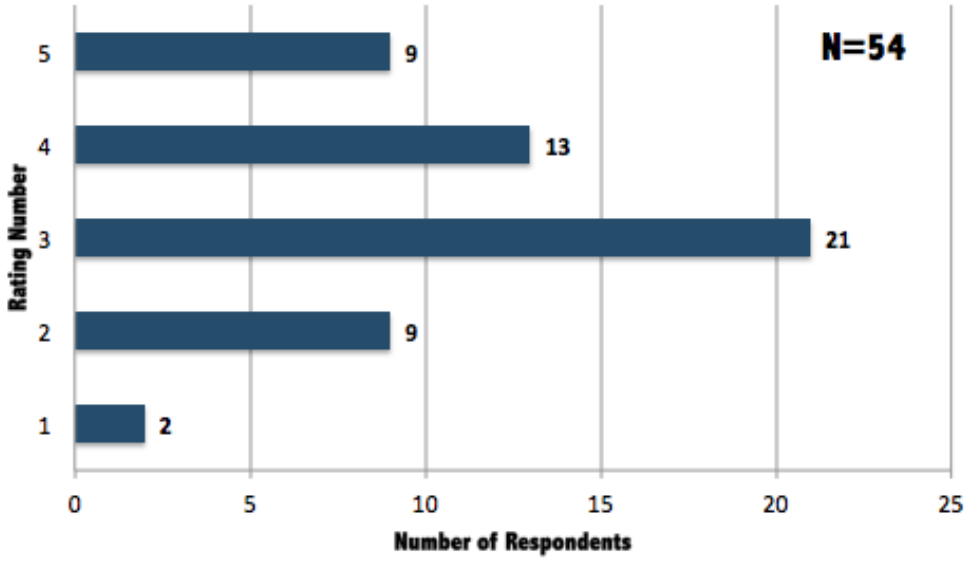


Figure 79: Surveyees Ranking of the Reliability of Public Transit

If the surveyee selected private vehicle or motorcycle in question two, Qualtrics would automatically direct the respondent to question five, which asks questions tailored for private transportation. There were 15 total respondents who commute to Madinat Al Irfane in a private car or motorcycle. Shown in Figure 80, is the percentage of respondents for public and private transportation. Approximately 26% of respondents commute privately and 74% commute publicly.

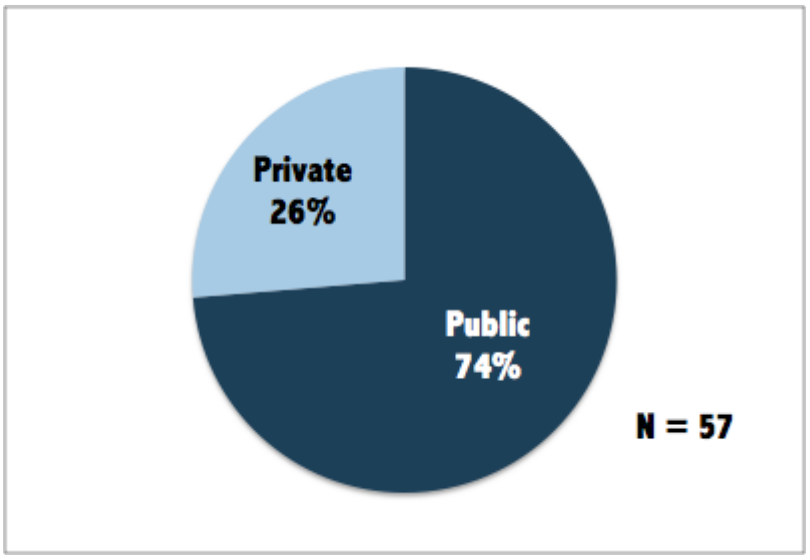


Figure 80: Private vs Public Transportation

The survey asked the same questions about the average commute and pricing of gas to allow for a comparison between public and private transportation. Figure 81 displays the mean, median, and mode commute time for private transportation.

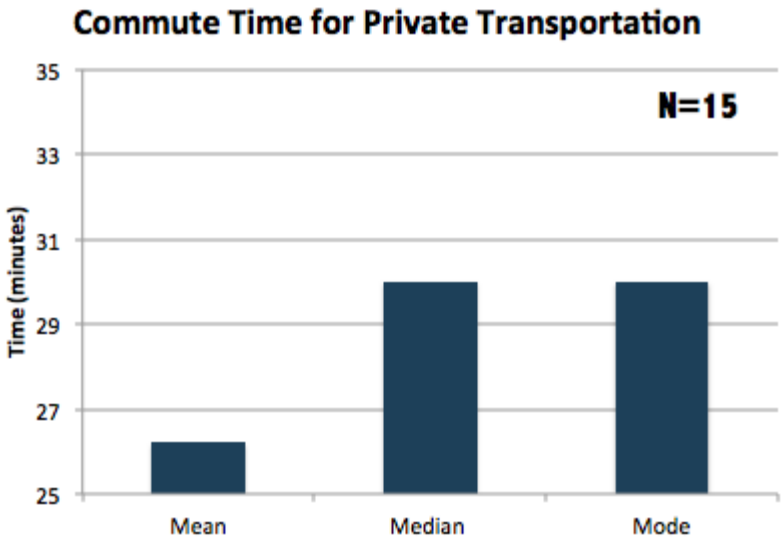


Figure 81: Mean, Median, Mode of Respondents Commute Times for Private Transportation

The average commute time is 26 minutes by private modes of transportation, which is seven minutes faster than the average commute time by public modes of transportation. Wait time for public transit along with no express options for Madinat Al Irfane may be the reason for an increased commute time. The collected data surprised the team as we predicted private transportation would have a larger commute time due to the noted private vehicle congestion throughout heat mapping. The raw data shows that private transportation is faster than public transit when looking at the mean statistic, but the team cannot make any conclusions because the lack of information including distance and speed. The mode and median commute time for private transportation is the same, 30 minutes, as is for public transportation. Overall, both public and private modes of transportation have approximately the same commute time; this may be due to the close proximity that respondents live to their work and school. While the commute times may be similar, but there is a large difference between the two transportation choices in monthly costs.

Figure 82, displays the mean, median, and mode for the monthly cost of gas for private transportation. The average price is 643 dirhams, only 43 dirhams off of the mode and median calculation equaling 600 dirhams. Private transportation is more than twice as expensive as the monthly cost for public transit, with a 400 dirhams difference between the two means. The team can conclude that a majority of our respondents, 74%, take public transportation instead of private transportation. This potentially could be because of expense of private transportation including purchasing a vehicle, maintenance, gas prices, and parking fees. Although the data collected may

show a slightly fastest average commute time of seven minutes for private transportation, not taking into account distance or speed, the lack of private vehicle commuters in our sample shows the importance for affordability versus efficiency.

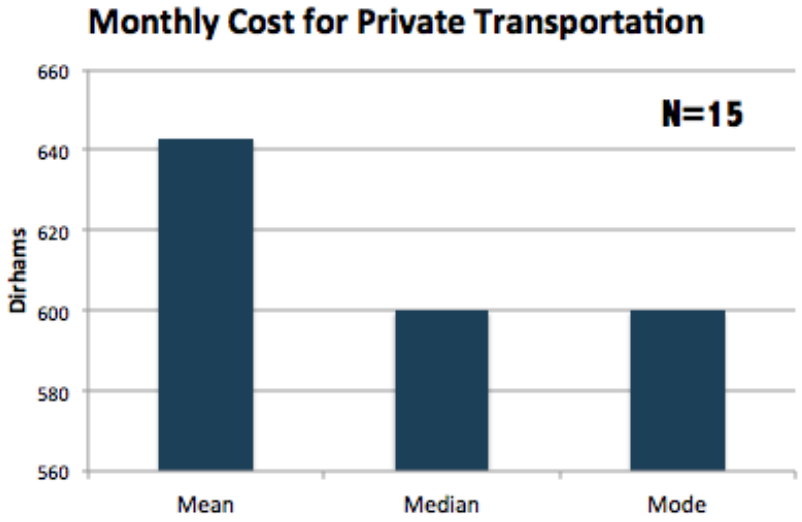


Figure 82: Mean, Median, Mode of Respondents Reported Monthly Private Transportation Spending

A way to make private transportation more affordable is to carpool. Carpooling is commuting with other people, and this allows for splitting the costs of gas. The survey asked respondents whether they travel with others in private transportation, the results are shown below in Figure 83. Out of the thirteen respondents, a majority of 62% replied they do not travel with others to Madinat Al Irfane. The lack of carpooling may have had an influence of the high monthly cost of private transportation.

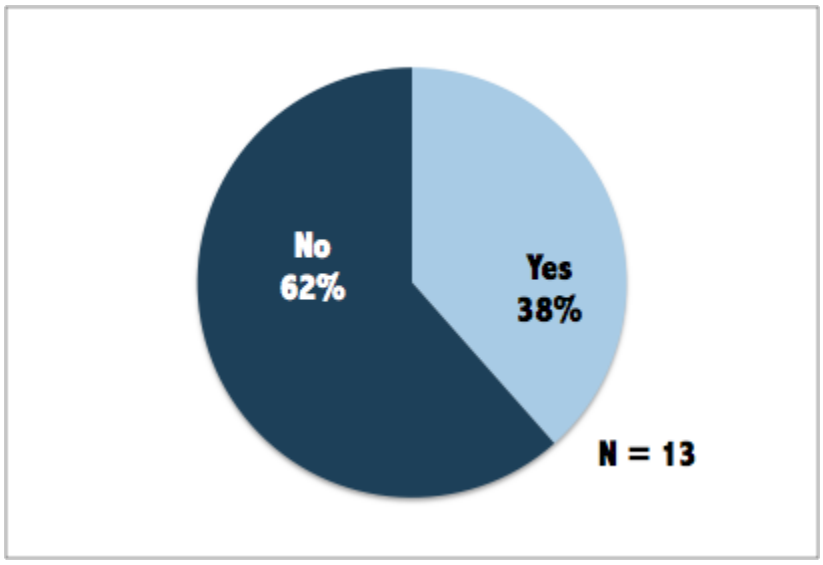


Figure 83: Percentage of private vehicle owners who carpool

Question six on the survey asked the 26% of respondents who commute privately if the availability of parking within Madinat Al Irfane satisfies their needs. There were only 17 surveyees who answered this question, and the most selected ranking was a four out of five seen in Figure 84. The commuters seem to be content with their availability of parking, and as observed by the team there are many large parking lots conveniently located at the schools along with vacant street parking. Fifteen respondents, 88%, rated the parking a three or above. Overall, those who commute by private vehicle express no concerns about parking in Madinat Al Irfane.

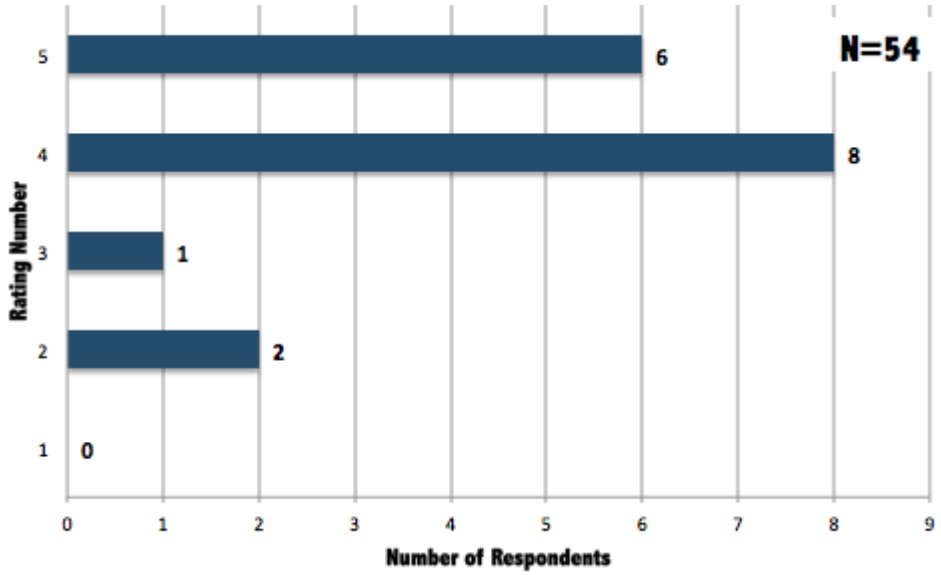


Figure 84: Satisfaction of parking for surveyees that chose private transportation

Private transportation is not as popular as the public transit in Madinat Al Irfane but commuters who do choose cars or motorcycles are content with the availability of parking and have a slightly faster commute time. The major downfall that the team can conclude from the data collected is the high monthly cost for private transportation. The average monthly cost is 407 dirhams more than the average public transit cost, which is not economically viable for the survey's demographics. Also information gained from our translator, a student at ENSIAS, is that an average student gets a 2000 dirhams stipend per three months. If a student is using private transportation this is most of their stipend leaving only 200 dirhams left for housing and food for three months. Using the average public transit cost, this is the most feasible option available for students, consuming only 47% of their three-month stipend. This is still a large amount, but much less than private transit. Throughout our intercept surveys, the team noticed that a majority of data collected about private vehicle use was from faculty of the university who we randomly selected to take the survey. This demonstrates how private transportation is not feasible for the survey demographics corresponding to the low percentage of respondents selecting private transportation.

The last quantitative question that the team asked the surveyee was to expand on why the days marked in the previous question were a difficult commute. Figure 85 shows the distribution of responses from the public. The team provided six factors that the respondent could pick from: reliability, cost, accessibility, congestion, and other. Out of the 56 respondents, the largest reason

for difficulty is congestion, selected by almost half of the surveyees. Following congestion, accessibility was the second most popular response with 34% respondents.

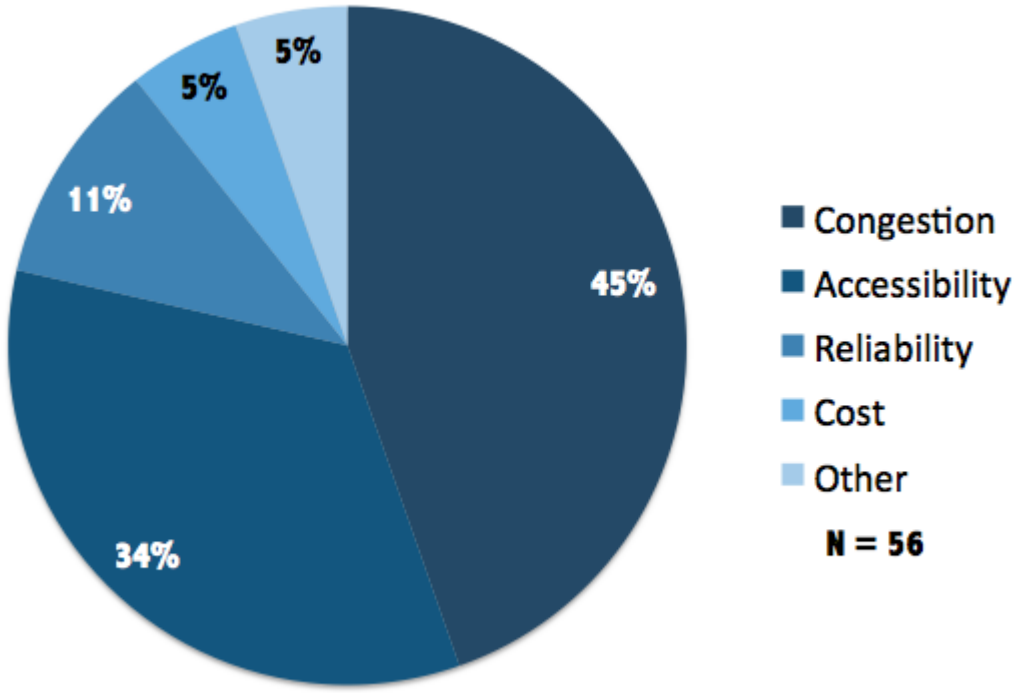


Figure 85: Reason for difficulty when commuting to Madinat Al Irfane

In addition to the quantitative data analyzed from the survey question one through nine, the team's survey also incorporated four free response questions. The team analyzed the responses and looked for common themes that each respondent had expressed, this is a process known as coding. For each common theme, the team assigned keywords and colors to make the data more concise and easier to understand. The Excel sheets can be seen in Appendix M. By asking for free responses the team allowed for the surveyee to express their own opinion and provided insight on the transportation system from a frequent long-term user. This information is valuable for our third objective to create a preliminary design review.

Our first free response question inquired as to what locations are most difficult to reach within Madinat Al Irfane. Out of the 31 respondents to this question, the team extracted five major themes from the raw data. Displayed in Figure 86 below are the three themes: universities, none,

and not applicable which includes responses indicating Agdal, Sale, and Tamera, which are both outside of Madinat Al Irfane, and not applicable to our study. Fifty six percent of respondents marked the universities within Madinat Al Irfane to be the most difficult to reach. Of these 18 respondents, 16 specified ENSIAS. The team believes this data collection shows a bias based on our survey pool which consisted primarily of students and faculty at universities, including ENSIAS. Five respondents emphasized that no places are difficult to reach within Madinat Al Irfane; considering the site assessment results, the team believes this could well be true. As for the other data collected, the question may not have been clear.

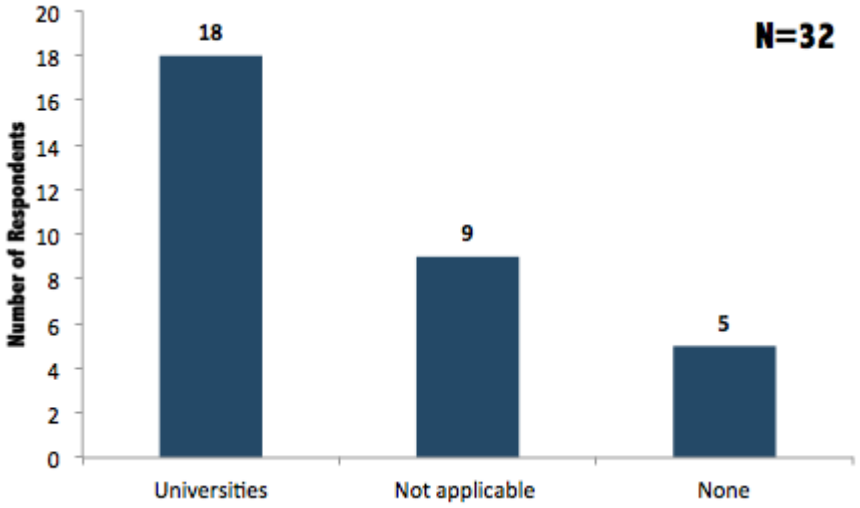


Figure 86: Most difficult areas to reach in Madinat Al Irfane

Question 10 asked the surveyee to express their personal opinion on what they believe is the biggest transportation problem facing Madinat Al Irfane. Out of the 52 respondents to this question, the most frequent response was availability, displayed below in Figure 87. The common theme of availability, derived from our coding process, includes the shortage of certain modes of transportation within this area. Fifteen percent of responses from surveyees indicated that the management of the system was a problem. The theme of management included responses that complained about the physical condition of the transit vehicle, the responsibilities of people in charge of the system, and in the case of taxis, the taxi driver. Many respondents expressed frustration towards taxi drivers because of cases when they refused to bring them to certain locations due to reasons such as congestion and personal choice. Tied with management at 15%

was price. The team organized any data collected that verbalized a transit system being expensive or economically not viable for students into this theme. Ninety four percent had issues that all related to one of the seven themes seen in the figure.

