QATAR UNIVERSITY

COLLEGE OF ENGINEERING

IMPROVING RESPONSE TIMES TO CUSTOMERS DRAINAGE COMPLAINTS IN QATAR

BY

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ABSTRACT

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Title: Improving Response Times to Customers Drainage Complaints in Qatar

Supervisor of Project: Tarek El Mekkawy

Public Works Authority of Qatar (Ashghal) is an independent body to design, deliver and manage all public buildings and infrastructure related projects of the State of Qatar. Ashghal consists of three main affairs: Building Affairs, Infrastructure Affairs, and Asset Affairs. In addition to two supportive affairs: Shared Services Affairs and Technical Support Affairs. Ashghal Asset affairs main task is to manage the operations and maintenance of its the infrastructural assets through two departments, Roads Maintenance Department (RMD) which is looking after maintaining roads, tunnels, bridges, and its accessories like street lighting equipment and traffic signs. While Drainage Operations & Maintenance Department (DOM) is responsible for all necessary arrangements related to treatment, pumping stations, and all kinds of networks including sewage, groundwater and treated water networks. DOM has a 24/7 central drainage emergency complaint office, located in Ashghal main asset affairs headquarters near Salwa Road at Ain Khalid - Doha, linked directly to Ashghal 24/7 contact center in order to attend any drainage emergency complaint and resolve it within a short time.

This study investigates the possibility to improve the response times to customer complaints by decentralizing the existing DOM fleet facility into optimally located sub-facilities or sub-stations around Qatar. In this study, DOM fleet facility case is cast as a facility location allocation problem. The existing complaints capacities and locations covered by the centralized DOM facility are studied and evaluated. Statistical analyses are applied to extract location allocation information from collected data from Ashghal DOM records. The location allocation model is built through GIS solver simulation. Results are evaluated; they indicate that the innovative approach is capable of recommending a more effective and more efficient location-allocation model for DOM drainage emergency complaint systems.

DEDICATION

To my loving mother, Haifa Ghunaim, who without her greatest motivation and continuous support, I would not be able to continue my education and achieve my goals.

To my wife, Duaa Maali, who always brings out the best in me.

To my Ashghal team, who are my second family that we share a lot for moments together.

To all of my relatives and friends in and outside Qatar who were with me during this journey.

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In particular, my sincere thanks, appreciation, and respect go to Dr. Tarek El Mekkawy and Dr. Fatih Mutlu for their guidance, patience, encouragement, and offering assistance which without this, my project would have been incomplete.

Special thanks to my great Scottish mates from Scottish Water Company, Mrs. Nina Macvinish, Mrs. Jenny Steel and Eng. Craig Low for their great support and kind assistance. Also, Eng. Amir Osman and Eng. Pooziliy Chandrahas From Ashghal for their technical input.

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CHAPTER 1: INTRODUCTION

Facility location allocation models provide an optimal location and allocation of facilities in order to serve a set of demand points. This field's literature is huge since facility location allocation is considered critical in strategic planning. In many cases, unsuitable facility location or bad allocation decisions cause major consequences mainly for those systems that are related to public services, where mistakes in the planning and processes create a big miss.

This study focuses around the effectiveness and efficiency of re-planning the current drainage complaint resolution layout at Ashghal, by studying decentralization of the existing DOM fleet facility and determining locations for new sub-facilities (permanent, temporary or both) as well as allocating DOM to demand points. The challenge in this task is that the success of a proposed DOM system is usually shown at the operational stage. Although it is correct that bad decisions at the operational level can result in poor performance, it is also correct that a poor planning will similarly affect operational issues. Based on that, it is important to implement the new DOM model that is planned for optimality.

Furthermore, there are a number of factors drives the decision making process for such systems in the public sector. First, operations will rely on unoptimized system for a long time before getting a decision to review and update because of the strategic nature of the decision making process. Therefore, the centralized DOM system may become ineffective in case there is fast population growth, quick expansions of infrastructure, random zoning or re-zoning of residential, industrial and commercial locations like what is happening nowadays in Qatar. In these cases, the existing system can be evaluated by predictive tools and simulations. For this, simulation is an essential tool in the strategic planning and decision making process.

Second, for public systems, budget availability may result in undesirable situations. If DOM budget is sufficient, then the new DOM layout will tend to be over designed to cover the uncertainties. Then again, layout may be under designed due to budget constraints. Above all, the challenges of planning for an optimal new DOM are made even more difficult by the uncertain nature of the complaints dynamics. Regardless the demand increases or decreases, planners have to review and update DOM system continuously. This leads to a number of cases that will be discussed in this study. In addition, this report will study whether increasing costs can be avoided by effective and efficient planning. Since different, methods, models, tools and techniques can be used to strategically determine optimal new DOM facilities locations, this study will also assess the effects of applying different methods, models, tools and techniques on the performance of the resulting new system.

1.1 About Ashghal DOM Operations

It is worth mentioning that drainage maintenance strategies vary from one country to another. In the state of Qatar, DOM services rely on the mobile fleet which attends the drainage complaint location and works on recovering it. DOM vehicles can be classified into three main types; Jetting Tankers used to clear blockages, the Suction Tankers used to remove water flooding, and Combined Units that have both capabilities of clearing blockages and removing flooding which help in complaints that requires a quick response.

1.2 Facility Location Allocation Models

Facility location allocation problems can be classified according to its objective function, constraints, solution methods, and demand patterns. Solution methods of facility location allocation models can be divided into classical, non-classical, or contemporary approaches. The classical approach is simply using mathematical programming methods in order to optimize particular problems. Linear and integer programming are examples of classical models. Generally, classical approach models are not able to solving complex, large size real problems. Although, it can be used as an optimality validation for the results generated by the non-classical approaches.

Alternatively, the non-classical and contemporary approaches are used to solve more complex and large size problems by generating a solution that consists of only one point or small set of points from a large space (Lindeskov, 2002; Vanegas, 2008). However, generating an optimal solution is not guaranteed, but mostly the generated solution is considered a good near optimal solution. Non-classical approaches are iterative that the generated solution pattern keeps getting enhanced after each trial until a solution with a desired degree is achieved. Examples of non-classical approaches are simulated annealing, genetic algorithm. In recent times, Geographic Information Systems (GIS) have been added as enhancements to contemporary approaches to generate solutions for location allocation problems. Also nowadays, planners started combining more than one tool in order to generate more advanced and reliable solutions for the facility location allocation models.

1.3 Problem Description

In the State of Qatar, the population is increasing continuously. Accordingly, it is necessary for Ashghal to have an effective and efficient drainage maintenance services to cope with the growing demand. Moreover, it is required to evaluate the performance of its existing drainage complaints DOM system continuously in order to avoid operating sub-optimal systems. The importance of the continuous evaluation for DOM performance is not only for rapid population growth, but also to consider the urban development of the state, that a lot of residential, commercial or industrial areas has been built or canceled in Qatar with a rapid expansions in infrastructures and drainage utilities, which must be reflected on the existing system. For these reasons, continuous evaluations and update to DOM system has to be planned and discussed on a strategic level to get an effective system.

GIS is a very promising tool for addressing facility location allocation problems which offers multiple functions that could be used for solving facility location allocation problems. For that reason, this study concentrates on upgrading the existing DOM service system by developing a GIS model to evaluate the performance of the existing DOM and optimize new system layout that improves the performance.

1.4 Project Objective

The aim of this project is to study the existing DOM service at Ashghal and develop a new approach that models, simulates and evaluates its facility location allocation problem. The goal is to upgrade DOM system and improve its response time to customers' drainage complaints around Qatar.

1.5 Methodology Description

In this study, a mathematical model will be built to be visualized, analyzed and simulated using ArcGIS software's modern location allocation modeling techniques. Required data records for this methodology was collected from; Ashghal DOM, and Ministry of Municipality and Urban Planning.

In Qatar, if there is a need for a drainage emergency maintenance, customers can dial Ashghal's call center hotline (188). Once the complaint is recorded, a service request is created with a unique service request number (SR) at DOM database. The response time of the dispatch fleet of DOM mainly depends on the location and allocation of DOM fleet units. This study concentrates on optimizing the location and allocation DOM fleet facility and units only without analyzing the dispatch process system or the complaints completion times as this is outside the scope of this study. Also, the quoted experimental response time is assumed to be the time from dispatching DOM fleet unit until it reaches the complaint location. The period between receiving the 188 call and dispatching the DOM fleet unit is not considered that it is assumed to consume minimum time possible without affecting the response time. Moreover, this study does not consider the different types of DOM fleet vehicles.

The results of this study will contribute in providing valuable information that can be used to improve DOM systems response times in Qatar.

1.6 Report Organization

Chapters included in this study are; (Chapter 2) which reviews the literature on; similar dispatching systems, location-allocation methods, geographical information systems. (Chapter 3) describes the methodology considered in this project. (Chapter 4) covers the data analysis and discussion of the results of this study. Finally, (Chapter 5) which summarizes the results and recommendations, and describes the future work related to this study.

CHAPTER 2: LITERATURE REVIEW

The main purpose of the drainage maintenance services like DOM is to guarantee a high level of service by minimizing the effect of drainage emergencies on the public customers. Protection of the assets, minimization of cost, and maximization of the area coverage are all other additional objectives of such systems (Araz, 2007). To maximize this level of service and avoid any asset loss, the maintenance operator has to provide a quick and accurate emergency assessment, and efficiently deliver the maintenance fleet to the incident location to work on recovering the service in short time. Hence, for such systems systematic analysis is a point of concern (Setzler, 2007).

Not many researches have been initiated talking about drainage maintenance operations specifically, but intensive studies have been done on public services location allocation problems, like Fire station or Medical ambulances stops (GU, 2009; Comber, 2011; Knight, 2012). For example, the purpose of medical ambulances stops studies was mostly improving the survival rate of patients by reduces the response time to the medical emergency calls. (Comber, 2011) studied the effect of relocating the ambulances in different locations in Nigata - Japan, on the response times to the emergency calls. By their analysis, he and his team could reduce the average response time 1 to 2 minutes which is considered a great improvement in terms to an emergency medical service. (Lightner, 2006) could minimizing the response time using a MOFLEET mixed integer programming model to locate facilities and vehicles. Different models studied by other researches are discussed in the following sections.

