WeGO Feasibility Study 2017

Implementing Smart Waste Management System in La Marsa, Tunisia

WeGO
World Smart Sustainable Cities Organization

ECUBE Labs

Abbreviation

Abbreviation	Full Name
ABS	Acrylonitrile Butadiene Styrene
ANGed	National Agency for Waste Management *(Agence Nationale de Gestion des Déchets)*
ANPE	National Employment Agency *(Agence Nationale pour l'Emploi)*
ATI	Tunisian Internet Agency
CIMF	IT Center of the Ministry of Finance *(Centre Informatique du Ministère des Finances)*
CIMSP	Computer Center of the Ministry of Health *(Centre Informatique du Ministère de la Santé)*
CCN	CleanCityNetworks
CCP	CleanCAP
CR	Cost Reduction
CTM	CleanTrack Module
CSF	Critical Success Factor
EGDI	e-Government Development Index
ENIT	National Engineering School of Tunis
EPI	e-Participation Index
EU	European Union
EULA	End-User License Agreement
FM	Fleet Management
F/S	Feasibility Study
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GII	Global Innovation Index
GIS	Geographic Information System
GNP	Gross National Product
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
IoT	Internet of Things
ICT	Information and Communication Technology

IDI	ICT Development Index
INS	National Institute of Statistics
ISP	Internet Service Provider
IT	Information Technology
ITU	International Telecommunication Union
KOICA	Korea International Cooperation Agency
LDC	Least Developed Countries
LoRa	Long-Range
LPWAN	Low-Power Wide-Area Network
MAF	Mobile Application Framework
MOU	Memorandum of Understanding
MTCEN	Ministry of Communication Technologies *(Ministère des Technologies de la Communication et de l'economie Numérique)*
NB-IoT	NarrowBand-IoT
NPV	Net Present Value
OBD	On-Board Diagnostics
PNS	National Strategic Plan *(Plan National Stratégique)*
RNN	Recurrent Neural Network
SWOT	Strength, Weakness, Opportunity, Threat
TCO	Total Cost of Ownership
TD2020	Digital Tunisia 2020 *(Tunisie Digitale 2020)*
TII	Telecommunication Infrastructure Index
TND	Tunisian Dinar
TUNEPS	Tunisia Online e-Procurement System
UN	United Nations
UNDP	United Nations Development Programme
USD	US Dollar ($)
WeGO	World e-Governments Organization of Cities and Local Governments
WM	Waste Management

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I. PROJECT OVERVIEW

1. Project Title

WeGO Feasibility Study 2017: Implementing Smart Waste Management System in La Marsa, Tunisia

2. Project Period

The project began on October 23, 2017, and ended on February 12, 2018. The pilot project will be operated until December 31, 2018.

The duration of the pilot system was appointed for one year to provide a platform for La Marsa's municipality and waste management operators to test the efficiency of smart sensors and reveal shortcomings before spending a significant amount of time, energy, or funds on a larger scale project. The one-year term would demonstrate the feasibility of the proposed solution and determine whether La Marsa's waste management will be productive with the new system. This pilot study will allow a thorough investigation of the statistical and analytical evaluations, and provide comprehensive suggestions for La Marsa's waste managers.

3. Project Background

The World Smart Sustainable Cities Organization (WeGO) provides Smart City & e-Government consultation services through Feasibility Studies (F/S) for WeGO members. This technical assistance program is designed to help members assess their current smart city status and draw realistic and concrete Smart City & e-Government strategies. In 2017, La Marsa, Tunisia was selected as the beneficiary city of the WeGO Feasibility Study project.

The government officials of Tunisia have initiated various smart city-related initiatives in recent years. In 2014, they announced a new vision for the ICT sector in hopes of achieving improvement in the people's quality of life as well as efficiency and transparency of government operations. Additionally, the Tunisian Government has made continuous strategic development efforts to expand the ICT industry and solidify their stance as a smart city leader in Africa. The city of La Marsa, located near the capital Tunis, is a popular tourist destination for many tourists both overseas and domestically. In an effort to maintain its inflow of tourists and gain additional attraction, the city has been active with the implementation of various IoT elements becoming the first city of Tunisia for initiating a smart city infrastructure. Among the various components that comprise a smart city, waste management plays a critical role. The smart waste management solutions for La Marsa's smart city infrastructure will utilize sensors capable of wireless telecommunication and data transmission, which will allow constant monitoring of waste bins and significantly enhance the present waste collection procedures.

The proposed To-Be model comprises of three main components: CleanCAP (CCP), CleanTRACK Module (CTM), and CleanCityNetworks (CCN). CleanCAP is an ultrasonic sensor that detects the fill-level of waste and CleanTRACK Module is a comprehensive vehicle data-gathering module and vehicle tracker. Both hardware technologies retrieve and transmit data to the CleanCityNetworks software for analysis such as waste generation, overflow volume/frequency, location of vehicles, route optimization, and fleet management. A total of 50 CleanCAPs and 5 CTM prototypes were installed for the pilot system in La Marsa. These numbers were considered appropriate for the one-year pilot project taking into consideration the budget and case studies of comparable scale and objectives. A smaller quantity of CleanCAPs would not have provided sufficient data for feasibility analysis. Similarly, a quantity of above 50 would have been too widespread for the municipality and difficult to regulate. Thus, 50 CleanCAPs and 5 trackers were considered to be most fitting for La Marsa's pilot project.

Despite being a niche market, smart waste management encompasses continuously growing interest and potential. Among the companies offering integrated waste collection solutions, Ecube Labs was selected for the pilot project due to their enhanced after-sales service (being well recognized for great customer service and maintenance), and for being one of the few companies who provide product customization (clients are able to choose the type of data they wish to receive and customize the program to conform to their specific needs). Additionally, Ecube Labs is currently the only company in the world that offers both the fill-level sensors and solar-compacting bins on a single platform. The substantial advantage of the ultrasonic fill-level sensors provided by Ecube Labs is their application versatility—which can be installed on a variety of containers ranging from public waste receptacles to dumpsters, underground bins, and more. The variety of configurations allows for creative applications that traditional sensors are not capable of, giving La Marsa the opportunity to test various arrangements throughout the pilot project period.

The WeGO Feasibility Study project on Smart Waste Management primarily focuses on analyzing the feasibility of implementing a smart waste management system in La Marsa, a solution that will infuse economic and environmental benefits for a smarter and sustainable city.

4. Project Objectives

The main purpose of implementing the feasibility study on smart waste management in La Marsa is to implement a smart waste management solution that will integrate fiscal and sustainable benefits for a smarter and greener city. The overall aim of the project concentrates on improving waste management efficiency that is cost-effective, environmentally-friendly, socially-beneficial, and globally-lined with smart system solutions. Through the integration of a cloud-based software (CleanCityNetworks) and an ultrasonic sensor (CleanCAP), certain data can be sent to the driver who can effectively monitor fill levels, optimize collection routes, check battery levels and overflow status, as well as fire or hazard events. This solution will greatly improve hygienic conditions on the street (by effectively managing waste and preventing the overflow of trash bins), mitigate air pollution and greenhouse gas emissions (by regulating the pickup schedules and reducing CO_2 emissions released from trucks), and significantly reduce waste collection costs (by efficiently monitoring the entire waste management operation through a computer or wireless device).

La Marsa has continuously been at the forefront in applying new and creative projects. Through collaborative efforts with the National Engineering School of Tunis (ENIT) and other consulting firms, two additional projects incorporating innovative technologies with IoT platforms targeting waste management and public lighting systems were launched.

The project directed towards waste management, entitled "SMART La Marsa City: Smart Containers," aims at incorporating photovoltaic and advanced IoT systems such as ultrasonic sensors and real-time image technologies. These smart technologies will be connected to the waste containers, which will transmit real-time information to the waste collectors via a cloud platform that can easily be conveyed through smart phones or computers 24 hours a day, 7 days a week. Through the integration of cloud-based networks and ultrasonic sensors, several benefits are predicted to emanate. The following are some of the outcomes that may be anticipated from the implementation of the project:

Table 1. Expected Outcomes of SMART La Marsa City Project

Municipality autonomy	Waste integrated into economic circuit
Improved environmental conditions	Waste valorization business implementation
Better hygiene and sightseeing	Transparent and confident citizen involvement
Reduced diseases and infection	Improved citizen well being
Management of resources, energy, & territory	ICT operators involved as partners
Rapid and efficient service quality	Stakeholders involved as partners
Elaboration of a viable data base	Promotion of talents in ICT/other related fields
Better control of waste management circuit	Green certification

5. Project Scope

The overall scope of the F/S will include a comprehensive approach beginning with assessments of the current waste management system of La Marsa, followed by a thorough investigation of the problems and concerns as well as areas that require improvement, and concluding with a one-year pilot project that will target the areas of concern and drastically enhance the operational management and related infrastructures for the municipality of La Marsa.

- ***As-Is Status Analysis***

  The first section of the project scope will entail a current status analysis of La Marsa, and the following areas will be targeted for review:

Table 2. Current Waste Management Analysis of La Marsa
Number and types of waste bins
Number and types of waste collection vehicles
Location and status of high frequency overflow bins
Current IT-related infrastructures
Applicability of new systems and infrastructures
Data utilization plans associated with big data analytics
Public and private sector stakeholders involved
Waste management laws, regulations, policies
Action plan for e-Government services

- ***Case Study***

  Several case studies from South Korea and other countries that have successfully implemented the proposed smart waste management solution have been assessed. These best practice analyses will help establish core values of the model system and review strategic directions for a successful implementation in La Marsa.

- ***To-Be Model***

  Upon evaluation of La Marsa's present waste management structure and examination of the type, number, and location of the waste bins, a service model catered to the needs of La Marsa's waste problems has been devised. This comprehensive smart waste management system will enable efficient management of waste collection vehicles, real-time monitoring of regional waste generation, as well as predictive analytics for waste operators to take preliminary actions when regulating personnel and resource allocation.

- ***Feasibility Analysis***

  In order to evaluate the potential for success and viability of the project, four areas (quantitative, qualitative, technical, and economic) were assessed.

- ***Pilot Project Implementation***

  The pilot project is expected to add a competitive edge to the city as a technology vanguard and contribute to the overall smart city development of Tunisia through economical and technologically-advanced mechanisms. The model system provides a flow of information from hardware apparatuses to a cloud-based server where information is analyzed and processed, which is ultimately transmitted to the CCN platform.

- ***Roadmap***

  Upon analysis of the current As-Is analysis and To-Be model, three directions for future steps have been presented. The following are the proposed actions:

  - Implementation of solution system in Central Government
  - Implementation of pilot system as business model
  - Expansion of other smart solution devices

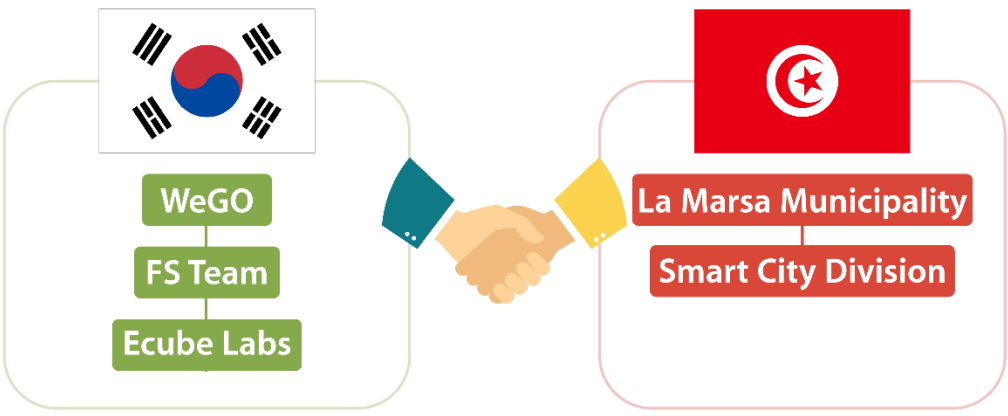
6. Target City & Recipient

The target city and beneficiary of this project is La Marsa, Tunisia.

7. Structure of Project Implementation

The organization of the project was formulated by professionals in South Korea and La Marsa.

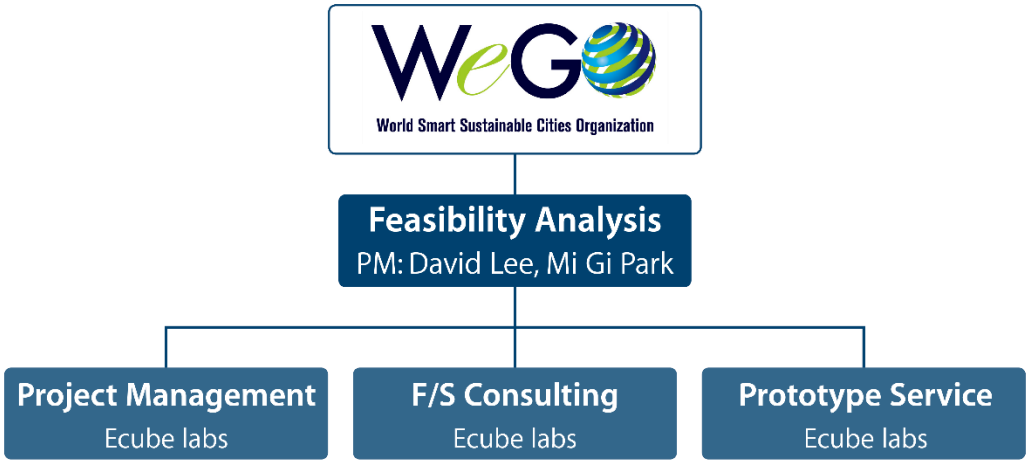
Figure 1. Structure of Project Implementation



8. Project Organization

Consulting was provided by professionals at Ecube Labs who have specialized in consulting, feasibility analyses, and smart waste management solutions.

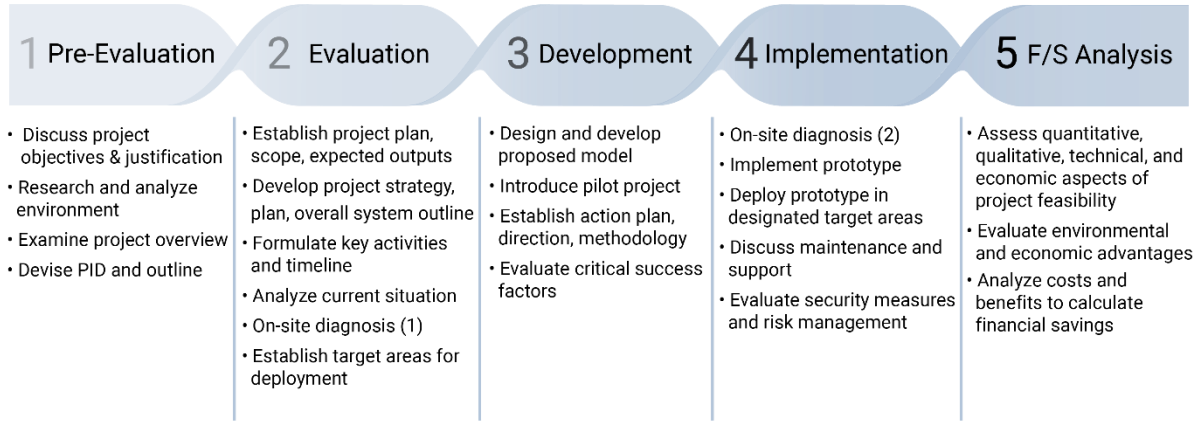
Figure 2. Project Organization



9. Project Approach

Through extensive experience on a myriad of projects throughout over 50 countries, Ecube Labs has garnered professionals who have expertise in the smart waste management industry and relevant IT technologies. Ecube Labs has conducted a feasibility analysis to assess the conditions and possibilities for a successful deployment of a smart waste management system in the city of La Marsa. The following five approaches will be employed for advisory analyses from the diagnostic (pre-evaluation) phase to the final report (F/S Analysis) phase.

Figure 3. Consulting Methodology



10. Expected Outputs

Smart waste management solutions come with many benefits for the municipality and the inhabitants. As waste management departments monitor and predict accurate times for collection, one of the biggest benefits can be easily noticed—cleaner environments. Since fill-levels of waste bins can be detected, waste bins are collected before overflows occur resulting in less odor and unwanted pests in the area. Public health and safety is also expected to increase. With more efficient routes and schedules to collect garbage, the waste management department will become more fuel-efficient and cost-effective, ultimately saving precious funds that could be used for other critical needs. Most importantly, having a smart waste management solution positions the city to implement a smart city project in other operations for the near future.

The real-time and predictive fill-level data provided by CleanCityNetworks (CCN) will enable La Marsa to depict waste containers that are full or ones that are going to become full before the next dispatch. This will decrease the amount of daily dispatches and required collection vehicles, and ensure the waste collection staff is not spending excess time collecting empty or nearly empty containers.

A reduction in waste collection dispatches further represents a reduction in driven kilometers, which also has a direct correlation on labor, fuel, and maintenance costs. With fewer collections, La Marsa can also expect to see a decrease in greenhouse gas emissions, noise pollution, and road destruction. Not only will these impacts be beneficial for the residents, but a smaller budget allocated for waste collections will also have an impact on local taxes.

The smart waste management solution is expected to improve the hygiene conditions around the waste containers since the sensors will alert the collection staff as soon as the bins are full. This will enable timely waste collections before the bins overflow, preventing unsightly scenes that may expose La Marsa's residents and visitors to bacteria, insects, and vermin. For a city that attracts millions of tourists all year round, the improved hygiene conditions will become a major plus factor to the city's overall presentation. Furthermore, reducing the amount of waste overflow will decrease the health risks evoked during the collection and handling of waste, thereby improving the work environments for the staff and personnel.

Lastly, the smart waste management system provides the city of La Marsa various types of insightful and analytical data reports, which will enable the local government to detect the seasonal changes in waste generation and collection performance. Through such reports, the city can target the waste generation and overflow areas that either require a larger deployment of waste containers or an additional collection dispatch cycle. Collectively, these outputs provide a stepping stone for La Marsa to effectively and economically utilize the resources to optimize waste management operations.

11. Project Schedule & Conducted Activities

- Project Period: October 23, 2017 – February 12, 2018
- Project Schedule: The following timeline indicates the schedule from the Pre-Evaluation phase, which was launched on October 23rd, to the progression of the installation and implementation to the final report phase.

Table 3. Project Schedule

STAGE		TASK	WORKING PERIOD				
			OCT	NOV	DEC	JAN	FEB
Project Initiation	Preparation	Working Group Formation					
		Pre-Research / Study					
Solution Model Implementation	1st On-Site Inspection	Environmental Research					
		Interview with Officials					
		Site Inspection					
		Current Industry Operational Study					
	Activities in Korea	Analysis on the 1st Inspection Results					
		Additional / Supplemental Development					
		Hardware / Software Revision					
	2nd On-Site Inspection	Product Installation (Pilot Program)					
		System Stabilization					
		Solution Employment (End User)					
		Discussion with Officials					
	Establishing Solution	The implantation of the Solution Model					

	Model	Data Understanding of Actual Usage / Confirmation of Solution Model Range					
Feasibility Analysis	Design of Action Plan	Establish a Budget and Action Plan					
		Confirm the Action Plan					
	Feasibility Analysis	Economical F/S					
		Technical F/S					
	Completion Report	Write the Final Report					
		Review and Approve the Report					
Project Completion	Final Report	Report the Results (WeGO)					
		Final Workshop					
		Final Report of Pilot Project					
Reporting Schedule				Inception	Interim	Final	

** Pilot Project Report to be submitted after twelve months of trial period (December, 2018)*

II. Environment Assessment

1. Overview of Host Country: Tunisia

Figure 4. Map of Tunisia

Table 4. Profile of Tunisia

Location	Northern Africa, between Algeria and Libya
Map references	Africa
Capital	Tunis
Area	Total: 163,610 sq km Land: 155,360 sq km Water: 8,250 sq km
Population	11,403,800 (since 2017)
Nationality	Tunisian
Ethnic groups	Arab 98% European 1% Jewish and other 1%
Languages	Arabic, French, Berber
Religions	Muslim 99.1%, Other (Christian, Jewish, Shia Muslim, Baha'i) 1%
GDP (billion)	$130.5 (2016) $127.6 (2015) $124.9 (2014)
GDP per capita (billion)	$11,600 (2016) $11,600 (2015) $11,600 (2014) *(CIA Library, 2017)*

1.1 History

Since the beginning of the 19th century, Tunisia has remained a prime geographic location for European trade. France, Italy, and the United Kingdom had desire to have Tunisia as a colony, but in Spring of 1881, the French army occupied Tunisia. By May of that year, Tunisia was officially made a French protectorate with the signing of the treaty of Bardo by Muhammed III as Sadiq.

Tunisia was not recognized as an independent state until 1956. The country's first president, Habib Bourguiba, established a strict one-party state. During his time, Bourguiba created programs to bring stability and economic progress, repressed Islamic fundamentalism, and established rights for women unmatched by any other Arab nation. Bourguiba remained in rule for 31 years but was overthrown by Zine El Abidine Ben Ali in 1987. Ben Ali remained in office until 2011, declaring a state of emergency and fleeing the country. As a result, a "national unity government" was formed and elections for a new Constituent Assembly were held at the end of the year. Moncef Marzouki was elected as interim president. However, due to political crises that stalled transition, parliamentary and presidential elections were eventually held at the end of 2014 that gave rise to Beji Caid Essebsi as the first president under the country's new constitution. Tunisia continues to seek balance in political cohesion under economic and social pressures.

1.2 Geography

Table 5. Geography of Tunisia

Location	Northern Africa, bordering the Mediterranean Sea, b/w Algeria and Libya		
Natural Resources	Petroleum, phosphates, iron ore, lead, zinc, salt		
Geography	Area	Total	163,610 km^2
		Land	155,360 km^2
		Water	8,250 km^2
	Land	Total	1,495 km
		Border Countries	Algeria 1,034 km, Libya 461 km
	Coastline		1,148 km
Climate	North: Temperate (mild, rainy winters and hot, dry summers) South: Desert		

1.3 Demographics

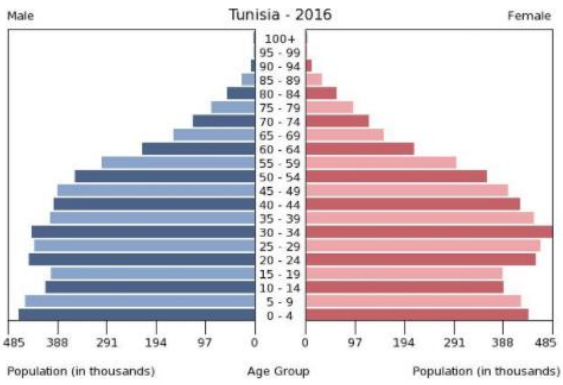
The Tunisian Government made attempts in the 1960s to decrease population growth and gender inequality in order to improve socio-economic development. A national family planning program, which was the first in Africa, was created. By raising the legal age of marriage, Tunisia rapidly reduced its total fertility rate from about 7 children per woman in 1960 to 2 today. According to the CIA, Tunisia has a population of 11,403,800 as of 2017.

Arabic is the official language of Tunisia and Tunisian Arabic, also known as Tounsi, is the national vernacular used by the public. There is also a small minority of speakers of Berber languages known as Jebbali or Shelha. French also has a big influence on Tunisian society despite having no official status. French is widely used in education, the press, and business. In 2010, there were 6,639,000 French speakers in Tunisia, which represents about 64% of the population. While Italian is also understood and spoken by a small part of the Tunisian population, the majority of shop signs, menus, and road signs are generally written in both Arabic and French.

About 98% of Tunisia's population are Muslims, while 2% follow Christianity, Judaism, or other religions. The constitution declares Islam as the official state religion and requires the President to be Muslim. Aside from the president, Tunisians enjoy a significant degree of religious freedom as well as the freedom of thoughts, beliefs, and to practice one's religion.

While the total adult literacy rate in 2008 was 78%, the rate goes up to 97.3% when accounting for only the people between the ages of 15 and 24 years old. Education is given high priority and accounts for 6% of the country's GNP. Since 1991, children between the ages of 6 and 16 are taught to read and write in standard Arabic. French and English are taught to children at the ages of 7 and 8, respectively.

Table 6. Demographics of Tunisia

Age Structure	Population Pyramid
0-14 year: 25.15% 15-24 years: 13.99% 25-54 years: 43.38% 55-64 years: 9.54% 65 years and over: 7.95%	

1.4 Economy

Tunisia has continuously strived to recover and stabilize its economy ever since the Arab Spring Revolution of 2011. High unemployment numbers, particularly among university graduates and women, was a key factor in the uprisings that led to the overthrow of the Ben Ali regime. Tunisia has focused strategically on bolstering exports, foreign investments, and tourism in the past, which have all become central to the country's economy. Key exports now include textiles and apparel, food products, petroleum products, chemicals, and phosphates, with about 75% of exports bound for Tunisia's main economic partner—the European Union. While the diverse, market-oriented economy has long been considered a big success in Africa and the Middle East, the country continues to face a variety of challenges.

Tunisia's Government is constantly under pressure to improve the life standards in the country as well as to mitigate socio-economic challenges; particularly high levels of unemployment and poverty, both of which have persisted since the revolution in 2011. Constant terrorist attacks against the tourism sector and worker strikes in the phosphate sector (which combined account for nearly 15% of the GDP) slowed growth to less than 1% of the GDP in 2015 and 1.5% in 2016. In recent years however, ecotourism, medical tourism, and spas have emerged in Tunisia's tourism market.

Tunisia has a history of labor emigration since the 1960s. Workers migrated to European countries to escape poor economic conditions and to fill Europe's need for low-skilled labor in construction and manufacturing. The Tunisian Government signed bilateral labor agreements with France, Germany, Belgium, Hungary, and the Netherlands, with the expectation that Tunisian workers would eventually return home. Tunisia also continues to look for increased foreign investment and works with labor unions in order to promote jobs.

1.5 Communications

Table 7. Communications of Tunisia

Telephones (fixed lines)	Telephones (mobile cellular)	Internet users
Total subscriptions:	*Total subscriptions:*	*Total number:*
974,975	14,282,078	5,665,242
No. of Subscriptions per 100:	*No. of Subscriptions per 100:*	*Percent of Population:*
9	128	50.9%

Table 7 indicates the number of telephone subscriptions collectively as well as the number of subscriptions per 100 inhabitants in Tunisia. The table also provides the number of Internet users actively using the Internet, accounting for approximately 51% of the population.