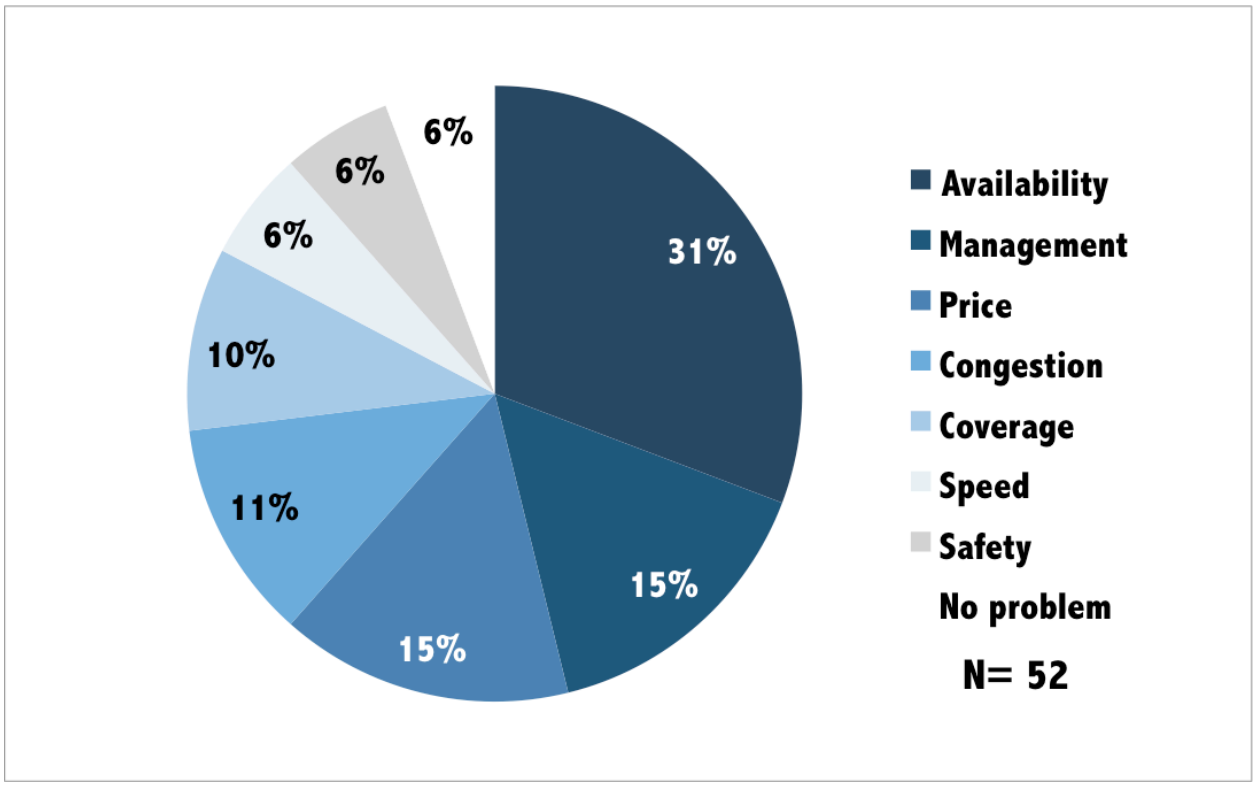


Figure 87: Biggest Transportation Problems Voiced by the Public

For the team to decipher the significance of the respondent's complaints about the transit system, the team performed another round of coding on the same set of raw data dividing comments up by transit system. Figure 88 showcases the percent of respondents who mentioned each available transportation method as a problem.

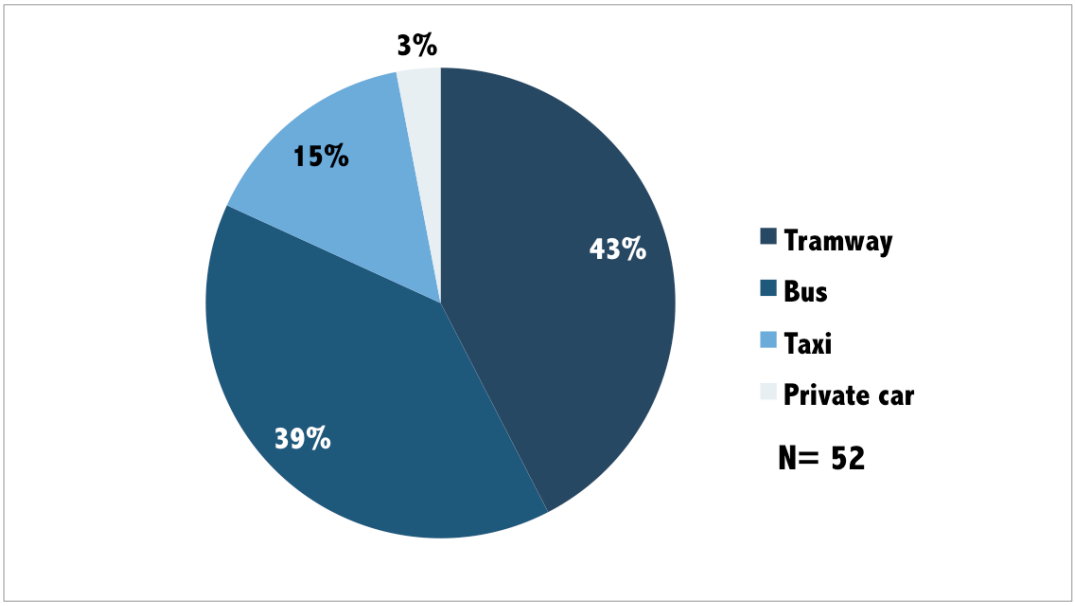


Figure 88: Percent Each System was referred to as the Biggest Problem

The tramway was the most referenced mode of transportation within all the raw qualitative data discussing the problems with transportation in Madinat Al Irfane. Respondents targeted 43% of all complaints at the tramway. This links the source of the previously stated issues including availability, management, and price at the tramway. Along with the tramway, the bus is also problematic receiving 39% of all free responses. Using the information that shows where the public believes needs attention; the team can define an area of focus within the transit system.

The research team wanted to hear from the public any suggestions on how to improve the services. This allowed for insight into what citizens imagined would benefit both themselves and the community. The team used the same coding themes from question 10 but with additions of themes such as new system and frequency. Figure 89 reveals the public ideas on how the city can improve the current transportation system in Madinat Al Irfane.

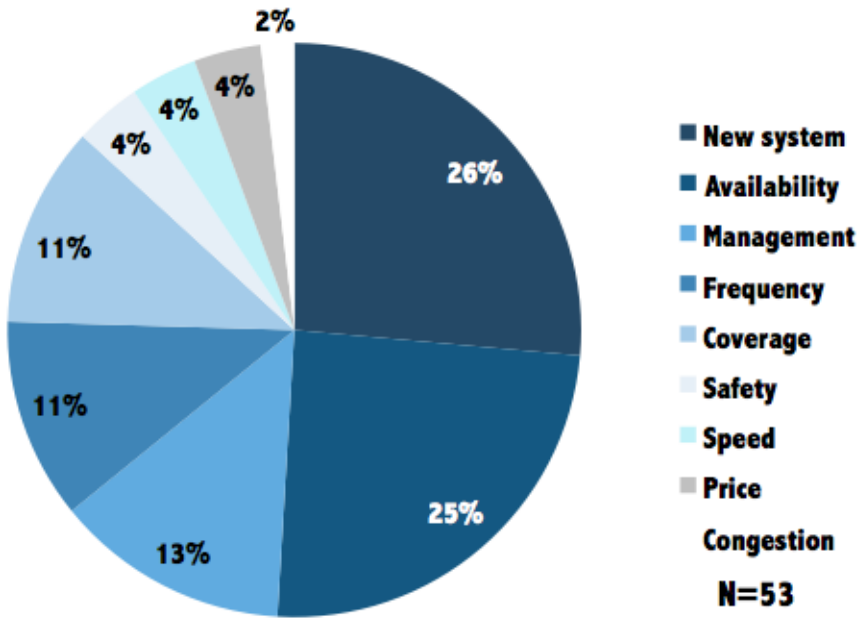


Figure 89: Suggestion to Improve Transportation Services

Twenty six percent of the responses to this question suggested investment in a new system, responses ranging from a subway system to a student bus system. The feasibility of the proposed new systems range from realistic to unrealistic, but the team took every response into consideration for a possible smart mobility initiative. Availability ranked high in survey responses, consisting of 25% of responses. Survey respondents suggested a new bus organization with a multitude of lines that stretch to Tamara and Irfane and also suggested having more tramways running at rush hour. The public knows the transportation system best because the lack of alternatives force them to take it every day and they are aware of improvements that would benefit the every day commute.

The team again coded the raw data a second time to uncover the public transit systems the public most wants to improve. The pie chart in Figure 90, breaks down into percentages the number of times a respondent referred to a certain system within the suggestions on how they want the future transit system to function.

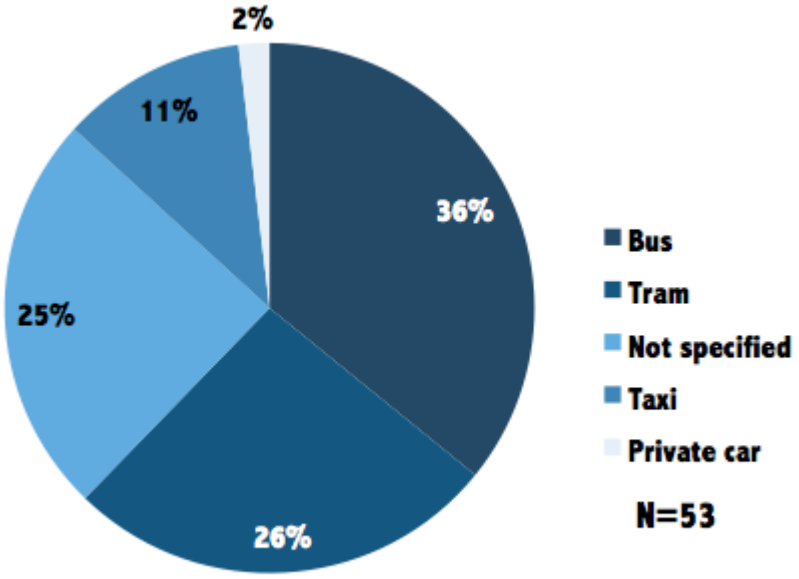


Figure 90: Percentage of References of Transit Systems for Suggestions

The most referenced transit system for recommendations was the bus system. This shows the public's frustration with the bus system quality. Thirty six responses, more than half of the respondents to this question, voiced suggestions that they felt were necessary for the bus system within Madinat Al Irfane. They believe the best way to address the crucial issues is with a new system and through making it more available. In conjunction with our site assessment, the team concludes that the bus system is the area of most concern. To improve mobility within this system, the city must address it. From our best practice comparative analysis the best way the city can address the issues with the transit system is by having a top level control over all systems. This is the case in all three of the case studies discussed earlier.

Whether the city achieves the improvement through a top level control or smart technology implementation or a revamp of a basic bus system, the survey pool has expressed the need for it. About one-fourth of the suggestions from respondents focused on the tramway and another one-fourth of responses there was no specification of the transit system made by the respondent.

Lastly, the team left space for the surveyee to express any additional comments. There were only 14 responses, half of which were not pertaining to this project. The team then coded the responses containing usable data about transportation. Figure 91 presents the common themes that

surveyees mentioned in this set of open responses. Some respondents used this area to continue stressing their concerns about the transportation systems, and to make a case for suggested improvements. Frequency and coverage were both mentioned twice while congestion, speed, and safety were only expressed one time each.

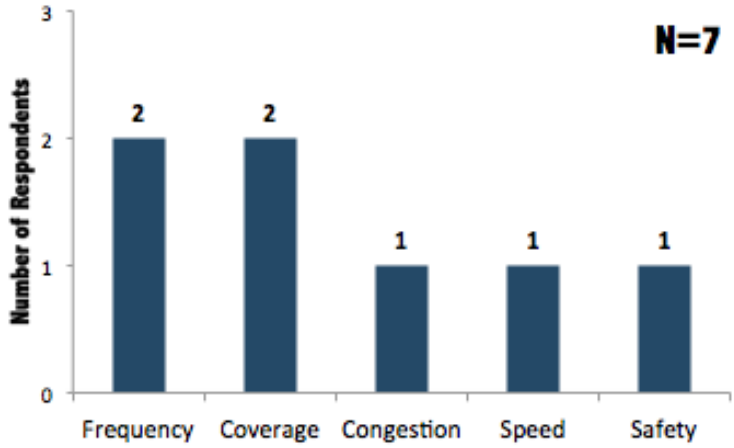


Figure 91: Themes of Additional Comments at the end of Survey

4.5.1- Survey Conclusion

The survey served as a method to gather more information on the commute into Madinat Al Irfane and the public's opinion about the available transportation system in the area. The quantitative questions gave the team useful statistics such as commute time, average monthly cost, and percent usage of transportation. The qualitative data served a different purpose, and allowed the surveyees to voice their frustrations with the current system and give suggestions for improvement. The complete analysis of all collected survey data led the team to conclude that the bus system is the transportation method in critical need of attention. No transportation system within this area is perfect or ranked top in the world. By moving forward with a people-centric approach and addressing some of survey respondents voiced issues, the transportation system could potentially have increased ridership and the improvements would enhance the quality of life for all commuters within Madinat Al Irfane.

4.6 Interviews

The team had the opportunity to interview professional representatives from our key stakeholders. The semi-standardized interviews allowed the team to better understand each representatives' role and personal opinions, addressing matters on the funding, acceptability, and process of implementation of mobility projects within Madinat Al Irfane. Recording each interview with the interviewee's approval, the team later transcribed the interviews, and transcriptions may be found in Appendices N through P. Upon completion of the interviews the team analyzed the transcription through coding to determine key themes and ideas presented by the interviewee.

4.6.1 - Mohammed V University, Student Body President & Treasurer Interview

On February 2nd, 2018, three team members interviewed the student body president alongside the student body treasurer of Mohammed V University, both named Mohammed Amine. The board members serve as representatives for the student body population. The transcription of this interview can be found in Appendix N. The interview questions focused on trying to understand the student population's opinions on current transportation systems. According to the board members, the students do not use public transportation systems frequently, due to the fact that they receive housing on campus within Madinat Al Irfane. Students mainly use the transportation systems to leave Madinat Al Irfane for restaurants. Although most students live on campus, a majority are still familiar with the transit system and some students do commute. However, when in need of public transportation students face high costs and unreliable systems. Three major themes that appeared in the transcription of the interview were price, management, and coverage. Our analysis shows that the two respondents spoke more about the bus system, in comparison to either the taxi or the tramway. This shows the team that the bus is a pressing problem.

Treasurer Amine mentioned pricing three times, thus reflecting that the cost of transportation is a major area of concern for students. Students receive a 2000 MAD stipend for 3 months. A student can spend an average of 400 dirhams a month on transportation, taking up more than 50% of their stipend given by the government. The student body officers mentioned taxis three times throughout the interview, saying they are very expensive for students to afford, and

can also take up a large portion of their stipend. The interviewees spoke about the tramway twice. They mentioned that the tramway provides the best quality for price but a major concern with the tramway is the lack of coverage. Students who commute from other cities, excluding Sale, are unable to use a direct tramway route into Madinat Al Irfane. This requires students to find alternative options or take multiple different modes of transit to get to Madinat Al Irfane.

Treasurer Amine expressed that despite the fact that the buses are cheaper than trams, they are not safe and they are unreliable. While the prices students are spending is not equal to the value and reliability given with the quality of the transport, there is no visible trade-off. Student Body President Amine, expressed the lack of availability three times during the interview. He moved from the tramways short hours of functioning to the bus's lack of availability: "for the bus, it's terrible, they have to wait for more than one hour." (Mohamed Amine, Personal Interview, February 2nd, 2018). These expressed frustrations underscore the groups' findings, showing how unreliable the buses actually are, and supports the team's experience with the bus system.

The team asked for the interviewees' opinions on the implementations and the acceptability of smart technologies within transportation systems. Treasurer Mohammed responded that there was a need for basic organization of transportation systems, and the city must fix the basics prior to the addition of any smart technologies. Treasurer Mohammed also mentioned the management and organization of the current system twice throughout the interview. Overall, the team learned that the students feel dissatisfied and frustrated with the pricing, management, and availability of the transportation systems. Their main concerns are with the bus, since for many, taking the bus is a necessity, and students must deal with the poor quality and unreliability of the system. This confirmed what the team had originally felt was the main problem with the transportation system, while providing more insight from the students.

4.6.2 Assistant Director for Studies of the Institute National D'aménagement Et D'urbanisme'(INAU)

The team interviewed the Assistant Director for Studies of the *Institute National D'aménagement Et D'urbanisme'* (INAU), Professor Mohamed Hanzaz, with the goal of attaining an expert opinion on smart initiatives pertaining to Madinat Al Irfane. Professor Hanzaz obtained his doctorate in Urban Planning and Geography. As part of his resume, Professor Hanzaz worked in the Moroccan Ministry of Interior as an Administrator of Rural Affairs as well as being the

Director of the Urban Agency in Rabat-Sale. He joined INAU in 2011 as a professor and a year later became the Director of the Center for Studies and Research in Planning and Urbanism.

Two team members carried-out a semi-structured interview with Professor Hanzaz. Also in attendance was our translator Professor Torya Balhoussin Idrissi. Our sponsor, Dean Essaaidi introduced her to our team. The interview took place at eleven o'clock in the morning on February 15th, 2018 at Professor Hanzaz's office in INAU. This section condenses the highlights of the interview. Professor Hanzaz's main language is French, which complicated the transcribing procedure. Instead, the team transcribed Professor Idrissi's answers on his behalf. The transcription is found in Appendix O. The team touched upon various subjects regarding smart cities, especially transportation mobility in Madinat Al Irfane. After the team transcribed and determined key findings, we coded Professor Hanzaz's transcribed interview in order to identify underlying themes during the interview. Through Excel, the team added he number of times the interviewee mentioned a recurring word. After the team highlighted each word and grouped the themes, we noticed the four categories that stood out the most: The bus, tram and private cars.

The team found the bus word count from the interviewee to be 15. In this bus category, Professor Hanzaz discussed various examples of the bus's lack of reliability, poor maintenance and how it affects students. Professor Hanzaz used words such as "catastrophic" and "[in] poor condition" which was an overall theme of the bus discussion, which implies dissatisfaction with the system. The team added the number of tramway mentions, which was 13. He deemed the tramway to be efficient, reliable, and effective. Professor Hanzaz praised the quality of the tramway as it is properly maintained and he had a few suggestions, such as expanding the tramway lines. The coverage was the only problem noted which was caused by lack of political will to expand.