2.1 Key Performance Indicators

Key Performance Indicator (KPI) is a measurable value that determines how effectively a company is achieving its objectives. Organizations use KPIs to evaluate their success at reaching targets. Decision makers, administrators, and service providers are always seeking to enhance the system's performance. For Example, Ashghal measures the performance of its DOM fleet by calculating the achieved percentage of the response and completion times in comparison with targets set by DOM planners. While completion time is driven by the technical nature of recovery processes of the complaints case by case, response time depends more on the planning and locating the fleet when called to be dispatched. At Ashghal, a committee of DOM administrators and planners set a KPI for the current DOM as the percentage of the response time to the recorded complaints within 3 hours on a monthly basis. During the last two years, DOM fleet could achieve around 80% of the DOM committee set KPI. DOM receives 50 complaints daily in average, which means around 40 complaints got resolved within the DOM target. This relatively acceptable rate indicates one of two options; the performance of the existing DOM is acceptable or the KPI is so wide and does not reflect the business need properly. Abu Dhabi Sewerage Services Company (ADSSC) which is similar to DOM, has stated in its Customer Standards and Quality of Service document, that "Where a Customer experiences wastewater flooding within their premises, ADSSC will make a site visit within 2 hours and ADSSC will report back to the customer within 4 hours". This gives an indication how similar systems are performing. As one of Ashghal' s goals is customer satisfaction, then the KPI could keep getting improved more and more by the planning strategies like improving the response time more.

2.2 Location Allocation Models

The purpose of Location-allocation problem is to locate a set of new facilities such that the transportation cost or/and response time from facilities to customers is minimized and an optimal number of facilities have to be placed in an area of interest in order to satisfy the customer demand (Azarmand, 2009). Therefore, strategic decision making are considering location allocation models important tools in linking facilities to demand points (Simchi, 1997). Facility location modeling importance can be vast in cases like EMS facilities as the effect of poor location systems will go beyond cost and customer satisfaction (Daskin, 2005).

There is many location Allocation models planners use for their facility location allocation problems. Some of the famous models are:

- Continuous and Discrete Location Models
- Covering Models
  - Set Covering Problem (SCP)
  - Maximal covering location problem(MCLP)
- P- center Models
- P-median Models

2.3 Geographical Information Systems (GIS)

During the past couple of decades, GIS has turned out to be a widely held application to be used in many diverse organizations like commercial, educational, and governmental (Environmental systems Research Institute, 1990). That is because it is a powerful and efficient tool (Harvey, 2008) for dynamic and complicated conditions location decisions (Vafaeinezhad, 2009) that optimizes the use of the available resources in order to find the optimal location and the best relative route to get there (Albrecht , 2007).

GIS is defined as "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information to support geographical decision making" (Environmental systems Research Institute, 1990; Murray, 2010). Geographic information and maps are represents principles and resolutions that deal with the complications of the world and guide choices that improve communication (Harvey, 2008). The core of a GIS is based on the location referencing system (coordinates) that represents and analyzes locations with respect to other locations (Church, 2002). Recently, the mathematical optimization integration into the real-life interactions has made it more complex which requires some advanced tools to deal with these more complex problems accurately. Therefore, location science generally has been developed by mathematical models that link the spatial problem to the optimization techniques (Murray, 2010). Heuristic solutions techniques also have been considered to control the processing time.

A paper Murray (2010), studied how GIS implements the analysis and modeling of location. He showed that there are main three functions that GIS is used in respect to location allocation sciences. First, GIS concept based on the location coordinates and its attributes which can pull out to be models' inputs. Second, GIS maps representation helps in visualizing the problems models which improves the understanding of its objective, geographic spaces, and even the result in terms of determining if the solution makes sense or not. Third, the integrated mathematical techniques in GIS supports solving location problems directly GIS only.

In the context of the above, GIS can be combined with other methods which may also lead to effective selection for locations (Zhang, 2011). This contributed in growing the usage of GIS in the location studies recently. For example, Vafaeinezhad,

(2009) used GIS to model an allocation of an earthquake rescue teams tasks where GIS helped as a source for the input information and in simulating the solution for such a complex problem due to the different elements like tasks, environment and unpredicted happenings. Rodrigues, (2012), Bender, (2002) and Murawski & Church (2009) have also used GIS to extract attribute and coordinate information to be used in location problems. Bozakaya, (2010), combined heuristic algorithm with GIS software to analyze and visualize a solution for a location routing problem. Alternatively, Murray (2005) molded a set covering problem (SCP) using GIS to overcome the spatial of the traditional SCP model. Cheng, (2007) used the benefit of GIS features to optimize a location for a super shopping mall that minimizes distance, maximize demand coverage, and to maximize average monthly income coverage. GIS was an effective tool for all of the previous-mentioned studies.

GIS has also been used in location problems related to customer service demand. GIS was used to evaluate the efficiency of fire station location coverage in terms of response time (Lui, 2006). Sasaki, (2010) used GIS to find the optimal location of ambulances by expecting future medical demand.

2.4 Summary of the Literature Review

It has been shown here in this literature review that organizations strategic decision makers, administrator, and planners need tools to optimize their resources distribution and cost in order to meet there KPIs. Also, it has been shown here that there are many models, tools and techniques can be used in developing a location allocation problem. Moreover, it is been discussed how GIS model has contributed in developing the location science recently through its efficiency in solving the complex real-life problems. As such, this project will study a live example of Ashghal DOM and show how the service response time could be reduced using the efficiency of the location allocation models developed by the software (ArcGIS version 10).

CHAPTER 3: PROJECT METHODOLOGY

Strategic planning is usually based on technical principles to achieve the looked-for targets in the required operations. Hence, for designing and developing an optimized location-allocation plan for Ashghal DOM facility, this project discusses some qualitative and quantitative methods. Qualitative which studies the specifications of how the current DOM facility is designed and operated in order to understand the dynamics of DOM operations and problems in such system. Quantitative focused on the capacities required by the new DOM model. Data collection for the quantitative approach was through studying and analyzing the available data sets and conducting interviews and meetings with stakeholders linked to DOM and its operations. The key stakeholders that were interviewed where from Ashghal Asset Affairs (AA), Ministry of Municipality and Urban Planning (MMUP) GIS Center, Ministry of Development Planning and Statistics (MDPS), and some citizens also. All of them have a direct or indirect link to DOM (Figure 1).

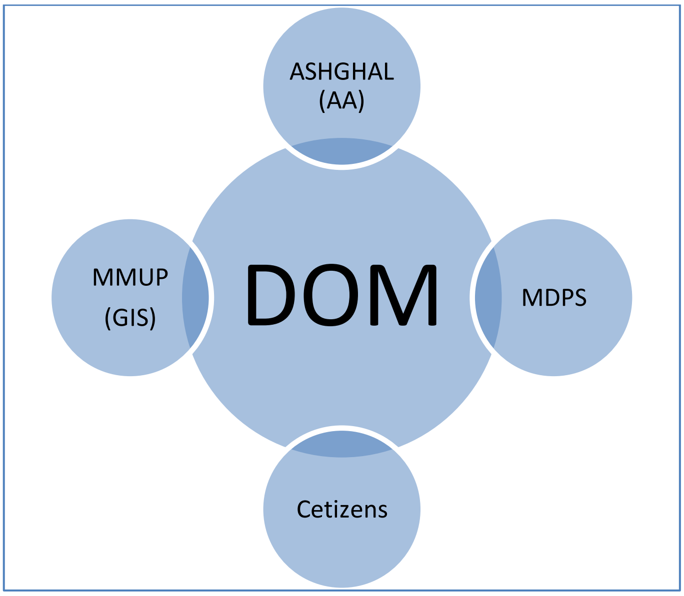

Figure 1. Summary of the key stakeholders of DOM

3.1 Project Plan

The approach considered in this project was extracted from similar and related work covered in the public literature. Results were then analyzed and accordingly conclusions were drawn. The overall project process is shown at the flowchart (Figure2).

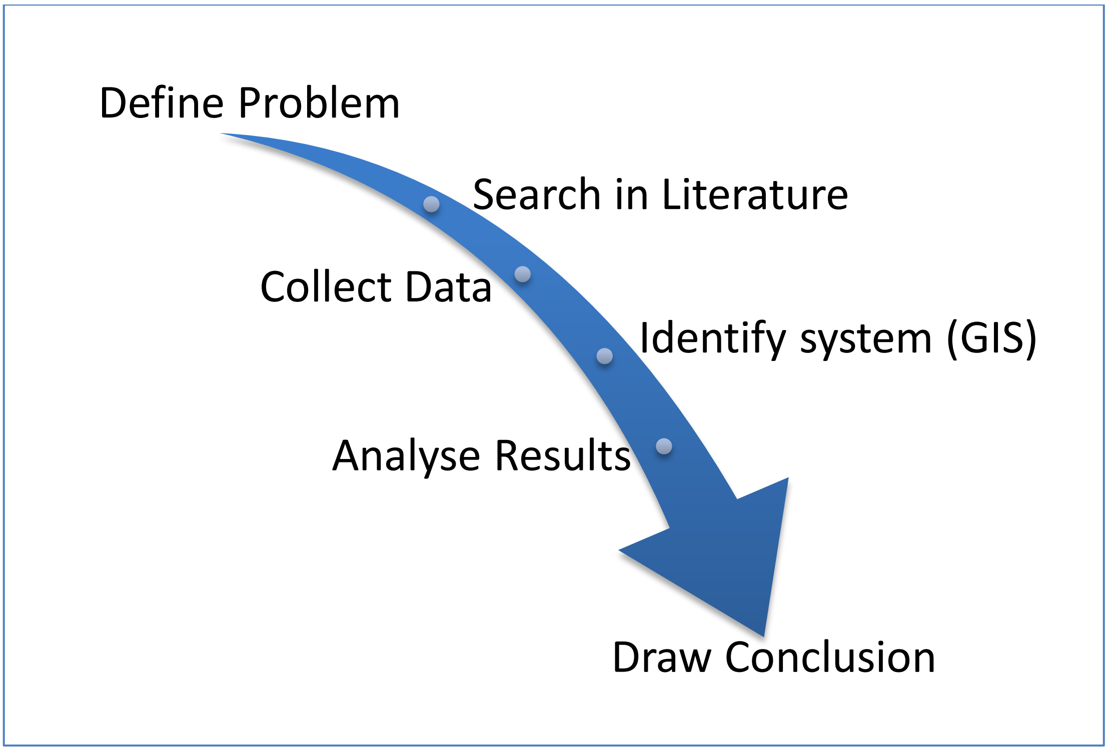

Figure 2. Project process flowchart

3.2 Tools Used

As this project is considering redesigning the existing DOM facility, some core data are required to be studied about the study area related to the drainage complaints concentration zones, population demographics, existing/planned coverage drainage networks, as well as the road networks in Qatar. Generally, the performance of any strategic service like DOM is directly affected by rapid population growth, expansion and the random relocation of the residential, commercial and industrial in

Qatar, planners need to keep assessing the performance of the service periodically. Figure 3 shows the population distribution around Qatar in 2015, while Figure 4 shows the current road/drainage networks distribution.