1.6 Government & Administration

Table 8. Government Profile of Tunisia		
Long Name **Short Name**	Republic of Tunisia Tunisia	
Government Type	Parliamentary Republic	
Independence	March 20, 1956 (from France)	
Legal System	Combined legal system based on French civil code and Islamic law	
Administrative Divisions	24 governorates: Beja (Bajah), Ben Arous (Bin 'Arus), Bizerte (Banzart), Gabes Qabis), Gafsa (Qafsah), Jendouba (Jundubah), Kairouan (Al Qayrawan), Kasserine (Al Qasrayn), Kebili (Qibili), Kef (Al Kaf), L'Ariana (Aryanah), Mahdia (Al Mahdiyah), Manouba (Manubah), Medenine (Madanin), Monastir (Al Munastir), Nabeul (Nabul), Sfax (Safaqis), Sidi Bouzid (Sidi Bu Zayd), Siliana (Silyanah), Sousse (Susah), Tataouine (Tatawin), Tozeur (Tawzar), Tunis, Zaghouan (Zaghwan)	

1.7 International Relationship

Tunisia has sought to maintain good relations with its neighbors despite occasionally strained relations. Tunisia has supported the development of the Arab Maghreb Union, which includes Algeria, Morocco, Mauritania, Libya, and Tunisia. However, progress on Maghreb integration remains stymied as a result of bilateral tensions between some member countries.

1.7.1 Foreign Relations

The following table provides a list of countries that have international relations with Tunisia:

Table 9. International Relationship between Africa and Tunisia	
Country	**Relations**
Algeria	Collaborated in construction of Trans-Mediterranean pipeline Jointly formed petroleum company (Numhyd) ; jointly owned (50% each)
Libya	Capricious relationship (1974 union formed, 1976 broken, 1977 restored, 1980 disintegrated, 1987 re-established) Slowly becoming major trading partner Currently undergoing nautical disagreement
Morocco	Increasing trade Direct nautical shipping began in 2008 Joint stock exchanges involving a stock market launch (IPO)
Comoros	Both countries have established diplomatic relations
Namibia	Both countries established diplomatic relations in 1990

Table 10. International Relationship between Middle East and Tunisia	
Country	**Relations**
Egypt	Tunisian-Egyptian relations were very good, especially after the 2011 elections in Tunisia
Iran	In May, 2005, Tunisia signed with Iran an agreement for cooperation in air, sea, and road transportation
Lebanon	Tunisia and Lebanon share historical and civilizational ties. Both countries want to support the process for the Euro-Mediterranean Partnership
Qatar	Qatar is among the largest Arab investors in Tunisia. Relations between the two improved immensely between 2011 and 2013
Saudi Arabia	In July 2010, a Tunisian-Saudi non-double taxation agreement was signed in Tunis
Syria	The two countries share experience and information on such issues as housing, shipping, and tourism
Turkey	Turkey has an embassy in Tunis. Both countries are full members of the Union for the Mediterranean

Table 11. International Relationship between America and Tunisia	
Country	**Relations**
Canada	Both countries represent each other through its respective embassies Both countries are full members of the Francophonie
United States	Very good relations, which date back more than 200 years The United States has maintained official representation in Tunis almost continuously since 1795, and the American Friendship Treaty with Tunisia was signed in 1799
Belize	Both countries have passed a number of bilateral agreements

Table 12. International Relationship between Asia and Tunisia	
Country	**Relations**
South Korea	Both countries established diplomacy March, 1969 Both countries are U.S. allies under the Major non-NATO ally agreement
Japan	Tunisia and Japan have a visa agreement Japan also supports Tunisia, with equipment and money donations
India	Diplomatic relations between India and Tunisia were established in 1958
Pakistan	People of Pakistan always supported Tunisia in their struggle of freedom

Table 13. International Relationship between Europe and Tunisia

Country	Relations
France	Tunisia and France retain a special relationship due to their history, geographic location, and economic relationship. In France there is a sizeable Tunisian diaspora, and the French language is widely used in Tunisia
Albania	Both countries have a number of bilateral agreements
Armenia	Both countries established diplomatic relations on 15 July 2002
Bulgaria	Both countries are full members of the Union for the Mediterranean
Croatia	Both countries represent each other through its respective embassies Both countries are full members of the Union for the Mediterranean
Cyprus	Both countries represent each other through its respective embassies Both countries are full members of the Union for the Mediterranean
Denmark	Both countries represent each other through its respective embassies Both countries are full members of the Union for the Mediterranean
Finland	Diplomatic relations between them were established on July 17, 1959
Greece	Both countries represent each other through its respective embassies
Italy	Both countries established diplomatic relations in 1957
Malta	Both countries established diplomacy after Malta's independence Both countries represent each other through its respective embassies
Romania	Both countries represent each other through its respective embassies
Russia	Both countries represent each other through its respective embassies
Serbia	Important trading partners. Tunisia is a hugely popular tourist destination for Serbians.

1.7.2 Relationship with Korea

The international ties between South Korea and Tunisia have remained quite strong with several collaboration projects, training workshops, and co-operation agreements between the government ministries as well as governmental organizations such as the Korea International Cooperation Agency (KOICA).

Since November 2010, the South Korean Ministry of Environment has held an annual "Korea-Africa Environmental Cooperation Forum," where 10 African countries gathered to discuss waste management and resource allocation. Tunisia was among the 10 countries that participated in the signing of an Environmental Cooperation MOU, and have continuously collaborated on enhancing the waste and sewage assistance programs. The bilateral cooperation between Tunisia and South Korea were further reinforced in 2016, where two Memorandum of Understandings were signed.

The first cooperation agreement, signed on April 15th, tackled energy efficiency with a pilot project implemented in the El Mourouj District. The investment for this project was 2 million US Dollars (about 4 million Tunisian Dinars).

The second MOU was signed in the same year on May 26th between the Ministry of the Interior of the Republic of Korea and the Ministry for Public Function, Good Governance, and Anti-Corruption of Tunisia for cooperation efforts associated with Tunisia's e-Government. The South Korean Government has provided 65 million US Dollars from 1987 to 2015, and has collaborated with Samsung SDS in establishing Tunisia Online e-Procurement System (TUNEPS), allowing the country to be recognized in the Open Government Partnership Awards. Continuous efforts between Korea and Tunisia have been expanding providing a platform for Tunisia to adopt and benchmark Korea's e-government and information systems.

In addition to MOUs, collaborative projects between Tunisia and governmental organizations in South Korea have been showing active support. The Korea International Cooperation Agency (KOICA), established in 1991 by the South Korean Ministry of Foreign Affairs and Trade to support developing countries by effectively implementing Korea's grant aid programs, has carried out several projects with Tunisia in various sectors. For example, KOICA and the United Nations Development Programme (UNDP) have worked together to raise awareness in improving democratization and to fight against corruption targeting Tunisian expatriates. KOICA has also established an office in Tunisia, sending eleven volunteers from Korea to support the Tunisian Government for a 2-year period. KOICA is committed to enhancing the quality of life in Tunisia and actively participating in global efforts to sustain the partnership between both countries.

2. Overview of Host City: La Marsa

Figure 5. Map of La Marsa

Table 14. Profile of La Marsa

Location	18 km north-east of Tunis
Population	92,987 (2014)
Infrastructure (Transport)	RN9 (Tunis-La Marsa) RN10 (Tunis-Carthage) RR 33 (Rades-Marsa) TGM (Tunis-Goulette-Marsa) Drinking water: 98.9% Sewage network: 91.7%
Landscape	Beaches, forests, land

(La Marsa PCGD, 2015; INS National Institute of Statistics, 2014)

2.1 Geography

The city of La Marsa enjoys a rich and diverse environment. An area that is often the vacation destination for wealthy Tunisians, tourists from Europe have also been known to travel to La Marsa due to its attractive physical elements like the white, sandy beaches and the natural blue body of water. Because of its geographic location on the coast of the Gulf of Tunis and the Mediterranean Sea, the average humidity in La Marsa tends to stay between 70-80%. La Marsa receives the most rainfall during the months between October and February, with October usually being the wettest month.

2.2 Infrastructure

The infrastructures of the municipality of La Marsa are as follows:

- Road Transport: The municipality of La Marsa constructed 40.6 km of road network in 2011, with 38km of classified roads and 2.35km of unclassified roads and tracks. The following are the roads that connect from La Marsa to various cities in Tunisia:
    - RN 9 (Tunis—La Marsa)
    - RN 10 (Tunis—Carthage)
    - RR 33 (Rades—La Marsa)

- Metro Transport: The TGM Train (Tunis—Goulette—Marsa) connects from coast to coast, passing through Sidi Bou Said, Carthage, La Goulette, and Tunis. It has a distance of about 18km with an average speed of 26km/h.

- Drinking water consumption: The drinking water service is 98.9% and 82.6m^3 is utilized for industrial use and 5,117.9m^3 for domestic use.

- Sewage network: There are 15 pumping stations and 1 wastewater treatment plant.

- Electricity: The circuit of electricity connects from the Rades Power Plant to the HT/MT transformer station, providing 90kV of electricity.

2.3 Demographics

The following table shows the demographic values for La Marsa, exhibiting the entire population number, population of males and females, number of households, and the number of dwellings in 10 districts of La Marsa.

Table 15. Demographics of La Marsa

	Population Number	Population of Males	Population of Females	Number of Households	Number of Dwellings
La Marsa Plage	6,498	3,255	3,243	1,736	2,832
La Marsa Medina	14,604	7,211	7,393	4,227	4,831
Marsa Hadayek	6,551	3,284	3,267	2,043	2,624
La Marsa Erriadh	6,047	2,997	3,050	1,647	2,000
Er-Rmila	14,210	7,097	7,113	3,889	4,858
El Montazeh	6,915	3,374	3,541	2,302	2,436
Gammarth	9,079	4,669	4,410	2,231	3,147
Gammarth Super.	4,299	2,096	2,203	1,333	1,594
Sidi Daoued	6,207	3,100	3,107	1,947	2,175
El Barh El Azrak	18,577	9,557	9,020	4,707	6,690
La Marsa	**92,987**	**46,640**	**46,347**	**26,062**	**33,187**

III. Smart City Development Analysis

The infusion of IoT-based technology in industries has provided the ability to collect a variety of data that had been previously unavailable and is bringing forth new opportunities to maximize operational efficiency. Achieving operational efficiency was first studied scientifically during the Second World War and has become the focus of countless academics spanning the fields of mathematics, computer science, supply chain management and business analytics. Some of the most critical problems tackled in this field include route optimization, task scheduling and staff management amongst many more.

Despite the high computational complexity of automation of these decision making processes, a number of mature and generally applicable methods have emerged due to the pervasiveness of these problems. Some algorithms search for exact solutions, notably mixed integer programming and boolean satisfiability. However, these approaches suffer an exponential increase in execution time as a function of the input size, making their use impractical for many real world applications. In order to solve the large scale problems arising from real world applications, approximate methods based on heuristic approaches are often employed. There is a rich variety of approaches that fall into this category, but the key feature they all share is the compromise of the global optimality of the solution found in order to increase computation speed. When well designed, these approaches allow very good, but non-optimal, solutions to be found in a fraction of the time required to find globally optimal solutions.

In addition to the integration between waste management and IoT, another key player that has been receiving growing attention is Information and Communication Technology (ICT). The Tunisian Government has been continuously committed to enhancing IT and ICT as a strategic approach not just for economic growth and employment creation, but also to further connect with private sectors and other stakeholders. Two policies were enacted in 2000 and 2001, the Communication Law and E-commerce Law respectively, accounting for the growth and expansion of the Tunisian ICT sector.

The information and communication technology (ICT) revolution is continuously showing an increasing trend and has shown to be the principal driving force behind the knowledge economy. Many developing countries have shown a proactive approach in establishing and implementing their ICT industries and the early adopters of such integrated services have exhibited numerous benefits such as increased economic growth, employment generation, and poverty reduction. Strategic efforts incorporating ICT in the developmental phases allow for actions and opportunities to be orchestrated with comprehensive approaches from both the public and private sectors. Bolstering the ICT sector and maximizing its efficacy to enhance competitiveness in local, regional, and global markets is a key objective for ICT development strategies.

Novel applications and activities have emerged as a result of new telecommunications platforms as well as the expansion of the World Wide Web. Continuous evidence demonstrates a positive impact on productivity growth, significant cost reduction in business operations, and increased access at the consumer level. Consequently, new and advanced software, IT services, media services, and e-commerce segments have been developed. Three critical factors have played a key role in giving rise to the universal IT revolution:

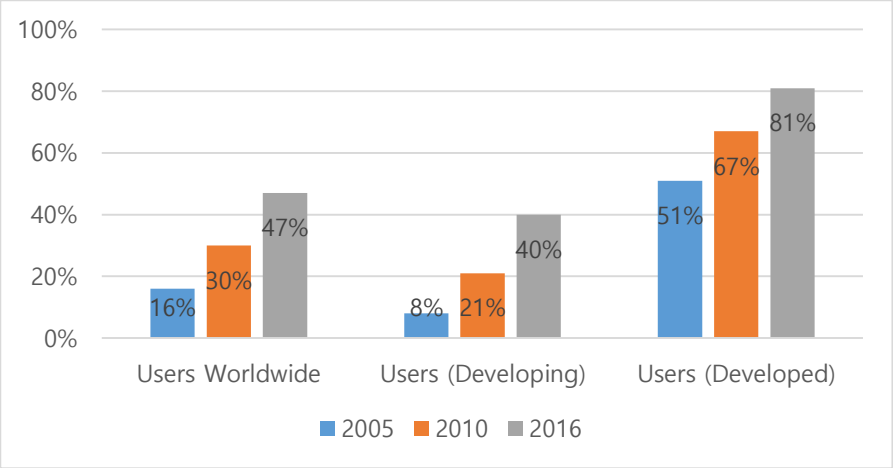
- **Rapid expansion of the Internet and e-commerce.** Currently, there are close to 3.9 billion Internet users globally, up from 3.2 billion in 2015 and 400 million in 2000. Among the 3.9 billion users worldwide, 2 billion have been reported from developing countries and 89 million in the least developed (LDC) regions. As a result of faster online and broadband services alongside the rapid spread of mobile applications and services, more than 50% of the world's population has been online.
- **Significant increases in computing power, connectivity and software technologies.** Computational power has been shown to rise exponentially, rather than linearly, and the rate of change is expected to follow a corresponding trend. As a result, the next 10 years will induce far more technological advancements than the past 10 years. The number of transistors per microprocessor has more than doubled every two years since the 1960s, giving rise to substantial increases in processing power. The capacity of computer hard disk drives is amplifying at twice the rate every nine months. Furthermore, the data and telecommunication speeds have been escalating at a significantly rapid rate, resulting in further accelerated connectivity.
- **Steep cost reductions.** The costs of hardware and communication have declined noticeably with the increase in new technological systems and advancements. Newly developed hardware tools have adapted to the market trends, which have prompted substantial reductions in hardware costs.

Table 16. Internet Users Worldwide

	2005	2010	2016
World Population	6.5 billion	6.9 billion	7.3 billion
Users Worldwide	16%	30%	47%
Users (Developing)	8%	21%	40%
Users (Developed)	51%	67%	81%

Table 16 exhibits the number of worldwide users of the Internet from 2005 to 2016. As shown in Figure 6 below, which is a bar graph of the data provided in Table 16, the number of global Internet users have continuously escalated. Numerous studies and reports indicate that this trend will continue to show an upward slope—further demonstrating an increase in IoT and ICT-related technologies and infrastructure.

Figure 6. Internet Users Worldwide



ITU Statistics (2005, 2010, 2016)

1. Smart City Development

1.1 Tunisia Smart City Roadmap

The Tunisian Government has announced ICT as a national priority, subsequently implementing the "Digital Tunisia 2020" National Strategic Plan. The primary focus is to increase the competitiveness of the Tunisian economy through the enhancement of the administration's performance, openness, transparency, and efficiency, as well as facilitation of export formalities (including customs, taxation, and visa). Digital Tunisia 2020 (TD2020) National Strategic Plan (PNS) was structured by the Ministry of Communication Technologies (MTCEN) through collaborative partnerships with major Tunisian ICT stakeholders (public authorities, private sector, and civil society). The general objective is to develop Tunisia into an international digital reference, generate employment opportunities, expand the use of digital technology in all sectors, and ultimately transform the ICT sector as the predominant source of tax revenue for Tunisia.

Figure 7. Tunisia Smart City Roadmap

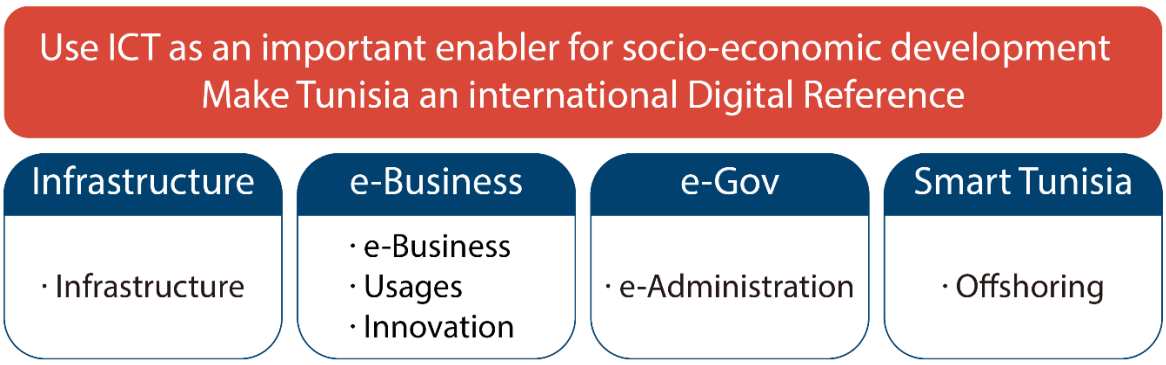
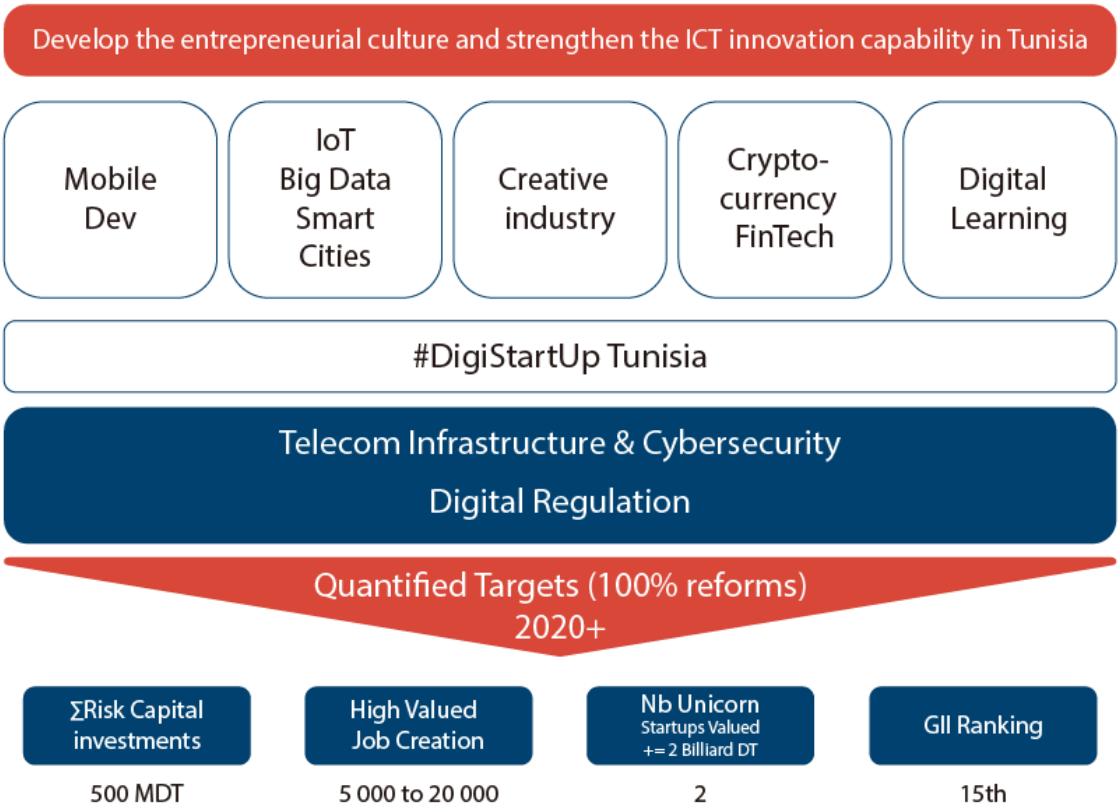


Figure 8. Digital Tunisia 2020 – Vision and Program Pillars

Pillar 1: Infrastructure - aimed at generalizing access to broadband internet and knowledge and developing ultra-high-speed internet.
Pillar 2: e-Gov - aimed at transforming administrative services through the use and adoption of digital technology to enhance the efficiency and transparency of operations for citizens and the business community.
Pillar 3: e-Business - aimed at transforming businesses through digital technology to enhance competitiveness, productivity and integration and making innovation the driving force of the digital industry by developing creative and functional solutions that support all sectors of activity and entrepreneurship.
Pillar 4: Smart Tunisia - geared towards placing Tunisia among the top three countries in Offshoring and making it the Leader in IT Offshoring in the Africa-Middle East region.

1.2 Tunisia Smart City Strategy

Figure 9. Tunisia Smart City Strategy



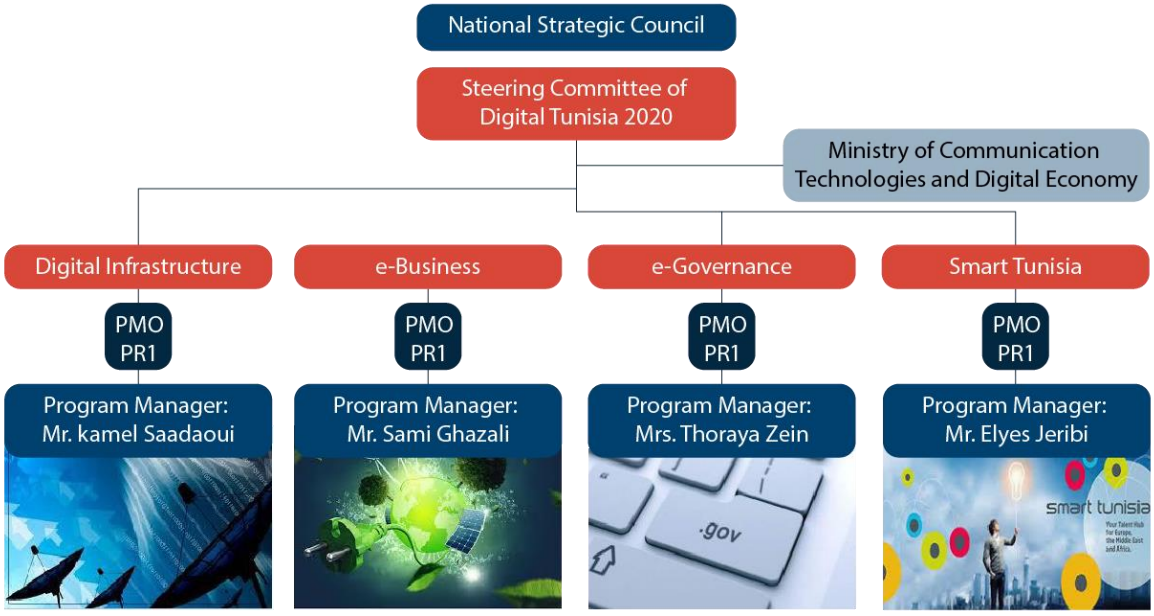
Under the main objective of TD2020, the strategic direction focuses on developing the entrepreneurial culture and reinforcing the ICT innovation capabilities and talents. Developing more startups and regulations in the field of mobile cell phones, IoT-integrated smart cities, creative industries, financial technologies, and digital learning are some of the approaches established by Tunisia to achieve the performance targets by 2020. Among the targets mentioned, TD2020's strategy for increasing ICT innovation is increasing the Global Innovation Index (GII) ranking to 15th place by 2020. According to the most recent reports published by the GII, Tunisia ranks 74th among 127 countries. The following table provides a list of ICT, general infrastructure, and ecological sustainability indicators and the corresponding index values for Tunisia in 2017.

Table 17. Global Innovation Index (GII)		
Global Innovation Index (2017)	**Score**	**Rank**
Out of 127	**32.3**	**74**

Information and Communication Technologies (ICT)	**58.4**	**64**
ICT access	52.9	79
ICT use	39.5	70
Government's online service	71.7	40
E-participation	69.5	43
General Infrastructure	**27.3**	**101**
Electricity output, kWh/cap	1,729.5	81
Logistics performance	20.1	104
Gross capital formation, % GDP	21.7	67
Ecological sustainability	**49.8**	**48**
GDP/unit of energy use	11.2	32
Environmental performance	77.3	52
ISO 14001 environmental certifications/bn PPP$ GDP	1.8	50

1.3 Smart City Promotion Organization

Figure 10. Smart City Promotion Organization



Tunisia's Ministry of Communication Technologies (MTCEN) orchestrates the Digital Tunisia 2020 national plan and oversees the digital infrastructure, e-Business, e-Governance, and Smart Tunisia projects. As shown from Figure 10, there are assigned program managers for each program, and the overseeing manager for smart city related projects are coordinated by Mr. Elyes Jeribi. There are several projects currently undergoing implementation with growing support for smart city infrastructures. The following table shows a list of three smart city projects in Tunisia:

1.4 Smart City Initiatives

Table 18. Smart City Initiatives

Project	Action Plan
Smart Rades City	- Focusing on 6 Components: Smart Governance, Smart Citizen, Smart Environment, Smart Living, Smart Mobility, Smart Economy
Kairouan Smart City	- Participating in pilot project "Key Performance Indicators for Smart Sustainable Cities" launched by ITU, which will participate in the Global Smart City Index 2018
El-Ghazala Smart City	- Implementing smart city infrastructure (ie. Smart metering, smart EV charger, smart bus shelter, IoT-based office/school, smart hospital, smart parking, digital exhibition and culture center)

Through ongoing efforts of establishing ICT as a national plan for economic growth and stability, several projects under the IoT and ICT umbrella have been actively pursued. Among such endeavors are smart city initiatives that are receiving widespread support from public and private sector stakeholders. Table 18 depicts the smart city initiatives throughout Tunisia and the infrastructure transformations.