Lastly, we noted the interviewee mentioned private cars a total of 12 times. Professor Hanzaz highlighted private cars as the main focus of the Rabat government, rather than public transportation. Professor Hanzaz criticized the usage of private cars and the role the Rabat government played in incentivizing these instead of investing in the public transportation. He noted there should be a tradeoff between the decreased number of circulating cars and increase in public transportation availability. The increase in cars per person, resulted in bottlenecks due to the congestion caused by traffic jams, making many places inaccessible during rush hour times; of 8 A.M. and 5 P.M.

Overall, these findings gave the team a broader perspective on expert opinion and granted for an open dialogue to better understand the underlying details of transportation assessments. The dialogue with Professor Hanzaz's made the team take into consideration multiple factors such as political willingness, when it comes to implementing projects.

The conversation with Professor Hanzaz concentrated on transportation within Madinat Al Irfane. We asked about the current problems with the transportation system. Professor Hanzaz pointed out the poor planning of transportation saying, "[the transportations systems] are not interrelated here to ease transportation for citizens" (M. Hanzaz, Personal Communication, 2018). During our conversation he mentioned that accessibility was not something urban planners took into account which contributes to poorly planned transportation. At the mention of the different qualities of the transportation systems, he noted the "tramway has no problem, it is very efficient. The bus is not safe, it is congested-crowded, and the third way means of transportation is private taxi. Those are very expensive because they put the counter on, and people can't afford to take the taxi" (M. Hanzaz, Personal communication, 2018). Having our survey findings reaffirmed by an expert both reassures us about the validity of our results and shows an awareness of the issue. He later described how students usually arrive late to class since the bus is not reliable, yet many students have no choice.

The team inquired about his opinion on public acceptance of smart initiatives despite the current poor state of the transportation. Professor Hanzaz replied "honestly people can't be against different innovation, they will just welcome [innovation]. People are very open, they will welcome new ways of transportation" (M. Hanzaz, Personal communication, 2018). He believes public transportation users would not oppose innovation, however, there is no "political will" to start such initiatives. However, he mentioned there is a lot of dialogue coming from students surrounding the improvement of transportation.

> "We, [the government] are just building larger roads for private cars, not focused on the public transportation systems. We include household also, who invest in private cars. Now you have to choose between two alternatives, if you want to increase public transportation. You have to decrease the number of cars in circulation, there is a tradeoff needed. This tradeoff doesn't exist" (M. Hanzaz, Personal communication, 2018).

According to our interview, the government would rather invest in facilitating the usage of private cars rather than public transportation. The interview with Professor Hanzaz informed us of possible obstructions that are deterring the planning and implementation of public transportation, such as the government's sole focus on private cars. This was a key finding that complements our data found in the survey open responses, since most surveyees complained about the poor quality of the public transportation.

4.6.3 Panel Discussion at Ecole Nationale d'Architecture

On February 15th, 2018 three team members met with several professors including Professor Reddad Ergingt, Professor Khalid El Harrouni, Professor Hansour Majid, and Professor Kharmich Hassan from the School Architecture in Madinat Al Irfane. Professor Kharmich Hassan is an English professor at the School of Architecture and served as our translator. Professor Hansour Majid was the main respondent as his area of expertise is Smart City research. He gave a presentation on the current state of Smart Cities in Rabat and we then conducted a semi-standardized interview with him which turned into a discussion. The coded transcription for this interview is in Appendix P. The team hoped to learn about the potential for smart city applications within Rabat. This interview focused on the expected and actual outcomes of smart city projects in both Rabat and France, the problems that Rabat faces when implementing smart city projects, and potential solutions to these problems.

In order to support the key ideas that we drew from the interview, we coded the interview transcript responses running a frequency count on words and ideas that the transcript inductively showed us to be important. For example we thought the problems that Rabat faces is an important category pertaining to this interview. While we were coding for this idea we found that it came up nine times throughout the interview showing us that there are significant number of problems that Rabat faces in this area. In part of our discussion, Professor Hassan explained that there is a lack of coordination between various modes of transportation here in Rabat. He said there needs to be a multi-modal system where the local government would have an official whose job is to regulate and control all modes of transit. We thought that proposed solution to the aforementioned problems was a key idea to our research. Coding for solutions to the problems we found five instances where the respondent brought up this multi-modal solution. For the expected smart city outcomes and actual smart city outcomes categories we found frequencies of four and three respectively. We

learned that there is a large discount between what researchers expect in terms of the success of a smart city project and the actual results of the project. Professor Hassan pointed out that in France, there was an initiative implemented where citizens could request government documents online, but it failed to work because they still had to physically go to city hall to get the document.

Additionally, we conducted the same process for the different forms of transportation, and we found that the respondent most frequently mentioned the bus and the tram at four occurrences each. Conversely we found that the car system was not important with only one mention throughout the entire interview. This analysis through coding helped verify and quantify the importance of the themes that we marked as significant.

During the interview, the respondents discussed the expected and actual outcomes of smart city projects in Rabat and France. Professor Majid explained that research in the 1960s led people to believe that smart cities would be a solution to the problem of growing cities. He explained that a lot of the research that the School of Architecture conducted on the subject of smart cities looked to France and their smart city initiatives. For example France's goal was to have all of their documentation processes become virtual However, the outcome of their initiatives is that only 2% of the services they hoped to digitize actually became digital. Additionally, Professor Majid pointed to the idea that people believed that smart cities would help to bridge the technological division between urban and rural communities, however, research shows that these initiatives have done nothing to bridge the gap, only to maintain it. These insights helped the team to understand the realities of implementing smart city initiatives and the limits of what they can accomplish.

Another main idea presented during the interview was the difficulty implementing smart city projects in Rabat. Professor Majid points to the transportation system being a major problem that could benefit from the implementation of smart city projects. Specifically he talks about how the existing public transport systems do not complement each other well because they cover the same areas but do not necessarily link up. Additionally, later in the interview, he mentioned how in terms of a smart city "Public transportation is the most critical issue, more than 60% of Moroccan people live in urban areas, so it is a big issue… there is always one factor that should ignite everything else, and for [me] it's transport" (H. Majid, Personal Interview, February 15, 2018). This quote is powerful because of how heavily this industry expert on smart cities is emphasizing the importance of having an effective transportation system. When speaking about the transportation system, one of our interviewers asked Professor Majid what the most difficult

problem facing transportation in Rabat is. Professor Majid made it clear that one large problem is the lack of balance in the transportation system. He mentioned that the tram system is good but has poor coverage. Additionally, he cited the declining status of the bus system, saying, "in 1990 we had one bus for 3000 people, now it is one bus for 4000 people" (Majid, Personal Communication, February 15, 2018). This is important to our project because it reaffirms other data we have collected showing that the bus is one of the biggest transportation problems facing Madinat Al Irfane.

4.7 Overall Conclusions

Our team collected a significant amount of data through heat mapping, transit evaluation through use of our rubric, surveys and interviews. The analysis performed revealed the strengths and weaknesses of each of the four types of transportation assessed. The transportation methods assessed include walking, taxis, the tramway, and buses.

Analyzing the heat maps revealed that Madinat Al Irfane is a fairly walkable area. While there were a couple of congested areas around intersections and the hospitals, none of our other data collection methods, surveys or interviews supported the idea that there is a significant enough issue to warrant a smart mobility project. Analyzing the data from the taxi rubric evaluation along with the surveys and interviews showed the team that while the taxi has good coverage within the city and is the fastest form public transportation, it is also the most expensive form of transit. Additionally, a taxi can only hold three people at a time, and it can be difficult to find a taxi making it unreliable. Our analysis of the tramway showed that during peak operating hours the tram is reliable, in good repair, and incorporates green technologies. However, we also learned that the tram is relatively expensive by Moroccan transit standards and that it has limited coverage.

The bus system scored the lowest out of the three forms of public transit we assessed with our rubric. This low score was in large part due to low reliability and bad repair of the buses. Buses often show up late and locals seem to be unaware of when the next bus will arrive. Many of the buses have cracked windows, exposed engines, are dirty and generally in bad repair. Additionally, the bus system yielded the most feedback from our surveys and interviews, all of which was negative. The poor quality of the bus combined with the fact that we learned that students spend 47% of their monthly income on transportation and more generally, roughly 15% of the cost of living in Rabat comes from transportation highlights the bus as a good target for improvement. If

riders are spending such a large portion of their income on transportation services, the services offered should be high quality and meet their needs. The public transit system should also work to reduce these costs to make public transit more accessible to the general public.

4.8 Preliminary Design Review

Throughout the team's data collection and analysis, we found recurrent issues with the bus system in Madinat Al Irfane. Many issues originated from the lack of availability, frequency, and quality of the bus system. The team let the public opinion guide the outline of the smart mobility initiative for this area, making the bus the focal point of our project. We asked survey respondents to give suggestions on how they would improve the bus system; one survey respondent answered: "use real time data to control public transport operation and provide accurate information to customers." The team took into account this consideration in addition to issues voiced by survey respondents and interviewees and developed a recommendation. The team's recommendation, a bus time prediction system (BTPS), could potentially relieve several issues the public expressed. A BTPS would notify riders the exact time of arrival of any bus. We give a more in depth presentation of this recommendation, below in the form of a preliminary design review (PDR). Our hope is that ENSIAS can use this PDR to begin work on an implementation of this project.

4.8.1 Background

The initiative the team designed, BTPS, is not a new technology, researchers from industry and university students have created and implemented this technology in a variety of ways. Below is an example of a company, Ride Systems, and an example of a university, Saveetha University, both of which produced bus tracking systems that are user-friendly and help to better manage the bus system.

Ride Systems, located in Utah, United States, is a company offering an integrated system of real time prediction and tracking technology for buses. Over 300 clients including cities, universities, corporations, airports, and hotels contract out this company for their services. Their system uses an innovative global positioning system (GPS), which allows users to know the exact location of their buses. Ride Systems provides GPS, a mobile application, passenger counting, digital signage, and electronic driver logs. All these features enhance the transit system which ultimately increases the quality of the transportation experience for the passengers (Ride Systems,

2017). The mobile application available to accompany the system is user-friendly and provides a live map of all the current vehicles on route, an estimated time of arrival, and any important announcements. Buses across the United States use Ride Systems' technology, and worldwide companies such as Aplicom and Navipedia offer comparable services.

In 2013 a group of four Ph.D students at Saveetha University in India created a database for a bus location system. The research team had a goal of creating a bus tracking system which uses GPS to determine the location of the bus, allows users to send a message requesting the location of the bus, and has a cost effective implementation process along with low maintenance (Joseph, C., Bharathy, B., Aswani, A., & Ayyaappan, A., 2017).The group took inspiration from the University of Ghana which developed a similar system, one that tracked and located buses while sending live Short Message Service (SMS) alerts and real-time tracking from a web application. The implementation of both university research teams' projects shows the feasibility of a bus tracker system. Additionally, the fact that several universities are conducting research on this project shows the demand for this type of system.

4.8.2 Bus Time Prediction System

Our team proposes that ENSIAS develops a Bus Time Prediction System (BTPS) to provide residents with live information about the buses in their area. This system could provide "service for the travelers, to improve public transport operation efficiency, guide the public travel mode choice, and advocate 'green travel'" (Wang, Wang, 2013). The project, outlined in Figure 92, would use sensors to track the location of the bus and a computer algorithm would predict the estimated time that the bus will arrive at the next bus stop. Users would be able to access this information on their phone, laptop or on a digital display at the bus stop and determine when their bus should arrive. The team broke this complex system into smaller more manageable sub-systems.

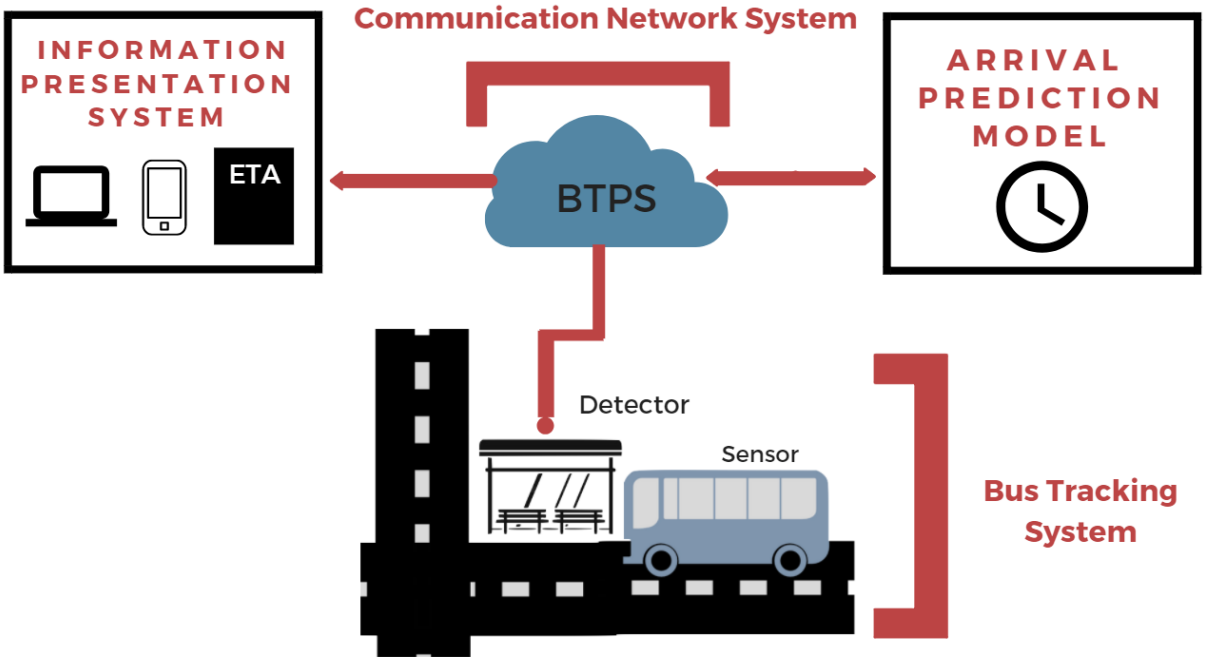


Figure 92: Model of the Bus Time Prediction System

The BTPS system consists of four major components: bus tracking system, arrival prediction model, communication network system, and an information presentation system. The bus tracking system determines where the bus is at each point along the route. Each bus would have localization sensors and the bus stop has a detector to transfer the information. This subsystem would provide the BTPS with information about each bus such as its current location, time, and average speed. Once the BTPS has data about the bus, the arrival prediction model subsystem, seen above, will calculate when the bus should arrive at the next bus stop. There are many different prediction models that ENSIAS can pursue to estimate when the bus will arrive. Academia is currently investigating the use of prediction models such as: dynamic models, artificial neural network models, and Kalman filter-based dynamic algorithm to accurately predict the arrival of the bus (Chen et. al, 2004; Jeong, R. Rilett, 2004). Another integral piece of this system is the communication network system. This system connects the buses' sensors to the BTPS through the use of wireless technology. Examples of potential wireless technologies include Bluetooth, 4G, WIFI, and 2.4 GHz radio. The final piece of BTPS is the information presentation system that

presents the predicted data to the customer. Users can view when their bus should arrive through a digital app on their phone or laptop. Additionally, there would be a digital display at each bus station with the predicted time of arrival so customers without access to internet would also be able to see this information. The BTPS incorporates multiple disciplines of engineering and technology and has the potential to address the problems that our team discovered through our research.

This smart mobility initiative has the potential to improve the efficiency, ridership, and reliability of the bus system. The bus company would be able to analyze the collected data and determine which bus routes consistently fall behind schedule and at what points along the route they are stopping. The company would be able to use this analyzed data to determine more optimal routes to cut down on distance and time the bus has to drive, while reducing costs and commute time for its customers. Riders would be able to easily check when their bus should arrive, allowing them to plan their day accordingly. Ideally, the BTPS will reduce the time spent commuting, giving the rider more free time.

4.8.3 Challenges

The team recognizes that there are challenges to the BTPS. A bus tracking system such as the one we recommend has inherent security risks as well as challenges when it comes to how the system scales up to the entire transportation system. Generally speaking, our recommendations have policy related hurdles involved with the implementation of the system.

As we discussed in section 2.6 of the background, there are several challenges when implementing a smart cities project; a bus tracking system is no exception. One of the biggest challenges with this bus tracking system specifically is the security involved in the information system. Since the system collects data on the exact location of each bus, this leads to possibility of misuse of that information. To prevent this, the BTPS should only present users with an ETA for the bus, as the exact location of the bus is not relevant information for a user. However, the system collects, stores and transmits this information internally. This leaves a window for exploitation if an adversary can gain access to this information through malicious methods. When implementing this technology, developers must take precautions to protect the storage and transfer of the data to deal with this potential risk.

Another challenge that the BTPS would face, is the scaling of the BTPS as ridership increases. As the bus quality increases, the ridership should as well. Due to this increase in service demand, the entity implementing the BTPS should expect an increase in user traffic to their system. More riders on the bus means more customers requesting arrival information from the BTPS. If developers do not design the system to easily incorporate more resources to accommodate increased user traffic, then the system can become unresponsive and difficult to use. Accordingly, developers should design the BTPS computing resources with the idea of scalability in mind and make it easy to add additionally computing resources to the system as necessary.

Finally, once the developers design and test all the technical details, the act of communicating with the company responsible for the bus system and creating a logistical plan for the implementation is another challenge. In order to minimize the difficulties in this stage, the developers of the BTPS should communicate and work in collaboration with the bus company and the City Planning Office to design and develop the system. This will enable communication to start early and all parties can address any implementation logistics in parallel with the system, design and construction.

4.8.4 Discussion

The quality and unreliability of the bus system has been a central issue shown through our site assessment, surveys, and interviews. Our team recommends that ENSIAS develops a sensor-based system, BTPS, to predict the time of arrival of each bus and present it to riders. Researchers that prototype a BTPS would be able to further their research in Internet of Things, wireless technology, state estimation, prediction model, networking and databases. City planners and engineers could implement this project at a smaller prototype level within Madinat Al Irfane. Ideally, the BTPS would be able to help address the unreliability of the bus system, by providing users with accurate real-time updates on the bus.

Chapter 5. Recommendations and Conclusions

The research team assessed Madinat Al Irfane to investigate the quality of current transportation systems and gauge the feasibility of implementing smart technologies. Chapter 4.8 exhibits our preliminary design review (PDR), serving as a technical project recommendation for ENSIAS to pilot as an initiative that would enhance the quality of the bus system. We discuss more recommendations for the transportation system in this chapter. In addition, the team provided general guidance for future teams working with smart cities.

5.1 Recommendations for Madinat Al Irfane's Transportation

Based on our results, the team has three recommendations for the bus system in Madinat Al Irfane for ENSIAS to develop and implement. The first recommendation is a bus time prediction system that is explained more in depth than the other recommendations in section 4.8, because it is the most feasible option for immediate implementation. The second and third recommendation comes from our research and site assessment and addresses the underlying problems limiting the transportation system but serves as a more futuristic plan. All these recommendations aim to addresses the availability, management, and frequency issues that the public voiced with the bus system.