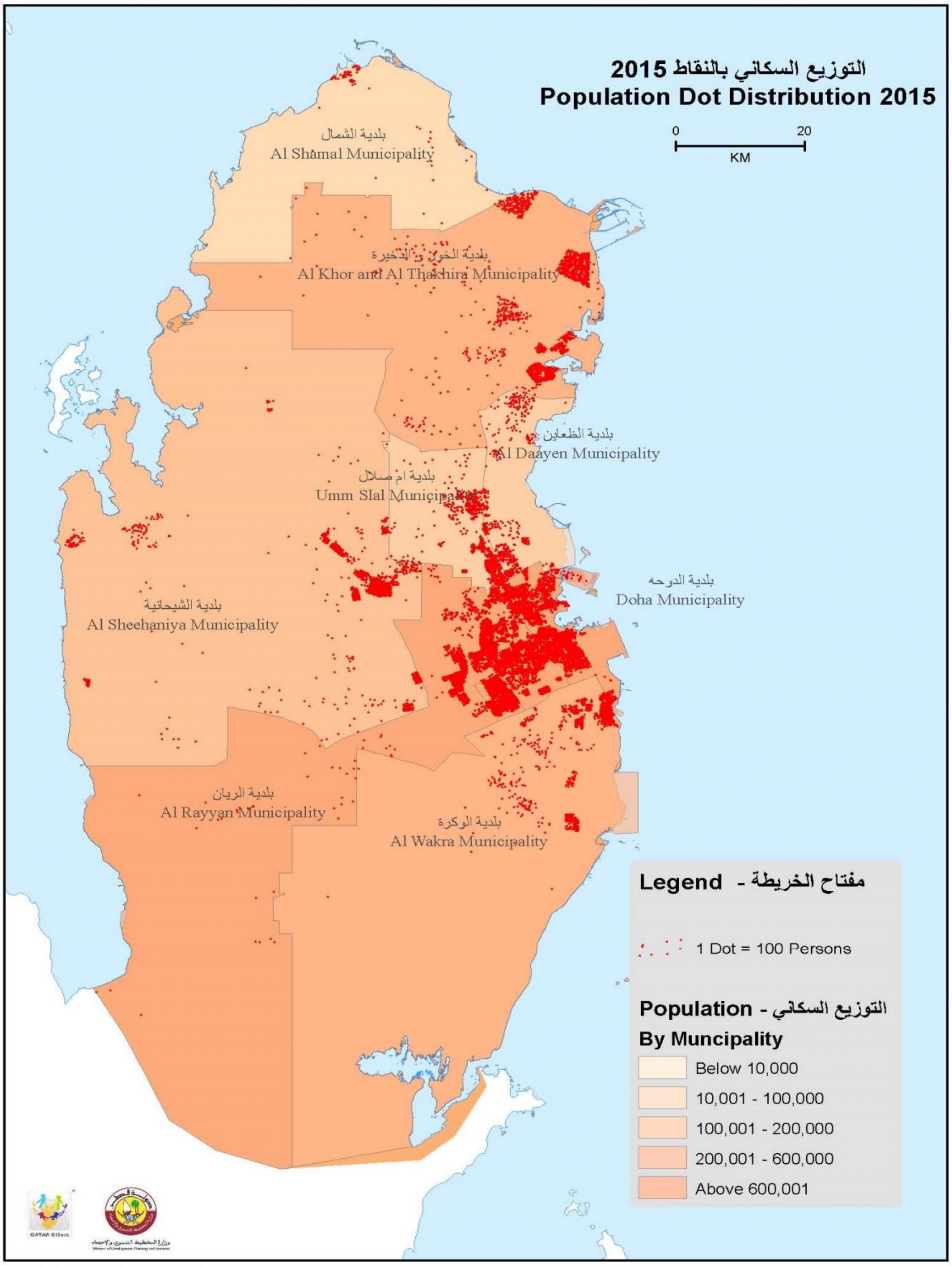

Figure 3. Population distribution around Qatar (2015)

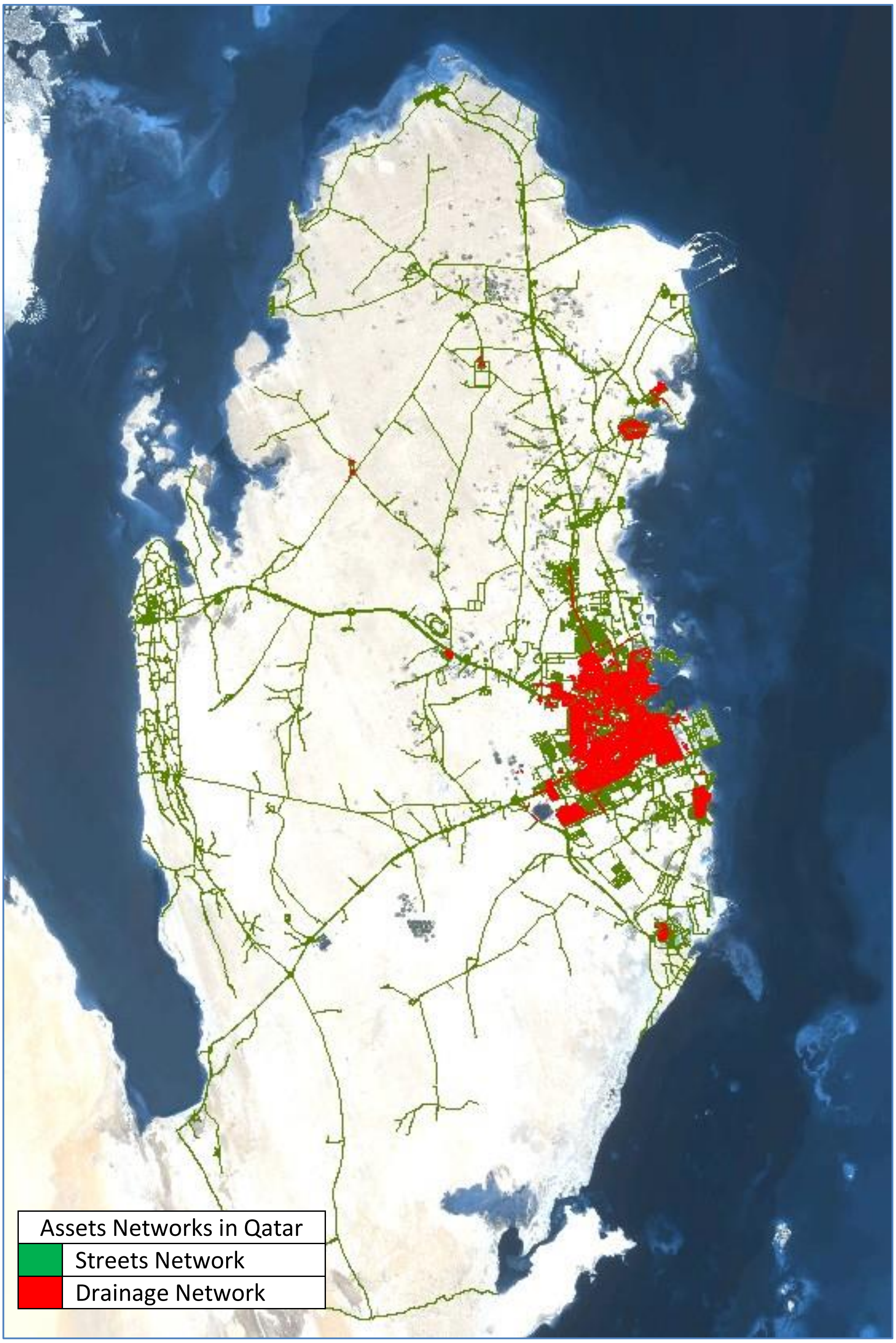

Figure 4. Distribution of the road & drainage networks in Qatar

Relative tools, mathematical models, and software were identified to implement optimal location and allocation of the new DOM facilities. Analysis of the service area and the demand was used to analyze the results statically and then to propose recommendations. The main tools used for this were ArcGIS software, and Microsoft Excel. As Excel software was used for statistical analysis of the various datasets used in the investigation. ArcGIS as a comprehensive system that collects, organizes, manages, analyzes, and distributes geographic information (Economic and Social Research Institute, 1995) was used to optimize the new DOM facilities, and to visualize the solution.

Figure 5. ArcGIS software logo

3.3 Data Collection

The data collected for this project are the elements that DOM deal with in any service provided. This includes drainage complaints, fleet vehicles, demand zones, population demographics, drainage networks, as well as the road networks in Qatar.

Drainage complaints data includes all drainage related service requests registered at DOM database. This data was used to identify patterns of the complaints concentrations with respect to location and time. The period considered for this data is 2 years lies between September, 2015 and September, 2017. The service requests data provided shows the recorded complaints classification, location, complaint time, resolve time,.. etc.

Drainage networks data is essential in this project as DOM provides the service only to areas covered with the governmental drainage services. Other areas which are not covered, do not fall under DOM responsibility and need to deal directly with Ministry of Municipality & Environment (MME) for drainage related complaints. Road networks data is important to calculate the service required distance and accordingly the route and time needed to attend the service requests.

CHAPTER 4: DATA ANALYSIS

In order to achieve the project objective, the sections in this chapter discuss the following investigations:

- Analyzing the existing DOM system database.
- Development of GIS simulation models for the existing and the proposed systems.
- Comparing the effectiveness of the existing and proposed layouts.

4.1 Pre-Optimization Analysis

Ashghal Asset Affairs has built network complaints database which contain detailed information about all recorded complaints' service requests (SR) received by DOM. The provided database for this study is obtained originally for the master network complaints database and it covers all resolved complaints recorded in period between September, 2015 and September, 2017. This data includes SRs creation, response, and resolution times. In addition to detailed description for the complaints with its specific locations in terms of zone, street, building numbers and the related coordinates.

4.1.1 Complaints Capacities Analysis

As per DOM records, it receives around 50 complaints daily In two years (730 days), DOM has recorded 38658 (Average of 53 complaints daily) distributed over the 91 zones of the State of Qatar with different capacities for each zone. (Figure 6) shows the complaints capacities distribution for Qatar zones.