Smart Rades City plans to target 6 areas including smart governance, smart citizen, smart environment, smart living, smart mobility, and smart economy. Kairouan Smart City has been involved in a pilot project coordinated by the ITU referred to as "Key Performance Indicators for Smart Sustainable Cities." The primary objective for this project is for Tunisia to participate as one of the countries being studied in the 2018 Global Smart City Index. Subsequently, the El-Ghazala Smart City initiative plans to enhance the city's current infrastructure to ones with IoT integration such as smart metering, smart EV charger, smart bus stops, smart office/schools, smart hospitals, smart parking, as well as digitized exhibition and culture centers.

2. ICT Development

The ICT Development Index (IDI) is a composite index that evaluates 11 key indicators and combines them into one benchmark measure. The Information and Communication Technology (ICT) is monitored and compared among several hundred countries over time. Since 2009, the ICT Development Index has been orchestrated by the International Telecommunication Union (ITU), which is a UN specialized agency for ICT evaluations, and is the official source for international ICT statistical data.

The primary objectives of the IDI are to evaluate the following:

1. Level and evolution of ICT developments over time
2. Progress in ICT development in both developed and developing countries
3. Level of ICT development differences between countries—digital divide
4. Development potential of ICTs and the extent to which countries can utilize them to promote growth and development

As previously explained, the IDI combines 11 indicators and is divided into three sub-indices (access, use, and skills).

3.3.1 **Access sub-index**: captures ICT readiness; includes five infrastructure and access indicators

3.3.2 **Use sub-index**: captures ICT intensity; includes three intensity and usage indicators

3.3.3 **Skills sub-index**: seeks to capture capabilities or skills essential for ICTs

2.1 ICT Development Index (IDI)

According to the 2016 and 2017 IDI, Tunisia ranked 95th and decreased to 99th, respectively. In comparison to regional Arab states, Tunisia placed among the top ten countries ranking in 9th place both in 2016 and 2017.

Table 19. ICT Development Index (IDI), 2017

	2017	2016
IDI Value	4.82	4.70
IDI Rank, Global	99	95
IDI Rank, Regional	9	9

Table 20. Key Indicators of IDI			
	Tunisia	**Regional**	**Developing**
IDI ACCESS SUB-INDEX	5.11	5.51	4.80
Fixed-telephone subscriptions / 100 inhabitants	8.59	7.70	8.54
Mobile-cellular telephone subscriptions / 100 inhabitants	125.82	107.10	96.25
International internet bandwidth / Internet user (Bit/s)	31166.81	39000	53000
Percentage of households with computer	37.00	43.30	34.35
Percentage of households with Internet access	33.00	45.30	40.43
IDI USE SUB-INDEX	4.11	3.96	3.32
Percentage of individuals using the Internet	50.88	41.80	38.98
Fixed (wired)-broadband subscriptions / 100 inhabitants	5.65	4.70	8.71
Active mobile-broadband subscriptions / 100 inhabitants	62.97	45.20	43.58
IDI SKILLS SUB-INDEX	5.67	5.26	5.05
Mean years of schooling	7.10	7.23	7.40
Secondary gross enrollment ratio	88.20	79.14	74.88
Tertiary gross enrollment ratio	34.61	31.54	28.25

** Regional: Arab States; Developing: Developing countries*

As shown in Table 20, Tunisia encompasses a higher IDI in the access sub-index, which evaluates the available ICT infrastructure and individuals' access to basic ICT technologies. Tunisia showed an overall 5.11 IDI value, which was higher than that of Developing countries (4.80) and slightly lower than that of other Arab states (5.51). For the IDI use sub-index, which captures the intensity and usage of ICT, Tunisia was shown to have an IDI value of 4.11, which was higher than both the Arab states' and Developing countries' averages. Moreover, the IDI skills sub-index, capturing data on mean years of schooling and gross secondary and tertiary enrollment ratios, indicated that Tunisia had a higher IDI (5.67) compared to Arab states as well as those of developing countries.

2.2 Telecommunications

Table 21. Telecommunication Services per 100 Inhabitants		
2017	**Telephone lines**	**Mobile cellular**
Tunisia	8.59	125.82
Arab States	7.70	107.10
Developing	8.54	96.25
World	13.57	101.83

According to Table 21, which shows statistical values of the Telecommunication services, Tunisia had 8.59 telephone lines and 125.82 mobile cellular connections per 100 inhabitants in 2017, demonstrating a higher average than other Arab countries as well as other developing countries collectively. The three primary operators of Tunisia's Telecommunications sector are Ooredoo (Orascom Telecom Tunisia), Tunisie Telecom, and Orange Tunisie.

Ooredoo is Tunisia's largest telecommunications company, accounting for 40% of the market. Tunisie Telecom is a big competitor dominating 32.2% of the industry, and Orange Tunisie is the third largest accounting for 26%.

2.3 Internet Service Providers

Table 22. Internet Service per 100 Inhabitants

2017	Fixed Broadband	Mobile Broadband	Internet users (%)
Tunisia	5.65	62.97	50.88
Arab States	4.70	45.20	41.80
Developing	8.71	43.58	38.98
World	12.39	52.23	45.91

As demonstrated in Table 22, evaluating Internet services among 100 inhabitants, 5.65 use fixed broadband Internet, 62.97 use mobile broadband Internet, and roughly 51% of the population are Internet users. In comparison to other developing countries, Tunisia shows a higher ratio of Internet services and usage exhibiting great potential for further penetration of information and communication infrastructure and technologies.

3. E-Government Development

The United Nations Department of Economic and Social Affairs has published five surveys related to e-Government development since 2003. The EGDI measures scope and quality of online services (examining the national website and websites of each ministries), telecommunication infrastructure (indicating the country's level of economic and ICT development), and human capital (measuring the aggregate level of education)

3.1 e-Government Development Index (EGDI)

According to the UN e-Government survey report published in 2016, Tunisia ranked 72 among 193 UN member states with a high EGDI level.

Table 23. UN e-Government Development Index (EGDI), 2016

Rank	Country	EGDI Level	EGDI	Online Service	Telecomm. Infrastructure	Human Capital
72	Tunisia	High	0.5682	0.7174	0.3476	0.6397

Index: Very High (More than 0.75), High (0.50-0.75), Middle (0.25-0.50), Low (Less than 0.25)

3.2 e-Government Development Index, Africa

In comparison to other sub-regions in Africa, Tunisia ranked 72nd globally and 2nd among other African countries as shown in Table 24.

Table 24. Sub-regional EGDI Comparison among African Countries

Rank	Country	EGDI Level	EGDI	Online Service	Telecomm. Infrastruct.	Human Capital
58	Mauritius	High	0.6231	0.7029	0.4596	0.7067
72	Tunisia	High	0.5682	0.7174	0.3476	0.6397
76	South Africa	High	0.5546	0.5580	0.3807	0.7253
85	Morocco	High	0.5186	0.7391	0.3429	0.4737
86	Seychelles	High	0.5181	0.4058	0.4624	0.6861
103	Cape Verde	Medium	0.4742	0.4565	0.3629	0.6031
108	Egypt	Medium	0.4594	0.4710	0.3025	0.6048
113	Botswana	Medium	0.4531	0.2826	0.4215	0.6553
118	Libyan Arab Jamahiriya	Medium	0.4322	0.1087	0.4291	0.7588
119	Kenya	Medium	0.4186	0.5580	0.1808	0.5169

3.3 Telecommunication Infrastructure Index (TII)

The following table shows the Telecommunication Infrastructure Index of Tunisia and its components.

Table 25. Telecommunication Infrastructure Index (TII) Components

Country	TII	Individuals Using Internet	Subscriptions per 100 Inhabitants			
			Fixed Telephone	Mobile Cell. Phone	Fixed Broadband	Wireless Broadband
Tunisia	0.3476	46.16%	8.54	128.49	4.44	26.10

3.4 e-Participation Index

The following lists the top 50 performers in e-participation from 2014-2016. These countries have utilized online public consultations (e-consultation) on a particular policy or service.

Table 26. e-Participation Index, Top 50 Countries

Rank	Country	Rank	Country	Rank	Country
1	United Kingdom	17	Lithuania	37	Brazil
2	Japan	17	Montenegro	37	Slovenia
2	Australia	17	Serbia	39	Uruguay
4	Republic of Korea	22	Estonia	39	Mongolia
5	Netherlands	22	China	39	Ireland
5	New Zealand	22	Denmark	39	Saudi Arabia
7	Spain	25	Malta	43	Tunisia
8	Singapore	25	Croatia	43	Luxemburg
8	Canada	27	Colombia	43	Vietnam
8	Italy	27	Germany	43	Bulgaria
8	Finland	27	Norway	47	Malaysia
12	France	27	India	47	Uzbekistan
12	USA	27	Sweden	47	Azerbaijan
14	Austria	32	Chile	50	Portugal
14	Mexico	32	UAE	50	Sri Lanka
14	Poland	32	Bahrain	50	Rep. of Moldova
17	Israel	32	Ukraine	50	Mauritius
17	Morocco	34	Russian Federation	50	Iceland

4. Implication of Smart City Development

4.1 Smart City

Through the Digital Tunisia 2020 plan, Tunisia hopes to utilize ICT as an important enabler for socio-economic development to further enhance the competitiveness of Tunisia's economy through various sectors. Among such efforts is Smart Tunisia where an emphasis is placed on Offshoring, in the hopes of making Tunisia one of the top three countries in Offshoring and the global leader in IT Offshoring among the African and Middle Eastern countries.

Several smart city projects have been developed receiving widespread popularity and support. Hence, Tunisia's ongoing smart city projects may provide a gateway for La Marsa's waste management pilot project further expanding the IoT market and ICT infrastructures. Collaborative efforts with other similar projects seems highly advantageous economically, environmentally, and socially. One drawback with the current system, despite being one of the top countries in the Arab and African region with strong telecommunication networks, is a slow rate of infrastructure implementation and continuous maintenance. By collaborating with the present systems and brainstorming ideas for further support and reinforcement, such shortcomings may be tackled together resulting in stronger, more feasible, yet sustainable improvement strategies.

4.2 ICT Infrastructure

According to the most recent reports of the ICT Development Index, Tunisia ranked 95th in 2016 and decreased by 4 rankings to 99th in 2017. Among the Arab state regions, the regional ranking did not show any movement in ranking positions; stayed at 9th place in both years.

In comparison to other neighboring countries in the Arab region as well as in the Developing countries, the international internet bandwidth per Internet user in Tunisia is noticeably lower (Tunisia: 31,000, Arab: 39,000, Developing: 53,000). This indicates that Tunisia uses a lower speed of Internet compared to the developing countries around the world.

The number of Internet users, however, show a drastic difference in values compared to the percentage of individuals using the Internet in Arab states and developing countries. Tunisia reported an IDI value of approximately 51%, whereas regional states reported 42% and 39% for developing countries. More than half the population in Tunisia is shown to utilize the Internet, accounting for an increased number of active mobile broadband subscriptions.

4.3 Telecommunication

The number of mobile cellular subscriptions per 100 inhabitants were significantly higher than the number of landline subscriptions, demonstrating that a larger majority of Tunisians use their mobile phones for communication compared to fixed telephone lines. In comparison with other Arab regions, the average number of mobile cell phone subscriptions were higher in Tunisia than that of other regional countries (Tunisia: 125.82, Arab: 107.10).

These values strongly indicate that Tunisians are showing a growing interest in new technologies, and now is the time for the adoption and implementation of smart infrastructures and systems. Moreover, due to the high number of Internet and mobile cell phone users, expanding services and systems that cater to these two arenas will continuously play a pivotal role moving forward. More individuals will utilize the Internet and sign up for mobile subscriptions, so integrating mobile applications and computerized services with smart technologies will not only allow La Marsa to be a technologically advanced country but also one that maneuvers and regulates efficiently and profitably.

4.4 e-Government

In accordance with the UN e-Government survey, Tunisia ranked 72 with a 'high' EGDI level (among very high, high, middle, and low standards) in 2017. Tunisia's ranking showed a substantial variation between 2010 and 2016 with the highest decline from 2010 to 2012 (66 to 103), followed by a 28 ranking increase to 75th place in 2014 and 3 ranking decrease in 2016. These trend analyses demonstrate that Tunisia's e-Government performance fell behind other similarly ranked countries in recent years.

Among African countries, Tunisia ranked 2nd after Mauritius with a slightly lower EGDI value (Tunisia: 0.5682, Mauritius: 0.6231). Despite the lower EGDI, however, Tunisia encompassed a higher indicator value in the online services component, and also reported in the top 50 performers in e-participation. Among other developed and developing countries among this list, Tunisia was the 43rd top performer in e-Participation and e-consultation, indicating potential for the e-Government sector.

IV. Current As-Is Analysis

1. Waste Status Analysis

At the national level, Tunisia has played a key role as an early adopter integrating IT systems into the country's infrastructure and a large allocation of resources and funding has been attributed to smart waste management. Due to the increase in trash along the roads, sidewalks, parks, and popular tourist locations, adverse impacts on health and the environment have also escalated. Such repercussions have stimulated public authorities to develop more stringent policies and laws regulating waste management.

1.1 National Waste Environment Analysis

In accordance with Law 96 – 41 (June 1996) on the regulation of waste management and disposal, the following definitions were established:

Table 27. Definitions of Waste Management Terminology

Waste	Any substance or thing that the holder discards or intends to dispose of, or that the holder has the obligation of discarding or disposing of under the law
Hazardous waste	Waste listed by the decree according to their constituents and the characteristics of the pollutants they contain
Producer	Any person whose activity produces waste and any person who carries out pre-treatment, mixing or other operations leading to a change in the nature of the waste or in its composition
Distributor	The importer or distributor of products and substances
Holder	Any person who holds waste in his possession
Management	All operations relating to the collection,, transport, treatment, recovery and disposal of waste including control of these operations and control of storage-disposal centers, landfills and units valuation
Disposal	All operations for the final disposal of waste
Valuation	All operations tending to recover materials and energy from waste and all

1.2 Municipal Waste Environment Analysis

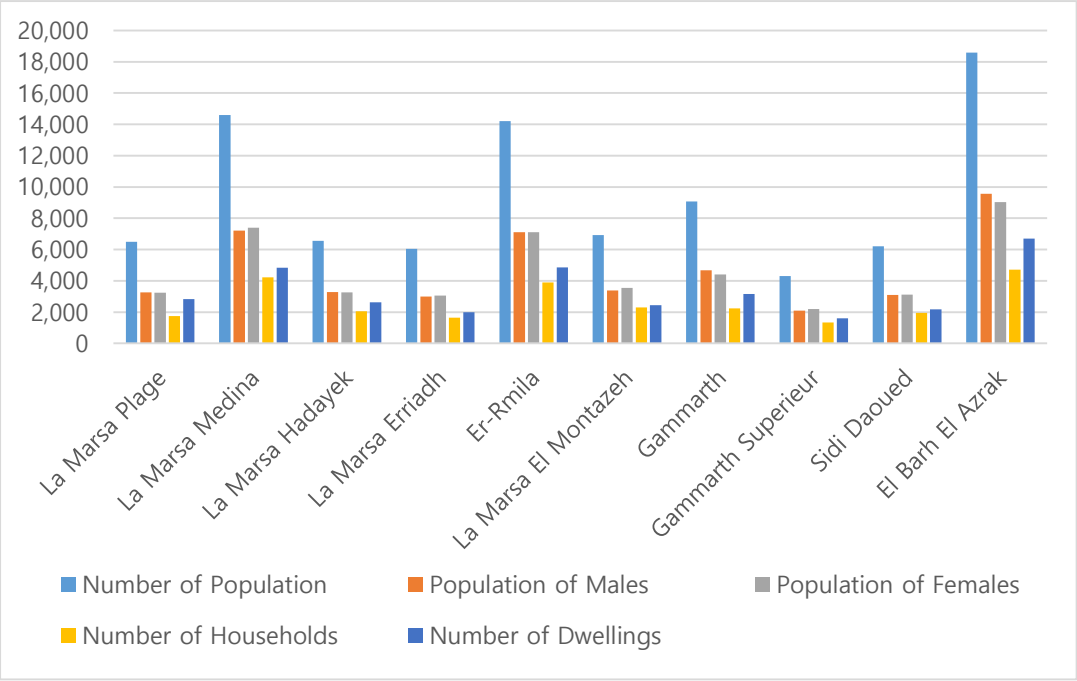
According to statistical reports conducted by the National Institute of Statistics in 2014, the municipality of La Marsa encompasses about 93,000 people and is classified into 10 districts: Marsa Beach, Marsa Medina, Marsa Hadayek, Marsa Erriadh, Er-Rmila, Marsa El Montazah, Gammarth, Gammarth Superior, Sidi Daoued, and Bhar Lazreg. The following table lists demographic information on the population, number of households, and dwellings of La Marsa:

Table 28. Demographic Data of La Marsa					
	Population Number	**Population of Males**	**Population of Females**	**Number of Households**	**Number of Dwellings**
La Marsa Plage	6,498	3,255	3,243	1,736	2,832
La Marsa Medina	14,604	7,211	7,393	4,227	4,831
Marsa Hadayek	6,551	3,284	3,267	2,043	2,624
La Marsa Erriadh	6,047	2,997	3,050	1,647	2,000
Er-Rmila	14,210	7,097	7,113	3,889	4,858
El Montazeh	6,915	3,374	3,541	2,302	2,436
Gammarth	9,079	4,669	4,410	2,231	3,147
Gammarth Super.	4,299	2,096	2,203	1,333	1,594
Sidi Daoued	6,207	3,100	3,107	1,947	2,175
El Barh El Azrak	18,577	9,557	9,020	4,707	6,690
La Marsa	**92,987**	**46,640**	**46,347**	**26,062**	**33,187**

(INS National Institute of Statistics, 2014)

The bar graph below (Figure 11) demonstrates a visual representation of the demographical data listed in the table above (Table 28).

Figure 11. Demographic Data of La Marsa



The municipality of La Marsa published a report in 2015 evaluating the composition and quantity of waste generated from the previous year (Table 29). The producers of waste were defined as citizens, industrialists, traders, animal breeders, hospital workers, administrators, and mechanics. The entire waste management supply chain included the production, collection, transport, and disposal of waste.

La Marsa is characterized by diverse economic activity, propagating a wide variety of waste in terms of quality and quantity. The total amount of waste generated per year was estimated at 37,000 tons where 35% was collected by the private sector. The table below shows demographic data as well as waste generation per year. The report documented the annual growth rate per population and the amount of daily and annual waste produced by each individual.

Table 29. Household and Other Solid Waste Assessment (2014-2019)

Year	Population		Waste Balance	
	Annual Growth Rate	Number	Kg/person/day	Tons/year
2014	1.16%	92,987	1.1	37,334
2015	1.16%	94,065	1.1	37,767
2017	1.16%	96,260	1.1	38,648
2019	1.16%	98,500	1.1	39,550

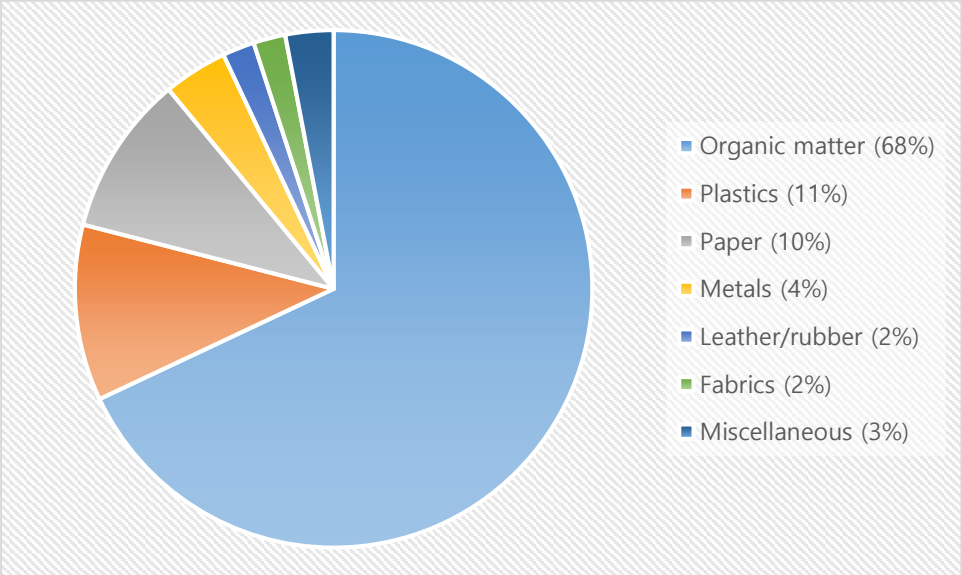
Similarly, the waste assessment investigated the composition of waste materials and the ratio of each type. The following table shows the quantity and percentage of household and similar solid waste materials discarded in 2013:

Table 30. Composition of Household and Other Solid Waste (2013)

Type of Waste Materials	Quantity (tons)	Ratio (%)
Organic matter	24,645	68%
Plastics	3,987	11%
Paper	3,624	10%
Metals	1,450	4%
Leather/rubber	725	2%
Fabrics	725	2%
Miscellaneous	--	3%

Among the distribution of household and similar wastes collected, the ratio of organic matter was the highest, representing roughly two-thirds of the entire waste composition. Plastics and paper showed similar percentages (11% and 10%, respectively). The quantity of organic materials accounted for more than 24,000 tons, which is more evident in the pie chart below:

Figure 12. Composition of Household Waste



In addition to the ratio allocation of wastes collected, the pie chart also exhibits a high proportion of recyclable waste potential. Almost 70% of the wastes comprised of organic matter, which is a type of material that may be composted or recycled back to the environment. A significant amount of recyclable waste is being discarded in La Marsa suggesting implications for government officials. Reducing such wastes may be one initiative for the municipality to consider, but increasing recycling efforts may provide substantial benefits for the economy and the environment.

The report also examined the daily average of waste generated per person in La Marsa and divided the data into three categories: urban, rural, total (national average). The following table lists the amount of waste produced by each resident per day.

Table 31. National Average of Household and Similar Waste Generation (kg/person/day)

Urban Area	0.60 to 0.80
Rural Area	0.15 to 0.20
National Average	0.60

In addition to waste data reported in the Community Waste Management Plan (PCGD) of La Marsa, supplementary details were provided by a local waste management company for detailed statistics on the current status of waste management. According to the company, 110 tons of waste are generated daily, with 750 waste bins being targeted for collection. The municipality also owns 24 collection vehicles (12 encompassing a 10-ton capacity, and 12 with a 1-ton capacity). The ratio of drivers to workers is 1:2 (30 drivers and 60 employees). Annual cost of fuel consumption, labor, and maintenance were estimated to be approximately 32,850, 65,700, and 14,400 TND, respectively.

2. Stakeholder Analysis

2.1 Waste Management Stakeholders

The stakeholder organization of La Marsa's waste management includes several public and private sector sectors whose tasks have been assigned by the government. The following are the stakeholders involved at the institutional level:

Figure 13. Waste Management Stakeholders

Planning	Ministry of the Environment
Implementation	National Agency for Waste Management (ANGed)
Regulation	Municipality regulates collection and transport of waste; ANGed regulates transfer and disposal
WM in Rural areas	Rural Council regulates waste management only in rural areas
WM Policies	ANPE, Ministry of Finance, Ministry of Public Health, Ministry of Industry and Technology, Ministry of Trade and Handicrafts
Private Operators	Collection, recovery, recycling, sweeping, transfer, landfill operation, and methane extraction

2.2 e-Government Stakeholders

The e-Government sector of Tunisia is government by the e-Government Unit and the Ministry of Information and Communication Technologies. There is also a national authority that protects personal data and computing centers (ie. CIMF, CIMSP).

Figure 14. e-Government Stakeholders

2.3 Telecommunication Networks

Tunisia has one of the most advanced telecommunication networks and broadband infrastructures in North Africa. With over 14.2 million cellular lines and a 134% penetration rate for fixed and mobile phones in 2016, Tunisia enjoys one of the highest mobile phone subscriber rates in Africa.

The phenomenal growth in Tunisia's mobile sector started in 2002 following the introduction of a second GSM network, operated initially by Egypt's Orascom under the name Tunisiana and now by Ooredoo, earlier known as Qatar Telecom. In 2010, Orange Group entered the market as the third network operator and launched the country's first 3G mobile network, followed by Tunicell in 2011 and Tunisiana in 2012.

In 2016, the market was controlled by three major telecommunication network operators: Ooredoo with a 40% share, Tunisie Telecom with a 32.2% share, and Orange Tunisia with a 26% share. All three networks are now operating their own LTE network, after being approved by the governmental regulator in March 2016.

2.4 Internet Service Providers

Tunisia currently embodies one of the most developed telecommunications infrastructures in Africa, and Internet accessibility is available throughout the country via submarine cables, terrestrial, and satellite connections. There are eleven Internet service providers (ISPs) n the country—six public ISPs (AIT, INBMI, CCK, CIMSP, IRESA, and Defense's ISP) and five private ones (3S Global Net, HEXABYTE, TopNet, Tunisia Telecom, Ooredoo Tunisia, and Orange Tunisia). The Tunisian Internet Agency (ATI) was established by the Ministry of Communication Technologies to regulate the country's Internet services, and acts as the gateway from which Tunisia's Internet service providers lease their bandwidth.

As for internet subscriptions, the exceptional market growth started in 2013 after a reform in the country's Telecommunications Act, abolishment of internet censorship, and passing of laws supporting e-commerce and digital signatures. In 2016, there were already 7.7 million internet subscribers in Tunisia, and 80% of them subscribed through their smartphones. The country has one of the most active e-government and e-commerce sectors in Africa, and the newly launched 4G networks are expected to boost the internet usage even further.

3. Policy & Regulation Analysis

3.1 Waste Management Laws

The following table provides a list of the laws and decrees regulating the overall waste cycle including collection, transfer, treatment, packaging, disposal, recycling, and taxation for various types of wastes. The list also indicates modifications and amendments that were made to the previous regulations.