The project team designed and discusses the bus time prediction system earlier in this paper. The public through surveys and interviews constantly expressed discontent with the bus system. This discontent did not stem from the system lacking modern aspects or not being efficient, it stemmed from the quality and reliability. These are issues that smart technologies alone cannot repair. In an interview the interviewee stated that, "We have not reached the level to apply it in Rabat because as you know, when we talk about smart cities it's an additional layer so if you don't have the basics you can't talk about the smart city". The bus system available in Madinat Al Irfane needs the basics such as being well maintained, and reliable to the users of the bus, before you can add the smart technologies. The most feasible and appropriate recommendation for ENSIAS to apply to the current bus system is a bus time prediction system that will increase the reliability of the bus system. With this implementation, the team believes ridership will increase and the quality of life of the citizens as well.

Another recommendation our team would like to make is a centralized computerized system for managing the coordination of the entire transportation network within Rabat. Ideally,

if a managing company improves the basic quality of the bus, they could also implement a centralized network similar to South Korea's TOPIS system. This system would contain a network of sensors connected to all forms of transportation including GPS trackers on the buses and tram, and traffic light cameras. The centralized computer system receives data from all these sensors, and processes it to determine the estimated times of arrival of each of the transportation systems. Additionally, the system knows the scheduled arrival times of each of the transit systems so it can predict if one will arrive early, late, or on time. The system can then display this information to users through a smartphone application, a website, or on screens at transit stations. This allows for ease of transfers between different methods of transit when traveling large distances. Additionally, using this information the centralized computer system can adapt certain factors such as switching traffic lights to help transit systems meet their expected arrival times.

The third set of recommendations stemming from our research and site assessment relates to the governance of the transportation systems. One of the common themes from the top three transportation systems in our comparative analysis on was that the government controlled the transportation systems to a relatively high degree. This control allows the government to standardize different transportation systems even if different companies operate them. By regulating and funding the various forms of transportation a governing body can control the method by which they connect with each other, allowing for a more synchronized and organized system. They can accomplish this through the placement of stations, regulation of which routes the transit systems run and with what frequency, and through the approval of transit related projects such as an express bus lane. The government could implement an express bus lane by sectioning off part of the road and making a lane that is exclusively used by the bus. As shown in other major cities, such as Hong Kong, an express bus lane can improve the efficiency and reliability of the bus system

5.2 Future Direction for Smart City Project Teams

In completing this project the team learned several valuable lessons both specific to smart city projects and generalized towards this type of research project. We believe that future project teams can use these lessons by future project teams in order to help improve the quality of their project. The team has listed recommendations below for any project teams working on the topic of smart cities.

Development and Application of the Comprehensive Weighted Rubric

The team developed the SCR in objective 3.1 of this report to evaluate the major public transportation options within a specific region. The team created the rubric through a best practice comparative analysis and an existing mobility index rubric from ARCADIS. From the best practice comparative analysis between the top public transit systems, the team discovered key metrics that they believed made the system successful. Some metrics were not a part of the rubric that ARCADIS had, and the team had to assign configured weights that were calculated through dividing the weights of the larger metrics in ARCADIS. For example, the people category in ARCADIS only has ten metrics with weights while the Smart Cities team's rubric has 22. The team had to distribute the weight ARCADIS gave to their ten metrics between 22, resulting in inaccuracies within the entire rubric. The planet category on the Smart Cities rubric only has five categories, with coverage weighing 50 points. This outweighs a majority of the people section and can sway the score too much. Overall, the team created a stepping-stone to the development of a tool that can assign a transit system a number score based on the best in the world. This allows for city planners to notice the weak attributes of the system and know where they should focus on improving. For future work, teams should refine weights and justify every weight based on research.

Since the rubric was a small part of the Smart Cities team's project, it was only applied twice on each transit system both in morning and evening rush hours. If the team had more time, we wished to largely increase our sample size. The user of the rubric should complete many more observations to fully understand the system, and then average all scores to gain an overall score. On the chosen days and times we assessed a system it may not have had congestion issues, ran late or broken down, but there are times when the team was not assessing and noticed these factors. This is why it is important to have a larger sample size to have the opportunity to encounter any issues that the system potentially has. Future project teams should also evaluate the transit systems with the rubric at different times of day, and on different days to understand if this affects the score given and to produce a more extensive data collection.

Focusing on One Transit System

Another issue our team encountered during data collection was not enough time to collect all the data needed for the four mobility options we were assessing. This unfortunately led to substandard data collection for each system. In contrast, if the team had prioritized one system from the beginning of the project, the data collected would be more substantial. The team believes the project would have been more successful if from the start they evaluated the system that was least popular with the citizens. The team could then assess the feasibility of implementing smart technologies into that system to increase ridership. With a centralized focus, the team could have had a better data collection phase both using the rubrics but also in the surveys and interviews. This would have allowed the researchers to ask specific questions about the one mode of transit and not the overall commute of the surveyee, as well as, contact different stakeholders for expert opinions. The team would have listed bus companies in the surrounding area as stakeholders for this project if time permitted.

Survey a More Heterogeneous Pool

The team had hoped during the preparatory course to be able to perform intercept surveys within the project site but due to government regulations, the process of approval for this was not achievable in the seven weeks on site. This would have enabled the team to gather a more diverse pool of respondents and not limit the conclusions that we can draw from the data collected. It is important that a team takes all steps during the preparatory course if necessary to be able to survey people on the streets on the project site. We believe that surveying the population at transit stations or stops would permit the team to have a more comprehensive understanding of the mobility in the area from a variety of demographics.

Stakeholder Information during Preparatory Course

The stakeholders of the project are most likely to possess valuable information about the topic. Unfortunately our team discovered this too late. The stakeholders could have access to a valuable information and documents that project teams cannot be access from overseas. We believe it is important to get their contact information during the preparatory course to reach out and introduce the team and project and ask if they have access to any learning materials that can aid in the planning of your project design and paper. Starting the dialogue with the stakeholders

early is important as there can be high overhead times to setting up a meeting with busy professionals.

5.3 Conclusion

The goal of this project was to assess the feasibility of implementing a smart mobility initiative in Madinat Al Irfane. By evaluating the current transportation system of the area using a comprehensive rubric created through a best practice comparative analysis, heat mapping, surveying the public, and interviewing experts, the team gathered a better understanding about pressing issues in the current system. The results highlighted the public's discontent with the current bus service. The team generated a preliminary design review for a bus time prediction system that will allow users to get real time updates on the estimated time of arrival of the bus on their phone, laptop and at the bus stop. This system will enhance the current system in place by increasing reliability to the users, therefore, growing the ridership of the system.

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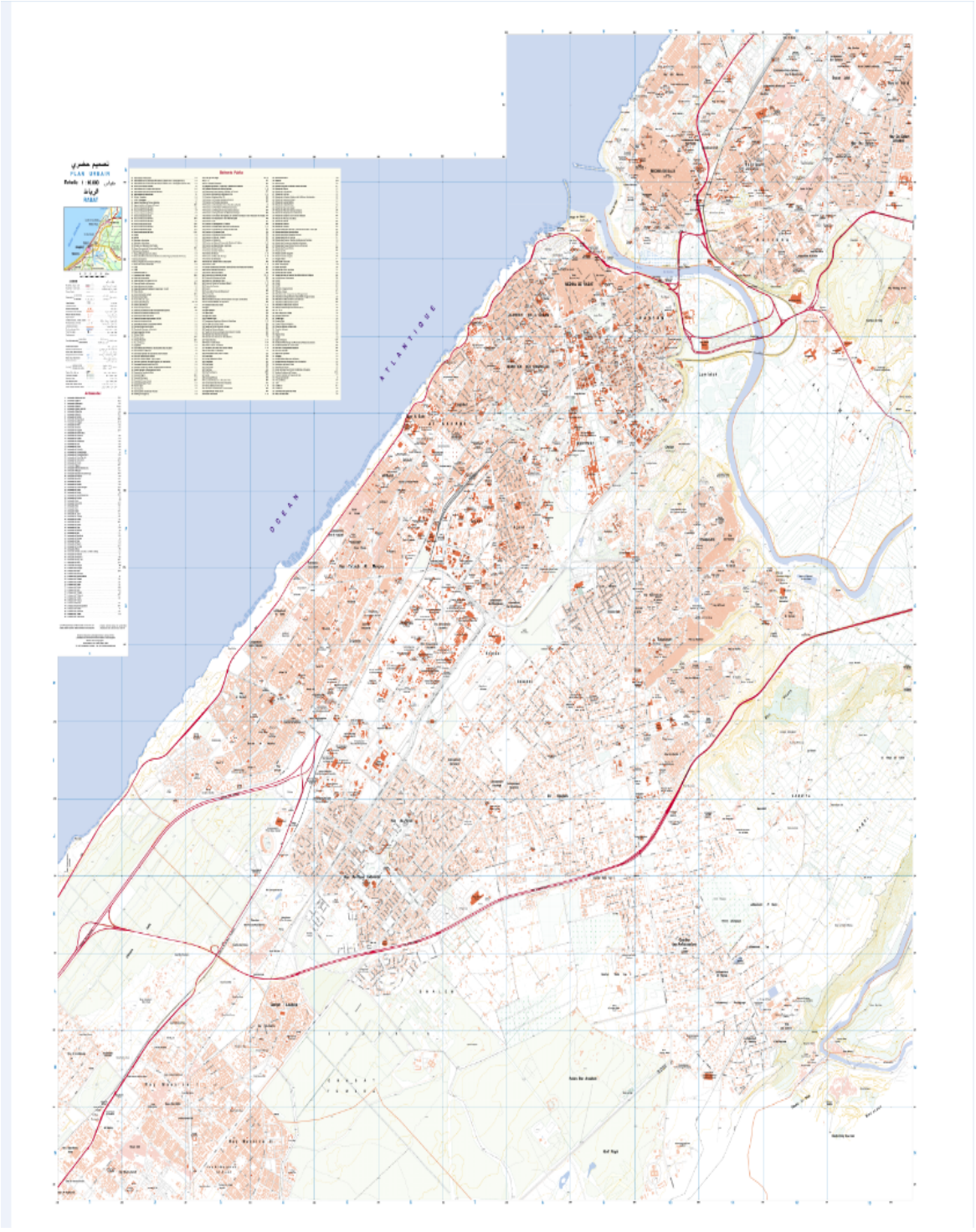
Appendix A: Comparative Case Study Notes

AppendixA.docx

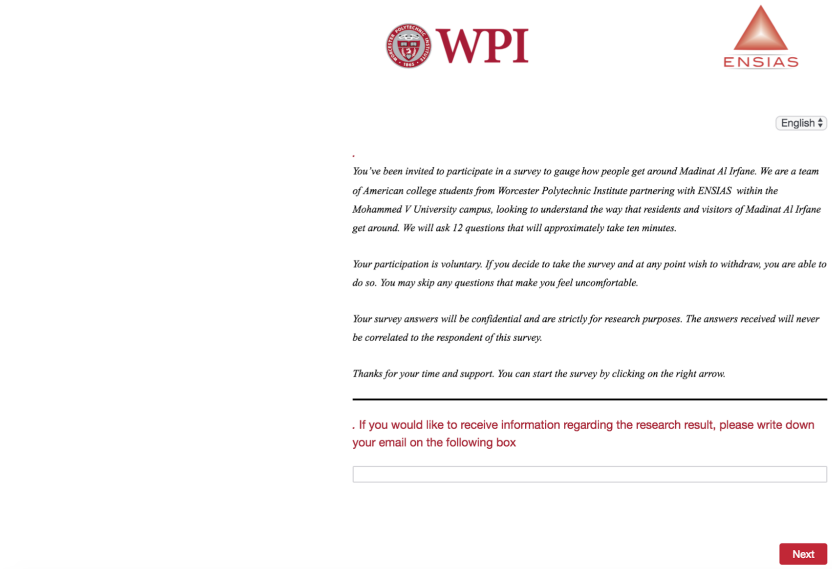
Appendix B: City Hall Map of Rabat, Morocco



Appendix C: Heat mapping observation table

Observation Matrix- Heat Mapping		
Set walking pace (min/mile)	Application used (Nike+ or Garmin)	Observers name
Route Information		
Start time		
Start location		
End time		
End location		
Duration of route (Hours and minutes)		
Areas of congestion to note on route		
Additional notes		

Appendix D: Household self-completion & intercept survey questions (will also be provided in Arabic)



WPI ENSIAS

English

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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 partnering with ENSIAS within the Mohammed V University campus, looking to understand the way that residents and visitors of Madinat Al Irfane get around. We will ask 12 questions that will approximately take ten minutes.

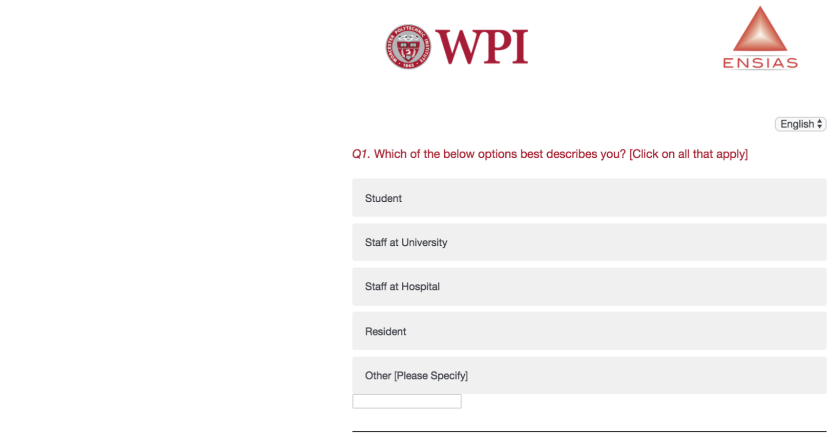
Your participation is voluntary. If you decide to take the survey and at any point wish to withdraw, you are able to do so. You may skip any questions that make you feel uncomfortable.

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 clicking on the right arrow.

. If you would like to receive information regarding the research result, please write down your email on the following box

Next



WPI ENSIAS

English

Q1. Which of the below options best describes you? [Click on all that apply]

- Student
- Staff at University
- Staff at Hospital
- Resident
- Other [Please Specify]

Q2. What percentage of the time do you use each of the following methods mode of transportation to commute to Madinat Al Irfane? [For example if you walk to school everyday: Walking 100% and all other options 0%. Your response should add up to 100.]

	0	20	40	60	80	100	
Walking							0
Bike							0
Private car							0
Bus							0
Tramway							0
Taxi							0
Motorcycle							0
Other [Please Specify]							0
Total:							**0**

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WPI ENSIAS

English

Q3. For the form of public transportation that you marked the highest in question 2, please answer the following:

A.
How long is your commute to Madinat Al Irfane? [in hours and minutes]

B.
How much, on average, do you typically spend in public transportation in MAD? Please specify if daily, weekly, monthly or yearly. *For example, 250 MAD per month.*

Q4. How would you rate the reliability of this public transit?
0 not applicable, 1 not reliable and 5 reliable

Not applicable	1	2	3	4	5
○	○	○	○	○	○

Back Next

WPI ENSIAS

English

Q5. If you selected private car in question number two:

A.
How long is your commute to Madinat Al Irfane? [For example 1hr30mins or 30mins]

B.
How much on average do you typically spend on gas in MAD? [Please specify if daily, weekly, monthly or yearly. For example 100MAD weekly]

C.
Do you travel with others? (Y/N)

Q6. If you selected private car in question number two:
0 not applicable, 1 not reliable and 5 reliable

	Not applicable	1	2	3	4	5
How satisfied are you with the availability of parking at your final destination?	○	○	○	○	○	○

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WPI ENSIAS

English

Q7. On which day(s) of the week is it most difficult for you to commute to Madinat Al Irfane? Select the closest arrival and departure times for that day. [Enter X on the day(s) that are most difficult]

	Arrival Time	Departure Time
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Q8. Why are the selected days most difficult for your commute? [Click all that apply]

- Reliability
- Cost
- Accessibility
- Congestion
- Other

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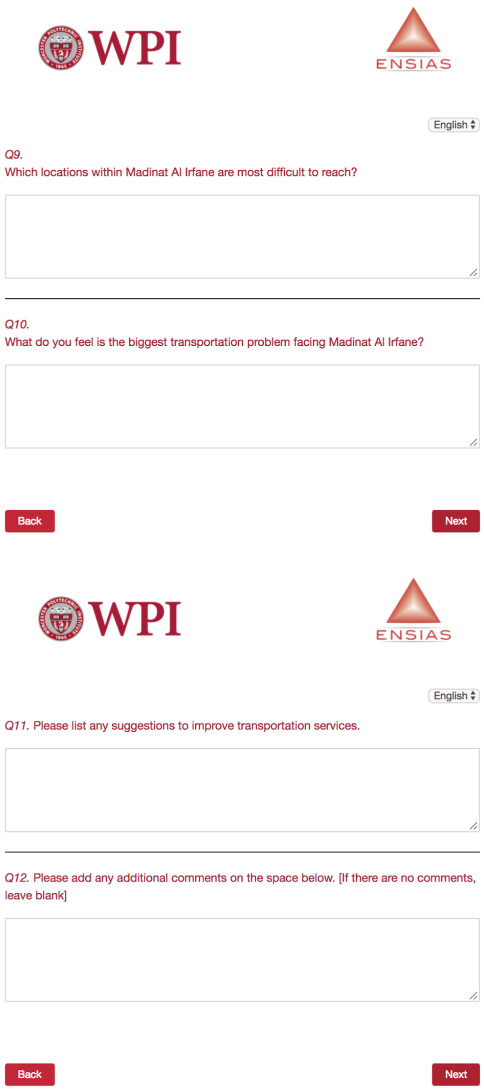


Greetings. You've been invited to participate in a survey to gauge how people get around Madinat Al Irfane. We are a team of American college students from Worcester Polytechnic Institute partnering with ENSIAS within the Mohammed V University campus, looking to understand the way that residents and visitors of Madinat Al Irfane get around. We will ask 11 questions that will take approximately ten minutes.

Your participation is voluntary. If you decide to take the survey and at any point 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 clicking on the right arrow.

If you would like to receive information regarding the research result, please write down your email on the following box

1. Which of the below options best describes you? [Click on all that apply]
   - Student
   - Staff at University
   - Staff at Hospital
   - Resident
   - Other [Please Specify] _____

2. What percentage of the time do you use each of the following methods mode of transportation to commute to Madinat Al Irfane? [For example if you walk to school every day: Walking 100% and all other options 0%. Your response should add up to 100.]

   - Walking _____
   - Bike _____
   - Private car _____
   - Bus _____
   - Tramway _____
   - Taxi _____
   - Other _____ [Please Specify]

3. For the form of public transportation that you marked the highest in question two, please answer the following:
   - How much do you spend on your full commute in MAD? Please specify if daily, weekly, monthly or yearly.