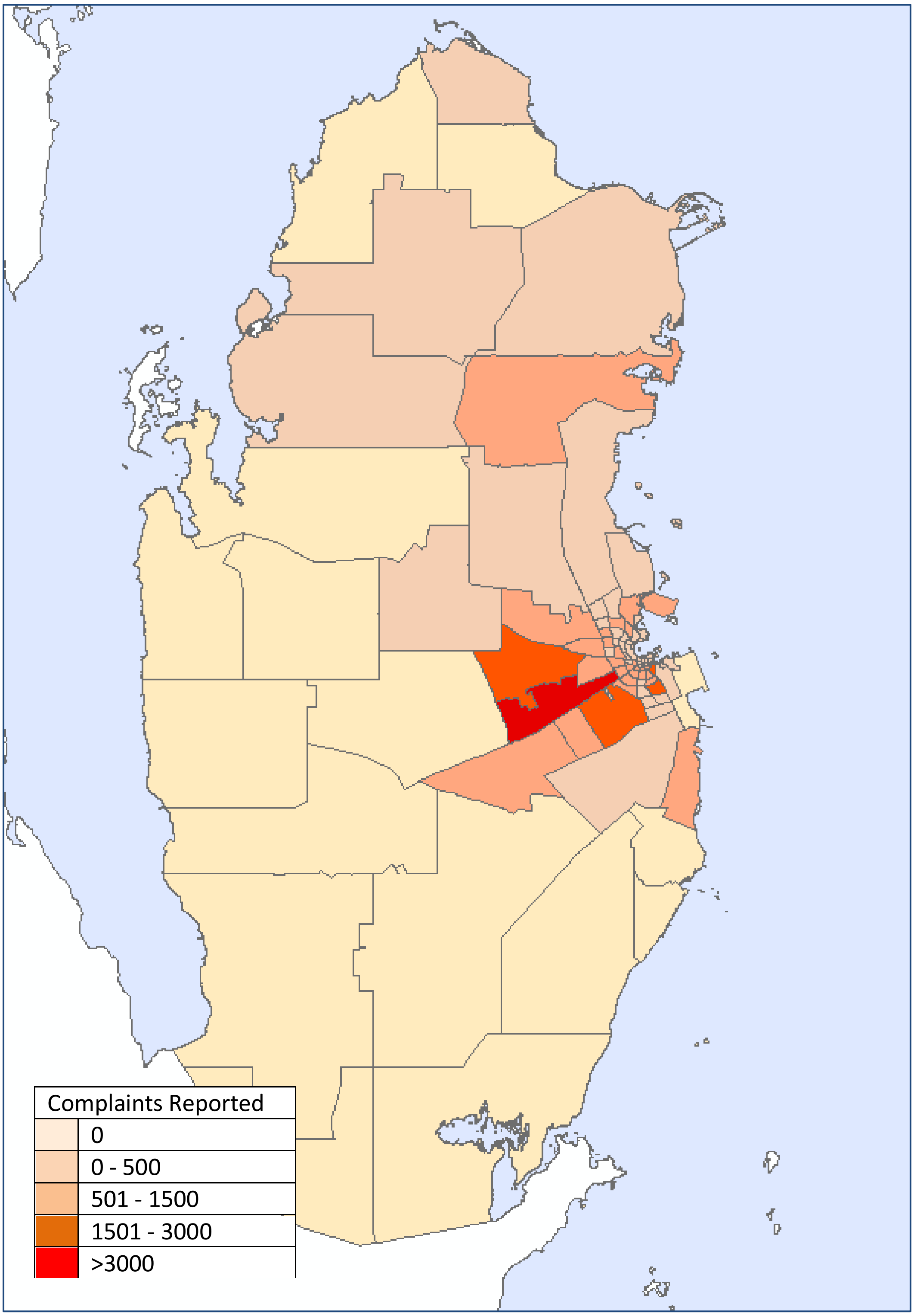

Figure 6. Complaints distribution capacity for Qatar zones.

Figure 7 and Table 1 show that 6 zones only out of the 91 zones contained around 33% of the total complaint capacity around the State of Qatar. By going farther in the capacity analysis, it will show that 14 zones have around 50% and 35 zones only have around 90% of the total complaint capacity. This shapes to some limits how the response time can be improved.

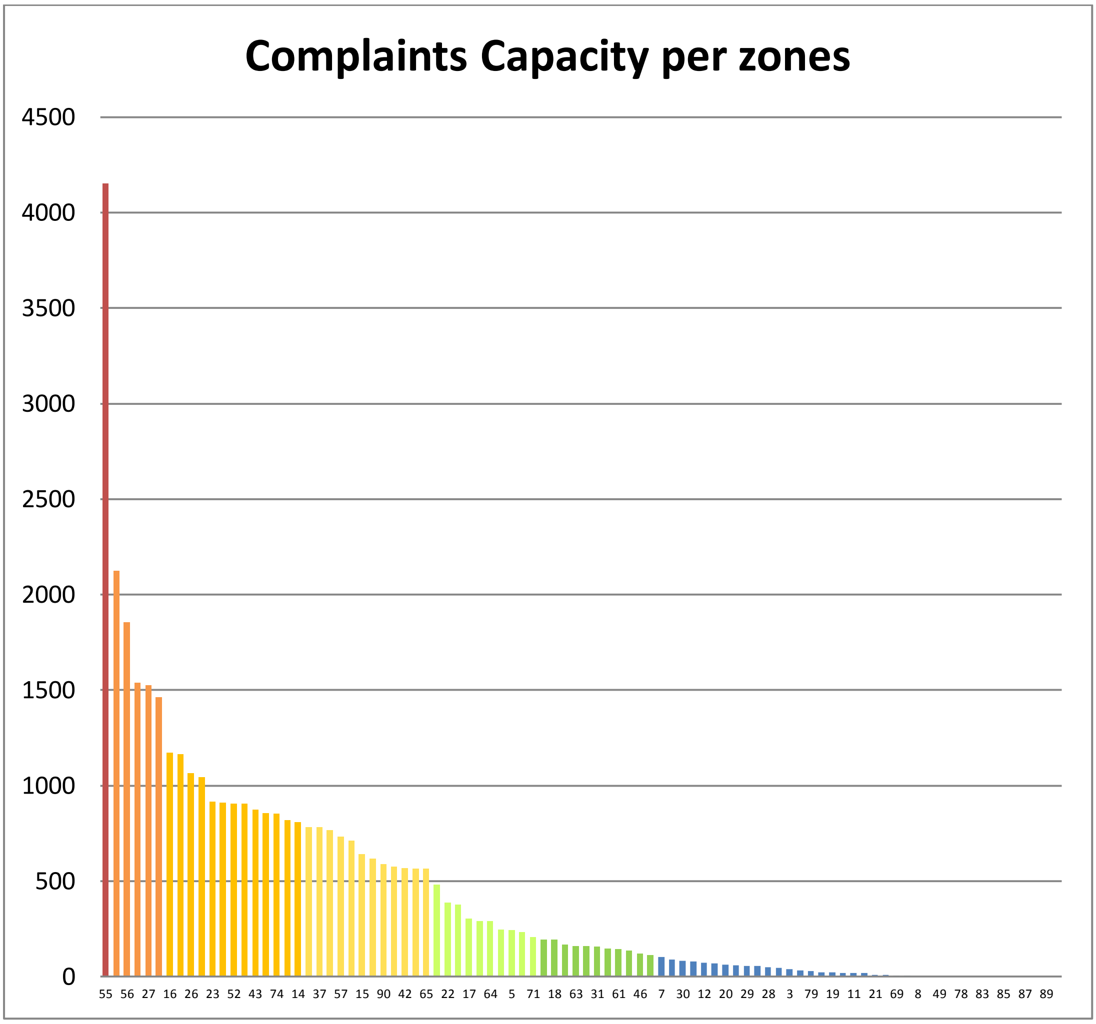

Figure 7. Complaints capacity per zones

Table 1

Complaints Capacity Per Zone

Districts	Municipality	Zone	Capacity	%
Al Aziziya / Al Sailiya / Muaither South	Al Rayyan	55	4154	10.74
AlWajba/ Muaither North / New Rayyan	Al Rayyan	53	2125	5.50
Ain Khaled / Bu Hamour / Mesaimeer	Al Rayyan	56	1854	4.80
Old Airport	Doha	45	1538	3.98
Umm Ghuwailina	Doha	27	1526	3.95
Madinat Khalifa South	Doha	34	1464	3.79
Old Al Ghanim	Doha	16	1173	3.03
Al Mansoura	Doha	25	1163	3.01
Najma	Doha	26	1064	2.75
Al Gharrafa / Bani Hajer	Al Rayyan	51	1043	2.70
Fereej Bin Mahmoud	Doha	23	918	2.38
Rawadat Al Khail	Doha	24	910	2.35
Al Luqta / Al Zaeem / Old Rayyan	Al Rayyan	52	906	2.34
Al Sadd / Al Nasr / New Al Mirqab	Doha	39	906	2.34
Nuaija	Doha	43	874	2.26
Fereej Al Amir / Al Soudan / Muraikh	Al Rayyan	54	857	2.22
Al Khor	Al Khor	74	853	2.21
Dahl Al Hamam/ Madinat Khalifa North	Doha	32	819	2.12
Fereej Abdel Aziz	Doha	14	811	2.10
Mebaireek	Al Rayyan	81	783	2.03
Fereej Bin Omran / New Al Hitmi	Doha	37	782	2.02
Al Qutaifiya	Doha	66	767	1.98
Industrial Area	Doha	57	734	1.90
Al Sadd	Doha	38	713	1.84
Al Doha Al Jadeeda	Doha	15	641	1.66
New Slata	Doha	40	620	1.60
Al Wakra	Al Wakra	90	590	1.53
Hazm Al Markhiya	Doha	67	573	1.48
Al Hilal	Doha	42	567	1.47
Mushaireb	Doha	13	565	1.46
Onaiza	Doha	65	565	1.46
Mushaireb	Doha	4	482	1.25
Fereej Bin Mahmoud	Doha	22	388	1.00
Nuaija	Doha	44	376	0.97
Al Rufaa / Old Al Hitmi	Doha	17	303	0.78
Other			4250	10.99
Total			38658	100.00

4.1.2 Fleet Analysis

As clarified in section 1.1, DOM tankers can be classified into three main types:

1- Jetting tankers or Jetters (Figures 8, 9, 10), are tankers equipped with long pressure hoses to jet high pressurized water into the drainage networks to clear blockages. These tankers need to be filled with water pre-attending complaints. It also worth mentioning that DOM has two different size options of jetters (big and mini jetters) to provide more accessibility flexibility to narrow locations like Residential houses gates. Jetters are considered as the main maintenance vehicle type at DOM.

Figure 8. Jetting Tanker (Jetter)

Figure 9. Big Jetter (10,000 L)

Figure 10. Mini Jetter (4,000 L)

2- Suction tankers (Figure 11), which are tankers with suction pumps used to remove water flooding and collect it in a storage tank. The tank can be emptied at the desired discharge location afterword.

Figure 11. Suction Tanker (12,000 L)

3- Combined Tankers or Comb. Units (Figure 12), those are tankers that have both options, Jetting and suction. They got water compressor with jetting hose and a suction pump. There are two adjacent storage tanks on the Comb. Unit, one is for filling water for jetting and another one is for suctioned water collection. The capabilities on these tankers are quite less than the main Jetters or Suction tankers, but good in general for unspecified complaints.

Figure 12. Combined Unit (2,600 L jetter, 5,000 L suction tanker)

Table 2 summarizes the fleet availability at DOM that is used to resolve drainage complaints recorded.

Table 2

Fleet Summary of DOM

Type	**Count**	**Size Capacity**
Big Jetters	5	10,000 L (J)
Mini Jetters	5	4,000 L (J)
Suction Tankers	6	12,000 L (S)
Comb Units	2	2,600 L (J) + 5,000 L (S)
Totals	18	

4.1.3 Response Times

As mentioned earlier this project is focusing on response times of DOM to attend the recorded complains. Network complaints database of Ashghal Asset Affairs provides all recorded complaints with SR creation time, Actual Start time for resolution, and the Actual Finish time of resolution. Response time is generated as the duration from the SR creation time up to the actual start time if resolution. By running a quick analysis for the response times generated from the database over the provided two years period data for all complaints SRs, the obtained average response time is 3:29:43. As per DOM set KPI, this violating the target of the 3 hours response time, even if the KPI target itself is still considered poor indicator as per Ashghal customer satisfaction guide (120 mins). Table 3 shows the response time achieved by each Municipality which gives a better reflection of the nature of the problem.