Table 32. Waste Management Laws

Law No. 1996-41	Law governing waste management and disposal
Law No. 2001-14	Simplifying the administrative procedures relating to authorizations issued by the Ministry of the Environment and Regional Planning
Law No. 92-122	Bearing the finance law for the 1993 management
Law No. 68-1995	Law governing the districts, who are in charge of the collection, transport and elimination of waste
Law No. 91-24	Modification of Law No. 75-33 of May 14th, 1975.
Law No. 37-1997	Transportation of dangerous goods by road
Law No. 16-1994	Development and maintenance of industrial zones
Decree No. 2317-2005	Establishment of a national waste management agency and setting out its mission, administrative, and financial organization
Decree No. 2001-843	Amending Decree No. 97-1102 of 2 June 1997 regarding packaging
Decree No. 97-1102	Amending the conditions and procedures for taking back and managing the packaging bags and packaging used (Ecolef)
Decree No. 2000-2339	Amending the list of hazardous wastes
Decree No. 2007-13	Management of wastewater treatment sludge for use in agriculture
Decree No. 2005-3395	Collection of used batteries
Decree No. 2002-693	Collecting lubricating oils and used oil filters (Ecozit and Eco-filter).
Decree No. 2008-2565	Amendment of Decree No. 2002-693 of April 1, 2002
Decree No. 2008-2745	Waste management of health-related industries
Decree No. 726-1989	Rural councils managing waste within territorial boundaries
Decree No. 2009- 73	Participation of industrialists in maintenance costs of industrial zone
Decree No. 1993-1429	Suspension of customs duties and tax on imports
Decree No. 1993-1614	Suspension of value added tax due to operations of public landfills, treatment, and destruction of domestic waste
Decree No. 2005-1156	Amendment of Decree No. 2004-1191 of May 25, 2004 on list of products exempted from tax exemption for environment protection
Decree No. 2007-1866	Regulation of hygiene

Decree No. 98-1428	Fixation of taxes collected by local public authorities
Law No. 97-11	Promulgation of local taxation
Ministry of Environment of March 23, 2006	Creation of hazardous waste storage and transfer treatment center
Ministry of Environment of January 17, 2007	Approval of specifications for carrying out collection, transport, storage, treatment, recycling and recovery of non-hazardous waste
Ministry of Environment & Finance and Trade of April 23, 2008 (joint)	Establishment of terms and mandatory deposit for the return of used accumulators used in industrial transport and other related purposes

3.2 e-Government Laws

Table 33 provides a list of e-Government related policies and regulations, from the legal validity of digital documents to computer security and electronic fund transfers. The e-Government Unit and Ministry of Information and Communication Technology is striving to further expand the e-Government sector of Tunisia, which will subsequently lead to an extension of laws governing electronic systems and infrastructures.

Table 33. e-Government Laws

Law No. 2000-57	Legal validity of an electronic document as conclusive evidence
Law No. 2000-83	e-Commerce / e-Signature
Law No. 2004-63	Protection of personal data
Law No. 2004-5	Computer Security
Law No. 99-89	Cyber-crime
Law No. 2007-13	PPP in the digital economy sector
Law No. 2005-51	Electronic fund transfer

4. Smart Waste Management Analysis

The public administrators of La Marsa have orchestrated a waste management strategy that focuses on prevention, integration, and participation. The following is the municipality's vision to be developed and implemented by 2030, which emphasizes

Figure 15. Sustainable Waste Management Strategy

Strategic vision → "By 2030, La Marsa will be the common reference in Tunisia.
It will remain open to the public and be welcoming, harmonious, and clean.
It will adopt waste management based on
preventive, integrated, and participatory approaches."
(English translation)

"D'ici l'horizon 2030 , La Marsa est la commune de référence en Tunisie,
elle demeure ouverte sur l'extérieur, accueillante, harmonieuse, et propre."
(French version)

The specific objectives of the national waste management strategy include:

1. Reducing the amount of waste production via prevention methods, by raising awareness and environmental education to change consumption habits
2. Strengthening the recovery, reuse, and disposal of waste through a specialized and economically-feasible strategy
3. Increasing partnership between the public and private sectors by having them participate in the institutional, legal, and financial sectors of waste management in accordance with the 'polluter pays' principle
4. Improving communication, consultation, and capacity of stakeholders at the local, regional, and national levels

There are 5 pillars constructing the preventive, integrated, and sustainable waste management:

Figure 16. Five Pillars of Sustainable Waste Management Strategy	
Pillar 1: ***Increased Communication & Awareness***	- Implementation of an information system - Reinforcement of consultation between stakeholders - Development of communication tools - Awareness and education regarding waste
Pillar 2: ***Laws and Policies***	- Improvement of legal framework for waste management - Reinforcement of institutional framework
Pillar 3: ***Human Resources & Personnel***	- Capacity building of local public authorities - Capacity building of public officials - Private sector capacity building - Capacity building of NGOs - Implementation of training system
Pillar 4: ***Financing & Cost Recovery***	- Strengthening financial capabilities of waste management - Control and optimization of waste management costs - Modification of waste management financing methods
Pillar 5: ***Technical & Organizational Framework***	- Adaptation of collection means to local realities - Strengthening the inter-municipalities - Improvement of treatment methods - Planning, monitoring, and evaluation of value chains

V. Case Study

Many of the major developing and developed cities around the world have embarked on smart city projects. For some, the concept of smart cities may be considered too futuristic, but the rate of innovation in the IoT and ICT sectors are vigorously expanding. Hence, adopting smart city models will become eminently feasible and even more attractive within the next 10 years. With many smart cities already being implemented and currently undergoing amplification procedures to expand the smart infrastructures and systems, such initiatives are expected to grow at attractive rates offering significant potential and advantages.

From the initial stages, smart cities require careful planning and participation from national and municipal governments and stakeholders to comply with the smart city definition and objectives. A clear definition and vision must be established in order for effective strategies and evaluations to ensue. Typically, smart cities have incorporated ICT and IoT into their smart systems and transformed the infrastructures. For many case studies, IT-integrated systems allow transmission of real-time data via sensors and processors as well as communication between technologies and systems.

This section presents five successful case studies that have implemented waste management technologies including solar compacting waste receptacles and ultrasonic fill-level sensors. These two types of smart waste management tools, infused with an IoT-integrated software system that monitors and regulates waste collection, provides a highly efficient yet economically and environmentally feasible option for managing the retrieval of waste. The case studies below will provide various uses and methods of installation from different stages of implementation.

Similar to our Discover, Insight, and Action methodologies, the case studies have been evaluated in three different categories. First, the problem was discovered and assessed. Second, the implementation process was reported. Finally, results and recommendations were provided, which have helped guide the designing and implementation of the pilot system in La Marsa. The case study results were also important in assessing the project's quantitative and qualitative feasibility.

01 Municipality (CleanCAP) : Melbourne City Council

The Problem

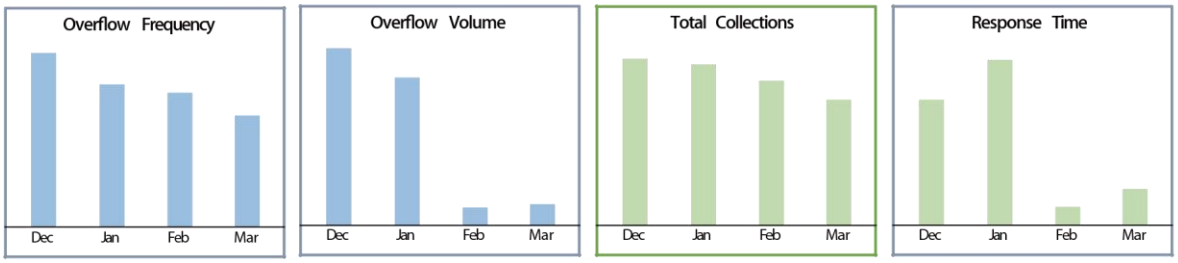
· Lack of data on the waste generation and collection performance
· Too many collections required and not enough workers to match the need
· Unpleasant environment for citizens due to overflowing bins

The Process

· Total installation of 700 CleanCUBEs planned
· Initial 47 CleanCAPs were installed
· CCN notifications and real-time data used to perform collections

The Result

· Total collections and inefficient collections (when fill-level is less than 30%) reduced by 25%
· Along with 35% fewer overflow occurrences, response time to an overflowing bin decreased by 71%
· Reduced response time resulted in roughly 85% less overflow volume, increasing quality of life for citizens



Data shown is from December 2016 to March 2017. Exact data cannot be provided due to privacy rules concerning Melbourne City Council.

Melbourne wanted to not only reduce collections but also reduce overflow, proven possible through CCN

02 Municipality (CleanCAP): Seodaemun-District, Seoul

The Problem

· Overflowing waste created nuance & image problem for its constituents
· All bins were collected 4 times a day
· Only high traffic areas' bins were full enough for such high collection frequency

The Process

· 76 bins were retrofitted with CleanCAPs
· Initial data revealed far too many collections
· Data showed varying collection requirements for different bins

The Result

· 45% collection efficiency increase with bins collected only 1.8 times, daily
· 25% increase in operational efficiency: enough time to give 2 of 8 administrators to be re-allocated elsewhere
· Not only did the area become cleaner, USD $950 was saved per bin, adding up to an annual total savings of USD $72,700

Pre-installation photos of bins.

Post-installation, CAPs leave little trace.

Heat maps are one tool staff can use to improve collection.

Main purpose was to reduce the operational costs for both admin and collection staff – all of which was accomplished

03 Facilities Management (CleanCAP): Dublin Airport

The Problem

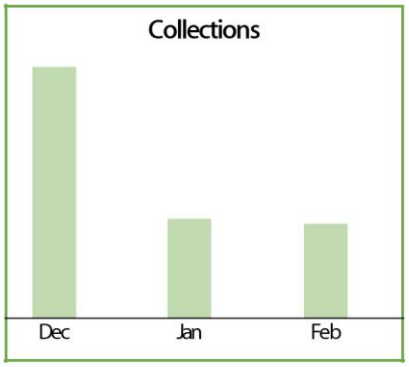
- Bins were creating issues in interior design, and over 1200 collections were being made per day.
- The high bin collection frequency for the high amount of bins was interfering with customer experience.

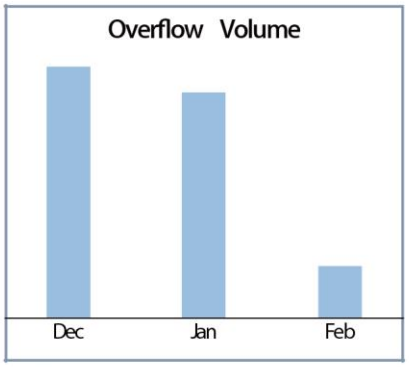
The Process

- 300 Clean CAPs were installed.
- Collected data revealed unknown trends in waste generation for an airport, paving the way for a far more efficient collection process.

The Result

- 94% decrease in collections: 93 bin collections per day
- Recycling rate increased 37%
- 90% increase in operational efficiency: workers reallocated from collection-related labor to elsewhere
- By using predictive models, collections can further be reduced to 42 collections a day, 1 case of overflow every other day, and these bins would only be left for an average of 19 minutes





Data shown is from December 2016 to February 2017. Exact data cannot be provided due to privacy rules of Dublin Airport.

Bins are kept from overflowing through proper usage of CCN.

As an airport, the management at Dublin Airport used our CAPs to focus on decreasing the workload on their staff, which would also, in turn, decrease costs and increase customer experience.

Optimizing waste management is essential in maximizing the work process, work environment, economic benefits, and overall cleanliness of the city and environment. Thus, businesses offering smart waste collection solutions with successful case studies have been rapidly expanding on the market worldwide. Smart waste management initiatives providing similar functions to the proposed To-Be Model system as well as other available technology used to address the waste management issue have been explored. Green initiatives have paved the road for the waste management industry to new niche markets with innovative technologies such as smart sensors, smart bins, and GPS trackers that offer low overhead costs and easy-to-manage practices. Several case studies from waste management systems in the United States and Europe have been provided.

In addition to the smart sensors, another type of technology is smart waste bins. There are several different types of waste bins, but the most common and popular type have been shown to be solar-powered or hybrid-powered waste compacting bins with built-in sensors. As shown in Case Study #4, the CleanCUBE is a smart waste bin that operates via solar, AC, or hybrid power and compacts waste at up to 720 kg of force allowing up to eight times capacity and preventing overflow. This bin has sensors that detect the fill-level of waste as well as elevated temperatures (for fire detection), and special locking mechanisms to ensure safety of personnel during collection.

Municipalities around the world have also been participating in smart waste management, and one key example is Cascais Ambiente, the environmental department of Portugal's local government who oversees all environmental operations for the municipality with over 200,000 citizens. Cascais Ambiente has implemented several new environmental technologies and is considered one of the leading European municipalities with smart city infrastructures. They have installed more than 400 smart waste bins across the city to monitor the waste and have seen numerous benefits. The cost of collection was drastically reduced while the level of service showed an upward improvement, and the town's scenic beauty was sustained while Cascais' citizens were shown to be satisfied through the elimination of waste overflow. The Control Center was able to monitor the fill-levels of all 400 bins simultaneously and plan optimized collection routes for their drivers.

One concern among waste management operation pertains to the organization of collection vehicles and finding effective ways to oversee and regulate the scheduling and maintenance of the vehicles and drivers. Hence, GPS and fleet management have been rising as a popular waste management practice. As shown in Case Study #5, the Peninsula Sanitary Service Inc. (PSSI), who is responsible for collecting daily waste and servicing roll-off debris boxes for construction projects, has implemented a GPS location tracking sensor throughout the campus of Stanford University to optimize the route schedules for each driver and retrieve swift data of the fill-level of containers and construction sites. The results are as follows: carbon dioxide emissions were reduced, operational management was significantly improved, and waste collections were reduced by more than 50%.

04 Facilities Management : Ghent, Belgium

The Problem

· Unpleasant environment for citizens due to overflowing bins
· Municipality of Ghent wanted to keep streets clean
· To increase civic consciousness toward environment

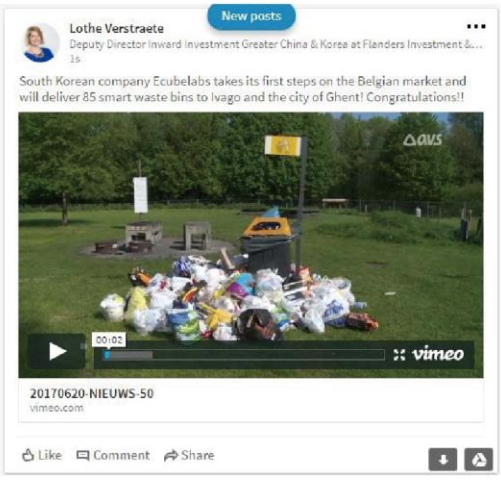
The Process

· Total installation of 85 CleanCUBEs are planned
· Currently 38 CleanCUBEs are deployed
· CCN notifications and real-time data used to perform collections

The Result

· 60% increase in operational efficiency: workers reallocated from collection-related labor to elsewhere
· Citizen satisfaction on public cleanness has increased
· Public area near Clean CUBEs become cleaner than before

Installation photos of bins.



City of Ghent mainly focused on maintaining a clean environment for its constituents by utilizing solar compaction bins.

05 Peninsula Sanitary Service Inc (PSSI)

The Problem

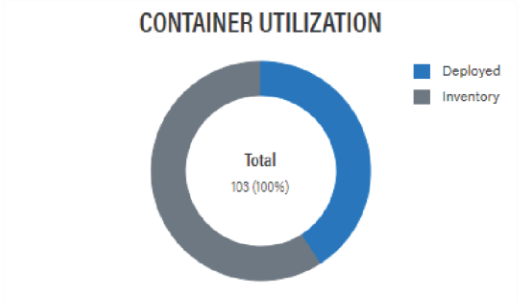
· 8,000+ acre campus of Stanford University in California, United States was generating enormous amounts of waste
· PSSI needed a more efficient method of collecting and hauling waste
· Used a whiteboard to keep track of the quantity, size, and type of container for each of the pick-up sites and had to visit the sites to see the availability of each container

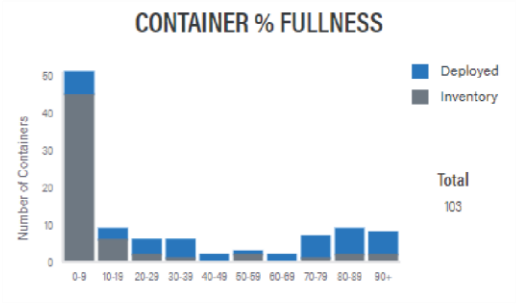
The Process

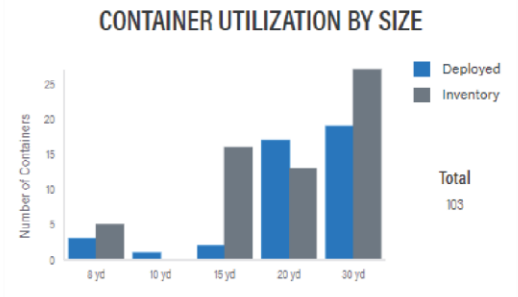
· Implemented GPS location tracker sensors throughout the campus in 2016
· Instead of using a whiteboard, a web-based software program was used in conjunction with the GPS tracker technologies

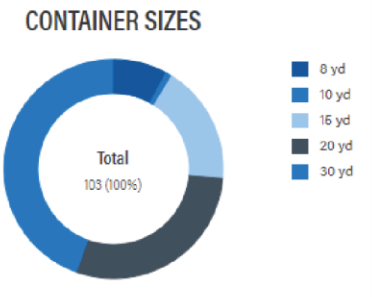
The Result

· Solution system provided accurate fill-levels and real-time images for error-proof, remote visual verification
· Through accurate and swift data collection, each service site was quickly addresed to by scheduling a driver's day according to each area's needs
· Time-consuming and inefficient procedures were quickly resolved and significantly reduced; inventory management was simplified
· Waste collections were reduced by 50%, CO2 emissions were reduced, and resource management was greatly improved









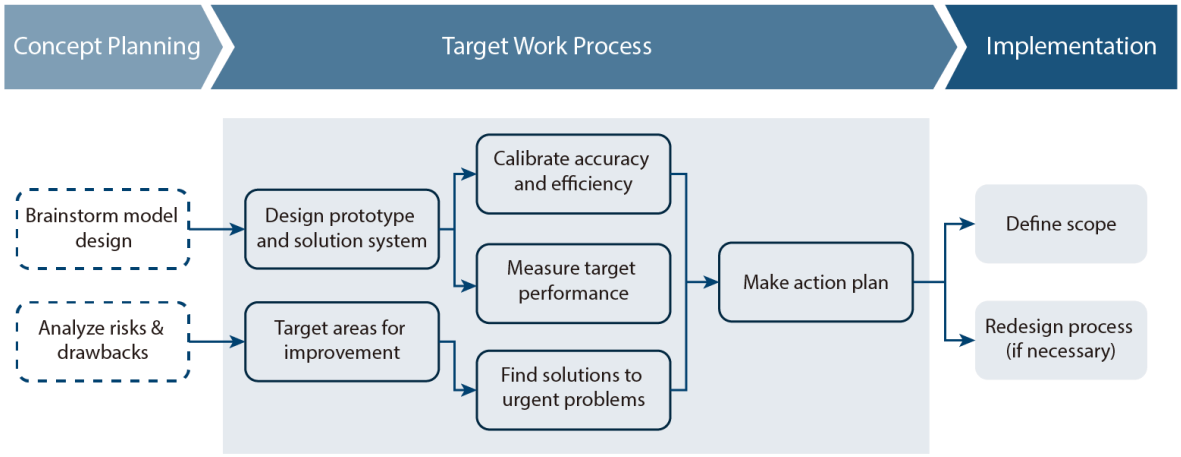
"PSSI realized the benefits for their drivers from pinpoint accuracy for container locations to reduce search time on routes to simplified data entry to simplify workflows and improve driver safety"

VI. To-Be Model

1. Approach for To-Be Model

The following flow diagram demonstrates the three phases for defining and creating the target work process leading up to the implementation plan for La Marsa's To-Be Model. Finding areas of improvement and making strategic plans to effectively redesign the solution system and preparing for a successful implementation in an efficient manner was crucial in the work process.

Figure 17. Approaches for Designing Target Work Process



Further details of the work flow have been elaborated below, including the steps taken to improve the solution system model in order to maximize the level of efficacy with high performance outputs. The procedures and data values were carefully assessed prior to establishing the comprehensive action plan and actual implementation of the pilot project. Defining the scope, vision, methodologies, and strategies for the project played a fundamental yet significantly important role in the composition of the target work process.

2. Vision and Strategy

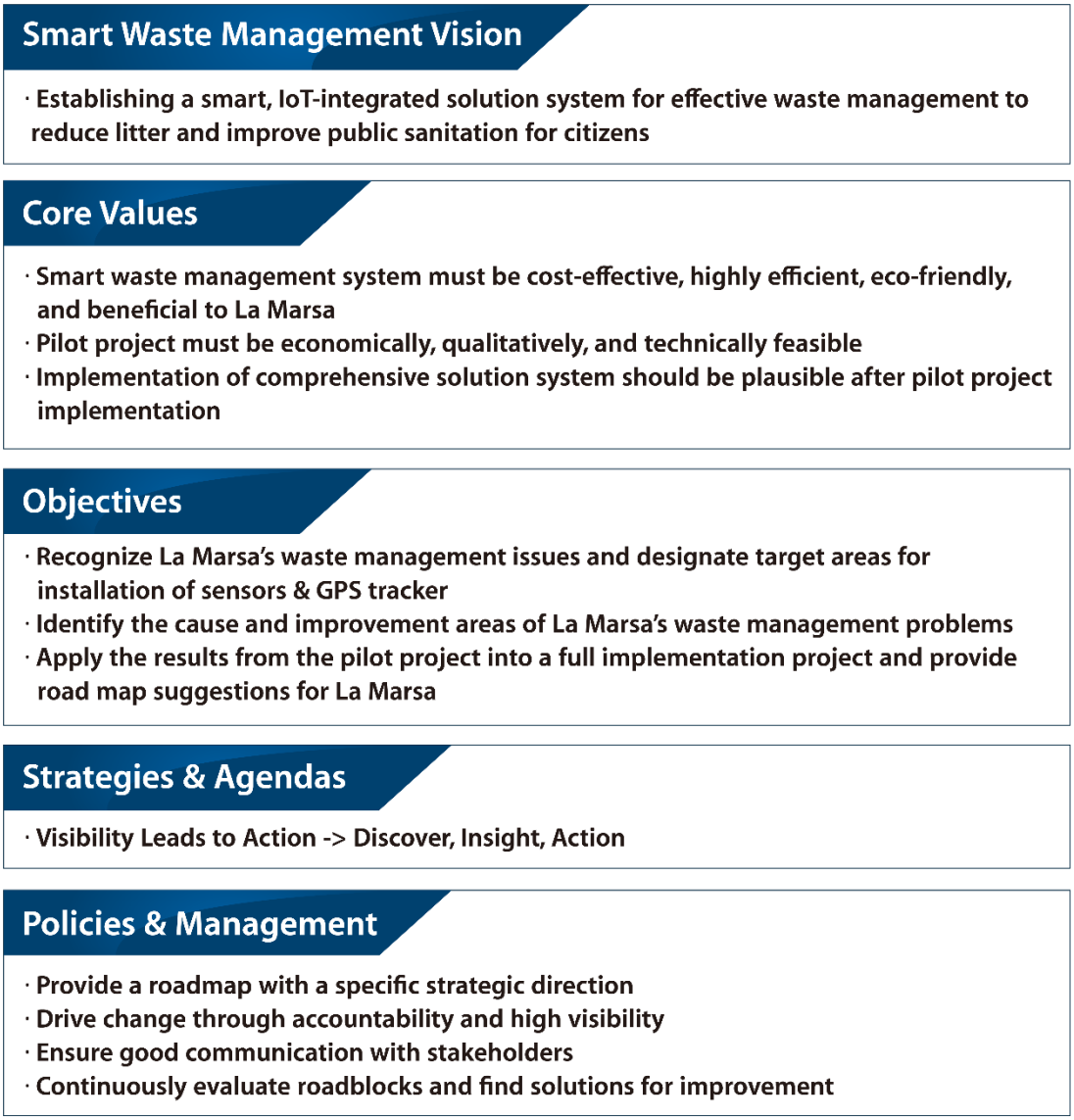
Establishing the vision and objectives in addition to the strategies and goals that underlie the feasibility study of La Marsa's waste management were formulated with the following organization below:

Figure 18. La Marsa's To-Be Waste Management Framework (1)

As shown in Figure 18, the scaffolding for the comprehensive action plan entails five key foundations. The vision provides a specific direction for the smart waste management project layout. The project's vision examines the ultimate goal and objectives of the smart waste management system, providing a platform for strategies and actions to enhance the overall framework and implementation.

Figure 18 displays the guidelines and critical questions that were inquired prior to establishing the actual framework. Hence, Figure 18 asks the questions and Figure 19 provides the answers and solutions. The Discovery, Insight, and Action phases as well as the Early, Mid, and Late stages have been key role players in the activation and implementation of La Marsa's To-Be model system, and have been explained in the sections below.

Figure 19. La Marsa's To-Be Waste Management Framework (2)



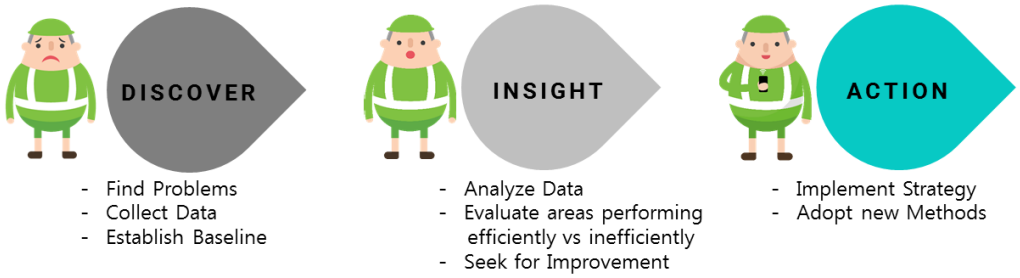
The objective of the To-Be model vision entails transparency in each phase and encompasses three different phases: Discovery, Insight, and Action. The motif behind all three phases is creating a platform where Visibility leads to Action.