4. How would you rate the reliability of this public transit?
Not applicable and 1 being not satisfied and 5 being satisfied

Not applicable 1 2 3 4 5

5. If you selected private car in question number two:
   - How long is your commute to Madinat Al Irfane? [For example 1hr30mins or 30mins]
   - How much on average do you typically spend on gas in MAD? [Please specify if daily, weekly, monthly or yearly. *For example 100MAD weekly*]
   - Do you travel with others? (Y/N)

6. If you selected private car in question number two:
How satisfied are you with the availability of parking at your final destination?
Not applicable and 1 being not satisfied and 5 being satisfied

Not applicable 1 2 3 4 5

7. On which day(s) of the week is it most difficult for you to commute to Madinat Al Irfane? Select the arrival and departure times for that day. [Enter X on the day(s) that are most difficult]

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

8. Why are the selected days most difficult? [Click all that apply]

- Reliability
- Cost
- Accessibility
- Congestion

9. Which locations within Madinat Al Irfane are most difficult to reach and at what times? Why?

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

11. Please list any suggestions to improve transportation services

Please add any additional comments on the space below

Thanks for completing this survey!

Appendix E: Interview Questions for School of Architecture

Hello, we are a team of American college students from Worcester Polytechnic Institute in conjunction with ENSIAS at Mohammed V University looking to understand the way that occupants of Madinat Al Irfane get around. We will use this information to propose options for smart city transportation projects within the Madinat. Smart transportation is the combination of technology such as sensors and software with existing transportation systems 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 six questions that will take approximately one hour in total.

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

1. Could you state your name and your title in the School of Architecture?
2. Have you heard of the term "smart cities" or "smart technology"? If yes, what is your definition of these terms?
3. Are there any regulations that would make the implementation of smart city infrastructure difficult?
4. What role do you think architecture plays within a Smart City?
5. Do you find any problems with adapting smart technologies to the building infrastructure in Madinat Al Irfane?
6. What infrastructure challenges would you identify when it comes to developing and implementing Smart Cities?

Shukran! Thank you for taking time out of your day to meet with us and answer our prevalent questions that will help us achieve our project of assessing the smart city initiatives in Madinat Al Irfane within Rabat, Morocco. If you have any further questions or any other information to share, our team email is smartcities18@wpi.edu. We value the information you have shared with us and will include it in our final project report. Thank you again.

Appendix F: Interview Questions for Student Body President

Interview Questions for Student Body President:

Hello, we are a team of American college students from Worcester Polytechnic Institute in conjunction with ENSIAS at Mohammed V University looking to understand the way that occupants of Madinat Al Irfane get around. We will use this information to propose options for smart city transportation projects within the Madinat. Smart transportation is the combination of technology such as sensors and software with existing transportation systems 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 seven questions that will take approximately one hour in total.

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

1. Could you state your name and your role in Mohammed V University?
2. What do you believe is your classmates' most preferred mode of transportation?
3. In your own opinion, what would you change about the public transportation system if you could?
4. Have you ever encountered any issues with the public transit available in Madinat Al Irfane (tram, bus, or taxi)?
5. What is your impression of the available transportation around Madinat Al Irfane? Is it comparable to other locations (Southern Africa, Europe, Asia, etc.)?
6. Have you ever been late due to transportation issues?
7. Have you heard of the term "smart cities" or "smart technology"? If yes, what is your definition of these terms?

Shukran! Thank you for taking time out of your day to meet with us and answer our prevalent questions that will help us achieve our project of assessing the smart city initiatives in Madinat Al Irfane within Rabat, Morocco. If you have any further questions or any other information to share, our team email is smartcities18@wpi.edu. We value the information you have shared with us and will include it in our final project report. Thank you again.

Appendix G: Interview Questions for School of Urban Planning

Hello, we are a team of American college students from Worcester Polytechnic Institute in conjunction with ENSIAS at Mohammed V University looking to understand the way that occupants of Madinat Al Irfane get around. We will use this information to propose options for smart city transportation projects within the Madinat. Smart transportation is the combination of technology such as sensors and software with existing transportation systems 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 seven questions that will take approximately one hour in total.

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

1. Could you state your name and your title in the School of Urban Planning?
2. Are there any codes or regulations pertaining to historical and cultural buildings that would making the implementation of a smart city difficult?
3. What would be the steps needed to implement an urban planning project within a small area such as Madinat Al Irfane?
4. What are the potential risks and challenges you may see with implementation of a smart cities project within Madinat Al Irfane?
    1. Climate change, natural disasters, public acceptance
5. What role do you think urban planning plays within a Smart City?
6. What problems do you see with the current public transportation system within Madinat Al Irfane (bus, taxi, tramway)?
7. Does the school of urban planning conduct any research for the city planning office?
    1. Is there any relationship?

Shukran! Thank you for taking time out of your day to meet with us and answer our prevalent questions that will help us achieve our project of assessing the smart city initiatives in Madinat Al Irfane within Rabat, Morocco. If you have any further questions or any other information to share, our team email is smartcities18@wpi.edu. We value the information you have shared with us and will include it in our final project report. Thank you again.

Appendix H: Key for Transportation Rubric

People:

Ride Quality	
Comfort of Seating (10)	Is the passenger comfortable? Graded on: leg room, cushion, personal space, area for bag
Availibility of seating (20)	Can I sit if I want to? Graded on: open seating
Handicap accessibility (10)	How easy is it for a handicapped citizen to use this transportation? Graded on: Handicap ramp, space for handicap seating, handicap amenities
Ease of authorization (ticket) (10)	Do I have access to a local machine to validate my ticket? Is it consistent? Graded on: a machine to validate your ticket, machine working, a person checking the ticket
Maintence (17)	Would you sit on the floor? Graded on: cleaniness, no vandilism
Amenities	
Wifi (11)	Graded on: Access to wifi, wifi password accessible
Cell Service (11)	Graded on: Able to make a phone call/send messages, 4G vs 3G
Heating/ AC system (11)	Graded on: System existent, in use when necessary

Station Layout/Location	
Garage Area/ Parking	
Designated Parking Area (25)	If I drive my car to the public transit station, is there a designated parking area? Graded on: if a parking lot exists, distance to the station
Availability of parking (25)	In the parking lot, are there spots avaliable? Graded on: avaliability of spots, size of parking lot
Land Use of Surrounding Area	
Commercial use (15)	Is the land around the route full of shops to purchase items?
Residential use (15)	Is the land around the route houses/apartments?
Industrial use (10)	Is the land around the route mostly producing goods?
Educational use (10)	Is the land around the route mostly univeristies/schools?

Presentation of Information	
Live Information	
Quality of static map at stop (15)	Can I understand the map at the station? Graded on: Avaliability, easy to understand, multiple lanuages, accuracy
Ease of navigation (15)	Can I explain the routes to others? Is it easy to get lost? Do I have to ask for directions? Graded on: simplistic design, color coordination, signage, maps avaliable
On board route visualization (10)	Is there a map inside the mode of transportation? Is it easy to understand? Graded on: avaliability, maintence of map, comprehendable
Live location (5)	Can I see when the next one is arriving? Graded on: Avalibility of display, accuracy of estimation
Purchasing a ticket	
Payment method (15)	How many different ways can I pay? Where can I buy tickets? Graded on: access to multiple places to buy tickets (mobile, web, in person, machine), if you can use cards or just cash
Cost calculation (10)	Is it based on distance (km) or one ticket no matter the distance? Graded on: One ticket for whatever distance (One ticket is better), ease of calculation
Cost (20)	How expensive is it? Graded on: Price relative to other forms of transportations
Versatility of ticket (10)	Can one ticket get you on other forms of transportation to transfer easily? Graded on: Avaliability of smart card, ability to use tickey for all forms of transit

Planet:

Planet	
Incorporation of green technologies (10)	Is the mode of transportation using green technology? Ex: electric or CNG
Promotion of green energy (5)	Are there signs promoting green technologies & going green to educate the riders about the benefits?
Display of environmental impact (5)	Is there signage displaying the air quality/pollution of the public transit?
Coverage (50)	Does the mode of transportation cover all neighborhoods in the city? Do you need to transfer/ take more than one form of transit to get to a final desitnation?
Pollution (30)	Is the mode of transportation disel fueled? Are there emissions from the system? Is there smoke noticed on top of the transit or at the back? Graded on: environmental impact, emissions present or absence

Profit:

Price	
Card options (5)	Are there multiple different types of cards you can purchase (if any)? Ex: monthly, semesterly, yearly Graded on: Amount of different types avaliable
Discounts (10)	Are their card/tickets with discounts for subgroups such as students or elderly?
Economic Viability for consumer (30)	Compared to the average income a citizen in the city, is the price feasible?
Government	
Subsidy (20)	Does the government provide any funding for the form of transportation to reduce the cost of ridership for the users? Graded on: Percentage of costs subsidized
Incentive (tax break etc.) (15)	Are there any monetary incentives for a company to operate the transportation system?
Regulatory hurdles for companies (20)	How difficult is it to operate within the city as the transportation company? E.g. is it difficult/expensive to become a taxi? To add a bus stop? Graded on: The lower the difficulty the higher the score

Travel Time	
Frequency	
Frequency (20)	How often does the mode of transportation run?
Adjustment for ridership traffic (5)	Does the mode of transportation run more frequently during rush hours (morning, lunchtime, evening)?
Express options (10)	Is there any option of the transit that gets the rider from point A to point B with no stops in between?
Reliability	
Arrive on time (20)	Based on the expected time of arrival, did the mode of transportation arrive on time?
Live ETA (5)	Is there digital signage at the station with a constantly updating estimated time of arrival of the mode of transportation?
Breakdowns (20)	Was there any malfunctions on the mode of transportation that lead to the vehicle breaking down and not allowing you to get to your final destination?

Connectivity	
Ease of transfer (10)	If you had to transfer between modes of transportation: how easy was it? were the directions clear? did you miss the other transit option?
Distance to transfer (5)	How far did you have to walk to transfer between the two modes of transportation?
Time between transfers(3)	How much time was allotted to get from one form of transit to the other? Was there too little time or too much? Was it synced up perfectly?
Live updates about transfers (2)	Was there digital signage that allowed for you to see updates about the ETA of the second form of transportation and where it was located?

Appendix I: Transportation Rubric

Morning rush hour tram ride from Hay Karima to Madinat Al Irfane

AppendixI_A.xls

Evening rush hour tram ride from Hay Karima to Madinat al Irfane

AppendixI_B.xls

Appendix J: Observation Tables

Jan 30th- Lunchtime rush hours top half of Madinat Al Irfane

Observation Matrix- Heat Mapping			
Set walking pace	Calculated Actual Avg Pace	Application used	Observers name
20 min/mile	19:40 min/mile	Nike	Haylea
Route Information			
Start time		12:14	
Start location		Madinat Irfane tram stop	
End time		12:38	
End location		Maternite Souissi	
Duration of route		24 minutes	
Areas of congestion to note on route		Outside hospital buildings, entire length of Avenue Hadiane Cherkaoui	

Observation Matrix- Heat Mapping			
Set walking pace	Calculated Actual Avg Pace	Application used	Observers name
20 min/ mile,	19:40 min/mile	Nike	Haylea
Route Information			
Start time		12:45	
Start location		Madinat Al Irfne tram stop	
End time		1:00	
End location		faculte des sciences l'education	
Duration of route		15 minutes	
Areas of congestion to note on route		Crossing the main street	
Entire duration of 2 trips	1:13:35		

Observation Matrix- Heat Mapping			
Set walking pace	Calculated Average walking pace	Application used	Observers name
20:00 min/mile	28:05:00	Garmin	Mark
Route Information			
Start time		12:14	
Start location		Madinat Irfane tram stop	
End time		12:38	
End location		Maternite Souissi	
Duration of route		24 minutes	
Areas of congestion to note on route		In front of the hospital and on the main road. People were walking towards the market most likely for lunch	
		Foot path congestion wasn't that bad, roads were really congested waiting for rotarty	

Observation Matrix- Heat Mapping			
Set walking pace	Calculated Average walking pace	Application used	Observers name
20:00 min/mile	28:05:00	Garmin	Mark
Route Information			
Start time		12:45	
Start location		Madinat Al Irfne tram stop	
End time		1:00	
End location		faculte des sciences l'education	
Duration of route		15 minutes	
Areas of congestion to note on route		Cross walk faded, walk button doesn't work	

February 6th- Morning rush hours top half of Madinat Al Irfane

Observation Matrix- Heat Mapping			
Set walking pace	Calculated Actual Avg Pace	Application used	Observers name
20 min/mile	20:07 min/mile	Nike	Haylea
Route Information			
Start time		8:08	
Start location		Campus Sweet cafe	
End time		9:01	
End location		Campus Sweet cafe	
Duration of route		50 mins 41 sec	
Areas of congestion to note on route		Bridge was congested with students and professors going to class	
		Many people using alleyways, avoiding main streets with sidewalks (maybe this is normal? or rain?)	
		Raining but everyone was still walking, maybe faster	
		Cars speeding through puddling -> you get soaked	

Observation Matrix- Heat Mapping			
Set walking pace	Calculated Actual Avg Pace	Application used	Observers name
20 min/mile	20:07 min/mile	Garmin	Mark
Route Information			
Start time		8:08	
Start location		Campus Sweet cafe	
End time		9:01	
End location		Campus Sweet cafe	
Duration of route		50 mins 41 sec	
Areas of congestion to note on route		Outside hospital buildings, bridge was slightly congested. It was raining out and there was still a steady stream of commuters.	
		Many students/employees walk from neighboorhood to madinat al irfane using the bridge	

February 6th- Afternoon rush hours bottom of Madinat Al Irfane

Observation Matrix- Heat Mapping			
Set walking pace	Calculated Actual Avg Pace	Application used	Observers name
20 min/mile	20:07 min/mile	Garmin & Nike	Mark
Route Information			
Start time		13:43	
Start location		madinat al irfane tram stop	
End time		14:40	
End location		madinat al irfane tram stop	
Duration of route		57 mins	
Areas of congestion to note on route		path walk obstructed due to construction in front of Université Internationale Abulcasis des Sciences de la Santé (UIASS)	
		sign for cross walk but no cross walk exists (see google photos)	
		Raining, but did not affect pedstrain flow	

February 8th- Morning rush hours bottom of Madinat Al Irfane

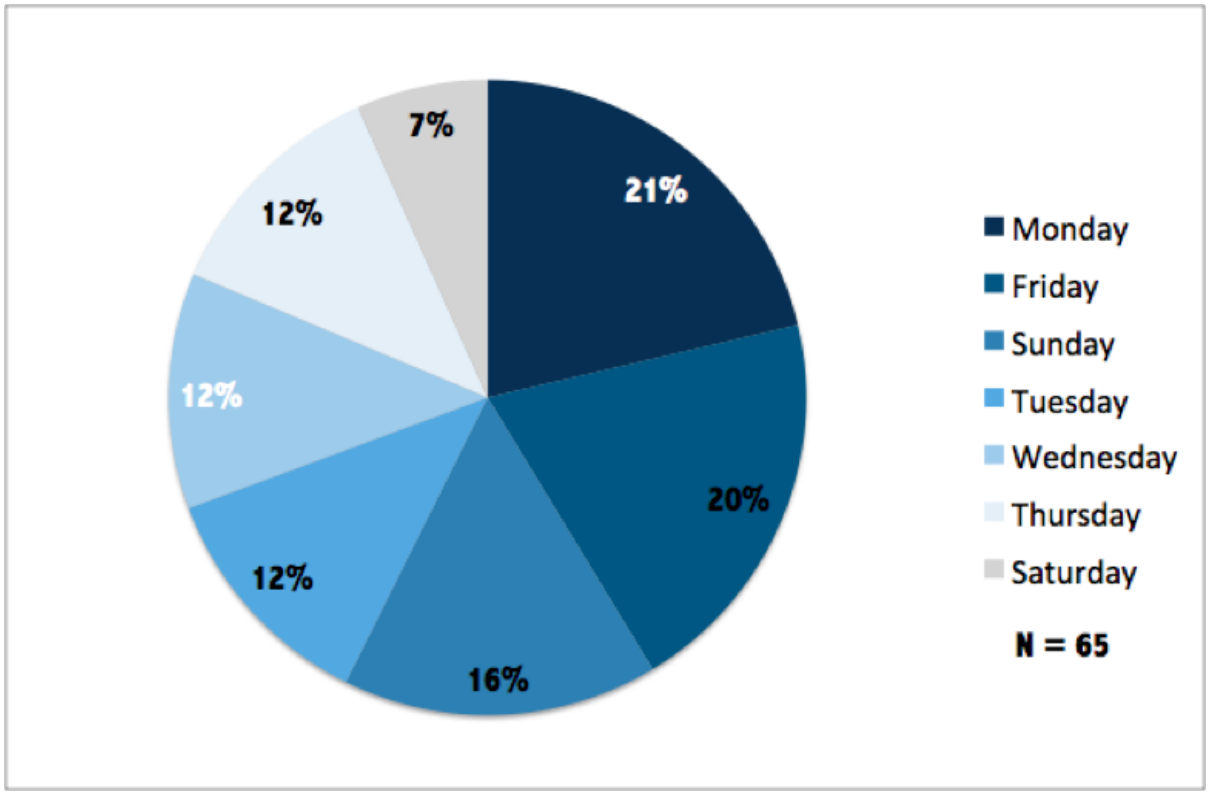
Observation Matrix- Heat Mapping			
Set walking pace	Calculated Actual Avg Pace	Application used	Observers name
20 min/mile	20:59 min/mile	Garmin & Nike	Mark
Route Information			
Start time		9:05	
Start location		final tram stop Madinat al irfane	
End time		10:01	
End location		Campus Sweet cafe	
Duration of route		56 mins 52 sec	
Areas of congestion to note on route		Constsruction area near school of medicine was difficult to walk thorugh	
		No cross walk at rotary, even though there is a sign for a cross walk. Police officer did not stop traffic for me. Had to run across road	
		Walkability wasn't bad, fairly easy to get around. Only thing I would improve is create sidewalks on side streets and put in proper cross walks with a light preventing cars from passing	

Appendix K: Python Script for Question Two Survey Analysis

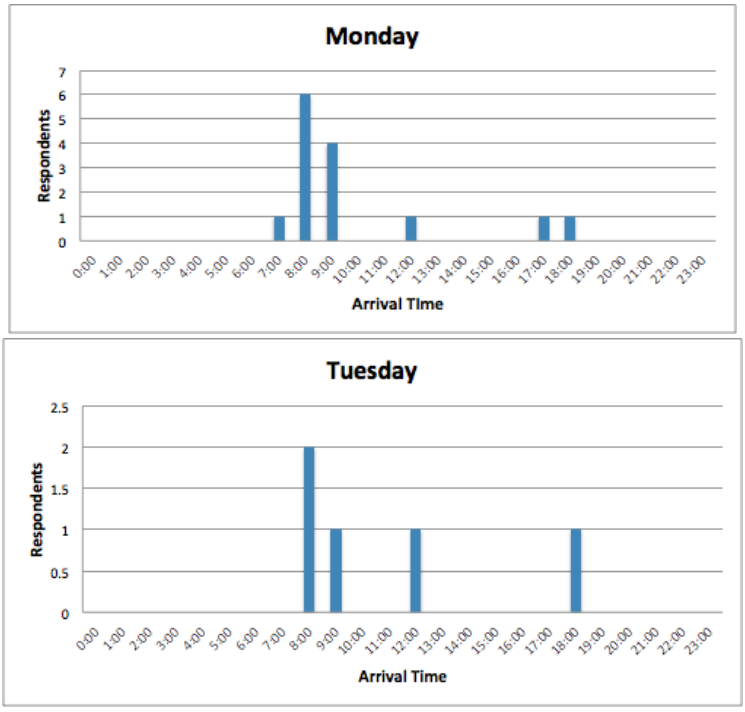
```
f = open("Madinat+Al+Irfane+Transportation+Survey_February+19%2C+2018_08.50.csv","r")
rawData = []
for line in f:
    line = line.strip()
    line = line.split(",")
    line = line[20:28]
    rawData.append(line)

rawData = rawData[3:]

for line in rawData:
    if not line:
        rawData.remove(line)
    else:
        for num in range(len(line)):
            if line[num] == '':
                line[num] = '0'
        print (line)

print(len(rawData))


processed_data = open("processed_Q2_data.csv","w")

processed_data.write("walking,biking,private car,bus,tramway,taxi,motorcycle,other\n")


for line in rawData:
    toWrite = ""
    for data in line:
        toWrite = toWrite + data + ","
    toWrite = toWrite[0:-1]
    toWrite = toWrite + "\n"
    processed_data.write(toWrite)
    print(toWrite)

processed_data.close()
```