Table 3

Average Response Times of DOM by Municipalities

Municipality	AV. Response Time	Capacity %	KPI %
Doha	2:52:34	63.20	89
Al Rayyan	3:44:59	30.32	73
Umm Slal	3:49:42	0.02	51
Al Wakra	4:50:39	1.15	57
Al Sheehaniya	5:41:15	0.03	7
Al Daayen	7:42:45	0.03	11
Al Khor and Al Thakhira	9:08:22	5.22	21
Al Shamal	10:09:46	0.03	0
Grand Total	3:29:43	100	AV. 80%

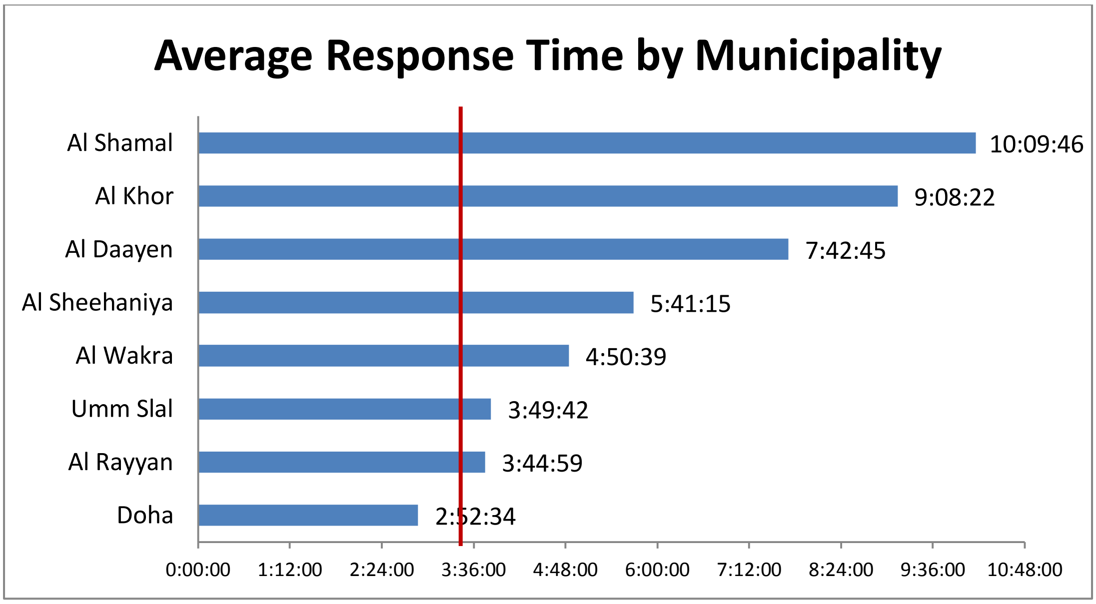

Figure 13. Response times of DOM by municipality

From Table 3, DOM has achieved around 80% of the set KPI target in general out all its response times all over the state during the two years period studied, with the highest score achieved at Doha Municipality by around 89% of KPI target, with an average of 2:52:34. Al Rayyan Municipality, where DOM fleet yard is located, scored less with 73% only of the KPI target, with an average of 3:44:59. Location priority is a main reason for such a response time difference which will be discussed in the next section. It worth mentioning that DOM failed to attend any complaint at Al Shamal Municipality within the KPI target in two years duration, which is quite understood that location, priority, fleet occupancy, and complaints capacity, .. etc. are all factors lead to that score failure.

4.1.4 Location Priority

Ashghal DOM center has classified zones of Qatar into five categories in terms of priority of service. This priority has been considered due many reasons like the importance of the locations within zones, capacity of population, activity level,..

etc. Location priority triggers are summarized in Table 4, while priority assignment is shown at Table 5 and Figure 14.

Table 4

Location Priority Triggers

Priority	Location Triggers
Very High Priority	Include main tourism landmarks & governmental buildings ex.: Diplomatic street, Souq Waqif, Hamad Int. Airport, Cornish, .. etc.
High Priority	Include shopping points and high activity locations ex.: Doha downtown, Whole sale market, .. etc.
Medium Priority	include residential neighborhoods (villas, compounds) ex.: Onaiza, Al Waab, Al Thumama, Al Hilal, .. etc.
Low Priority	include normal residential buildings Ex. Freej Abdulaziz, Bin Mahmoud, Mouaither, Rayyan, Industrial area.. etc.
No Priority	Locations with no drainage assets development or controlled by others ex.: Khuraitiat, Al Kheisa, Al Shamal, Al Wukair, Mesaieed (QP).. etc.

Table 5

Zones and Districts Priority Assignment

District	Zone	Priority	District	Zone	Priority
Al Jasra	1	4	Al Thumama	50	2
Al Bidda	2	4	Al Gharrafa / Bni Hajer	51	2
Al Mirqab / Slata	18	4	Al Luqta / Old Rayyan	52	2
Doha Port	19	4	Al Soudan / Muraikh	54	2
Ras BuAbod	28	4	Al Jebailat	64	2
Doha Int. Airport	48	4	Onaiza	65	2
Al Dafna	60	4	Hazm Al Markhiya	67	2
Al Qassar	61	4	Mushaireb	4	1
Al Khuwair	62	4	Fereej Abdel Aziz	14	1
Al Qutaifiya	66	4	Al Doha Al Jadeeda	15	1
Lusail / Wadi Al Banat	69	4	Old Al Ghanim	16	1
Al Najada / Al Asmakh	5	3	Fereej Bin Mahmoud	22	1
Old Al Ghanim	6	3	Fereej Bin Mahmoud	23	1
Al Souq	7	3	Rawadat Al Khail	24	1
Wadi Al Sail	10	3	Al Mansoura	25	1
Al Rumaila	11	3	Najma	26	1
Al Bidda	12	3	Umm Ghuwailina	27	1
Al Rufaa / Old Al Hitmi	17	3	Madinat Khalifa South	34	1
Wadi Al Sail	20	3	Fereej Kulaib	35	1
Al Rumaila	21	3	Fereej Bin Omran	37	1
Ras Bu Abboud	29	3	Old Airport	45	1
Whole Sale Market	58	3	Muaither / New Rayyan	53	1
Onaiza	63	3	Al Aziziya / Al Sailiya	55	1
Al Khor	74	3	Ain Khaled	56	1
Al Thahkira	75	3	Industrial Area	57	1
Al Wakra	90	3	Lijmiliya	73	1
Umm Lekhba	31	2	Al Sheehaniya	80	1
Madinat Khalifa North	32	2	Mebaireek	81	1
Al Markihya	33	2	Al Duhail	30	0
Al Messila	36	2	Al Tarfa	68	0
Al Sadd / Al Nasr	39	2	Al Kheesa / Semisma	70	0
New Slata	40	2	AlKharityat / Umm Slal	71	0
Nuaija	41	2	Al Ghuwaria	76	0
Al Hilal	42	2	Al Ruwais / Al Shamal	79	0
Nuaija	44	2	Al Mashaf	91	0

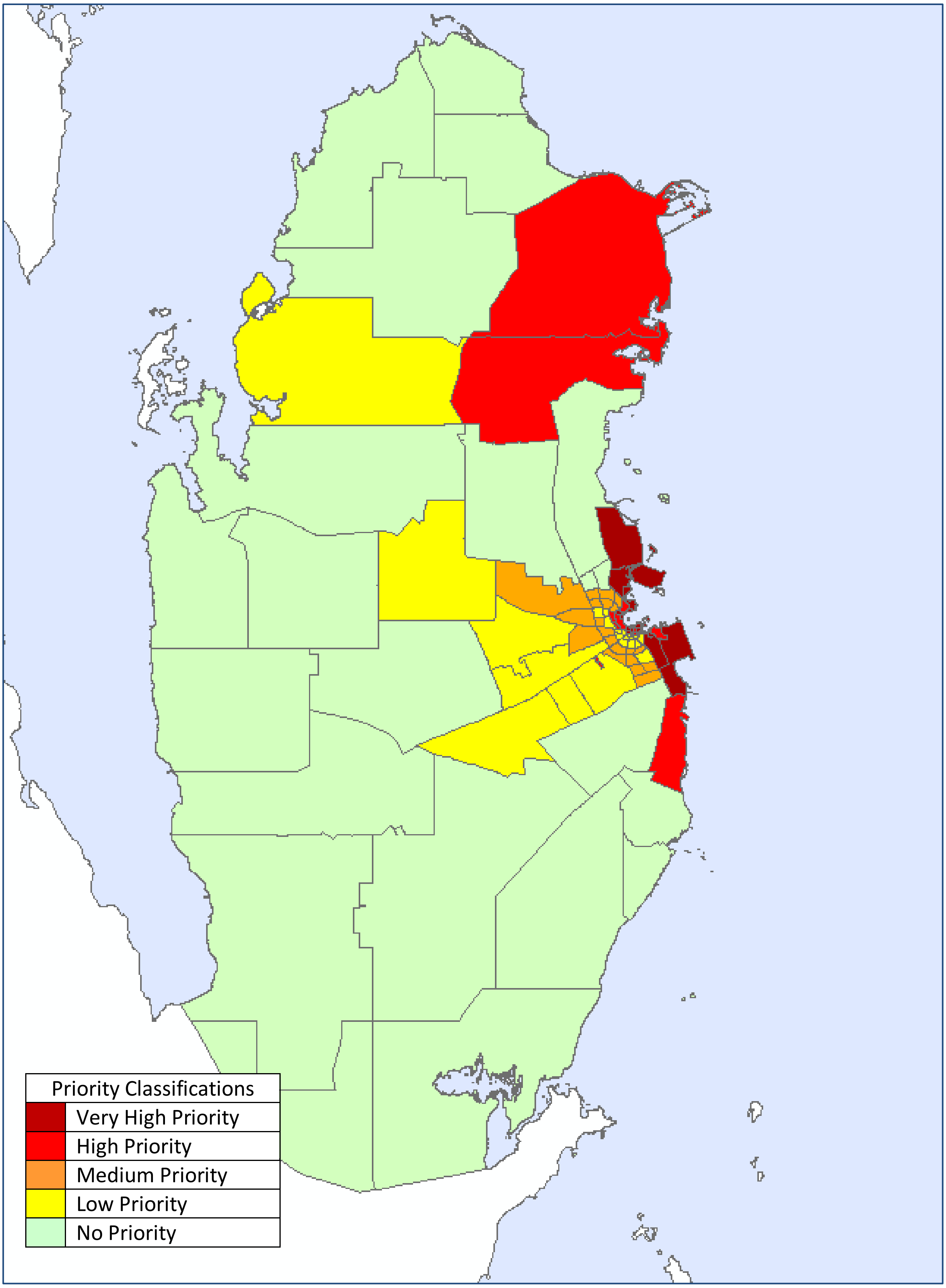

Figure 14. Priority distribution for zones of Qatar

4.1.5 Cases Classification

By going through the complaints types, most of the complaints are falling under one of five types. Mostly, the assessment of complaint type determines the nature of service needed, and yet the type of vehicle assigned to attend the job. The main five classifications of the drainage complaints types are as the following:

1- **Internal Flooding** (Figure 15); which means that water gathered inside the drainage manhole, usually due to clogging in the drainage house connection to the main drainage line. DOM does not attend inside customer premises drainage problems like bathrooms or kitchens, but dose provide consultation services to the approaching customers in order to support them solving the problem. Internal Flooding get resolved by Jetters or Comb. Units.