In the **Discovery Stage**, a baseline is established by evaluating and detecting the problems associated with the current waste management procedures, and a thorough investigation is implemented for data collection.

In the **Insight Stage**, the compiled data is further assessed, gathering insight as to which areas are performing efficiently and which ones need improvement.

In the **Action Stage**, further assessments are made taking into account the problems and improvement-requiring areas, ultimately implementing a comprehensive, feasible action plan that is highly effective—economically and technologically.

Figure 20. Discover, Insight, Action Strategy



Recognizing the Issue

The primary objective behind the Discovery Stage was to collect data in order to recognize La Marsa's waste management issues that were both mentioned and discussed during the stakeholder meetings, as well as issues that were not immediately visible. An environment assessment of La Marsa's current waste management status was investigated prior to installation of the pilot project in order to create a data baseline. These analyses and data values were subsequently compared against the data provided by CCN to create visibility of any operational issues. These issues ranged from inefficient management of waste generation and collection policies to sub-optimal delegation of resources including waste receptacle locations.

Identifying the Cause

The Insight Stage focused on using the collected data, along with data from other sources as well as heuristic input, to pinpoint the cause of the issue. If the causes identified are obviously simple to fix without disruption to current operations, adjustments were made in real time from which further insights can be gathered (both positive and negative).

Applying the Solution

The real long-term value for La Marsa's smart waste management lies in applying broad strategy and policy changes to waste management operations. The insights derived become more accurate and effective over longer periods of time. The 50 CleanCAP sensors installed as part of the pilot system in La Marsa will continue to compile data over time, which will allow drastic improvements in operational efficiency. Even with the data that was collected for several weeks solely for this feasibility study, sufficient assessments of collection and operational efficiency were made. Therefore, the proposed To-Be Model will allow significant improvements in La Marsa's waste management more so over time. This 3-step cycle is mimicked at the macro scale—manifesting as Early, Mid, and Late stage—which we will explore in the pilot project implementation phase and recommended road maps.

3. Strategic Direction

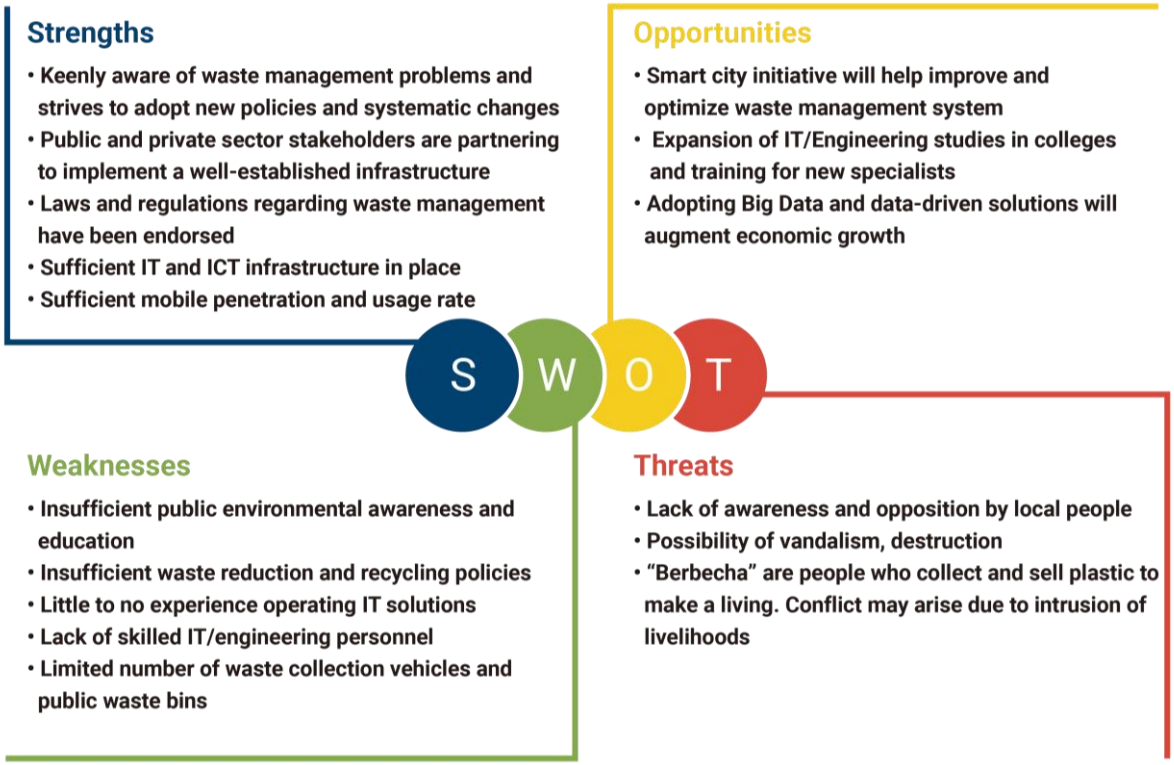
After establishing a vision and core values, the short-term, mid-term, and long-term strategies were formed following an Early, Mid, and Late Stage assessment. For this Feasibility Study, SWOT Analysis and SWOT Matrix tools were utilized allowing us to formulate certain critical success factors for La Marsa's waste management.

Figure 21. Strategic Direction

3.1 SWOT Analysis

SWOT analysis is an analytical tool used in the development of strategies by evaluating the strengths, weaknesses, opportunities, and threats of an organization.

Figure 22. SWOT Analysis



The following SWOT characteristics were assessed based on La Marsa's current waste environment:

- **Strengths:**

One of La Marsa's strengths is that the municipality officials and administrators are very much aware of the current waste management issues and shortcomings. They have raised these issues during the stakeholder meeting at the first on-site inspection. The public and private sector stakeholders have shown to make collaborative efforts in working together towards reinforcing La Marsa's ICT infrastructures and striving to find ways to improve the waste management procedures. Through such efforts, policies regulating waste management have been continuously expanding. Furthermore, Tunisia is ranked among the top ten countries in regards to ICT development, demonstrating a progression in ICT infrastructure and development potential, and ranked second among other African countries with respect to e-Government development, which shows to encompass high telecommunication penetration and usage.

- **Weaknesses:**

During the stakeholder meeting, several weak points in La Marsa's current waste management methods were specified and discussed. Among such weaknesses was insufficient public environmental awareness and education; the administrators mentioned that there was a lack of knowledge for waste disposal and its impacts on the environment. Another issue was the inadequacy in waste reduction and recycling regulations; although policies and laws are present, they are not strictly enforced. Moreover, despite the growing interest in IT and ICT sectors in La Marsa, the number and level of experts and professionals in this industry are still limited. Lastly, the number of waste collection vehicles and waste bins were inspected, and results demonstrated that there was an inadequate quantity of pickup vehicles and public waste bins even in high density areas where tourists are heavily populated, accounting for high waste generation and overflow frequency.

- **Opportunities:**

With an expanding number of initiatives geared towards advanced technologies, the countries adopting smart solutions with smart waste management systems will partake in the digitalizing cycle that is spreading globally. Hence, if La Marsa were to be an early adopter in this rapidly growing arena, La Marsa will be well-recognized for such efforts, especially among the bordering African and Arab regions. New projects such as waste management will result in new infrastructures, which will further expand IT and ICT-related solutions. This trend is expected to continue advancing eliciting substantial advantages. Optimizing the efficiency of waste management will not only provide economic benefits boosting the city's economy and economic status, but improvements in the overall sanitation and cleanliness will allow the city officials to make La Marsa more attractive for tourists thereby increasing the tourism market. Hence, integrating Big Data and cloud-based solutions will assist in cultivating the municipality's growth and development.

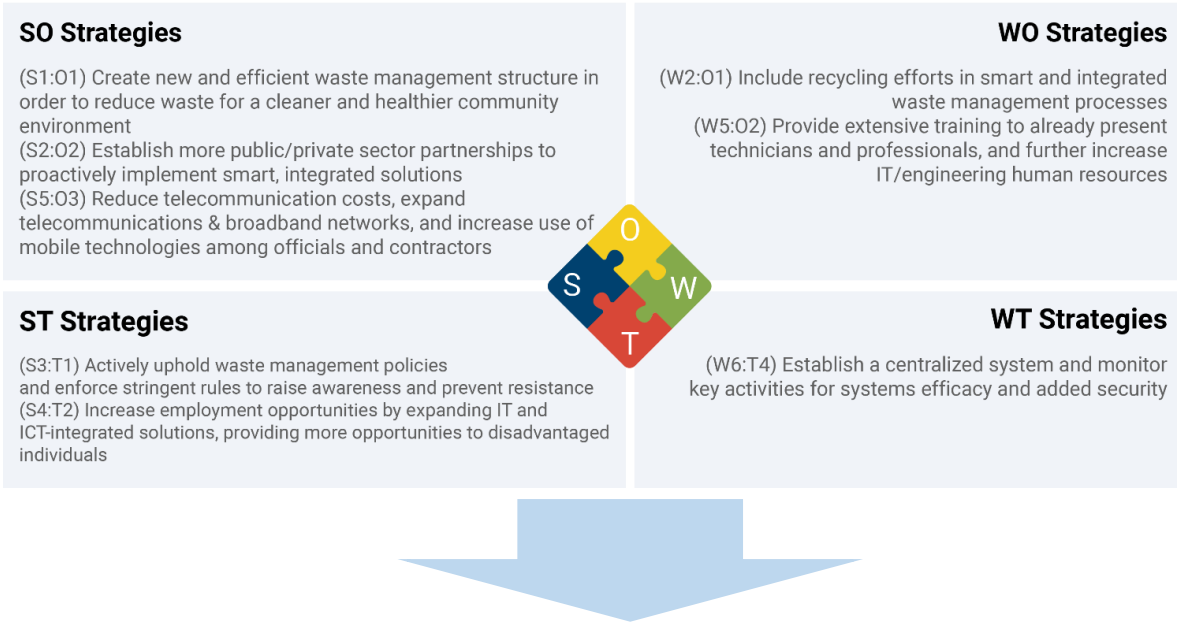
➢ **Threats:**

There has been opposition by the local people for waste management systems in the past. The company is dependent on the public's care and concern to maintain a clean community. Thus, a foundation of environmental education is in dire need. Moreover, there is a possibility of vandalism or destruction of the technologies due to a lack of awareness. The "Berbecha" are people who collect plastic and sell them to companies who then use them to make new packages. This is how they make a living, since plastic is considered one of the most profitable waste products in Tunisia. Thus, conflict may arise due to what may be perceived as intrusion to their livelihoods.

3.2 SWOT Matrix

SO Strategies: Utilizing strengths to take advantage of opportunities
ST Strategies: Utilizing strengths to avoid threats
WO Strategies: Taking advantage of opportunities by overcoming weaknesses
WT Strategies: Minimizing weaknesses and avoiding threats

Figure 23. SWOT Matrix



3.3 Critical Success Factors

- Create centralized waste management system
- Enhance public/private partnerships
- Vigorously implement IT infrastructure & technologies
- Optimize efficiency and incorporate recycling
- Increase transparency, security, and prevent corruption

4. To-Be Model

Figure 24. Solution System Diagram

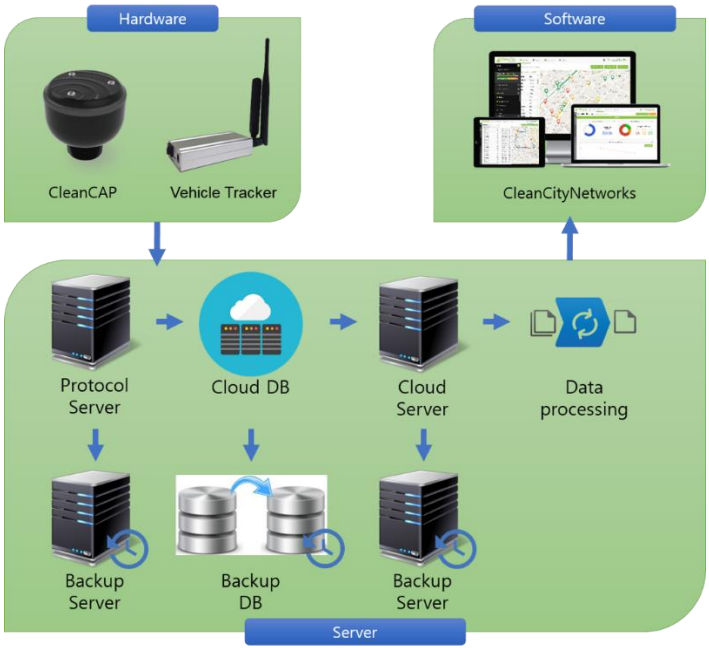


Figure 25. Components of Smart Solution System

CleanCAP (CCP)	**CleanCityNetworks (CCN)**	**CleanTRACK Module (CTM)**
Ultrasonic fill-level sensor	Real-time analytics and monitoring software	Comprehensive vehicle data gathering module and vehicle tracker; GPS

The prototype system entails three primary components: two types of hardware technologies (CleanCAP and CleanTRACK) and a cloud software network (CleanCityNetworks, CCN).

VII. Pilot Project Implementation

1. As-Is Analysis

In order to assess the waste management system and infrastructure of La Marsa, an on-site inspection of the deployment area was initiated prior to planning the strategies for implementation. The first step involved a thorough examination of the collecting vehicles and waste bins, which was followed by a meeting with city officials and critical stakeholders participating in the pilot project establishment and implementation. Several issues were discussed at the meetings, including shortcomings of the current waste management system and requests for sustainable improvement.

1.1 Research and Planning of Deployment Site

In-depth analysis of the project site and understanding of the environment was crucial for adequate preparation and appropriate resource allocation. Research primarily focused on the current waste management situation of the target area as well as the city's most recent smart city related activities. Extensive research and planning played a critical role in recognizing the problems of waste management and determining which areas were in need of optimized solutions. The agendas of the on-site inspections included:

Table 34. On-Site Inspection Agendas

- Analyzing the waste management issues of the region
- Inspecting the waste bins and collection vehicles (Figure 26)
- Exploring the types of waste being discarded
- Testing for compatibility with the devices and La Marsa's current infrastructure
- Examining the telecommunication network connectivity and strength (2G, 3G or LTE)
- Strategically targeting high-frequency waste areas for deployment
- Understanding the local waste collection practices
- Establishing the installation protocols
- Training the local staff and providing education workshops

The following figure (Figure 26) shows the different types of waste collecting vehicles and bins that were assessed in the target site. Examining the bins and vehicles played a key role in assessing which type of smart solution prototype would be most suitable providing maximized efficiency. As a result, the overall assessments allowed us to designate the CleanCAP sensor, which may easily be attached to any type of waste bin, and the CleanTrack Module, which provides a GPS tracker system.

Figure 26. Pictures of Waste Collection Vehicles and Waste Bins		
Collecting Vehicle 1	**Collecting Vehicle 2**	**Collecting Vehicle 3**
		
Waste Bin 1	**Waste Bin 2**	**Waste Bin 3**
		

1.2 Discussion with City Officials

Several trips to La Marsa were orchestrated for on-site observations and meetings with public and private officials regulating the city's waste management system. The discussions between the stakeholders included Tunisia's IoT status, the operation of the current waste management system, objectives of the pilot program, advantages post-implementation, business model creation, expected outputs, and what the people and municipalities can anticipate from the smart solution.

Figure 27. High Level Meetings	
	

During the first on-site inspection, the waste bins were thoroughly examined—material composition, configuration, and compatibility with CleanCAP sensor in particular. Additionally, the operation of waste collection, collection vehicles, dumping sites, and current system of collecting stages were investigated. The table below lists the data and results gathered after the first on-site analysis in November 2017.

Table 35. Data and Results after Site Inspection

- Tunisia is one of the leading countries in Africa for ICT and IoT technology
- City officials and stakeholders were highly interested in the adaptation of novel technology; Waste collection has been a great challenge for La Marsa, but remains widely open to accept new solutions with IoT technologies
- Obstacles hindering ICT/IoT expansion: financial limitations, insufficient infrastructure and technology
- Foreign funds have been invested to several residential sites to reduce the generation and enhance the collection of waste
- New technologies have been incorporated since 2015; 5 new vehicles and collecting containers
- Collection vehicles now have GPS modules (made in Tunisia) to constantly monitor the vehicles' location, but they have not been used or checked frequently
- Network communication: Good
- With gradual development and implementation, successful outcome is expected

Overall inspection issues have been well studied and appropriate documents have been provided. However, as a developing country, special treatment may be needed in terms of hardware and software. The biggest issue, the communication network, has been well tested and the result is better than expected. Ecube Labs Korea office was able to see the sample device after it had been installed and data has been retrieved without any complications. The unstable network issue will be measured with some timeline. It was our impression that the Tunisian and La Marsan government understood the smart solution system and its potential in a variety of industries.

2. System Development

2.1 CleanCAP (CCP)

Figure 28. Illustrations of CleanCAP

Side view	Front view	Top view
		

Table 36. Technical Specifications of CleanCAP

Product Dimension	- Size (L x W x H): 80 x 85 x 53 mm - Weight: 350g
Features	- Fill-level sensor (sonar) - Fire detection sensor (temperature algorithm) - Tilt sensor (gyro)
Fill-level Sensor	- Measurement Technology: ultrasonic/sonar - Range: 2 to 400 cm (0.7″ to 157″) - Accuracy: +/-4cm (1.57″) for solid materials[1], +/-1cm (0.39″) for liquids[1] - Resolution: 1cm (0.4″)
Communication	- GPRS over GSM: 850/900/1800/1900 MHz - WCDMA over UMTS: 800/850/900/1700/1900/2100 MHz - LPWAN: LoRa, NB-IoT available - Network: Internal SIM card
Durability	- Ingress Protection Rating: IP67 - Impact Rating: IK10 - Operational Temperature: -30° to 80°C (-22° to 176°F)
Power	- Battery Type: 3.6V high performance lithium battery (D-type) - Battery Life: approximately 5 years[2]
Physical Characteristics	- Material: High Impact ABS/Polycarbonate - Installation: Optional mounting brackets available

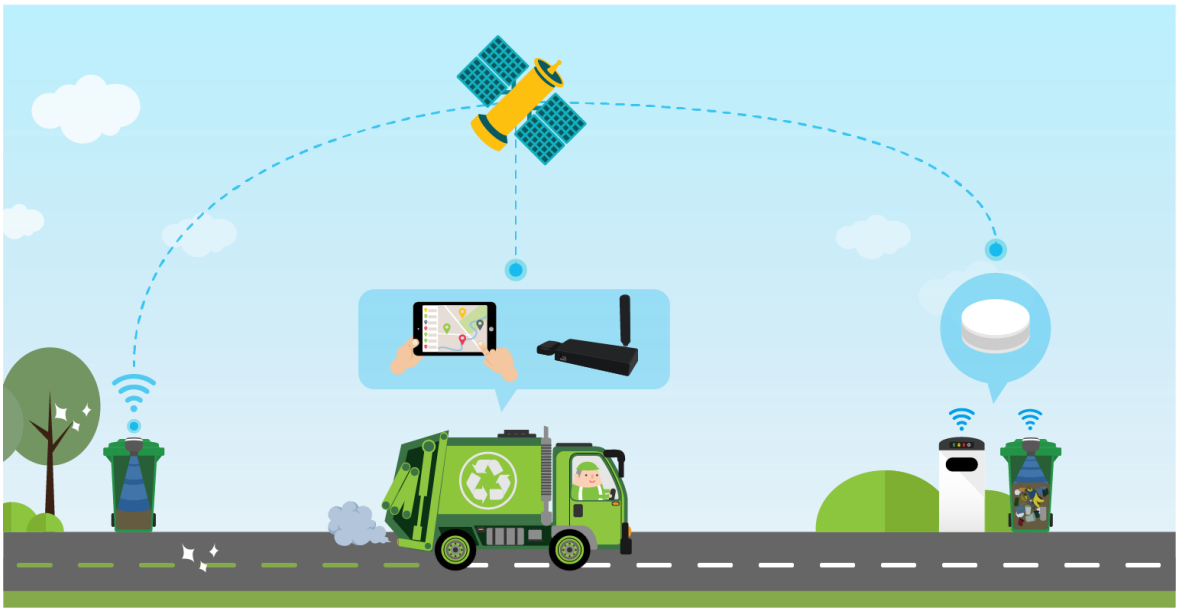
1: Also depends on setting profile of waste composition

2: Assuming 4 transmissions per day and acceptable local network quality.

Depending on transmission frequency, actual battery life may range from 1 to 10 years.

2.2 CleanTRACK Module (CTM)

Figure 29. Diagram of CleanTRACK Module (CTM)



Our CTM is a GPS tracker/OBD module designed to seamlessly integrate with fleet vehicles and relay a myriad of useful data logs back to CCN, where the information can be monitored live (in real-time). Historical data can also be evaluated, which can provide actionable insights and make on-the-fly adjustments.

CTM provides real-time data on GPS tracking, vehicle speed, throttle position (gas pedal), engine oil temperature, air intake temperature, outside temperature, coolant temperature, atmospheric pressure, engine torque, battery voltage, and more.

CTM data can be customized to client needs to assess data such as air gauge, fuel gauge, trip mileage, trip fuel consumption, fuel injection efficiency, braking patterns, shifting patterns, etc.
The CleanTRACK GPS system can be connected to smart phones and tablets, providing access to real-time data at one's convenience—24 hours a day, 7 days a week.

Figure 30. Illustrations of CleanTRACK Module (CTM)	
Front view	**Side view**
	
Connection via Smart Phone	**Connection via Tablet**
	

This diagram demonstates the front and side views of the CTM, as well as applications of the tracker module being connected to smart phones and handheld computers.

2.3 CleanCityNetworks (CCN)

CCN allows the monitoring and storing of data regarding waste bin fill levels and fill level history. The software also optimizes collection routes for the most efficient course, taking into account the fill levels of each bin and prioritizing which ones need collection first. Hence, drivers are able to initially collect waste from the bins that are full and subsequently attend to ones that are less full. The system also checks battery levels, geographical locations, collection history, overflow status, response times, and even fire events.

Other features of CCN are organized in the chart below:

Figure 31. Features of CCN Software

Predictive Analysis

As data is collected, our machine learning algorithm will intelligently learn from the waste generation patterns to predict similar patterns 24 hours in advance. This enables optimized collection routes and generates more efficient routes compared to real-time data.

Actionable Insights

Collection performance/efficiency, overflow frequency, waste generation, sub-optimal collections, and comprehensive analyses are provided as a tool to better understand the operations of the current waste management and pinpoint areas that can be improved.

Universally Accessible

CCN is a cloud-based service and can be accessed from any device with an internet browser. Optimized for desktop, mobile, and tablet devices, CCN is accessible anywhere anytime. No special software is required, no downloads or installations—it merely requires a simple login.

Hardware & Asset Integration

CCNx is an extended-feature version of CCN for users who require fleet management capabilities. It integrates our CleanTRACK Module (CTM) and software/application to provide real-time monitoring, analysis, and asset management.

Automated Route Optimization

CCNx provides a one-click route optimization that substantially enhances WM operations and maximizes efficiency. These optimized routes may be received by all assets and drivers via the CCNx application, which is updated dynamically.

Advanced Fleet Management Features

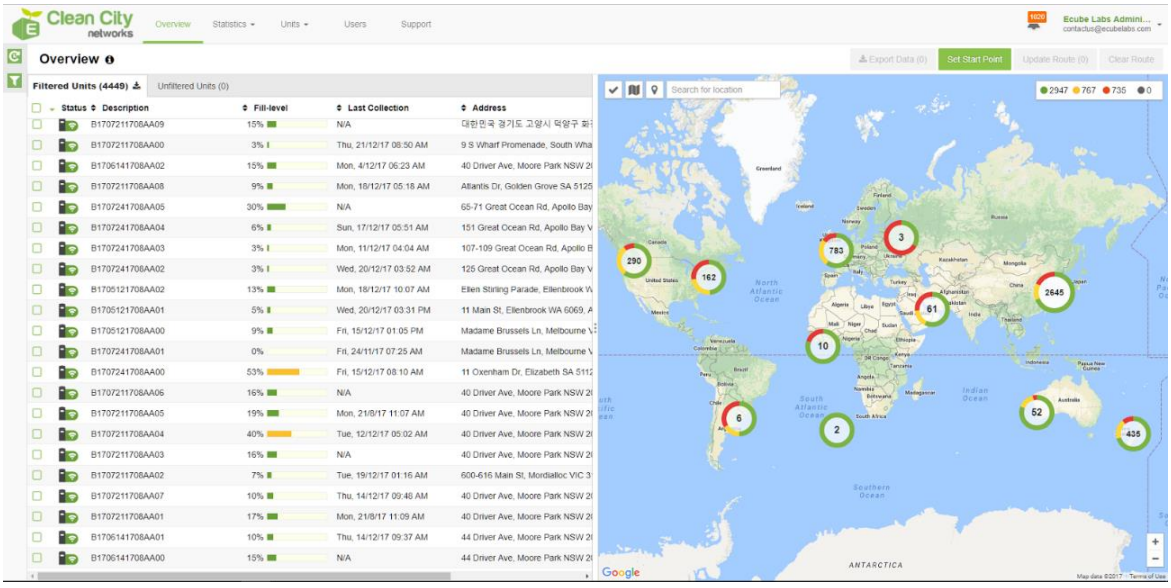
Monitor vehicle statuses, control schedule dispatch times, track driver behavior and fuel consumption, and give drivers access to reporting tools for a comprehensive and purpose-made fleet management solution.

Upon successful installation of the hardware prototypes, connectivity and ease of access to the CCN platform is essential to retrieve important data for analysis and management. Hence, the following pages provides a step-by-step manual for technical and support assistance.