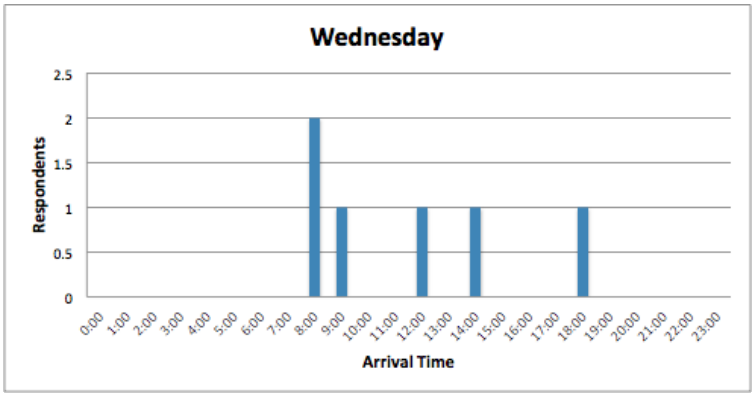
Appendix L: Extra Survey Graphs

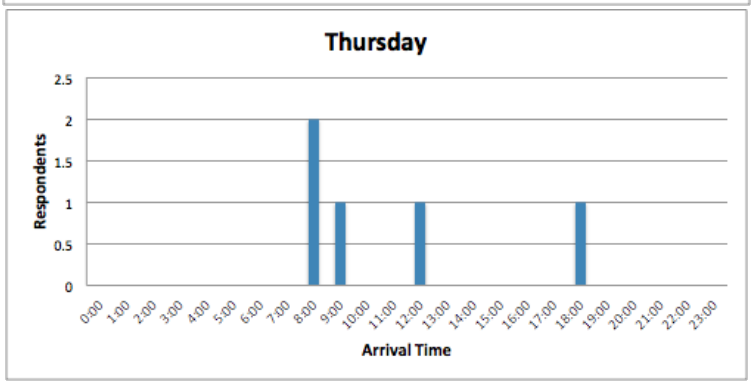
Q7. Most difficult dates to commute to Madinat Al Irfane

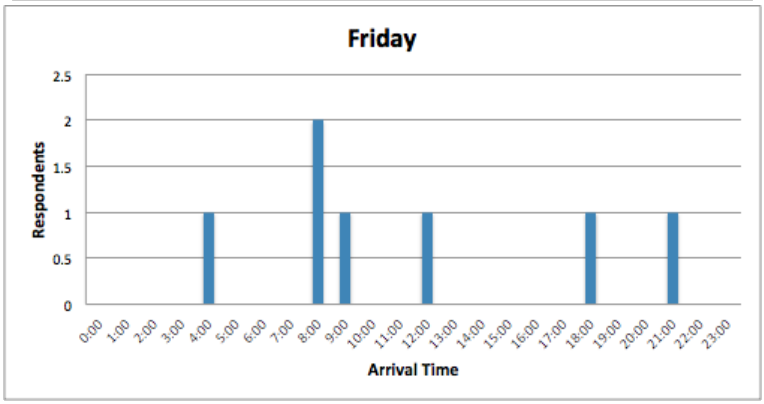


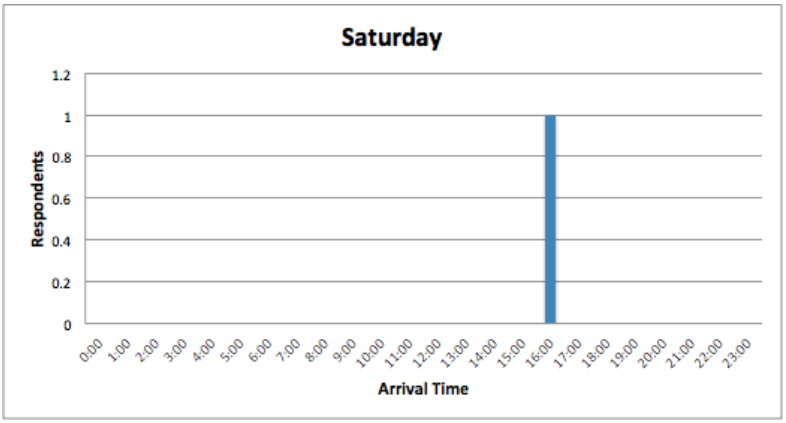
Q7. Most difficult arrival times to Madinat Al Irfane

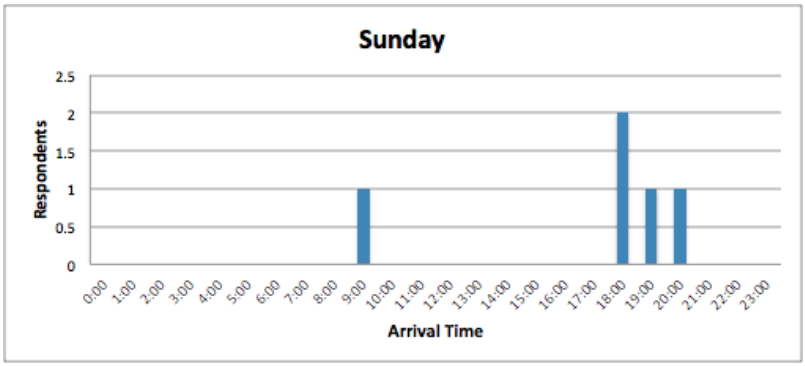



Wednesday
Respondents
Arrival Time

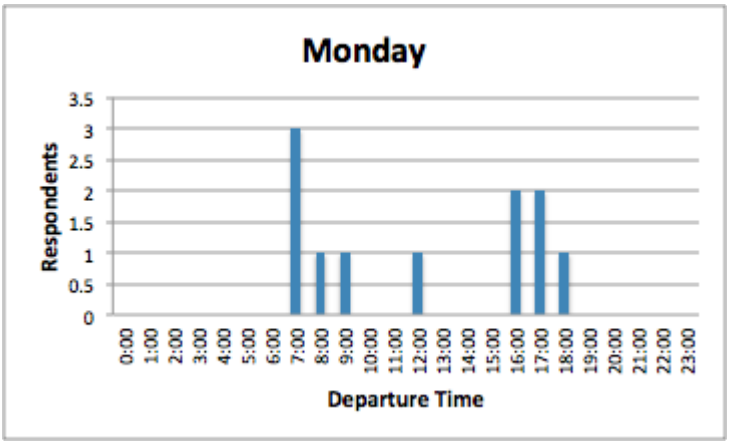

Thursday
Respondents
Arrival Time

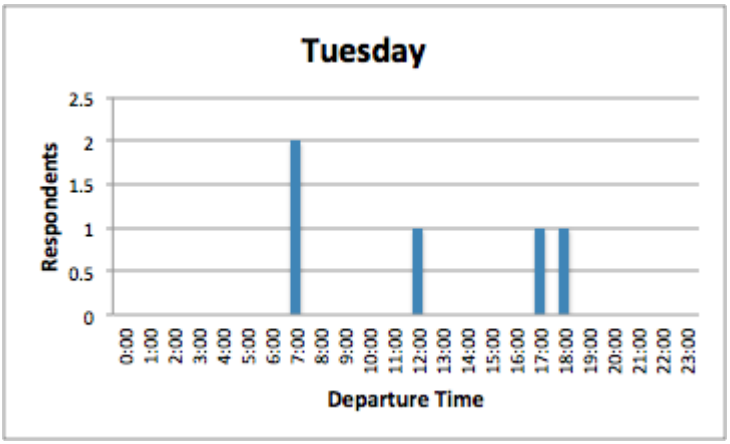

Friday
Respondents
Arrival Time

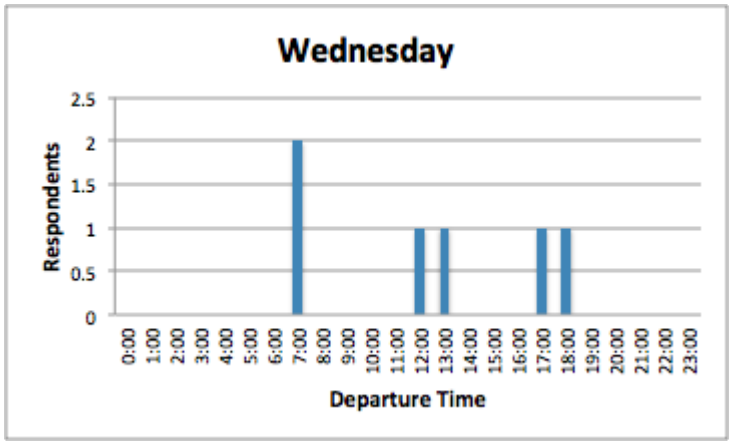

Saturday
Respondents
Arrival Time

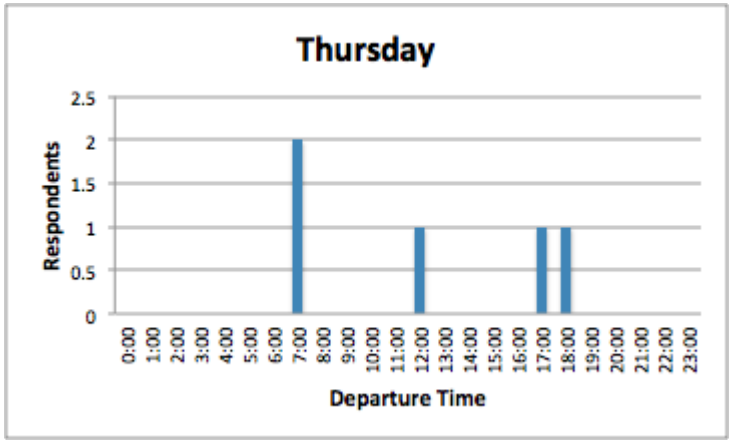


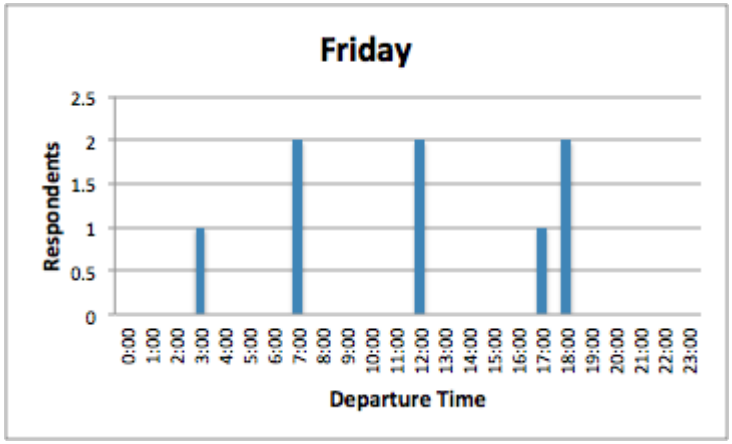
Most difficult departure times from Madinat Al Irfane






Wednesday
Respondents
2.5
2
1.5
1
0.5
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Departure Time


Thursday
Respondents
2.5
2
1.5
1
0.5
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Departure Time


Friday
Respondents
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2
1.5
1
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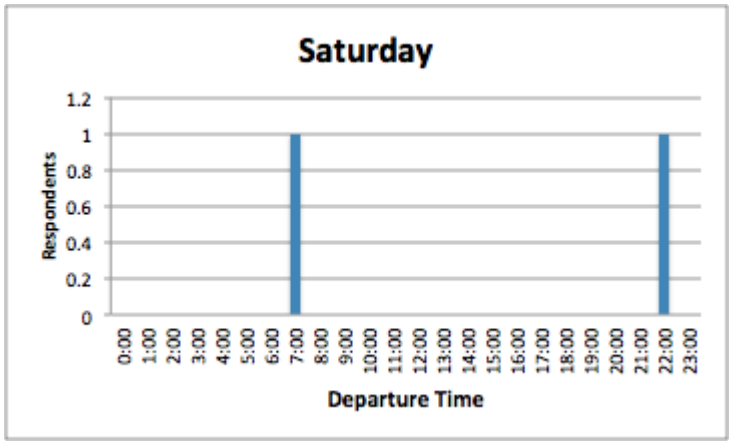
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Departure Time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Respondents
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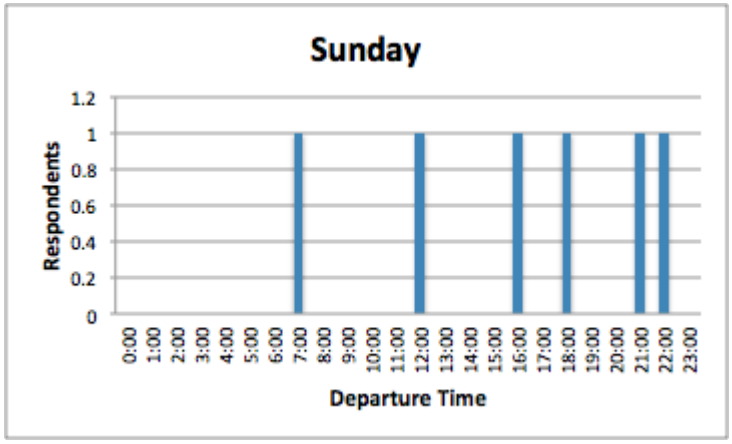
0.8
0.6
0.4
0.2
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Departure Time

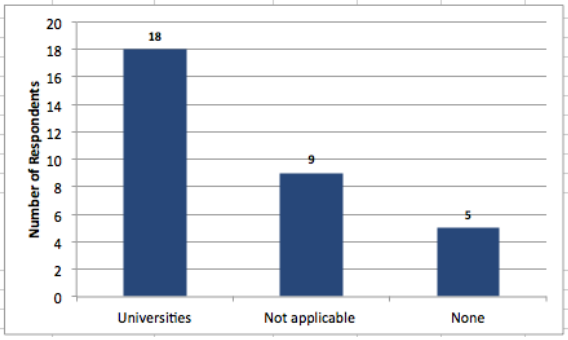

Sunday
Respondents
1.2
1
0.8
0.6
0.4
0.2
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Departure Time

Appendix M: Coded Excel Sheet for Survey Questions 9-12

Question 9:

#	Response	
1	ensias	U
2	ensias	U
3	ensias	U
4	ensias	U
5	Nothing	N
6	ensias	U
7	ensias	U
8	INPT	I
9	Nothing	N
10	ENSIAS	U
11	ENSIAS	U
12	ENSIAS	U
13	None, all locations are reachable	N
14	Near ENSIAS 8 oclock, and 16 oclock	U
15	near CNSRT	C
16	ensias	U
17	ENSIAS	U
18	I think all the location are reachable .	N
19	ensias	U
20	ENSIAS	U
21	Campus (near tramway's terminus)	U
22	None	N
23	Agdal	A
24	train station	TS
25	Temara, Bab el hadd	T
26	The univeristies	U
27	ensias	U
28	avenue hassan 2, in fact if you want to go to the gym wich is after the train railway, you can't do that unless you go to the one bridge available wich is far and dark at night	A
29	places where there is no tramway	N
30	near to Tamera and so many places especially at night	T
31	sale, bab el had	S

Theme	Color	Code		
Universities		U	18	16 ENSIAS
INPT		I	1	
Train station		TS	1	
cnsrt		C	1	
No problem		N	5	
Agdal		A	2	
Sale		S	1	
Tamera		T	2	
	Total		31	
	Universities	18		
	Not applicable	9		
	None	5		



Question 10:

#	Response	Code1	Code 2
1	there is not enough lines and dont come enough	A	NS
2	the tramway doesn't have enough coverage, only two lines	C	T
	not enough buses	A	B
	tramway is slow	D	T
3	there are no grande taxis that will come to madinat al irfane, just petit taxis.	A	X
4	the number of the lines of the buses	A	B
	the network of the buses doesnt cover all areas	C	B
5	In tramway terminus even if taxies have no one abroad they refuse to take people to places that donâ€™t meet their course	M	X
6	the problem is that there are not enough bus lines	C	B
	grande taxis do not come directly here	A	T
	Petit taxis are expensive	P	X
7	Crowded hours	J	NS
8	the biggest transportation problem few ways of transportation.	A	NS
	is that they are many people but	J	NS
9	the biggest transportation problem is when you want to go to a near place using transport especially taxis it's a little bit expensive.	P	X
	and for the bus we never use it because it's nearly inexistant	A	B
	Unsafe	S	B
	Bad state	M	B
	tram does not reach it all	C	T
10	people that come from sale or center of rabat, that are unable to afford taxi or private car	P	X
	that are unable to afford taxi or private car	P	C
11	waste alot of time during commute, distance , tram to slow	D	T
12	not enough buses	A	B
13	Tramway is more expensive for students.	P	T
	The fact that there is no public transport going to "hay eriad" & "hay elfath"	C	NS
14	tramway with taxis make circulation very difficult	M	T
15	Small road	M	NS

15	Small road	M	NS
16	cost	P	NS
17	I think that the tramway has solved the problem of transportation	NP	T
18	Costs of transportation	P	NS
19	Here in Madinat Al Irfane, the most probleme that i face is the crowd in rush hours.	J	NS
20	less transport	A	NS
21	a lot of persons	J	NS
22	The organization	M	NS
	Truly it's not a problem of transportation	NP	NS
23	but it's a problem of security to achieve our school ENSIAS.	S	NS
24	i dont think we've a transportation problem	NP	NS
25	the biggest problem for me is when you tell a taxi driver to take you somewhere he says that he can not, so you should search for an other taxi. some times that make you angry. in law the taxi driver must take you but they do not respect it .	M	X
26	tram services ends at 22h	A	T
27	There is a lot of places in rabat where you cannot use the tramway to get to Al Irfane, the only choices are taxi or bus;	A	T
28	taxi is expensive	P	T
29	and if u want to use a bus u need long time	A	B
30	Congestion in the tramway	J	T
31	lack of bus	A	B
32	Tramway	A	T
33	-the absence of variety in transportation offer	M	NS
34	Insecurity	S	NS
	Delays	D	NS
	There is a shortage of trams that reach Madinat Al Irfane,	A	T
35	and also the problem of congestion.	J	NS
	The bus? Cus it s in a bad condition	M	B
	and rarely respect timing	A	B