Figure 15. Internal flooding

2- **External Flooding** (Figure 16); where water gathering is located at the road corridor, sidewalks, or pedestrian underpasses blocking completely or partially the service of the assets. DOM is involved in this case to solve the problem regardless the cause source which could be not related to drainage like tab water leaking or customer car wash water overuse. Suction Tankers are mainly used for such cases, while Jetters and Comb Units can still be called in case the flooding reason is drainage blockage.

Figure 16. External flooding

3- **Rain Water Flooding** (Figure 17); This is part of external flooding, but rainy seasons related incidents have special programs designed by Ashghal where DOM contracts suction tankers suppliers to take care of the rain complaints and keep the business as usual resources not utilized.

Figure 17. Rain water flooding

4- **Sewer Back-up (No-Flooding)**; which are considered the most common complaint recorded at DOM database. It is generally a main sewer or drainage line has blockage obstructing the drainage water flow with no flooding reported on street. Jetters are the main vehicles to clear such blockages and return the level of service of the networks. Comb Units can be used also.

5- **Manhole Related issues** (Figure 18); these complaints are mainly related to manhole covers of the drainage networks like missing covers, noisy covers, ..etc. DOM vehicles are NOT involved in such complaints.

Figure 18. Manhole related complaint

Table 6

Drainage Complaints Typs Summary

Type	Count	%	Main Vehicle Used (by DOM)
Internal Flooding	2242	5.80	Jetters
External Flooding	6036	15.61	Suction / Jetters
Rain Water Flooding	2213	5.72	Suction (SUP)
Manhole Related	498	1.29	-
Sewer Back Up (No Flooding)	26629	68.88	Jetters
Others	1040	2.69	-
Totals	38658	100	

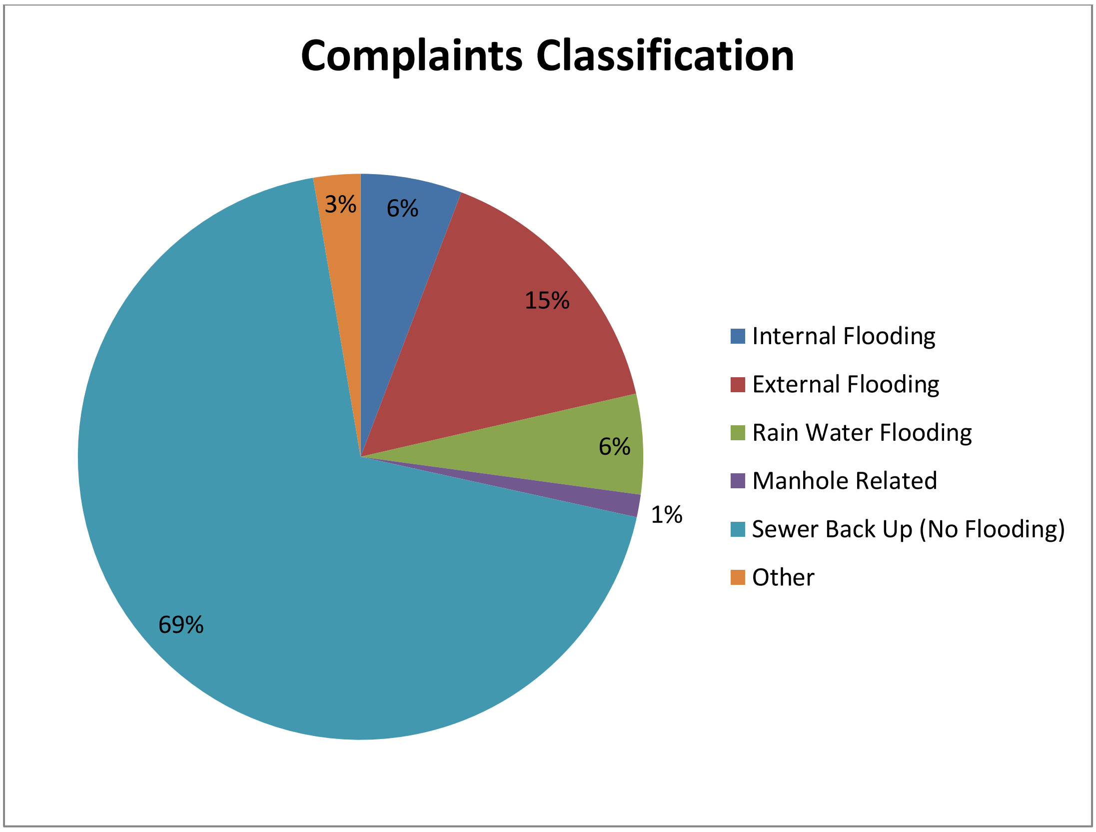

Figure 19. DOM complaints classification

Table 6 and Figure 19 summarize the complaints classifications recoded at DOM contact center which has been extracted from the Networks complaints database of Ashghal.

4.2 GIS model Analysis

In this section, GIS simulation will be used in evaluating the performance of the existing centralized DOM facility and to optimize and propose new more effective decentralized solution. The proposed facility layout will be evaluated using two models; minimize impedance model which is basic p-median model that selects optimal locations based on impedance to facilities, and maximize coverage model which is good for DOM case because facilities are chosen based on greatest demand within an impedance cut-off. A priority factor of the demand locations will be studied to guarantee a more desirable solution.

4.2.1 Simulation Primary Data

Pre-building the model, the simulation primary data are defined at Table 7.

Table 7

Simulation Primary Data

<table>
<tr><th>Parameter</th><th>Discretion</th></tr>
<tr><td>Complaints Demand</td><td>Demand weighted Nodes per zone
A node will represent the total complaints of each zone, and weight will reflect the demand of the node.</td></tr>
<tr><td>Priority Factor</td><td>This factor will be multiplied by each zone demand based on its service priority (Table 5) as following:
<table>
<tr><td>Priority</td><td>V. High</td><td>High</td><td>Medium</td><td>Low</td><td>No</td></tr>
<tr><td>Factor</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
</table></td></tr>
<tr><td>Number of Sub-Stations (SS)</td><td>5*Sub-Stations
As the number of vehicles is pre-defined, it will be defined number of sub-stations as following:
- Vehicles available are:
<table>
<tr><td>Big Jetter</td><td>Mini Jetter</td><td>Suction Tanker</td><td>Comb. Unit</td></tr>
<tr><td>5</td><td>5</td><td>6</td><td>2</td></tr>
</table>
- SS fleet: (1)Big Jetter/ (1)Mini Jetter/ (1)Suction Tanker
- Central Yard: (1) Suction Tanker/ (2) Comb. Units</td></tr>
<tr><td>Traffic Data</td><td>Reflected by factored average speed = 35 km/h* 0.33~12 km/h</td></tr>
</table>

4.2.2 AcrGIS Geometry

In order to optimize the required location allocation problem using ArcGIS, some layers has to be created and defined. The main layers created are:

- Streets Network Layer
- Streets Network Dataset
- Complaints Nodes Layer
- Priority Complaints Nodes Layer
- Proposed Facilities Nodes Layer

ArcGIS provides a Network Analyst solver for Location Allocation problems, Service Area Analysis, Closest Location Analysis, .. etc. This solver like all solvers software requires some data input to run the optimization analysis. Those requirements are mainly the potential facilities the will be optimized and the demand points to be studied. Figure 20 clarifies Network Analyst solver appearance where problems options are shown in addition to the requirements list.

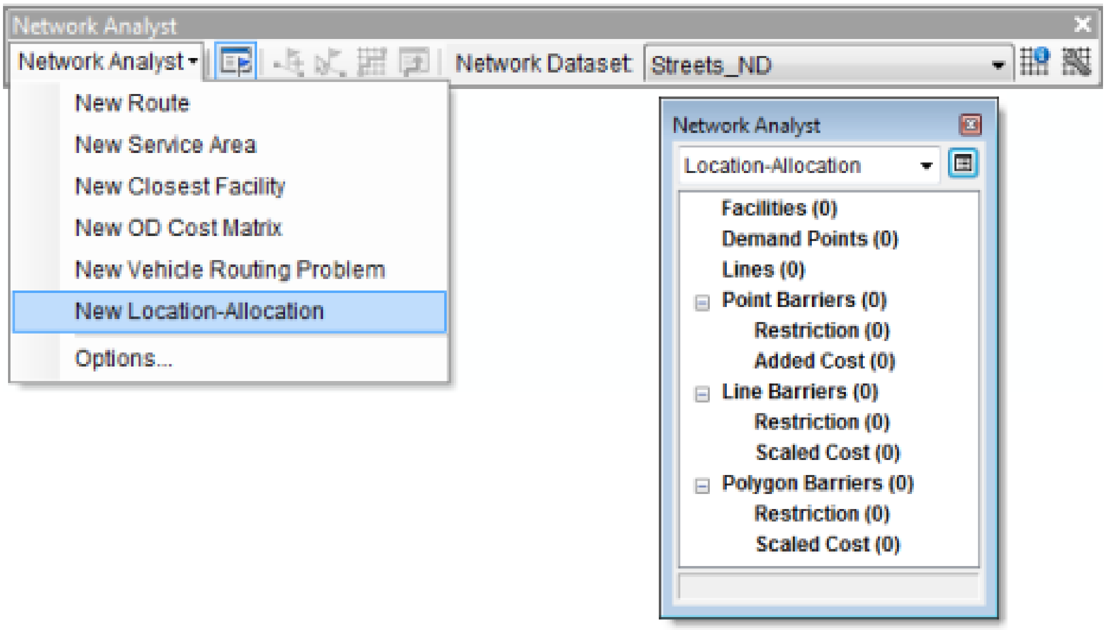

Figure 20. “Network Analyst” solver

4.2.3 Existing Model Evaluation

In order to evaluate the existing Centralized layout model, the location of DOM facility yard was integrated into the GIS environment. As mentioned in the previous sections, DOM's KPI is to respond to complaints within 3 hours or 180 minutes. Although the actual response time average in Ashghal Asset Affairs network database was 3:29:43 hours which is around 210 minutes. The GIS simulation has been used to study DOM's facility capabilities based on the running simulations on distance and time.