Figure 32. Login Page

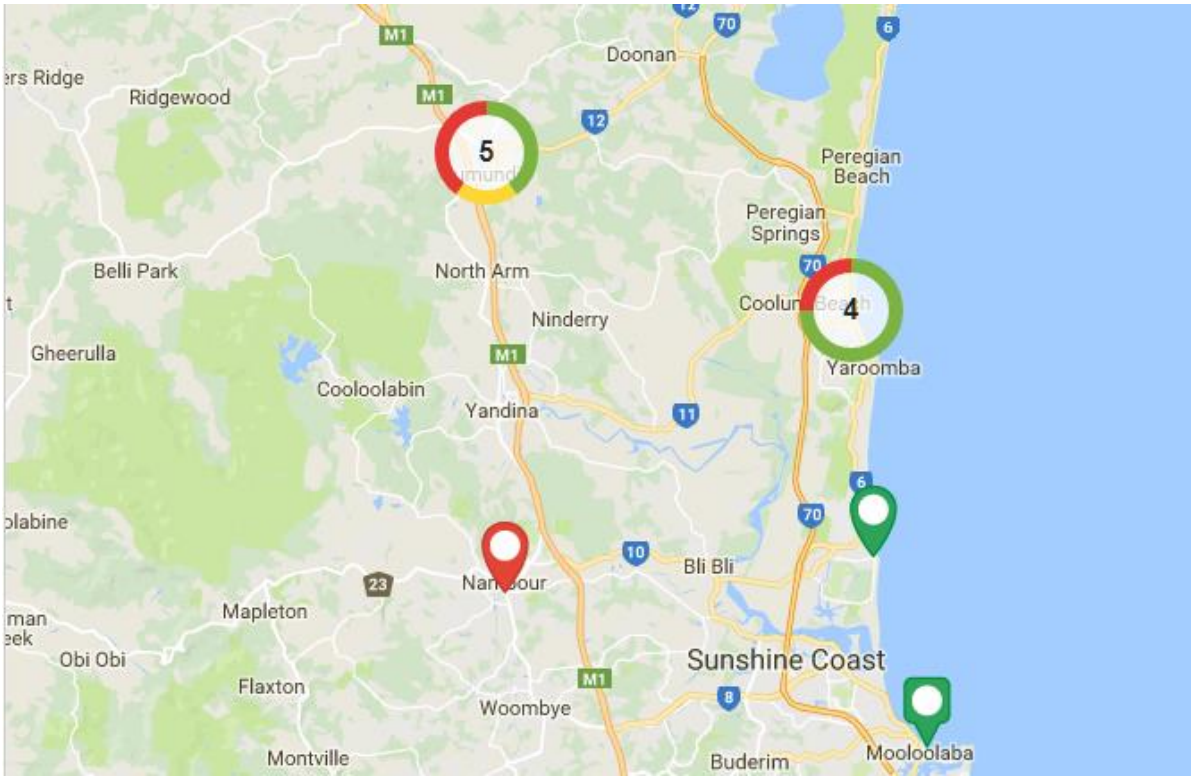
Here is your basic login screen. Log in by entering your account information and agreeing to our EULA and Privacy Policy. If you would like to change the language settings, you may do so by using the dropdown menu in the top right corner.

Figure 33. Main Page



Detailed information of individual units (left side) and location of distributed units (right side, map) is shown.

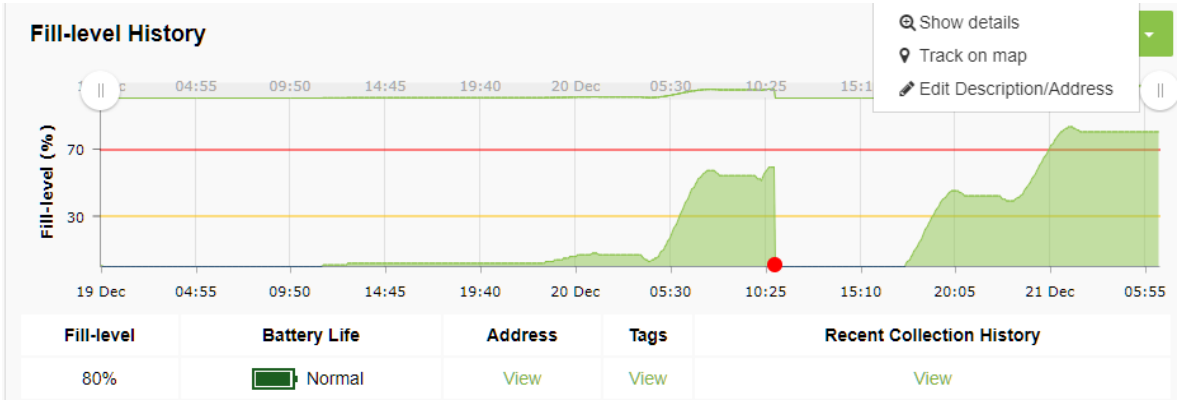
Figure 34. Fill-level Indicators



On the map, you will see your units clustered until you zoom further into the map. The colors indicate the fill level of the containers:

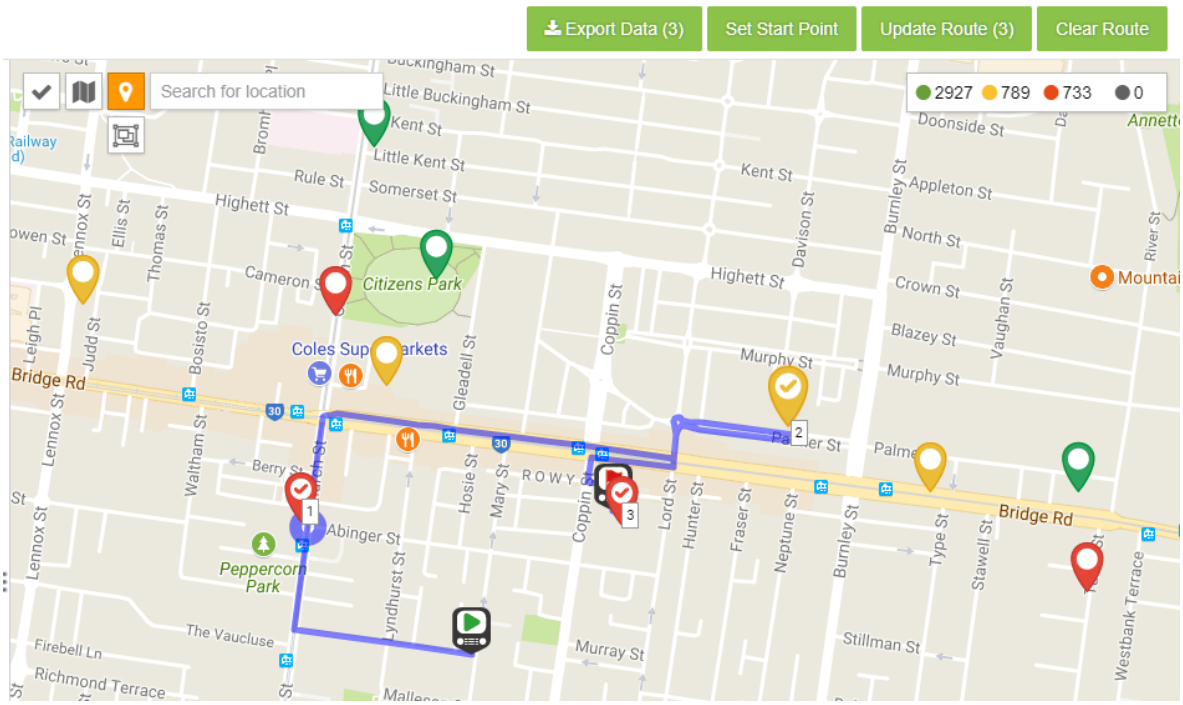
Green: **0-30% Filled**
Yellow: **31-70% Filled**
Red: **71-100% Filled**

Figure 35. Graphical Data



Detailed information on fill-level, battery life and collection history may be viewed.

Figure 36. Optimized Collection Routes

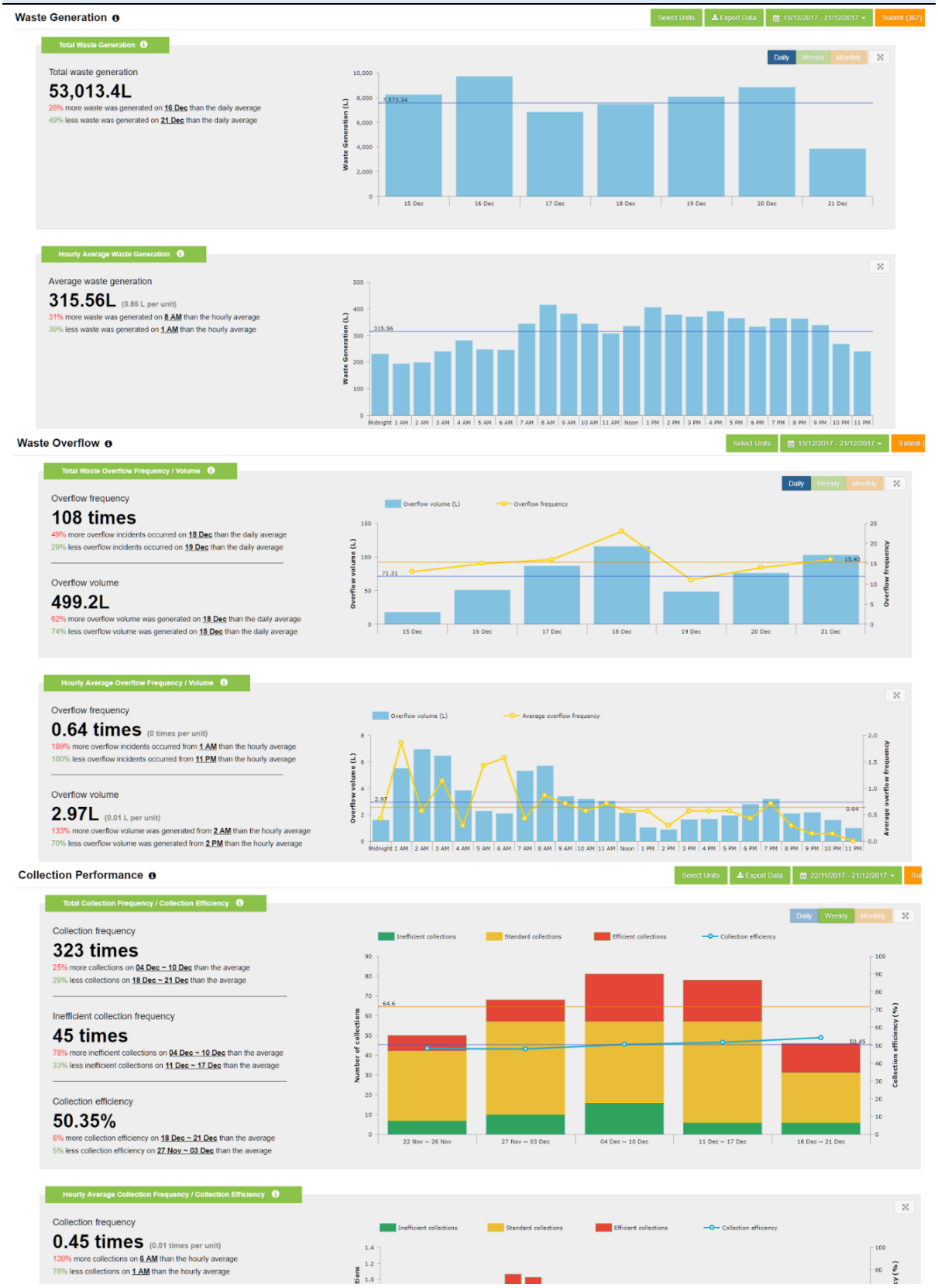


CCN can determine the optimal routes for collection once 3 or more units are selected.

You may drag the Starting Point icon  on the map to the location desired. Once you have determined the location, click Update Route in order to view your optimized route.

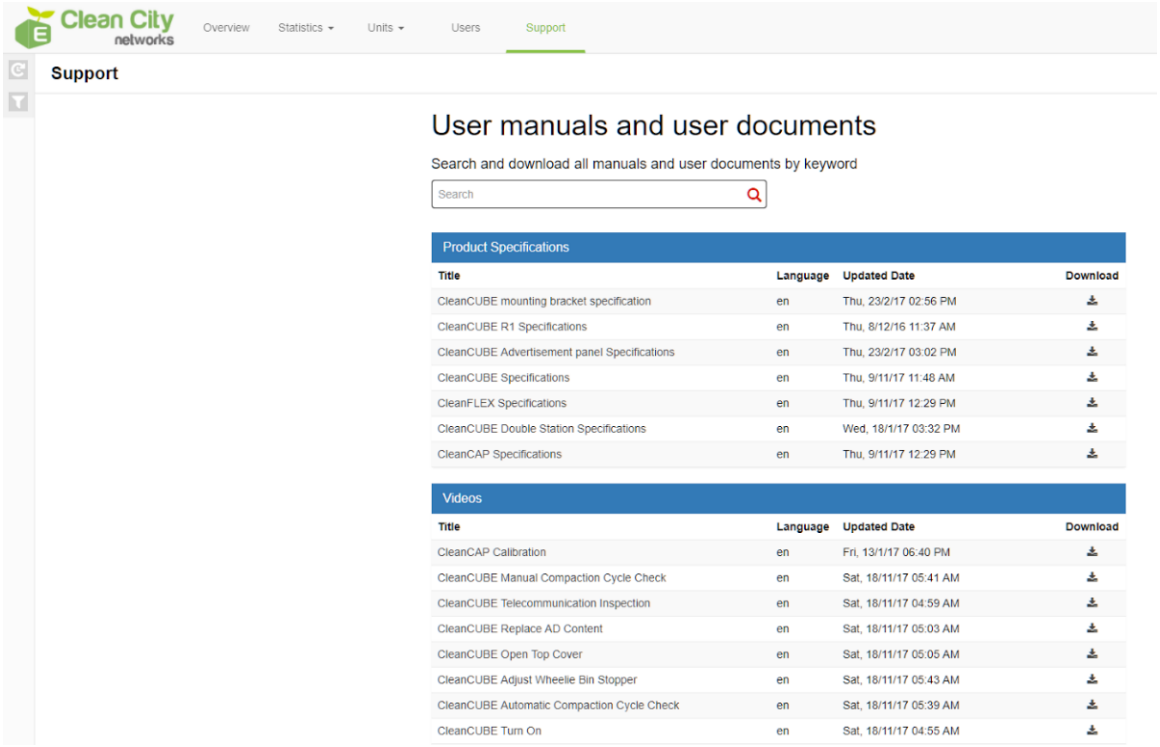
The purple indicator will show you which direction the collection vehicle should go. If any changes are made, you will need to reset the starting point and update the route. The Clear Route option will erase all start/end points and routes.

Figure 37. Statistics



CCN also provides statistical analyses on waste generation, waste overflow, and collection performances.

Figure 38. Support



Under the Support tab, you can find downloadable guides for various topics.

The CCN Manual (Step-by-Step Guide) was provided to map the core processes and outline sections of the software platform that would be helpful for administrators and stakeholders who would be utilizing the CCN to manage the system in La Marsa. The manual has been succinctly organized for easy navigation enabling efficient management of waste collection vehicles, real-time monitoring of regional waste generation, as well as predictive analytics to take regulatory action ahead of time in areas requiring attention in terms of staffing and resource allocation.

Upon evaluation of La Marsa's present waste management structure and examination of the type, number, and location of the waste bins, a service model catered to the needs of La Marsa's waste problems has been devised. Comprehensive support to the municipality of La Marsa from the initial steps of the implementation to the maintenance and support ensuing implementation will be provided.

3. System Implementation

A total of 5 CleanTRACK modules and 50 CleanCAP sensors were deployed with customized brackets for mounting on the waste bins. Training sessions for the CCN analytics software also took place after the installation to ensure that efficient management and operation of waste collection procedures continue throughout the entire pilot project duration. All members associated with the project were obliged to attend this session. A step-by-step manual as well as actual data from CCN have been enclosed in later sections.

Table 37. Overview of Installations 1-3

Installation	Target Area of Deployment	CleanCAP	CleanTRACK
1	Le Suf Suf Restaurant	1	
	Ramada Plaza Hotel	1	
2	La Marsa's Main Street	5	
	Collecting Vehicle Garage		1
3	Residential / Hotel & Resort / Street / Beach	43	
	Collection Vehicle		4
Total Number of Hardware Installed in La Marsa		**50**	**5**

3.1 On-Site Installation 1

Table 38. Number of Hardware Installed (Installation 1)

Target Area of Deployment	Prototype	Quantity
Le Suf Suf Restaurant	CleanCAP	1
Ramada Plaza Hotel	CleanCAP	1

Figure 39. Pictures of Installation 1



Table 39. Data and Results after Installation 1

- 2 units of CleanCAP sensors were installed on the waste bins
- External factors that were considered prior to installation of CCP included size/shape of bins, type of waste being thrown away, areas of high waste overflow
- In comparison to CleanCAP, CleanTRACK is not affected by external factors but proper installation practice is important to ensure smooth and error-free data transmission
- One factor important to CTM was the length of the cable that slightly varied between vehicles
- Despite training of CCN, one concern was that the staff might not be accustomed to the dynamic collection routes generated by the software and being reluctant to use the mobile application and handheld devices
- In order to overcome such hurdle, initial participating staff will be volunteers and Ecube Labs will provide sufficient amount of education materials (user manual and service manuals)
- Continuous technical support and maintenance is also guaranteed

3.2 On-Site Installation 2

Table 40. Number of Hardware Installed (Installation 2)		
Target Area of Deployment	**Prototype**	**Quantity**
La Marsa's Main Street	CleanCAP	5
Collecting Vehicle Garage	CleanTRACK	1

Figure 40. Pictures of Installation 2

Table 41. Data and Results after Installation 2

- 2 CleanCAP sensors have been installed in the waste collection area
- Waste collector bins will be distributed in waste dumping areas and garages
- 3 CleanCAPs have been installed in the busiest streets of La Marsa (La Corniche Street)
- CleanCAPs have been installed near train stations and Beach areas
- Data retrieved from the actual installation on street bins will enhance the status analysis and patterns of waste generation
- Data transmission through telecommunication network has been confirmed; Waste generation, collection, and pattern data have been detected and analyzed
- The collected data is currently being assessed and processed to provide suggestions for future enhancement

3.3 On-Site Installation 3

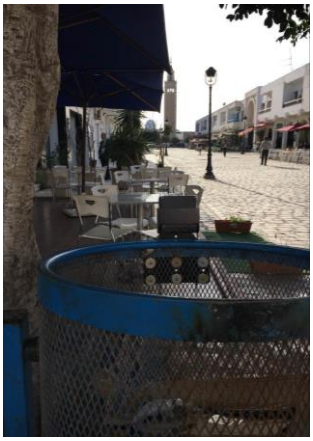
Table 42. Number of Hardware Installed (Installation 3)

Target Area of Deployment	Prototype	Quantity
Residential / Hotel & Resort Street / Beach area	CleanCAP	45
Collection Vehicle	CleanTRACK	4

Table 43. Data and Results after Installation 3

- 20 CleanCAPs were installed on January 28, 2018
- Data transfer was enhanced by upgrading the Tier level of global telecom network
- Data on waste generation and collection has been collected for supplementary analyses
- La Marsa's appointed personnel have been constantly monitoring and updating prototype status through daily notifications to Ecube Labs' team
- CleanTRACK module was installed on 4 collection trucks to check GPS location on system
- CleanTRACK module will soon be upgraded to have smart collection route navigation
- Issues: As Tunisia's Central Government was not aware of such new technology and its implementation in La Marsa, Customs temporarily halted the acquisition of the devices. Thus, there was a slight delay in the third installation but the prototype devices were delivered and efficiently installed. Despite the safe delivery and installment of the devices, however, Customs has been retaining the batteries which are necessary for activation. All paperwork has been approved, and waiting for clearance.

Figure 41. Pictures of Installation 3



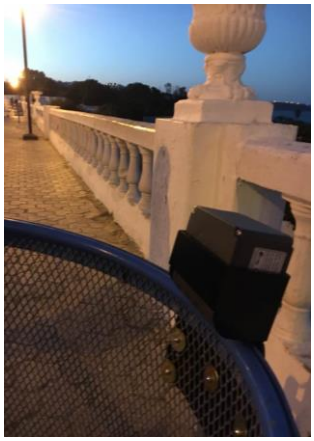
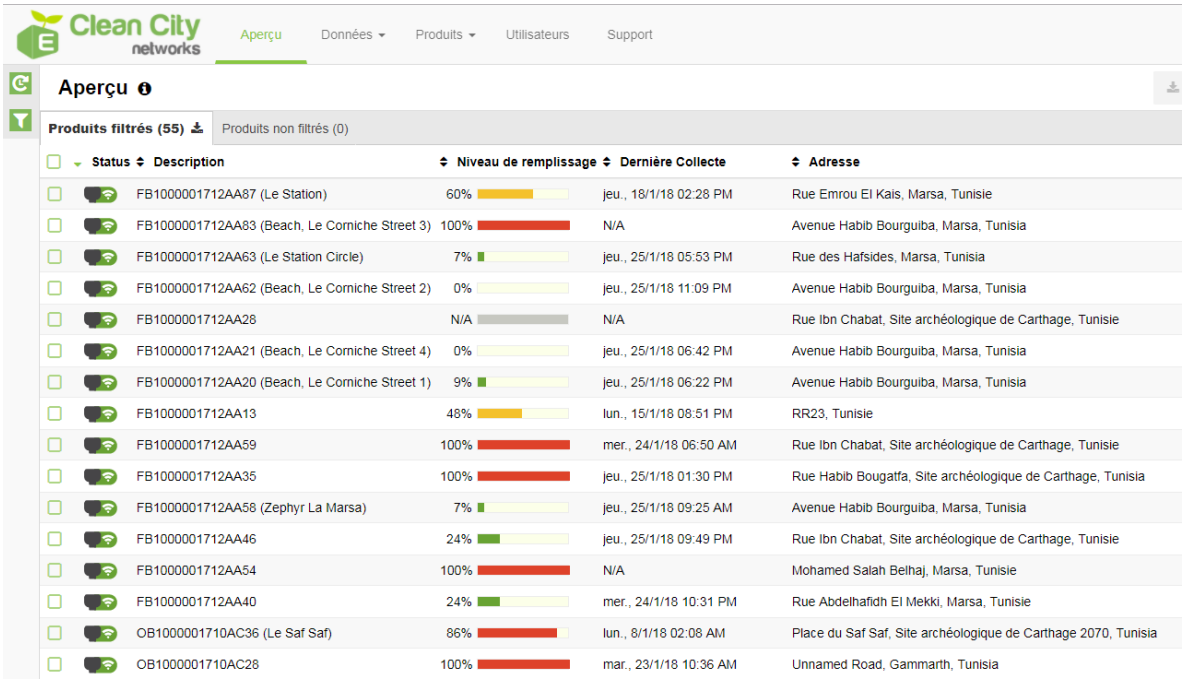






Figure 42. Monitoring of CleanCAPs in La Marsa



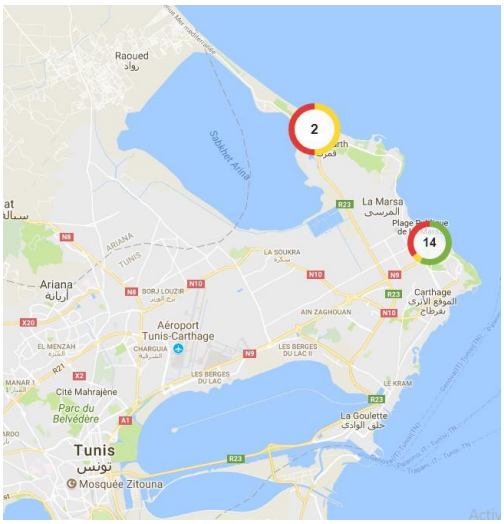
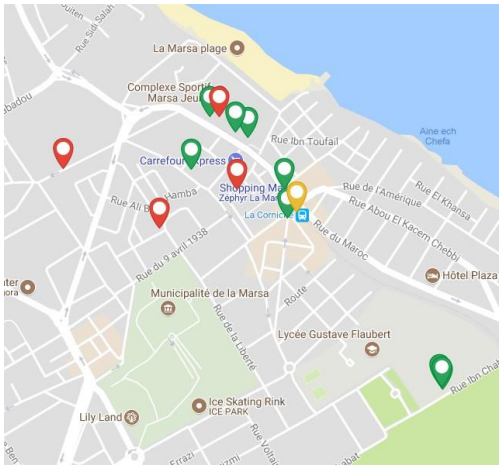
Status	Description	Niveau de remplissage	Dernière Collecte	Adresse
	FB1000001712AA87 (Le Station)	60%	jeu., 18/1/18 02:28 PM	Rue Emrou El Kais, Marsa, Tunisie
	FB1000001712AA83 (Beach, Le Corniche Street 3)	100%	N/A	Avenue Habib Bourguiba, Marsa, Tunisia
	FB1000001712AA63 (Le Station Circle)	7%	jeu., 25/1/18 05:53 PM	Rue des Hafsides, Marsa, Tunisia
	FB1000001712AA62 (Beach, Le Corniche Street 2)	0%	jeu., 25/1/18 11:09 PM	Avenue Habib Bourguiba, Marsa, Tunisia
	FB1000001712AA28	N/A	N/A	Rue Ibn Chabat, Site archéologique de Carthage, Tunisie
	FB1000001712AA21 (Beach, Le Corniche Street 4)	0%	jeu., 25/1/18 06:42 PM	Avenue Habib Bourguiba, Marsa, Tunisia
	FB1000001712AA20 (Beach, Le Corniche Street 1)	9%	jeu., 25/1/18 06:22 PM	Avenue Habib Bourguiba, Marsa, Tunisia
	FB1000001712AA13	48%	lun., 15/1/18 08:51 PM	RR23, Tunisie
	FB1000001712AA59	100%	mer., 24/1/18 06:50 AM	Rue Ibn Chabat, Site archéologique de Carthage, Tunisie
	FB1000001712AA35	100%	jeu., 25/1/18 01:30 PM	Rue Habib Bougatfa, Site archéologique de Carthage, Tunisia
	FB1000001712AA58 (Zephyr La Marsa)	7%	jeu., 25/1/18 09:25 AM	Avenue Habib Bourguiba, Marsa, Tunisia
	FB1000001712AA46	24%	jeu., 25/1/18 09:49 PM	Rue Ibn Chabat, Site archéologique de Carthage, Tunisie
	FB1000001712AA54	100%	N/A	Mohamed Salah Belhaj, Marsa, Tunisie
	FB1000001712AA40	24%	mer., 24/1/18 10:31 PM	Rue Abdelhafidh El Mekki, Marsa, Tunisie
	OB1000001710AC36 (Le Saf Saf)	86%	lun., 8/1/18 02:08 AM	Place du Saf Saf, Site archéologique de Carthage 2070, Tunisia
	OB1000001710AC28	100%	mar., 23/1/18 10:36 AM	Unnamed Road, Gammarth, Tunisia

Figure 42 displays the data provided by the CCN website. The first page exhibits the total number of CleanCAPs installed as well as the number of active sensors (all 50 sensors are depicted on the CCN platform, but 16 active sensors were tracked and monitored for feasibility analyses). The active sensors shown in the figure above are further illustrated on the maps below. As previously explained in the CCN Manual—Step by Step Guide, green indicates a fill-level of 0-30%, yellow indicates 31-70%, and red 71-100%.