Code 1:			
Theme	Color	Code	Stat
Congestion		J	6
Speed		D	3
Management		M	8
Price		P	8
Availability		A	16
Safety		S	3
No problem		NP	3
Coverage		C	5
New system		NW	0
		Sum	**52**
Code 2:			
Theme	Color	Code	Stat
Tram		T	14
Bus		B	13
Taxi		X	5
Private car		C	1
Not specified		NS	19

Question 11:

#	Response	Code	Code 2
1	more bus lines and coverage from other places to madinat al irfane	C	B
2	more buses	A	B
	more tramway lines needed	T	T
	subway system is needed	NW	NS
	more grande taxis to madinat al irfane because they don't reach here, just tramwayn no direct taxi from where I live to madinat al irfane.	C	X
3	grande taxis don't want to come to madinat al irfane, too few	A	X
4	Information system about taxis traffic	NW	X
	Dynamic signalization system	NW	NS
5	tramway should be faster	D	T
	More frequent	F	T
6	more bus lines,	C	B
	bus time is not reliable (maybe in 15min maybe 30min)	M	B
	frequent tramway	F	T
	frequent buses	F	B
	Bus time is not reliable	M	B
7	More frequent trams	F	T
	more bike-ways	NW	NS
8	White taxis should reach madinat irfane	A	X
9	having more tramways	A	T
10	more control of taxi drivers.	M	X
	taking care of buses	M	B
11	the tramway's arrival is not as frequent the sundays , it takes sometimes 40 min for the next one to arrive	F	T
12	network of lines for buses just for government employees.	NW	B
13	subway system	NW	NS
14	a network bus system only for students	NW	B
	help reduce cost of transportation methods for students	P	NS
15	More bus lines	C	B
	lowering the taxi pricing	P	X
16	Build bridges passing through the train railway	NW	NS
	Add more bus paths going to "hay eriad" and "hay alfath"	A	B
	improving the quality of the bus wich is far to be acceptable (all the busses are shabby	M	B
17	Use public transport instead of private cars	A	NS
18	manage and monitor the public transportation systems	M	NS
19	have more tramway availability at rush hour	A	T
20	Allocation of bikes	NW	NS
	Or student bus in madinat el irfane	NW	B

21	transportations other than tramways are insecure	S	B
	unreliable	A	B
22	more of tram	A	T
	to have a taxi-station	NW	X
23	Providing more bus between Tamara and Irfane	A	B
24	for me the solution is the integration of Uber and Kareem in the transportation services, they should legalise the use of this apps to protect the companies from the violence of the taxi drivers .	NW	C
25	reliability of the train oncf	D	NS
26	Improve the accessibility of tramway in rabat	S	T
27	More places in the tramway	C	T
	Not letting more ppl getting in the tramway if itâ€™s full	J	T
28	Extension of the tramway lines to encompass the whole city of Rabat	C	T
	Bus frequency	F	B
	Passenger Comfort	M	NS
	Provide dedicated lanes for public transport	NW	NS
	Use real time data to control public transport operations and provide accurate information to customers	NW	NS
29	I suggest to add more tram torlleys	A	T
	to provide efficent services related to bus transportation in case of bad technical problems that can maybe happen to the trams	A	B

Code 1:			
Theme	**Color**	**Code**	**Stat**
Congestion		J	1
Speed		D	2
Management		M	7
Price		P	2
Availability		A	13
Frequency		F	6
Safety		S	2
No problem		NP	0
Coverage		C	6
New system		NW	14
		Sum	**53**
Code 2:			
Theme	**Color**	**Code**	**Stat**
Tram		T	14
Bus		B	19
Taxi		X	6
Private car		C	1
Not specified		NS	13
		Sum	**53**

Question 12:

#	Response				Code 1:			
					Theme	Color	Code	Stat
					Congestion		J	1
	Q12				Speed		D	1
1	the problem of transportation affects the people coming to study since there is not a lot of coverage of bus lines that come to madinat al irfane	C	B		Management		M	0
	n/a				Price		P	0
	n/a				Availability		A	0
2	on the weekend the time between the trams is 20 min; tramway on the weekend is not as frequent as the weekday, needs earlier tramway times on the weekend	F	T		Frequency		F	2
	there is no security in using any alternative ways (illegal),people volunteering to give rides for money; they accept the illegal but there is no safety,	S	NS		Safety		S	1
3	In the week end there is a leak of number of tramways	F	T		No problem		NP	0
4	if there is no tramway reaching a person's place it is a big problem	C	T		Coverage		C	2
5	sometimes the petit taxis do not want to drive to madinat al irfane because the roads are congested	J	X		New system		NW	0
6	I hope that I've helped you collecte more data.						Sum	7
7	I have no idea why you doing this				Code 2:			
8	Each employee would work at a location closest to them, to shorten commute	D	NS		Theme	Color	Code	Stat
9	Good luck ! I'm available for any further informations				Tram		T	3
10	good luck				Bus		B	1
11	Thank you for your efforts				Taxi		X	1
12	Thank you for your efforts.				Private car		C	0
13	I live here inside of ENSIAS so i cannot help you a lot in your research, and also 95% of ensias students are the same, not only ensias but also all other engeneering schools, however there are universities that don't provide hostel to their students such as economic university wich is near to ensias , so my suggestion is to try with universities students and don't waist your time with school ingeneering students. Welcome to Morocco! I hope you enjoy your time here! If you need any help do not hesitate to contact me assia.lafqiri@gmail.com.				Not specified		NS	2
14	As an INAU student, I think that the absence of urban planners in Rabat and in Morocco in general is one of the reasons why the traffic and transportation system is catastrophic, I think we should give them a chance because they can really help in the improvement of this situation.						Sum	7
	Thank you.							

Appendix N: Coded Transcription of Interview with Student Body President and Treasurer

Interview 2/5/18
Present Parties:
Mohammed Amine - Student Body President - Interviewee
Mohammed Amine - Student Body Treasurer - Interviewee
Mohammed Salhi - Translator
Mark Landergan - Interviewer
Pawan Dodani - Interviewer
Rushdi Abualhaija - Interviewer

Coding Legend used:

Code 1:		
Theme	Color	Code
Congestion		J
Speed		D
Management		M
Price		P
Availability		A
Safety		S
No problem		NP
Coverage		C
New system		NW
Poor Condition		PC
Code 2:		
Theme	Color	Code
Tram		T
Bus		B
Taxi		X
Private car		C
Not specified		NS
Code 3:		
Theme	Color	Code
Solution		SO
Problem		P
Expected Outcome		EC
Actual Outcome		AC
Social Impact		SI
Growth		G

Abualhaija: Is it ok if we record this interview?
Amine (SBP): Yes
Dodani: *Reads introductory excerpt*

Dodani: Please state your name and role at ENSIAS
Amine (SBP): Mohammed Amine, I am the student body president
Amine (SBT): Mohammed Amine, I am the student body treasurer
Dodani: What do you believe is your classmates most prefered form of transportation?
Amine (SBP): Arabic
Salhi: He asked you invited him here just to answer these questions, he says he can answer these by email

Salhi goes over the questions with Amine (SBP) and translates them for him to make sure he understands them

Salhi: He will answer the questions by email, you can ask him what you want but just open debate, just send it to me.

Landergan: Are there any questions he doesn't understand does he need us to explain?

Salhi: No, he understands but for example you asked him what smart city means for him and he needs some time to think about this he will answer it later

Landergan: Ok we just want to make sure that he understands that we want him to answer for everyone not just for himself, like for the whole student body

Salhi: Yes, do you have any additional questions I think it's an opportunity for you because it's an interactive qualifying project, its not just to write and rewrite as you are doing right now so he is the student body president and he is the treasurer for the school council

Landergan: So I guess one of the things we were thinking about is what do students need or want the most for example in our school they created a bike share program to help students get around the city and it was very successful, have you guys done any projects or like as the treasurer have you looked into funding any projects that increase transportation i know there is the tram but i don't know if there are other areas of rabat or madinat al irfane that people are looking into projects related to mobility that people are looking into right now

Salhi: One direct question please

Landergan: Are there any mobility projects being worked on right now

Salhi: *translates question to Amine (SBP) and Amine (SBT)*

Salhi: No they haven't thought about it

Abualhaija: Do you have anything that's obviously an issue with transportation in Rabat that you know about?

Salhi: *Translates*

Salhi: So he says that the tramway finishes at 10 P.M. and generally we have responsibilities beyond this time and we need to go to agdal to get dinner and a taxi at that time is very expensive

Landergan: So in the united states we have uber and here you have uber and kareem, its very popular because the prices are very competitive, do you think students would be interested in that here?

Salhi: Have you tried to use uber here in morocco? Just try it. Sometimes when I ask people if you ask someone how much they pay the taxi between two points they will use the uber counter, it is the same and uber ads taxes and they are united states taxes not moroccan taxes, the amount of the taxes is high, did you ever take a taxi from agdal to here? I pay only 14 dirhams

Landergan: So is everyone here engineering students?

Salhi: No not everyone, the goal of ENSIAS is engineering, the undergraduate students are engineering students but the graduate program here is not like the graduate program in the united states, a professor can open a masters program for 3 years and then close it so here from ENSIAS a masters degree is frequent but not always this is a school not a facultes, generally in a school they have computer science degree, here we have computer science engineering degree, you have to complete 3 years of preparatory studies to get access to the masters program so i did 3 years of preporatory classes and got access to the P.h.D. program directly. It's two different types of schooling.

Landergan: So what we were saying is that we are all engineering students back in Worcester and coming from an engineering background, do you see any technology that can improve the transportation here in madinat al irfane?

Salhi: Do you want him to suggest some solutions?

Landergan: Yes.

Salhi: *Translates*

Salhi: he says he has a lot of ideas about smart cities but we have not reached the level to apply it in Rabat so because as you know - I will add something he didn't say - when we talk about smart cities its an additional layer so if you don't have the basics you can't talk about the smart city usually when you talk to the student body you are talking to pessimists because in their minds they have a lot of problems they have to solve at ENSIAS for example at ENSIAS we don't care about transportation, we care about for example the restaurants. When we talk about issues the last thing we think about is transportation because we live here and we study here and everything is here so we are discussing only in our meetings basic problems so as I tell you the only need in terms of transportation is to go to Al Kama, everything else is a luxury

Landergan: So if we don't need this high level, or we can't address it right now, what do you think is the first step that needs to be fixed, the bus? The tram? What are the basics?

Salhi: *Translates*

Salhi: If we talk about the buses before we talk about smart cities or adding additional lines, what we have already should be organized

Landergan: So we were trying to find the bus but we were having trouble finding where to get picked up, is it a private company or is it subsidized by the government do you guys know?

Salhi: So in Rabat we have a private french company, its not the government that delegated this company its the city government, the ministry of the interior charged this company to manage transportation within Rabat and not just Rabat also Sale, its a big network.

Abualhaija: So the tramway is 6 dirhams per ride and the bus is 4, is the living cost more difficult for students if they are unable to ride the bus?

Salhi: I will answer this one so to give you an idea students at ENSIAS don't use public transit very often, they don't leave ENSIAS frequently so for me just food off the campus between ENSIAS and al kamara are the only places we go and we go walking but if we are talking about students generally if they pay 4 dirhams at 8 and 4 at 2 and 4 at 6, that means 12 dirhams a day and 120 in 10 days so about 400 dirhams a month and thats very expensive, I will give you a reference, the scholarship that the government gives the students here in morocco, nearly 2000 dirhams in 3 months, if we cut off 400 dirhams every month, thats a lot, more than 50% of the scholarship, if we add the food its gone. But normally students buy cards for the bus it think its 100 dirhams for a month, yes 100 dirhams for a month, so there are only 3 lines they can ride, that is with the student discount. For the tram its 150 dirhams per month.

Landergan: So the tram is pretty good with showing up on time, we tried riding the bus, and we waited over an hour and it never came, do students have trouble with this?

Salhi: *Translates*

Salhi: As you know, we came from all around morocco and some came from Rabat, sale and tamara, these are the students who have the most trouble, for those who live in Rabat they have the tramway for those who live in tamara they have to take the bus because there is no direct petit taxi between Tamara and rabat, for the grand taxi, they don't go till irfane, so they have to go to the center of Rabat then take the tram to irfane. For the bus, it's terrible, they have to wait more than an hour, so for me I have only one experience with this, I had to go to tamara and take the bus back, it stopped parallel to the hospital, it broke down there, so they said you have to wait for another bus or go walking, I went walking because I knew to wait for another bus would be more than 2 hours.

Landergan: So I guess we have asked a lot of questions about the initiatives and technology, are there any questions you have for us, is there anything you want us to know so we can understand what you are dealing with?

Salhi: He asks what do you have as the basic transportation in the united states? Should it be applied here in Morocco?

Landergan: We have a bike share and we have a shuttle service…. ...Mark explains SNAP...

Salhi: I'll explain it to him *translates*

Salhi: So he asks if you have everything in your university or is there something that wyou would need from outside your university

Abualhaija: So basics we have everything like school supplies and food but if you need clothes, bedding, groceries are kind of far

Salhi: *Translates*

Salhi: So he says that we don't have a need for this here because we have a small campus and although madinat al irfane is large, they are different universities so this public transportation would be more expensive than in your school
Landergan: So I have a question, in Worcester there are many different schools, all spread out and we have a shuttle that goes from university to university and stops at other spots too

Salhi: What is its purpose?

Abualhaija: To take people to events or to classes at other universities

Salhi: So it would not be valuable for us, we don't care what other schools do, only in one time, next week all the moroccan students will start the sports days in every weekend, students will go to other schools and compete in many sports, so in those sports days we need transportation from one university to another that's the only time and it's on the weekends and generally we walk except for when we go to casablanca and then we use the train.

Dodani: So we can send him the questions we have?

Salhi: yes, email them to me and I will send them to him

Appendix O: Transcription of Interview with Assistant Director of Studies: Professor Mohammed Hanzaz

Interview – 2/16/18
Present Parties:
Pawan Dodani- Interviewer
Veronica Hartnett- Interviewer
Professor Torya Balhoussin Idrissi- Translator
Professor Mohamed Hanzaz- Assistant director for studies

Coding Legend used:

Code 1:		
Theme	Color	Code
Congestion		J
Speed		D
Management		M
Price		P
Availability		A
Safety		S
No problem		NP
Coverage		C
New system		NW
Poor Condition		PC
Code 2:		
Theme	Color	Code
Tram		T
Bus		B
Taxi		X
Private car		C
Not specified		NS
Code 3:		
Theme	Color	Code
Solution		SO
Problem		P
Expected Outcome		EC
Actual Outcome		AC
Social Impact		SI
Growth		G

Idrissi: You are asking about the kind of transportation between Madinat Al Irfane and the other neighborhoods, and the satisfaction and efficiency of the transportation systems

Veronica: So it's pretty much the transportation coming into Madinat Al Irfane

Pawan: And how people come into Madinat AL IRFANE,

Idrissi: first of all you have to understand that Madinat Al Irfane is a special neighborhood dedicated for students. On top of this they have many administration and different kinds of universities and schools. A campus which was built over time

Idrissi: So it started this neighborhood in 1980s and every year we see different constructions come up on the campus, nowadays its located between three large neighborhoods. The first one is agdal riat,

Idrissi: the red wall is making the accessibility between Madinat Al Irfane, and yacoub el Mansour very difficult, why why, it is much easier to relate Madinat Al Irfane and Agdal because we have these simple roads

Veronica: We have a set of questions, that we would like to like translate to like ask him which are very specific

Idrissi: You have some questions would you like to answer these questions, or when is he going to go with you to the abroad, to the Massachusetts, it is fine here, we do it here

Veronica: So the first question is, what is your role in the school of urban planning, so what does he do here.

Idrissi: Okay, so here in the institute we do have two heads, one is Mr. aditti he is the general head, mr hanzaz he is in charge for the planning of the different activities,

Veronica: What is his background, in urban planning what research has he done with this?

Idrissi: he works for the urban agency of rabat, by the way, he did before joining the urban institute. He worked first in the ministry of domestic affairs for 10 years, urban agency, 15 years. First of all he studied geography in france, he got his doctorate in urban planning and geography, in Université Paul Valéry Montpellier III in france. Each city has its own urban agency, for 15 years. And I did happen to work with him, when he was at the urban agency

Idrissi: He joined the urban institute since 2011, at INAU, and he is the head of the study department.

Pawan: so a next question we had, was how does INAU contribute to the planning and development of urban cities, also are there any current research projects that relate to planning and mobility.

Idrissi: What we are teaching, we work with the local city government

Pawan: so there is a correlation between the school and the city

Veronica: so does the university report to the city of rabat as well or is there just a correlation.

Idrissi: Okay what he say that our graduate student, when they finish, they can go and work with the ministry , or those in the civil the local authorities. And private offices that deal with urban planning , so they become urban planners . and work either for the public sector or the private sector

Idrissi: INAU can be involved for different kinds of studies commanded by the ministry or agencies. INAU can work as a consultant for the ministries or different public offices.

Veronica: Is this students working, are they the ones consulting. Or is it the school as a whole.

Idrissi: The professor can be consultant, but students are involved also because it is a learning opportunity to find out what's going on in the real world.

Veronica: So the students are doing research and report to the professor

Idrissi: So the students are in charge of different kinds of surveys, and the field work to collect all kinds of data

Veronica: Do you know what kind of projects they are currently doing or what the projects usually focus on.

Pawan: Has there been a project recently that is working with urban planning and mobility.

Idrissi: They have a really small work, coming from the Agdal riyah on the management of the really small public space. Public space involving other project,

Idrissi: The other project is dealing with declining cities, declining city where a city was diffing different mineral like coal. Where they close down factories, the cities completely decline. Here we have different examples. Such as Jamalda, people don't have other opportunities to get jobs

Pawan: Has there been any projects done in regards to mobility or transportation systems by the school of urban planning.

Idrissi: They just launched, he is in charge for a new master. This new master is really dedicated to the transportation and mobility.

Veronica: Oh so it is similar to what we are trying to do here, we are trying to assessing the transportation and we actually want to know, if its feasible to incorporate smart technologies, like the bus the tram the taxi, and does he think, and are there projects pertaining to smart cities. Not from INAU, in general to Madinat Al Irfane

Idrissi: Because rabat was specificated as a green city, yea a green city. Was in Amsterdam presenting something, yea rabat is a green city. In related to those transportation systems. I am inviting you to google this and try to find out If you are able to.

Idrissi: He says we cannot imagine, think about efficient transportation without thinking about smart technologies, one example is the tramway. An example of the smart technology.

Veronica: Based on this, does he think what are the risks or are there any challenges, implementing smart technologies into the transportation, perhaps for example the public acceptance, political resistance to

Idrissi: Planning of urban mobility, these are the main courses. He is talking about the new master dedicated to the mobility. And he is giving the main courses. This new master

Veronica: So this is just focusing on the new masters pertaining on mobility.