4.2.3.1 Existing Model Closest Facility Analysis

Figure 21, shows the relationship in terms of distance between zones complaints demand around Qatar and the closest service facility, DOM central facility in this case. While the relationship is represented by linear distances which does not reflect real numbers, it still can show the trend of distance serviceability provided to be compared with the new proposed solution data. Figure 22 captures the result analysis of the traveled distance of DOM fleet from yard to demand points by GIS. The average distance travelled reported from in linear lines reaches around 40 km while the maximum reaches around 100 km. Considering the average travel speed of DOM vehicles around 12 km/h, this means the average response time is around 200 minutes in the ideal world which still high if we apply a reality factor. The standard aviation reported was around 18.

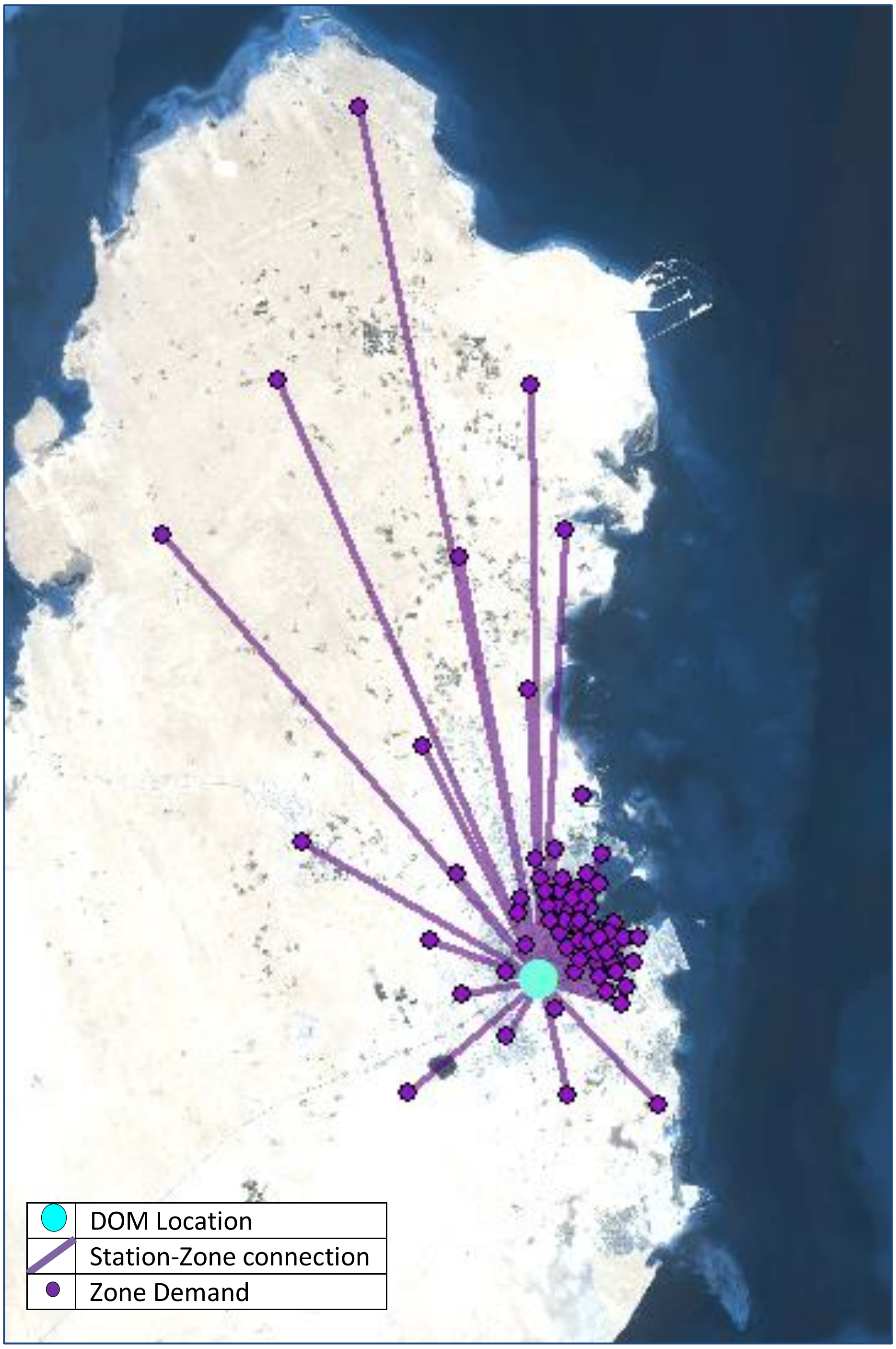

Figure 21. Zone demand of DOM service yard in terms of distance

Total_Distance			
Average Total_Distance	3849.256808	Count Total_Distance	78
Max Total_Distance	9886.151662	Min Total_Distance	566.700242
Standard Deviation	1760.103915	Sum Total_Distance	300242.031007

Figure 22. Distance report generated by ArcGIS for DOM simulation

4.2.3.2 Existing Model Service Area Analysis

The service area analysis presents a more accurate view over coverage of the facility service. Table 8 summarizes how DOM performs in terms of time. The simulation shows that DOM fleet can attend more than 86% of the complaints within the KPI target of 3 hours, this is pretty close to the actual 80% recorded score. Although and as mentioned earlier, the objective of this project is to improve the response time of DOM generally even the KPI target itself. At the coming sections, the proposed solution will be evaluated and compared to DOM performance.

Table 8

Coverage Percentage of DOM Existing Centralized Station

Coverage *of..*	***within..***	**<60 mins**	**<120 mins**	**<180 mins *KPI***	**>180 mins**
Complaints	Numbers	6311	13599	33447	38658
	Percentage	16.33%	35.18%	86.52%	100%

Figure 23, presents the service area boundaries based on average speed (12 km/h) and roads network lengths. It is clear that DOM capability does cover most of Doha and Al Rayyan municipalities' urban locations within 3 hours, but still away from some northern districts of Doha, Al Rayyan, Al Wakra and Umm Salal, while it is completely missing Al Khor, Al Shamal, and Al Sheehaniya municipalities.

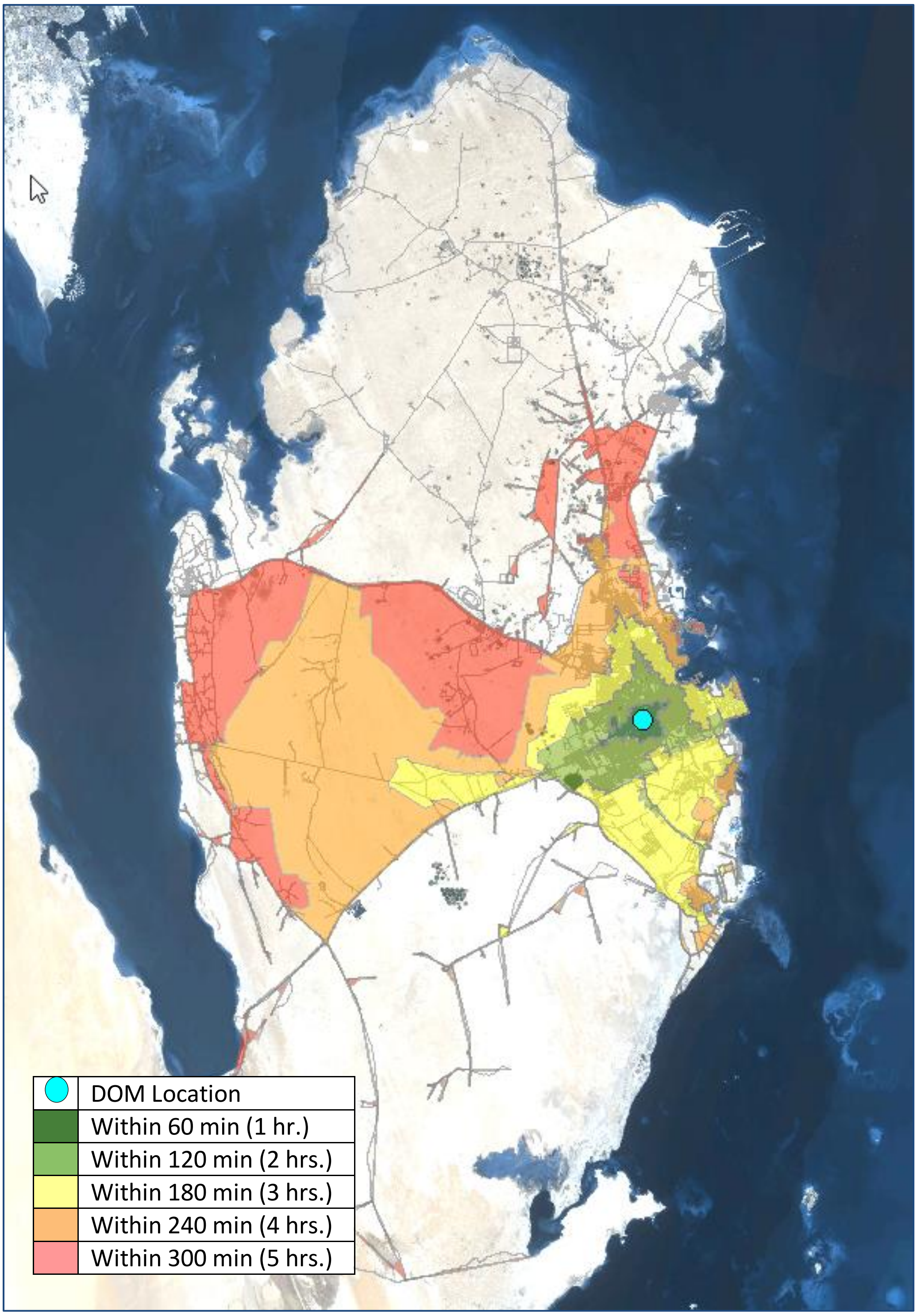

Figure 23. Service area of DOM centralized yard in terms of time

4.2.4 Proposed Model Evaluation

In this section, a new location allocation model will be built to optimize 5 sub-stations facility locations to replace DOM centralized facility considering the pre-optimization analysis reviewed in section 4.1 and referring to Table 7 for the simulation primary data. There will be two proposed options; Option (1) which is built on the bases of the regular demand distribution around the zones. While option (2) will be built considering location priority factor for each demand zone in order to reflect a more desirable result. Optimized options will be evaluated in terms of the closest facility and service area in order to come out with the optimal response time that can be achieved.

4.2.4.1 Option (1) : Optimized Model based on Demand

By defining the potential locations (Facilities) as all complaints locations, and defining Demand Point as all complaints demand locations and capacities, Plus setting the number of facilities required to 5, the Network Analyst solver using the Streets Network dataset optimized the optimal 5 locations that are maximizing the service coverage area within the shortest response time.