Figure 43 in the following page shows the location of each active CleanCAP. The first map on the top left corner shows that there are 16 sensors in Tunisia, which is further zoomed in on the second map in the top right corner. The two maps located on the bottom half of the figure exhibit a further fixated photograph of the specific location of the sensors. The color-coordinated markers constantly monitor and indicate the fill-levels of each CCP in real-time.

Additional data and graphs (data waste generation, daily fill rate, total number of collections, overflow frequency, and collection efficiency) that are provided by CCN have been assessed in the Quantitative and Qualitative Analyses sections.

Figure 43. Map of CleanCAPs Indicated on CleanCityNetworks

Location of CCP within Tunisia	Location of CCP within La Marsa
	
Location of CCP Zoomed In (Cluster 1)	**Location of CCP Zoomed In (Cluster 2)**
	

VIII. Road Map

Proper implementation of the proposed solution is similar to that of any other smart city solution in that it requires frequent utilization of a cyclic methodology. The proposed solution will allow the discovery of problems that are not inherently visible. This visualization and filtering of data will provide insights into the underlying cause of the waste problems in La Marsa. Subsequently, we can then formulate recommendations and road map strategies to remedy the issues.

Figure 44. Early, Mid, Late Stage Approaches for La Marsa

Early Stage	✧ Deploy fill-level sensor in designated target areas; collect and monitor data ✧ Assess and track performance while gaining insights ✧ Evaluate La Marsa's waste management issues; contact local stakeholders
Mid Stage	✧ Use CCN data to modify collection schedules and optimize routes ✧ Ensure that there is a decrease in operational costs & increase in efficiency
Late Stage	✧ Analyze feasibility of pilot project ✧ If pilot project deems successful, consult with municipality for full deployment ✧ Strategize road maps for future steps; provide full support after F/S

- ***The Early Stage***

The goal of the Early Stage is to collect data for better visibility of La Marsa's waste collection operations in order to reveal insights into waste generation and collection patterns. Such data will help demonstrate that CleanCAPs (CCP) and GPS trackers (CTM) may be helpful in improving the city's waste management operations. As municipalities often contract waste management companies for collection operations, this stage will also increase transparency and accountability. By retrieving and analyzing waste generation and collection data, La Marsa's waste management operations may achieve optimized efficacy while also reducing greenhouse gas emissions and operational costs.

During the on-site inspection phase, several key agendas were appointed and extensively discussed. Key issues with the current waste management system as well as any areas needing improvement were duly noted and prioritized. These areas were specifically targeted during the implementation and incorporated into the road maps.

- ***Mid Stage***

The goal of the Mid Stage is to improve La Marsa's waste management operations using insights gathered in real time throughout a given period. The software system provided data for all 50 sensors installed, but only 16 sensors were evaluated for La Marsa's feasibility study. These sensors

were installed during the first and second installation periods thereby collecting data for several weeks (30-80 days) compared to those that were installed thereafter that were only able to accumulate data for 7-20 days. These data sets were assessed for La Marsa's pilot project to observe the amount of waste generated hourly and daily, how many times waste was collected each day, and how frequent waste overflowed in the selected target areas, which were strategically chosen due to high number of foot traffic and high population or tourist density. Such insight was utilized to evaluate the current situation and calculate the benefits achieved from using a smarter solution.

- ***Late Stage***

The goal of La Marsa's Late Stage plan is to strategically execute operational policy changes based on conclusions drawn from the collected data and proposed insights. During this stage, municipalities will now be equipped with predictive data and test results to finally deep-dive into the identified issues to reach the targeted efficiency level. With such data, La Marsa's waste management stakeholders will have clear fiscal, environmental, or operational goals they wish to achieve.

Long-term management plans may be devised based on experiential patterns and pre-established collection schedules. The end goal is to apply policy changes to achieve targeted levels of operational efficiency as well as qualitative goals. The proposed road maps may maximize the impact of transforming La Marsa's pilot project into a comprehensive solution—not just for other neighboring areas of La Marsa, but possibly for Tunisia as a whole. The objectives of the Late Stage are immersed in the road map strategies for subsequent steps to be taken following the pilot project implementation. The road maps are elaborated below:

1. Implementation of Solution System in Central Government
2. Implementation of Pilot System as Business Model
3. Expansion of Other Smart Solution Devices

1. Implementation of Solution System in Central Government

It is always difficult to change an already established field with a new system or technology. A significant amount of time and effort is required in order to spawn change especially to a field such as the waste management industry where systems for processing and refinement have been in operation over many years of its existence. Through extensive research of La Marsa's waste management systems and issues that have been proposed by the municipality administrators and stakeholders, we were able to conclude that there is a dire need for improvement in the waste management procedures, particularly waste collection.

Just by reducing day-to-day errors and redundancies that were undergoing a repetitive cycle, La Marsa would be able to create a *smarter* system of operation and generate significant economic, environmental, and societal benefits. Additionally, adopting new technology by integrating ICT and IT infrastructures have been eagerly promoted in La Marsa, and smart waste management is one avenue to induce technological innovation and economic development.

Through the CleanCAP sensors, GPS trackers, and real-time analytics platform, new patterns of waste generation and disposal may continuously be monitored and analyzed. With this data, compelling support and strong reinforcement pushing towards waste management and smart city establishments may be further justified, allowing La Marsa to be a pioneer in this sector opening more possibilities and doors for financial support and pilot project suggestions. The introduction of smart, efficient technologies has the ability to renovate the city, improve public hygiene, and generate economic development. With La Marsa at the forefront of such change, Tunisia's transformation may be even more stimulated allowing continuous growth and expansion.

2. Implementation of Pilot System as Business Model

The process after waste collection has always been an issue and a necessary field to be developed. Thus, newer industries have emerged in recent times. Key points of those industries include: creating recycled products, producing energy using recycled materials, recycling waste, and producing fertilizer and compost through food waste. These fundamental precedents demonstrate that the waste industry still encompasses a significant development potential, which is the reason for the growing interest and much drawn attention to the current waste industry.

New markets can be created by integrating a Smart City project with other ICT technologies in Tunisia. The integration can be with another form of technology or the waste industry itself. For instance, a new type of waste bin was installed in residential areas of La Marsa in collaboration with a European firm which included a GPS system in the collection vehicles to constantly monitor the collection process. These projects were initially launched in efforts to develop the local technological

sector, but these initiatives also played a role in enhancing the country's economy and environment. The proposed GPS system in the To-Be Model, CleanTRACKER, is very similar to the one already installed. With the Clean City Networks software, however, further enhanced data including route optimization and in-vehicle data may be provided. This solution will deliver a customized solution that is specific to each pickup driver's route and schedule history.

Smart City technologies and systems are expected to grow exponentially within the next decade all around the world, and many cities have already begun taking initiatives and implementing such infrastructures. With these implemented technologies, La Marsa can present itself as a Smart City in Northern Africa stimulating great economic growth and global standing. Not only will it attract more foreign nations to its already growing tourism market, but it will also strengthen La Marsa's ability to adapt to the rapidly changing technology and assist in the city's development and globalization.

3. Expansion of Other Smart Solution Devices

Through the combination of the CleanCAP sensor hardware and CleanCityNetworks software, a wide variety of data can be collected for analysis including waste generation, collection frequency, overflow volume, overflow frequency, pickup schedules, battery levels, map locations, as well as fill-levels of the waste bins. The sensors were proposed as the most suitable solution for La Marsa due to its cost-effectiveness and high efficiency. In conjunction with other types of waste collection technologies, such as a solar-powered trash compactor that is another type of commonly used waste collection system, the rate of efficiency and optimization is bound to increase dramatically. Both tools provide enormous benefits in the waste management process, each encompassing individual advantages, but the consolidation of various types together has the potential to induce synergistic impacts.

IX. Budget

Table 44. Smart Waste Management System Budget

Category		Quantity	Price per Unit	Duration	Subtotal
Software	CleanCityNetworks	50	$15/month	12 months	$9,000
	Telecommunication				
	Wireless Network				
Hardware	CleanCAP	50	$150	N/A	$7,500
	Brackets	35	$25		$875
	Batteries	50	$10		$500
	Magnet	2	$5		$10
	Tools	1	$350		$350
	CleanTRACK	5	$170		$850
Maintenance	--	50	$15	5 years	$3,750
Total (USD)					**$22,835**

** Costs are indicated in US Dollars ($); N/A = Not Applicable*

The city of La Marsa is a popular tourist destination for many tourists both internationally and domestically. The city has actively implemented various IoT elements as an effort to maintain its inflow of tourists and gain additional attraction. The main objective of implementing the pilot project in La Marsa is to introduce a smart waste management solution that will infuse economic and environmental benefits to improve waste management efficiency. The pilot system aims to reduce La Marsa's operational costs by eliminating unnecessary pick-ups, providing transparency in the waste management practices, and increasing operational efficacy in the waste collection chain thereby reducing costs and labor associated with such services.

The overall scope of the project incorporated a comprehensive approach with current assessments of La Marsa's waste management operations, thorough investigation of the problems and areas that need improvement, strategic assignment of the deployment areas, and continuous surveillance of data collection to keep track of La Marsa's waste management operations. For the 2017 F/S pilot program in La Marsa, a total of 50 CleanCAPs and 5 CleanTRACK modules have been installed. These numbers were considered appropriate for the one-year pilot project taking into consideration the budget and case studies of analogous scale as La Marsa. A deployment volume of less than 50 CleanCAPs might have generated inadequate data for statistical and diagnostic analyses, but more than 50 might have been too pervasive for La Marsa. Additionally, the radius where the target areas of deployment were appointed was relatively nearby each other, so 50 CleanCAPs distributed along

these areas seemed quite suitable. Therefore, 50 CleanCAPs and 5 trackers were considered to be most fitting for La Marsa's pilot project.

The hardware cost for a single unit of CleanCAP sensor was $150, and a single CleanTRACK module was $170. Several components (including brackets, batteries, magnets, and tools) were included in the budget as shown in Table 44. The total cost for 50 units of CleanCAPs were $9,235 USD and the total cost for 5 modules of CleanTRACK were calculated to be $850 USD. The total hardware cost, therefore, was computed to be $10,085 USD. Additional hardware devices were provided to La Marsa in case of future emergencies such as loss or damage free of charge.

In order for the CleanCAPs and CleanTRACK modules to be monitored in real-time and ensure efficient optimization, it is imperative that they be used in conjunction with the CleanCityNetworks software, which allows the waste data to be collected and analyzed. The subscription rates for the CCN software varied from a monthly basis to a 3 or 5-year plan, but the 12-month plan was selected for this short-term feasibility project.

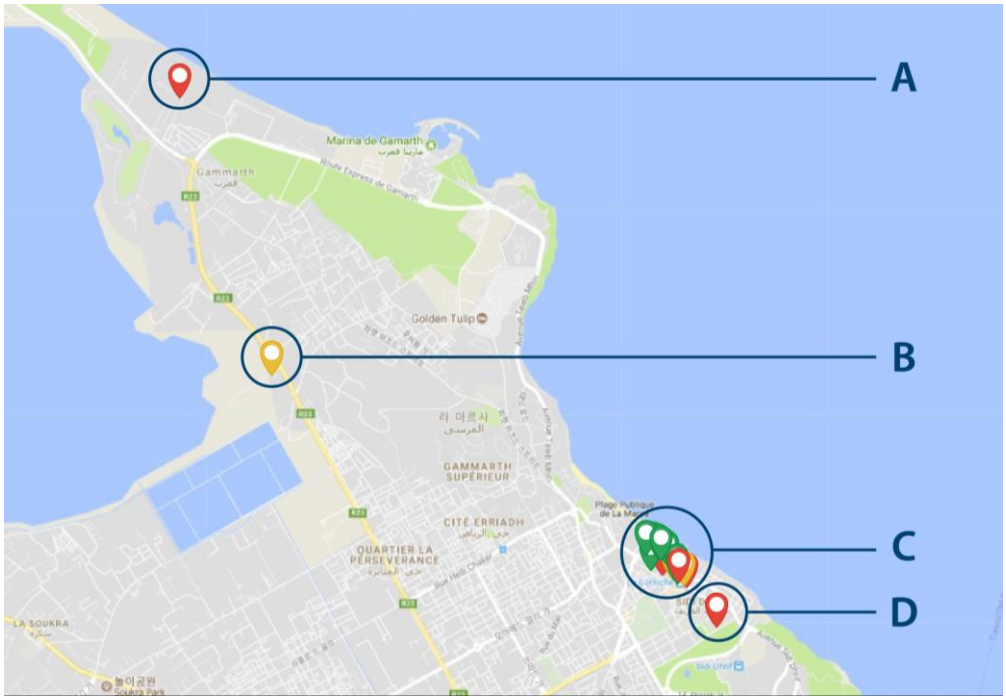
The software cost incorporated annual subscription of CleanCityNetworks (CCN), telecommunication, and wireless network fees. The price per unit of CCN was $15 per month. Thus, for a 12-month subscription of CCN software service for 50 units, the total cost was $9,000 USD. This price included telecommunication and wireless connectivity fees. Despite the completion of hardware installation in a period of 3 months, the CleanCityNetworks subscription was extended to twelve months (until December 31, 2018) in order for La Marsa to continue retrieving data for further analyses on the city's waste management status.

Upon termination of the twelve-month subscription, future use of the solution will be discussed to provide subsequent measures that will further enhance La Marsa's waste management system and provide further financial benefits. A reduction in waste collection cycles further represents a reduction in driven kilometers, which has a direct correlation on labor, fuel, and maintenance costs. With fewer collections, La Marsa can also expect to see a decrease in greenhouse gas emissions, noise pollution, and road destruction. Not only will these impacts be beneficial for the residents, but a smaller budget allocated for waste collections will also have an impact on local taxes. The influence of such effects will start from a small town that has the potential to quickly spread to the entire city and eventually throughout the entire nation. New technology can bring systematic transformation on a global scale and La Marsa's pilot system may spur Tunisia's transformation by actively spearheading technological progress.

X. Feasibility Analysis

1. Quantitative Analysis

Figure 45. Map of CleanCAP Locations



As shown in Figure 45, the locations have been labeled A-D in accordance with clustering of deployment sites. Among the 50 CleanCAPs that were installed, 16 were selected for quantitative analyses. These 16 were chosen due to their adjacent locations and were the first ones to be installed, thus retrieving continuous data. Further insights will be gained from all 50 CleanCAPs throughout the pilot project period. The following table indicates the serial number for each specific CleanCAP evaluated and the location (labeled A-D) with the corresponding reference number (labeled 1-5).

Table 45. Serial Number and Corresponding Reference Number

Location	Reference	Serial No.
A	1	OB1000001710AC28
B	1	FB1000001712AA13
C	1	FB1000001712AA40
	2	FB1000001712AA54
	3	FB1000001712AA58
	4	FB1000001712AA87
	5	OB1000001710AC36
D	1	FB1000001712AA46
	2	FB1000001712AA59

Table 46. Daily Waste Analysis via CCN					
Location	**Reference**	**Waste Bin Capacity (L)**	**Waste Generation (L)**	**Overflow Frequency**	**Collection Frequency**
A	1	660	56.45	0.27	0.19
B	1	120	39.96	0.29	0.12
C	1	660	103.61	0.29	0.2
	2	660	3.82	0	0
	3	70	71.87	0.51	0.4
	4	120	58.72	0.62	0.35
	5	120	12.55	0.04	0.11
D	1	120	48.92	0.17	0.33
	2	120	5.54	0.02	0.02

The daily rates of waste generation, overflow frequency, and collection frequency were measured and recorded for each CleanCAP (Table 46). With the computed data, implementation effects before and after the installation of smart waste management solutions were further assessed to observe the expected effects with the smart cap sensors. Pre-implementation waste generation data was calculated using the waste generation data provided in Section IV—Municipal Waste Environment Analysis (38,648L per year; 105.89L per day). Overflow and collection frequency data was based on the assumption that each bin would overflow twice a day with collection schedules occurring once a day (Table 47).

Table 47. Expected Outcomes with Smart Waste Management Solution				
Category	**Location**	**Pre-Implementation**	**Post-Implementation**	**Expected Effects**
Waste Generation (L)	A	105.89	56.45	49.44
	B	105.89	39.96	65.93
	C	529.45	250.57	278.88
	D	211.78	54.46	157.32
Overflow Frequency	A	2	0.27	1.73
	B	2	0.29	1.71
	C	10	1.46	8.54
	D	4	0.19	3.81
Collection Frequency	A	1	0.19	0.81
	B	1	0.12	0.88
	C	5	1.06	3.94
	D	2	0.35	1.65

** Daily rate multiplied by 5 for Location C; multiplied by 2 for Location D*

Figure 46. Benefits of Smart Waste Management Solution			
Location	**Waste Generation**	**Overflow Frequency**	**Collection Frequency**
A	53%	85%	79%
B	74%	95%	83%
C	63%	86%	88%
D	47%	87%	81%
Average	***60% Reduction***	***88% Reduction***	***83% Increase***

As displayed in Figure 46, the advantages upon implementation of the smart waste management solution system have been assessed and calculated. Waste generation is shown to have reduced by 60%, overflow frequency by 88%, and collection frequency has shown to drastically increase by 83%.

The rates of overflow and collection have changed significantly, and the impacts of implementing the solution system is expected to further escalate with the addition of the tracker system. Collaborating with other smart technologies such as the solar compacting waste bins (CleanCUBES), as mentioned in the road map, will provide a synergistic effect on the expansion of benefits listed above.

2. Qualitative Analysis

Table 48. Population Distribution of Tunisia		
Name	**Status**	**Population (2014)**
Tunis	**Governorate**	**1,056,247**
Bab El Bhar	Delegation	36,210
Bab Souika	Delegation	29,185
Carthage	Delegation	24,216
Cite El Khadra	Delegation	35,173
Djebel Jelloud	Delegation	23,638
El Hrairia	Delegation	110,184
El Kabaria	Delegation	86,024
El Menzah	Delegation	41,830
El Omrane	Delegation	42,208
El Omrane Superieur	Delegation	55,513
El Ouardia	Delegation	32,147
Ettahrir	Delegation	21,709
Ezzouhour	Delegation	40,728
La Goulette	Delegation	45,711
La Marsa	Delegation	92,987
Le Bardo	Delegation	71,961
Le Kram	Delegation	74,132
Medina	Delegation	21,400
Sejoumi	Delegation	33,870
Sidi El Bechir	Delegation	27,749
Sidi Hassine	Delegation	109,672
Tunisie [Tunisia]	**Republic**	**10,982,476**

According to the 2014 Census, La Marsa municipality makes up for roughly 9% of the entire population of the capital city, Tunis, which is located only 25 kilometers away. La Marsa has a geographic area of 30.6 km² and a population density of 3,037 people per km². Generally, we recommend 1 CleanCAP unit for every 350-400 people per km². With that as the standard, we recommend between 233-266 units to be deployed in La Marsa for a proper implementation.

Table 49. Distribution of La Marsa Districts		
Name	**Status**	**Population (2014)**
La Marsa	**Commune**	**92,987**
El Bahr El Azrak	Sector	18,577
Er Rmila	Sector	14,210
Gammarth	Sector	9,079
Gammarth Superieur	Sector	4,299
La Marsa El Montazeh	Sector	6,915
La Marsa Erriadh	Sector	6,047
La Marsa Hadayek	Sector	6,551
La Marsa Medina	Sector	14,604
La Marsa Plage	Sector	6,498
Sidi Daoued	Sector	6,207
Tunis	**Urban Agglomeration**	**2,368,810**

La Marsa is separated into 10 sectors with several sectors more heavily populated in comparison to others. As a result, we recommend that our CleanCAP units be distributed in accordance with the population density and foot traffic. Exceptions to this case would be areas of high foot-traffic due to attractions like recreational centers, shopping malls, restaurants, hotels, etc. For example, The Saf-Saf district in the heart of La Marsa Plage sector is known for the high amounts of foot-traffic due to tourists visiting famous locations like the Cafe de Flore.

Moreover, several impacts upon implementation of the smart system in La Marsa is expected:

1. **Improved quality of life:** The solution will replace inefficient waste collection methods and unnecessary pickup routes within the CleanCAPs installed in La Marsa, which will subsequently enhance the management processes and work environment
2. **Reduced environmental impact:** Waste collection traffic is expected to decrease by 83%, which will also reduce CO_2 (GHG) emissions.
3. **Reduced noise and pollution:** With the reduction in waste overflow and increase in collection frequency, La Marsa's citizens will show an increased satisfaction and pride due to increased cleanliness and less pollution.
4. **Increased sanitation and public health:** The people of La Marsa will also feel satisfied with the increase in public sanitation and improved efficiency in waste collection methods and procedures
5. **Promotion of sustainable economic development:** Through the exposure of smart waste management technology and infrastructure, economic development efforts will further expand via environmentally sustainable methods

3. Technical Analysis

The ultrasonic fill-level sensor (CleanCAP) was proposed because it could be retrofitted to any type of existing container. The CleanCAP, CleanTracker, and CleanCityNetworks (CCN) serve as the underlying resource management platform designed to optimize efficiency within the waste collection value chain. They provide a cloud-based software solution that enables mass monitoring and collection of data from transmitting sensors, which can then be analyzed to extract actionable insights.

The first enhancement to CCN provided at the late phase of roll out is fill-level prediction. A predictive model of the fill-level of each CleanCAP is constructed by training a recurrent neural network (RNN) with 3+ months of fill-level history. These RNNs use the current time, date and preceding waste generation to predict the fill level of each receptacle up to twenty-four hours ahead with above ninety-percent accuracy. These predictions are easily visible via the CCN interface where they can be utilized by the operator to decide which receptacles require collection on a given day. Additionally, the predictions can be used by our route optimization tool to automatically formulate efficient routes.

For the CleanCAPs installed in La Marsa, which occurred from November 2017 to January 2018, CCN was able to provide predictive analyses after generating RNN for the initially installed CCPs. The accuracy of CCN's predictive analysis algorithm is further enhanced with the accruement of data—the longer CCN collects data, the more accurate CCN is with forecasting fill-levels. In order to provide a more accurate predictive model for La Marsa, further data may need to be accumulated.

In order to analyze the technical feasibility of La Marsa's pilot system, CCN has generated RNN for the initially installed CleanCAPs to predict future fill levels of La Marsa's waste. Among the CleanCAPs installed in La Marsa, two were selected for comprehensive technical analysis. These two sensors were selected because they were amongst the sensors that were initially installed and were thus able to retrieve and analyze data that was not only extensive but clearly discernable as well. The serial numbers for the two sensors are as follows: FB1000001712AB80 and FB1000001712AA97.

As a means of evaluating the technical feasibility of the project, the technical specifications of the CleanCAP were utilized as a measure of technological analysis. The parameters listed in Table 36 (Technical Specifications of CleanCAP) were compared against La Marsa's CleanCAPs, and the following variables were evaluated:

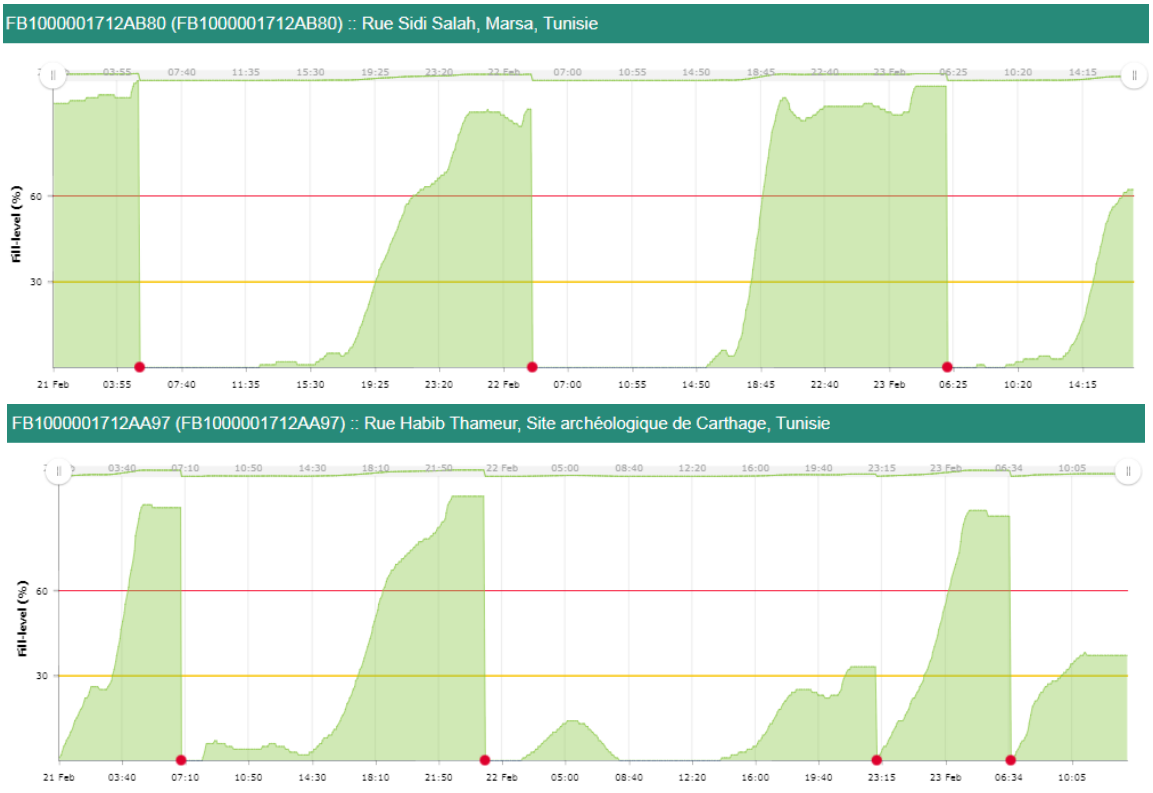
- Fill-level sensor
- Fire detection sensor
- Range
- LPWAN: LoRa, NB-IoT

- Battery life
- Material
- Signal Strength
- GPS tracking system

Fill-level Sensor

The fill-level graph for the two CleanCAPs were assessed. This data illustrates the volume and percentage of waste detected every 10 minutes, where the information is reported to CCN every 6 hours. The sensing interval, which may be customized according to the necessary cycle for each location, was appointed to sense every 10 minutes in order to meticulously observe the fill-levels for waste collection in La Marsa. This not only corroborates that waste collection is occurring (which is an important indicator that clearly shows and affirms the visibility of waste management), but further demonstrates that the amount of waste being collected is occurring at relatively similar frequencies (which shows that waste is being collected on time at the optimized schedule).