Idrissi: Because there is this need to for much more efficient smart technology. Its mandatory because cities are getting bigger and bigger larger and larger. The mobility sector will take a larger weight. Transportation is like a vein in the body, in relation to sociology the people connecting people in the suburbs that are far away from cities, commuting, they need the transportation to come work and go back. Precisely for those commuters, Let me ask you a question. How do people commute in the city where you are coming from.

Veronica: So it depends, as a student we walk to campus. Other people who work will either drive, or use public transportation or use trains.

Idrissi: I am pretty sure in Boston it's quite the same

Veronica: Most people they drive or take the train.

Idrissi: So they are just like three main transportation over there.

Veronica: Does he see any potential risks or challenges with implementing any mobility projects in especially Madinat Al Irfane

Idrissi: Each university is gated university; first thing is easy accessibility. He is thinking about an open campus. For handicapped people, these are the challenges. To open the campus on other neighborhoods, and precisely the neighborhoods of yacoub el Mansour that he was talking about. There are no means of transportation between yacoub el Mansour and the campus. They have to walk, it's really nearby, but they have to walk, to get inside. Many students are living over there because the rent is very low. We just have small bridges, so he is saying we have one bridge for pedestrians and the two other bridges are for cars, and its still not enough.

Pawan: What does he see that can be a possible fix to this?

Idrissi: He said that one way is to increase the number of bridges, and the bridges are supposed to be accessible to all individuals. And the bus, create new bus lines to help commute between yacoub el Mansour and the campus. It seems that the city government is completely ignoring, saying that the students can walk. In the morning there is a traffic jam, so between 7:30 to 9 o'clock. We do have on a daily basis traffic jam.

Veronica: Besides walkability what are the other challenges with mobility, and the tramway only has one line. The bus are in poor condition, the taxi doesn't reach all locations

Pawan: What problems does he see with the transportation systems.

Veronica: I know he mentioned the gated community top open up, but does he see any problems with the transportation systems.

Idrissi: The actual system is creating different kind of problems. We have 3 different types of transportation, the tram. The gated neighborhoods, the tram is only going 1 way. We have some gated neighborhoods which the tram doesn't reach. Tram goes from point A to Point B, and one going from Sale to south. The neighborhoods, Yacoub el Mansour isn't reached by the tramway. The bus are in very poor condition.

Veronica: we rode some of the buses, they are in terrible condition.

Hanzaz: Catastrophic

Idrissi: People are avoiding buses, they are in poor condition, secondly they are really congested. You cannot rely on the buses, they are late, and they don't come on time. We don't have any scheduled buses. Whether one will be here at 10:10, you don't know.

Veronica: So the bus just kind of appears and disappears.

Idrissi: Because the buses are in such poor condition, to rely on schedule to get from point a to point b. Its suppose to take 30 minutes, because of what I have said it takes 1 hour 30 minutes. In terms of profitability, it is not profitable for the corporation , they are in losses.

Veronica: even if the tickets are affordable to people, people don't want to use it and avoid them

Idrissi: Those who do have other alternatives, are avoiding to take buses, they walk or they drive. Or take subways. However if you have no choice, you are stuck to the buses.

Veronica: The students at Madinat Al Irfane, who might not have any other option, for example the tramway does not stop later. They have to take the bus.

Idrissi: Yes they walk, it is true there are many students who have come late. A whole bunch of students who sometimes. Even with the subway, we have breakdown. And the students have to walk. Tramway

has no problem, it is very efficient. The bus is not safe, it is congested crowded, the third way means of transportation is private taxi. Those are very expensive because they put the counter on, and people cant afford to take the taxi.

Veronica: Based on all these 3 systems that come into Madinat Al Irfane, what does he think is the major, greatest mobility problem.

Idrissi: Transportation are poorly planned, this is the main problem. So the first problem is connecting the different modes of transportation. For example in United States you can take the tram and then next take the bus after. They are not interrelated here to ease transportation for citizens. Roads are to narrow, when they built the subway they took up a large part of road. The other thing is that the city is growing, we have Temara and Sale. We have small cities, which are the suburbs. The accessibility was not deeply implemented by planners. For example, our students do come from Temara very far away. The tram start at Madinat Al Irfane, we had a colleague who was head of the planning department. He did fight with those people who were supposed to build and extend the line to Temara. However they said no. It would have helped avoid the traffic jam. People would leave their car at home and then ride. If we had done this extension of public transportation, we would have a very efficient way to go from one way to the other way. People wouldn't invest in cars, now we have an increase in cars. Because people don't have this other alternative, and also causes pollution. Morocco was able to now bring economical cars, non expensive. So middle income household can buy these cars.

Pawan: So if a new transportation system is implemented, or smart technologies to increase efficiency, reduce congestion. Would there be any problems he sees, or acceptance of any technologies.

Idrissi: Honestly people cant be against different innovation, they will just welcome. People are very open, they will welcome new ways of transportation.

Veronica: Besides the people will there be any structural or political problems against it. For example someone proposed the extended line to temara, but they said no. Any political opposition.

Idrissi: This enterprise had a logic of gaining money, one meter could cost $200,000 so they were afraid to extend it. But planners were thinking of how to bring those people from outside. Morocco has a low household purchasing power. This is why we face different kind of logical, the politician need to smooth the transportation, private sector here is to make profit.

Veronica: Right because the public transportation here is not run by the government, it is by private companies.

Idrissi: First step the government was managing the public transportation in Rabat, 100% of all public transportation was managed by the government. After 2000, there was an entrance of different corporations managing this transportations. These enterprises were fighting, then the government had to make some rules and regulations. 3rd step, after 2000 the government is supervising and looking after the shoulders of the companies. To make sure there is only one enterprise doing the path from point a to point

b. Those buses don't have specific lines, the roads are not large enough. The bus has to drive on same road as cars, it cannot be efficient.

Veronica: So they don't have assigned roads for the buses, so can they take any road? As long as they get to the next stop

Idrissi: Yes, not like in paris or united states. The streets are very large. For the tram two meters was taken from the roads. Making it smaller. The idea of what Professor Hanzaz is thinking is there a political will. To develop this public transportation, he is not sure if he can answer yes to this question.

Veronica: So that's more of a question to the city hall, if there is a will to make the transportation better, and to cater it to the students and the population.

Idrissi: He is not sure if it is a yes. There is a political speech, that we would like to have a very efficient transportation system. But the reality we are just building larger roads for private cars, not focused on the public transportation systems. We include household also, who invest in private cars. Now you have to choose between two alternatives, if you want to increase public transportation. You have to decrease the number of cars in circulation, there is a tradeoff needed. This tradeoff doesn't exist.

Idrissi: It's a need coming from students, the population. But in the same time we don't see the reality different ways or means of

Veronica: By the government ?

Idrissi: The government is just making it better for cars

Pawan: Another question, if smart technologies were introduced to help assist in making these transportation systems more effective, more reliable. What would the steps be needed to have this be implemented?

Idrissi: The transportation should not only include downtown, but also the metropolitan area. We need some supervising, the godfather better management. The other idea is to allow commuters to take different transportation method.
With only one ticket, to smooth the links, the other way. Here in morocco, the transportation doesn't reach, and households that it doesn't reach have to come to Rabat to send their kids to school

Veronica: Before implementing a smart initiative does there have to be a basic service, like the bus, you can't really just add smart technologies to it. First it has to be organized well, before all the layers can be applied. What are the basic?

Idrissi: When you think about transportation, we think about within the city, within downtown, within different neighborhoods. But you have to think about extending and reaching far away neighborhoods to link, the metropolitan areas and the close city. It is only linked by the cars, the roads are very congested in the morning.

Veronica: Madinat Al Irfane, everyone is coming in cars.

Idrissi: Did you ride the tramway? Its very efficient

Veronica; There's not many problems, we tried to ride the bus and we waited for one hour . Wanted to experience the bus in first hand.

Idrissi: You live in Agdal and rode the tramway

Appendix P: Coded Transcription of Interview/ Discussion with School of Architecture

Professor Interview with School of Architecture 2/15/18

Present Parties:
Reddad Erging- Professor

Mark Landergan - Interviewer
Haylea Northcott - Interviewer
Rushdi Abualhaija - Interviewer
Profesor Kharmich Hassan- Translator

Coding Legend used:

Code 1:		
Theme	**Color**	**Code**
Congestion		J
Speed		D
Management		M
Price		P
Availability		A
Frequency		F
Safety		S
No problem		NP
Coverage		C
New system		NW
Problem in Rabat		PR
Solution		SO
Expected Smart City Outcome		E
Actual Smart City Outcome		AC
Social Impact		SI
Growth		G
		Sum
Code 2:		
Theme	**Color**	**Code**
Tram		T
Bus		B
Taxi		X
Private car		C
Not specified		NS

Interview with school of architecture 2/15/18

Present Parties:
Reddad Erging- Professor

Mark Landergan - Interviewer
Haylea Northcott - Interviewer
Rushdi Abualhaija - Interviewer
Profesor Kharmich Hassan- Translator

Professor Kharmich Hassan: We would like to work in collaboration with your university, to conduct Research on smart cities with specific focus on the moroccan context. Research on smart cities is still in its embryonic stage in Morocco. But when it comes to practice, to real life, we notice that many achievements are being made. Which is a dilemma actually, normally research should precede…

So there were theories in the 1960s that smart cities would be an answer, a solution to this crisis of cities, but that's not true.

A lot of research was conducted in France and this research shows there were a lot of problems, so we are interested in this kind of research so we can avoid the same kind of mistakes, let me give you a few examples.

So there was a threat of this territorialization of the … so the concern is there might be these smart cities where you have high tech but it's totally disconnected from the vicinity, there is a total mismatch…

Mark Landergan: The vicinity being the infrastructure or the people?

Professor Kharmich Hassan: We find ourselves in this situation where there is a high chance we are connected globally but at the local level, that isn't really achieved

So the idea that we had is that once we engage in smart cities, everything will become virtual, but when we look at the achievements they are minimal, in France research shows only 2% was achieved, for example you can order some documents online but in reality the achievement is only 2%.

Mark Landergan: Yeah, so do you mind if we ask some questions? We have all these great technologies that are out there but there's a disconnect between the user and what's available, people don't understand how to use the system, so is it a design flaw that people don't know how to use the website or the app?

Professor Kharmich Hassan: So high tech has not really replaced the traditional way of doing things in the city, people still have to go to places to pick up a document so there is still this physical movement. So the assumption was that this technology would put an end to this division between urban and rural, but it still exists, the 50 biggest cities have the internet concentrated there, so we still have this discrepancy,

Mark Landergan: One of the concerns we had before we came here was that we are not that knowledgeable about the division of rural vs. urban, and the worry was that if we introduce this technology it would just grow the division between rural and urban by giving more opportunities to the urban with the rural staying the same, is that what he's talking about ?

Professor Kharmich Hassan : Yes, that's what he's talking about, he is saying that despite technology, it's just maintaining this divide, so he's trying to make the point that we should take "high tech" with a pinch of salt, we should be cautious. Ok, he's going to talk about another myth.

Ok so another myth is that research in France shows that companies will establish themselves in the places with good internet connections, but companies are established in areas where there is the labor force and where the premises are cheap.

Mark Landergan: So he's saying the impact isn't as good because it's staying in these already concentrated tech areas as opposed to going out further.

Professor Kharmich Hassan: Yes, so they are looking for places that are cheap and efficient. But it's not up to the expectations of revolutionizing a city, so we still have the traditional kind of city, there are additions, there are innovations but not up the point where we can claim it's a total revolution. So it's kind of enriching the cities that are already rich. Only certain are cities such as Casablanca have benefited substantially from high tech.

When morocco engaged in this project of smart cities, morocco was aware that the experiences of other countries can be insightful to us but cannot be directly implemented, so a lot of emphasis is laid on contextualizing those experiences, so we learn from other countries but we need to take into consideration the socio-cultural context of the country. So for the last 3 years i have been organizing a seminar on this very issue, so we've been working on Casablanca, Rabat, and Marakech to explore the ways in which what we learned from other countries has been implemented. So he's making the point that we have gated communities, but it's in the Moroccan way, so there's always the influence of the culture. We conducted surveys with a number of ministries and we have noticed that some ministries or departments such as ministry of state, or department of state or whatever some of them are very involved and others are not. So one

example to illustrate the importance of the socio-economic state is ecommerce, we have a lot of ecommerce businesses and industries going on but people are not totally involved, so people probably still have their reservations or doubts, they aren't fully engaged in this project of ecommerce.

Mark Landergan: So one question we've been looking into, so our group is looking into transportation systems, the tram, the bus, the taxi, and we are trying to see if smart technology can improve the efficiency and reliability.

Professor Kharmich Hassan: So when we talk about the problem of transport in most moroccan cities we have this problem of overlap, so we don't have means of transport that are complementary, so we have different means of transport that will take you within the same route, but they are not really complementary. So what we need is a multi-modal kind of approach to transport.

Mark Landergan: So what I was asking is that , we looked into Seoul, South Korea, Hong Kong, China, Munich, Germany, rated the best in the world, and all these countries have a centralized computer network that can connect all these services, and one thing.. All these systems are owned and operated by a single company, or the government. So they can then coordinate and have all these very efficient systems, so the bus is run by STARIO and then the tram is run by a spanish company we believe…

Professor Kharmich Hassan : It's a french company, this project is underway but it has not yet been achieved, so the ministry of state has conducted several studies into this to see if it is beneficial to city to have one company running these different forms of transport, he mentioned the ministry of interior because the management of the transportation systems within urban areas is the business of the city council, it's the mayor.

Mark Landergan: So it's not the ministry of transportation?

Professor Kharmich Hassan : They cooperate but that's a different thing. So the ministry of interior supervises the city council, the mayor, whatever and they are in charge of the transportation within the city. So the tramway is operated by a private company, La Capital is the name of the body ..that manages, so the city council is thinking of hiring or recruiting just one company that would be in charge of the whole thing, the tram, the bus, etc. We borrow a lot of things from France and that's what they have in place.

Mark Landergan: So to clarify some places have one governing body but they have multiple companies a different tram, bus system.

Professor Kharmich Hassan : So we talk about regulations setting the norms on the laws, but it's the body that regulates, the city council, so we have this objective of this multi-modal approach to urban transport in urban areas, there is a body now, but they are different companies. It could be one company or it could be different companies, but they want more coordination when it comes to… we have a document, a framework, a roadmap, scheme but it's dated, it needs to be updated.

Mark Landergan: Is that public, would we be able to get that

Professor Kharmich Hassan: We have a copy so we can make it available. So it provides you with data… it's a diagnosis… sort of some action plan.

Mark Landergan So you mentioned this body that oversees it, the city council, what is the name of that?

Professor Kharmich Hassan: Ok so you have the ministry of interior and you have different departments, like Human resources or whatever, but there is one in charge of city councils and within that you have the body that can give you information on all the moroccan cities. There is a fund and my colleague is really stressing this: because the city council funds for sponsors part of these, which means when I use the bus and buy the ticket, I don't pay the full amount, it's subsidized.

Mark Landergan: So that's one thing we've been looking at is that in all these countries puts a lot of money to get the system up and running, but the problem is that it's very difficult to get it up and running, so you said there's a fund but I assume it's a fairly small fund, so is there money from the king or the government to bring these new projects in? So for example we are looking into smart mobility, so if we wanted to revamp the bus system here, so if we wanted to implement a green bus system, are there current funds for that or…

Professor Kharmich Hassan: Ok, so my colleague made it clear, and I agree with him that we don't talk about the king in these matters, ok it's the business of the government. So when we look at the project of the tram, we notice that the ministry of the interior provides a lot of financial support, especially in the first few years. Public transport is a non-profit kind of business, it has to be subsidized by the authorities, and my colleague made the point that the tram system especially in the first few years was heavily subsidized. This also holds true for water. So taxis now, taxis in morocco are in very bad condition, so the government is helping get rid of the old taxis by helping the drivers buy new ones because they want clean environment and quality taxis and so on, so it's not just the tram it's also taxis.

So we have many public parking lots for cars, people pay a small fee but it's to help people to use the tram. There is one here in Madinat Al Irfane.

Mark Landergan: So in your presentation, you mentioned the need to address energy, security, environmental factors, water, in order to this it is a lot of different areas, what do you think needs to be addressed first going forward?

Professor Kharmich Hassan: He says public transportation is the most critical issue. More than 60% of Moroccan people live in urban areas, so it's a big issue. So cities are getting bigger and bigger, they have the suburbs and people need transportation systems to get to the center of the city. For example, in some cases if you ask for a taxi and they ask for your direction and you tell them some crowded area, they might say no, they won't take you there. Traffic is a big issue.

Ok, so he talked about a number of smart city components like energy security, transport, etc. but he thinks that there is always one factor that should ignite everything else, and for him it's transport.

Mark Landergan: So we've been looking into transport here in Madinat Al Irfane and what we want to do is look at Madinat Al Irfane as a test platform, and bring it to a bigger scale, so we want to find out what the biggest problem with transportation is in the area, and we are wondering what you see as the biggest problem facing transportation here in Rabat…

Professor Kharmich Hassan: So there is lack of balance here, there are areas where the public transport is good, for example you have the tram but there are areas where you cannot have access, the quality differs from area to area. So we talk about the tram, it is good quality but it only serves certain areas, and we should not forget about the other areas, the bus is a big problem, low quality…. So there is a paradox, in the same way that the quality of tram is improving dramatically, we have the quality of the buses going down, we used to have much better buses. So in 1990 we had 1 bus for 3000 people, so now it's 1 bus for 4000 people. A single bus for 4000 people.We cannot solve this problem of transport we need to be aware of this once and for all, we need to pay a lot of attention to people who use it, the ordinary user. You are concerned with the Madinat Al Irfane, so you need to keep in mind that the kind of people who come into Madinat Al Irfane are students, your task is so easy because you are dealing with students because it's a smart category of people it's probably much easier for you. So it's very easy for you to approach and talk to students, your research is going to work because you have smart people, you can use your data collection tools.

Mark Landergan: So our project, we only have 7 weeks to look at this and we understand that this one small population is not representative of the city, so we don't want to claim that this will

help us understand the problems the of the whole city, we hope that this can help us start at a smaller level, our hope is to ignite research that can be used on a larger scale.

Rushdi Abualhaija: So our university does these projects every year, so there are 5 other project teams from our university working here and this is the first year that our university is doing a smart city project, however in future years if this project is successful, then in future years another team will come back and continue our work.

Professor Kharmich Hassan: I equally think that… so there are a number of higher education systems here in Madinat Al Irfane so probably what we need is some kind of auditing of energy, research is probably needed about gas emissions. There are a lot of students who take their cars here, so it is an issue to investigate. Within the school there is no residence.

Mark Landergan: Since we work with ENSIAS, we are able to communicate with the students easily and we are wondering if we would be able to bring our online survey here because everyone commutes so we were hoping to diversify our data.

Professor Kharmich Hassan: Yeah it's ok to contact students in this school.

Rushdi Abualhaija: Is there a mailing list?

Professor Kharmich Hassan: So he will provide you with the student club, the leader of that club has access to all the emails of the students.