Figure 47. Fill-level Sensor Data of La Marsa



This information also depicts when waste is filled, which allows the pickup drivers to select which bins to collect first and which may be postponed for later retrieval. CCN also indicates the location of each installed bin, which allows the drivers to select the most optimized routes for each day. Route optimization will be more useful in designating the routes through prediction model analysis.

Fire Detection Sensor

In addition to the sonar fill-level sensor, CleanCAPs also have a fire detection sensor with a specific temperature algorithm. This type of sensing system allows the CleanCAP to detect when the temperature rises above a certain temperature during a specific time interval. Two types of fire sensing algorithms are incorporated: (1) when the temperature rises above 80° Celsius for over 200 seconds, and (2) when the temperature rises 3° Celsius in a minute or if the temperature rises by 1° Celsius continuously for 5 minutes. The following chart is from a manual provided by the Support Team at Ecube Labs which depicts the different type of errors (referring to irregular, aberrant, or unusual events that require immediate attention).

Figure 48. Fire Detection Sensor Data of La Marsa

Error Type	Description
Fire1	When the unit's temperature rises above 80 degrees Celsius for over 200 seconds.
BinLidTurnedOver	When the top lid on which the sensor is installed is left turned over.
MagnetError1	When a magnet is attached to the unit continuously for longer than one minute.
USWCommError	When the ultrasonic sensor is defective and unable to sense.
BinFellDown	When the bin fell down to the side or the front.
MagnetError2	When a magnet is attached and detached to the unit 10 times consecutively.
Fire2	When the unit's temperature rises 3 degrees Celsius in a minute, or if the temperature rises by 1 degree Celsius continuously for 5 minutes.

This feature plays a critical role in alerting La Marsa's waste management during high temperature situations to help prevent combustion or explosion of waste bins that may potentially cause harm to the local buildings or citizens. Without this system, fire events may not be detected or may be detected too late. Thus, the fire detection sensor provides a way to avert potential emergencies and respond to such situations quickly and effectively.

Range

The range detected by the ultrasonic sensor is shown to be 2 to 400 cm (0.7" to 157"). The significance of this spectrum lies in the ability of the CleanCAP to be affixed on any type of waste bin (from small, household bins to large, industrial collection bins) and effectively transmit data on the amount of waste. Once the size and volume of the bins are registered in the system, CCN will be able to calculate the distance from the sensor and the bottom of the bins (which is the overall height of the bin) and subsequently calculate the distance from the sensor and the waste accumulated. By measuring the distance between the container and its content, the range provides important data on the quantity of waste that may be monitored in real-time.

LPWAN: LoRa, NB-IoT

With respect to the cellular communication interface, the cloud-based service CCN is compatible with 2G, 3G, LTE, and LPWAN (NB-IoT and LoRa). The CleanFLEX sensors may connect via NB-IoT with successful connection and performance being reported in South Korea, and LoRa connectivity may be tested if this type of cellular infrastructure is to be implemented in the future. There is a growing interest in LPWAN (Low-Power Wide-Area Network), which is a wireless telecommunication network designed to allow long range communications at a low bit rate allowing connections to carry more data using less power at a cheaper cost. If La Marsa's ICT network were to be expanded with this type of connection, CleanCAPs would be able to accommodate for such transformation and have no difficulty transmitting data from the waste bins to the CCN server. The all-embracing connective capacity will allow extensive growth and expansion without any confinements in terms of cellular and network connection.

Battery Life

In order to examine whether or not the components of the model system would endure throughout the pilot project period, the types and lifespan of the batteries were investigated. The units typically encompass an average lifespan of approximately 5 years, depending on the telecommunication signal and telecommunication interval. In other words, a weaker telecommunication signal would result in higher voltage consumption where the CleanCAPs would continuously make an effort to connect to the telecommunication server thereby depleting the battery life. Additionally, if the telecommunication interval is high, where the sensing interval is set at a high frequency (sensing every 10 minutes compared to 30 minutes or more), then the battery usage would further deplete. Figure 49 demonstrates the voltage of a CleanCAP before telecommunication with the server (yellow) and the voltage of a CleanCAP during telecommunication with the server (orange).

Upon analysis of La Marsa's CleanCAP and CleanTRACK batteries, with average telecommunication signal and interval, the longevity of the battery was computed to last roughly 4-5 years. Since the duration of the pilot project was designated for one year, the battery will be more than capable of performing at high capacity throughout the one-year period.

Additionally, the batteries are interchangeable and are compatible with two C-type batteries (that are commonly found in supermarkets around the world, including Tunisia). Supplementary batteries were also provided just in case batteries would need to be replaced. Therefore, the long battery lifespan ensures technical longevity in terms of continuous performance output without any signal interruption.

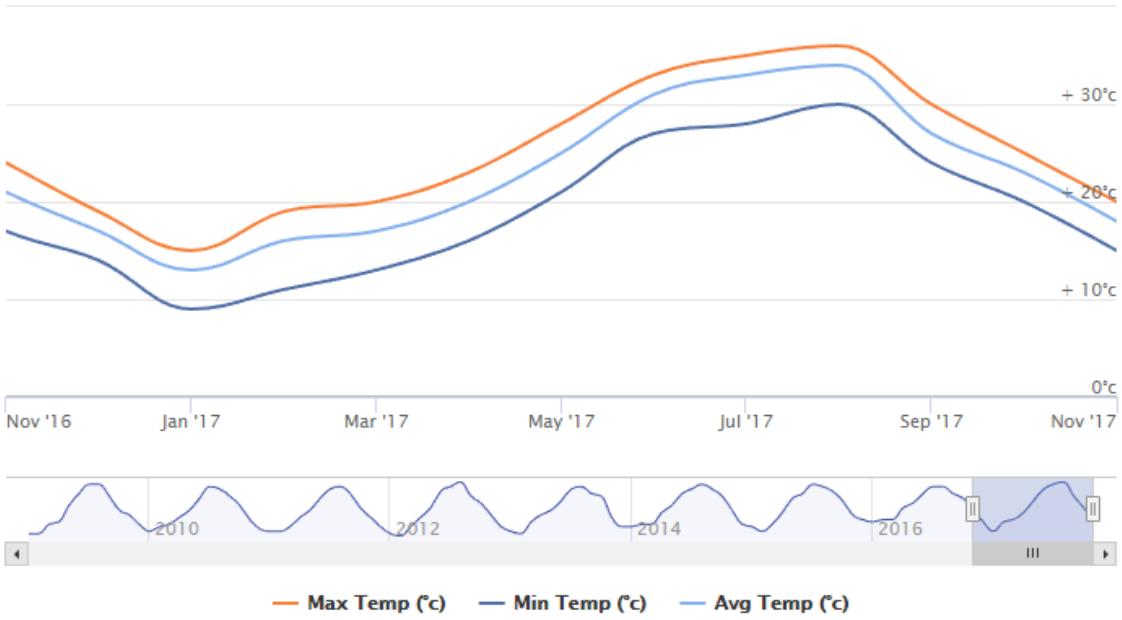
Figure 49. Battery Life Data of La Marsa

Material

The type of material for a model system acts as a crucial indicator for technical analysis, particularly in regards to hardware durability. The CleanCAP is composed of high impact ABS and Polycarbonate, which is an opaque thermoplastic and amorphous polymer that is highly resistant to heat and easily recyclable. ABS is highly resistant to chemical attack and is a light-weight, cost-effective material, whereas Polycarbonate is highly heat-resistant and is able to withstand a wide range of temperature fluctuations. The coating is strong enough to endure harsh climate conditions (shown to provide high performance output even at -30° to 80° Celsius).

According to the annual average of La Marsa's temperature spectrum, the temperature ranges from 10° to 35° Celsius throughout the year. Figure 50 illustrates the temperature fluctuations from November 2016 to November 2017. In consonance with this trend, the pilot project sensors would have no complications withstanding La Marsa's temperature range as the scope (10° to 35° Celsius) lies within the extreme temperature range (-30° to 80° Celsius).

Figure 50. Annual Average Temperature of La Marsa



World Weather Online, La Marsa

Signal Strength

Analysis of the signal strength, which is a measure of communication signal from the sensor to the CCN software, is a fundamental and paramount role player in signifying that transmission of data is occurring efficiently and in real-time. The CleanCAPs are shown to be compatible with 2G, 3G, 4G, LTE, GPRS, and LoRa. For La Marsa, the wireless connection is using a GPRS system, which transmits data at a lower cost than satellite or LoRa options with a much lower latency time.

The power of the communication signal of La Marsa's caps were evaluated in order to examine the efficacy of data transmission. The scope of the signal strength ranges from 0 to 3,500 where values over 1,000 are shown to encompass good transmission. As shown in Figure 51, La Marsa's CleanCAPs were reported to transmit data with a signal intensity of 2,100 to 3,100 on average (indicated in the far right column).

Figure 51. Signal Strength Data of La Marsa

FB1000001712AB80

Date	USW	RT	Err	Curr	Volt	Volt2	AT	Sens
01/23/18 06:33:20 PM (GMT+09:00)	010,000,000,010,000	Boot(0)	N/A	CommTimeout, Reset	3.2	3.43	24	3099
01/23/18 03:02:45 PM (GMT+09:00)	189,190,189	Event(3)	N/A	GPSTimeout	3.4	3.66	0	2399
01/23/18 02:35:19 PM (GMT+09:00)	155,155,155,155,155	Boot(0)	N/A	Reset	3.3	3.41	0	2099
01/23/18 10:37:36 AM (GMT+09:00)	156,156,155	Event(3)	N/A	N/A	3.4	3.66	0	2599
01/23/18 10:18:16 AM (GMT+09:00)	156,156,156,157,157	Boot(0)	N/A	Reset	3.4	3.55	0	2699
01/23/18 06:26:56 AM (GMT+09:00)	999,999,999,999,999,999	Periodic(1)	N/A	N/A	3.3	3.66	0	2399
01/23/18 12:24:53 AM (GMT+09:00)	999,999,999,999,999,999	Periodic(1)	N/A	N/A	3.2	3.65	0	2399
01/22/18 06:22:49 PM (GMT+09:00)	155,155,155,155,155,155	Periodic(1)	N/A	N/A	3.3	3.64	0	2599
01/22/18 06:16:22 PM (GMT+09:00)	155,155,154,155,155,155	Periodic(1)	N/A	N/A	3.4	3.65	0	2499
01/22/18 06:09:56 PM (GMT+09:00)	155,155,155,155,155,155	Periodic(1)	N/A	N/A	3.3	3.65	0	2499
01/22/18 06:03:19 PM (GMT+09:00)	155,155,155,155,155,154	Periodic(1)	N/A	N/A	3.3	3.63	0	2499
01/22/18 05:56:43 PM (GMT+09:00)	155,155,155,155,154,154	Periodic(1)	N/A	N/A	3.3	3.65	0	2599

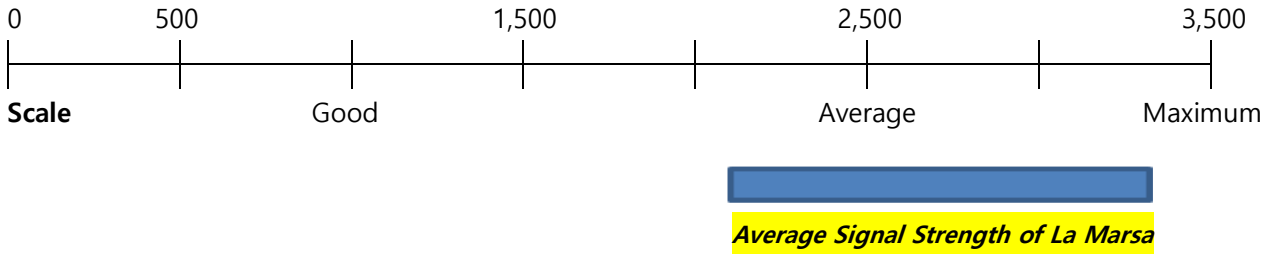
FB1000001712AA97

Date	USW	RT	Err	Curr	Volt	Volt2	AT	Sens
01/23/18 03:13:24 PM (GMT+09:00)	139,999,999,189,190	Event(3)	N/A	GPSTimeout	3.3	3.74	0	2599
01/23/18 02:35:41 PM (GMT+09:00)	156,155,155,156,156	Boot(0)	N/A	Reset	3.4	3.56	0	2399
01/23/18 10:38:39 AM (GMT+09:00)	156,156,156	Event(3)	N/A	N/A	3.4	3.72	0	2299
01/23/18 10:22:03 AM (GMT+09:00)	157,157,157,157,157	Boot(0)	N/A	Reset	3.4	3.65	0	2399
01/23/18 06:33:19 AM (GMT+09:00)	999,999,999,999,999,999	Periodic(1)	N/A	CommTimeout	3.4	3.75	16	2299
01/23/18 12:24:11 AM (GMT+09:00)	999,999,999,999,999,999	Periodic(1)	N/A	N/A	3.4	3.73	0	2399
01/22/18 06:21:47 PM (GMT+09:00)	156,156,155,156,155,155	Periodic(1)	N/A	N/A	3.5	3.72	0	2399
01/22/18 06:15:31 PM (GMT+09:00)	155,155,155,155,155,155	Periodic(1)	N/A	N/A	3.5	3.7	0	2599
01/22/18 06:09:04 PM (GMT+09:00)	155,156,155,155,155,155	Periodic(1)	N/A	N/A	3.5	3.71	0	2699
01/22/18 06:02:38 PM (GMT+09:00)	156,156,155,155,154,155	Periodic(1)	N/A	N/A	3.5	3.71	0	2699
01/22/18 05:56:23 PM (GMT+09:00)	155,156,155,155,155,155	Periodic(1)	N/A	N/A	3.5	3.71	0	2699
01/22/18 05:49:28 PM (GMT+09:00)	155,156,155,155,155,156	Periodic(1)	N/A	N/A	3.5	3.7	0	2299
01/22/18 05:43:02 PM (GMT+09:00)	155,155,155,155,155,155	Periodic(1)	N/A	N/A	3.5	3.72	0	2599

Signal Strength Index:

Numerical Value	0	1,000	2,500	3,500
Signal Strength	Minimum	Good	Average	Maximum

In accordance with the signal strength index, the following compass depicts the average signal strength of La Marsa, which has been shown to range from 2,100 to 3,100 for the two CleanCAPs reviewed. The blue bar demonstrates the average transmission of La Marsa's sensors. As a result, these data verify that the installed CleanCAPs in La Marsa have been performing above average providing high signaling output.



Average Signal Strength of La Marsa

GPS Tracking System

With the GPS tracking system, La Marsa's waste managers will be able to monitor their vehicles and protect the CleanCAPs and CleanTRACK Modules from theft and misuse. This monitoring system will allow the position of the collection vehicles to be tracked in real-time through the wireless network connections already compatible with CCN thereby reducing the need for expensive components or handling complex maintenance issues. The GPS tracking devices comprise of an external antenna that are not only accurate but can provide information such as fuel levels, temperature, navigation system, and fleet management, which allow La Marsa's waste management managers to ensure safe and efficient operation.

Technical Feasibility Conclusion

As a result, the compilation of the technical feature analyses of the CleanCAP and CleanTRACK Module technologies demonstrate that the system components are technically feasible for La Marsa's infrastructure. The fill-level sensor, fire detection sensor, range, connectivity, battery life, high impact coating material, signal strength, and GPS tracking system are all suitable and encompass benefits that collectively allow the pilot project system to be technologically feasible and advantageous for the city of La Marsa.

4. Economic Analysis

Table 50. Cost Breakdown (USD)

Year	CleanCAP	CleanTRACK	CleanCityNetworks	Maintenance	Total Cost / Year	Total Cost
2017	$9,235	$850	$9,000	$3,750	$22,835	
2018	--	--	$9,000	$3,750	$12,750	
2019	--	--	$9,000	$3,750	$12,750	
2020	--	--	$9,000	$3,750	$12,750	
2021	--	--	$9,000	$3,750	$12,750	**$124,835**
2022	--	--	$9,000	$3,750	$12,750	
2023	--	--	$9,000	$3,750	$12,750	
2024	--	--	$9,000	$3,750	$12,750	
2025	--	--	$9,000	$3,750	$12,750	

Table 51. Benefit Breakdown (USD)

Year	Fuel CR	Labor CR	Maintenance CR	Benefits / Year	Total Benefit
2017	$6,181.51	$10,989.35	$3,313.08	$20,483.94	
2018	$6,181.51	$10,989.35	$3,313.08	$20,483.94	
2019	$6,181.51	$10,989.35	$3,313.08	$20,483.94	
2020	$6,181.51	$10,989.35	$3,313.08	$20,483.94	
2021	$6,181.51	$10,989.35	$3,313.08	$20,483.94	**$184,355.44**
2022	$6,181.51	$10,989.35	$3,313.08	$20,483.94	
2023	$6,181.51	$10,989.35	$3,313.08	$20,483.94	
2024	$6,181.51	$10,989.35	$3,313.08	$20,483.94	
2025	$6,181.51	$10,989.35	$3,313.08	$20,483.94	

** Annual costs: Fuel - 32,850 TND ($13,736.69), Labor - 65,700 TND ($27,473.37), Maintenance - 14,400 TND ($6,023.78)*

** Cost reduction (CR) rate: Fuel - 45%, Labor - 40%, Maintenance - 55%*

Table 52. Cost-Benefit Analysis (USD)

Year	Undiscounted Flows			Rate	Discounted Flows			
	Costs	Benefits	Net	3% Disc	Costs	Benefits	Net	Cumulative
2017	-$22,835	$20,483.94	-$2,351.06	1.0000	-$22,835	$20,483.94	-$2351.06	-$2,351.06
2018	-$12,750	$20,483.94	$7,733.94	0.9709	-$12,379	$19,887.85	$7,508.85	$5,157.79
2019	-$12,750	$20,483.94	$7,733.94	0.9426	-$12,018	$19,308.16	$7,290.16	$12,447.95
2020	-$12,750	$20,483.94	$7,733.94	0.9151	-$11,668	$18,744.85	$7,076.85	$19,524.80
2021	-$12,750	$20,483.94	$7,733.94	0.8885	-$11,328	$18,199.98	$6,871.98	$26,396.78
2022	-$12,750	$20,483.94	$7,733.94	0.8626	-$10,998	$17,669.44	$6,671.44	$33,068.22
2023	-$12,750	$20,483.94	$7,733.94	0.8375	-$10,678	$17,155.30	$6,477.30	$39,545.52
2024	-$12,750	$20,483.94	$7,733.94	0.8131	-$10,367	$16,655.49	$6,288.49	$45,834.01
2025	-$12,750	$20,483.94	$7,733.94	0.7894	-$10,065	$16,170.02	$6,105.02	**$51,939.03**

** Discount rate of 3% was applied to Discounted Flows*

The economic appraisal was broken down into three sections: (1) Cost breakdown, (2) Benefit breakdown, and (3) Cost-Benefit analysis. We have compiled a comprehensive list of all the costs and benefits incorporated in the F/S pilot project. Costs included direct and indirect costs, opportunity costs, and the cost of maintenance and support for 5 years. Moreover, benefits included all direct and indirect revenues. A common unit of monetary measurement was applied to all items (calculated with USD). The range of costs and benefits was assessed from 2017, base year, to the year 2025. Quantitative comparison of the aggregate costs and benefits were utilized to examine whether or not the benefits outweigh the costs invested in the project. Such economic analyses would provide rational justification and numerical support for the viability of La Marsa's feasibility project.

The Cost Breakdown (Table 50) included the hardware, software, and maintenance costs. The total cost of ownership (TCO) was broken down into 10 categories—further itemization of each category is detailed in the Budget section and the sum of each category has been provided in the table. The total cost was $22,835 for 2017, which includes a one-time hardware fee, and $12,750 each year from 2018 onward. The cumulative project cost from 2017 to 2025 is estimated to be $124,835 USD.

The Benefit Breakdown analyzed the cost reduction in fuel, labor, and maintenance costs, which was calculated by multiplying the yearly costs with the rate of cost reduction. Annual costs of fuel consumption, labor, and maintenance were estimated to be 32,850 TND ($13,736.69 USD), 65,700 TND ($27,473.37 USD), and 14,400 TND ($6,023.78 USD), respectively. The Tunisian Dinar (TND) currency was converted to US Dollars (USD) according to the foreign currency exchange rate of April 2018 (1 TND = 0.42 USD; 1 USD = 2.40 TND). In order to quantify the benefits for each category, the average percentage of benefits calculated from previous waste management case studies with relatively similar sample sizes were used for comparison. The case study of Melbourne City Council, with an installment of 47 CleanCAPs, was shown to generate 45% savings in fuel consumption, 40% in labor, and 55% in maintenance costs. Taking into account that La Marsa's pilot project with 50 caps had a similar size deployment as Melbourne's case study, the same percentage of cost reduction was applied. The values shown in Table 51 indicate the financial cost savings after calculating the relative change of 45%, 40%, and 55% yielding $6,181.51 for fuel, $10,989.35 for labor, and $3,313.08 for maintenance costs. The total benefits generated from the model is projected to be $184,355.44 USD by 2025.

Table 52 shows the Cost-Benefit Analysis with a 3% discount rate. The net costs and benefits were summed providing a net present value (NPV) of $51,939.03 USD. A positive cash flow was observed upon implementation of the To-Be solution with an average of $6,800 USD accumulated with each subsequent year. This quantitative appraisal demonstrates that La Marsa's To-Be model is economically feasible and economically advantageous providing financial benefits and escalating net profit with every surpassing year.

XI. Conclusion

Although waste management services exist in nearly every community, the current operating standards have proven to be highly resource-intensive without much innovation. The inefficiency can be largely contributed to outdated manual collection methods and logistical processes that are devoid of efficient data-driven solutions. As cities around the world race to adopt new smart solutions, there has been a wave of innovation in a variety of city infrastructure ranging from connected transport systems and power grids to web-enabled monitoring of city infrastructure and services. Among these innovations, IoT-based hardware and software solution is a critical puzzle piece in every smart city initiative. Smart waste management does not simply entail emptying trash receptacles; it incorporates health, economic, and sustainability implications as well. From densely populated cities to smaller rural communities, waste management systems are an integral part of our businesses and public areas.

The primary objective of this Feasibility Study was to examine ways to keep La Marsa clean by implementing innovative means and methods of collecting waste and recyclables. The Feasibility Study has evaluated smart, IoT-integrated waste management technologies and their significance in the establishment of global smart city transformations. The overall scope of the project encompassed an in-depth analysis of the current status of La Marsa assessing the waste management procedures, current challenges and problems, adverse impacts of such management system, and municipality initiatives.

Upon evaluation of the current waste management system, a smart model has been designed and developed for La Marsa. The pilot project comprises of three main components including two hardware systems (CleanCAP, CleanTRACKER) and one software platform (CleanCityNetworks). Comprehensive analyses embodying quantitative, qualitative, and technical data have been examined post-installation. Several case studies have also been included to provide aggregated data that will provide insights for important waste management regulators. By reaching maximum efficiency and optimization of waste collection operations through innovative technologies, we are essentially helping ourselves and our neighbors live in a world that is more environmental-conscience.

The Feasibility Study includes the current As-Is analysis, pilot project implementation, future road map approaches, and feasibility analyses to help make a decision regarding whether or not the smart waste management solution is feasible for La Marsa. Additionally, a pilot project was implemented, which further demonstrated that a full phase implementation of the proposed model solution was technically and economically feasible in La Marsa. According to the qualitative analyses, the beneficial impacts upon implementation of the smart waste management solution system is reported to show a 60% reduction in waste generation, 88% reduction in overflow frequency, and

83% increase in optimized collection. Through daily and hourly waste collection assessments, CCN was able to provide extensive insights on La Marsa's current waste environment status.

In addition to the economic impacts, the environmental and societal benefits were also evaluated to explore how the To-Be model will influence the people of La Marsa and the environment. Providing a clean and safe environment, especially to enhance the city's tourism market expansion and development, were one of the priorities of the quantitative impact assessments. Several advantageous impacts were observed including improved quality of life, reduced greenhouse gas emissions, reduced noise and pollution, increased sanitation and public health, as well as increased promotion of sustainable economic development. These effects are not only environmentally-friendly but socially-beneficial; less waste on the streets and improved work environments will increase the people's overall level of satisfaction.

The economic appraisal evaluated the overall costs as well as revenues generated from fuel cost reduction, labor cost reduction, and maintenance cost reduction. The net present value after computing the costs and benefits were reported to be $51,939.03 USD by 2025, with an average of $6,800 USD accrued each year. The benefits significantly outweighed the associated costs and the impact of the F/S was shown to be positive. Each subsequent year after implementation generated positive benefits, demonstrating that the F/S is economically feasible and financially beneficial for the municipality of La Marsa.

In conclusion, each of these assessments were carefully considered for La Marsa and the 2017 WeGO Feasibility Study for the establishment of smart waste management solutions in La Marsa was shown to be highly feasible in many aspects. The proposed solution is shown to be economically beneficial, eco-friendly, and beneficial for the people and leaders of La Marsa.

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