Table 9 summarize the location allocation optimization result, that shows that the 5 optimized facility location are so close in the demand distribution that it ranges between 17 - 24 %.

Table 9

Option (1) Optimization Result

Facility	Zone	Number	Demand	%	Coordinates
Location 1	Umm Salal	71	6590	17.05	222435, 403287
Location 2	Hazm Al Mrkhiya	67	6851	17.72	227264, 397770
Location 3	Al Sadd	39	8255	21.35	228931, 393153
Location 4	Old al Ghanem	16	7977	20.63	232820, 392015
Location 5	Industrial area	57	8985	23.24	225073, 382608
Total			38658	100	(AV. 7732)

Figure 24 shows the relationship in terms of distance between zones complaints demand around Qatar and the closest service facility of option (1) five optimized sub-facilities locations. The linear relationship lies represent the travel distance from each assigned optimized facility to the demand point within its service boundary.

Figure 25 captures the result analysis of the traveled distance of DOM fleet from the five optimized locations to the assigned demand points by GIS. The average distance need to be travelled from option () optimized 5 sub-facilities in linear lines reaches around 20 km which is half the distance reported for DOM centralized facility. The maximum distance reaches around 60 km which is around 40% less than the maximum distance reported for DOM centralized facility. Considering the average travel speed, the average response time is dropped from around 200 minutes for the centralized facility to just around 100 min which is 50% reduction in response time. The distance standard deviation has also dropped by 6.

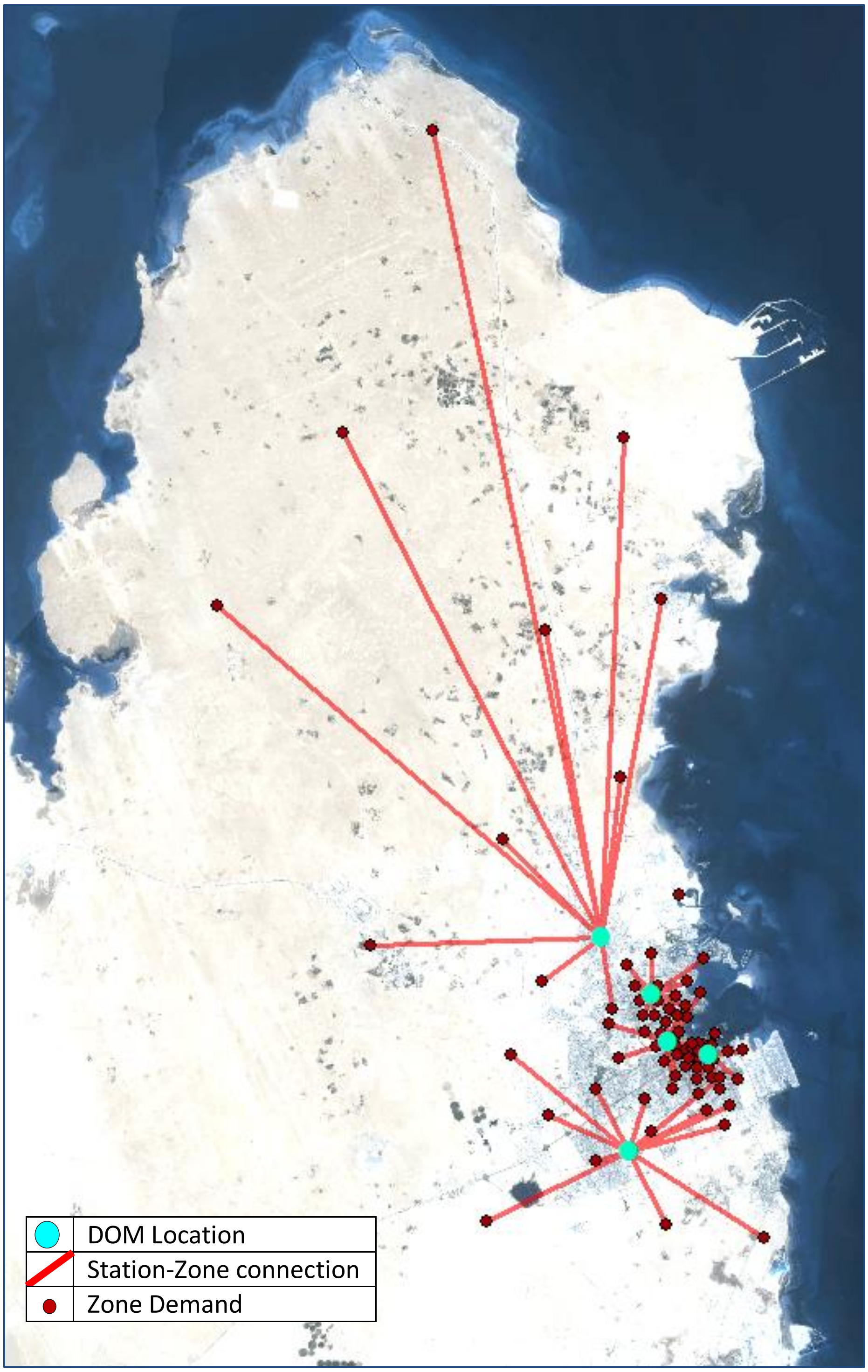

Figure 24. Optimal 5 locations by GIS using complaints capacities

Total_Distance			
Average Total_Distance	1973.015473	Count Total_Distance	78
Max Total_Distance	5719.005314	Standard Deviation	1141.222841

Figure 25. Distance report generated by ArcGIS forthe 5 optimal locations

4.2.4.2 Option (1) : Service Area Analysis

The service area analysis summarized in Table 10 shows how Option (1) 5 optimized sub-facilities got improved in terms of time. The simulation shows that option (1) facilities fleet can attend more than 97% of the complaints within the KPI target of 3 hours, which is 11% more than DOM score and 17% more than the actual score.

Table 10

Coverage Percentage of Option (1) 5 Optimized Facilities

Coverage of..	***within..***	**<60 mins**	**<120 mins**	**<180 mins *KPI***	**>180 mins**
Complaints	Numbers	14378	27263	37690	38658
	Percentage	37.19%	70.52%	97.50%	100%

Figure 26, presents the service area boundaries. It is clear that Option (1) capability is remarkably better than the existing DOM central facility. At option (1), facilities are covering all of Doha, Umm Salal, and most of Al Rayyan municipalities urban locations are within 2 hours duration, Also Al Wakra, Al Sheehaniya, and most of Al Khor are reachable slightly above the KPI target, Al Shamal municipalities has also become reachable even if it still require around 5 hours duration.

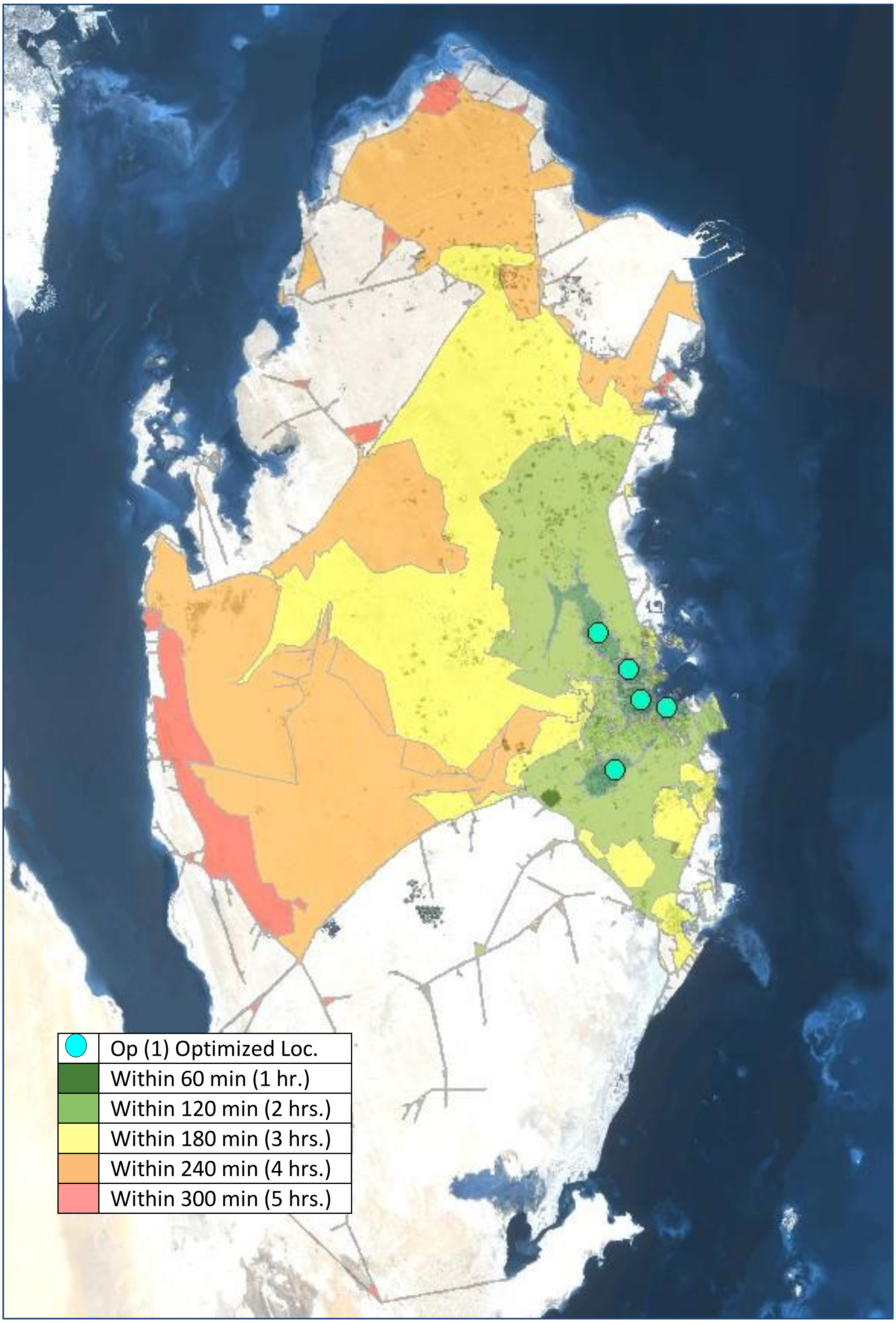

Figure 26. Service area of option (1) 5 optimized sub-facilities in terms of time

4.2.4.3 Option (2) : Optimized Model based on Demand with Priority

At Option (2), the complaints demand will be altered. It will not be based on capacity only, but also on priority factor of the zones. It worthies mentioning that after applying the priority factor, the total number of complaints presented will increase to (58135) which is 1.5 times more than the original total complaints number as the average priority factor for all zones equals 1.5. Figure 27 show the capacity redistribution after applying the priority factor on the complaint capacity which can be compared with original capacities at Figure 6.

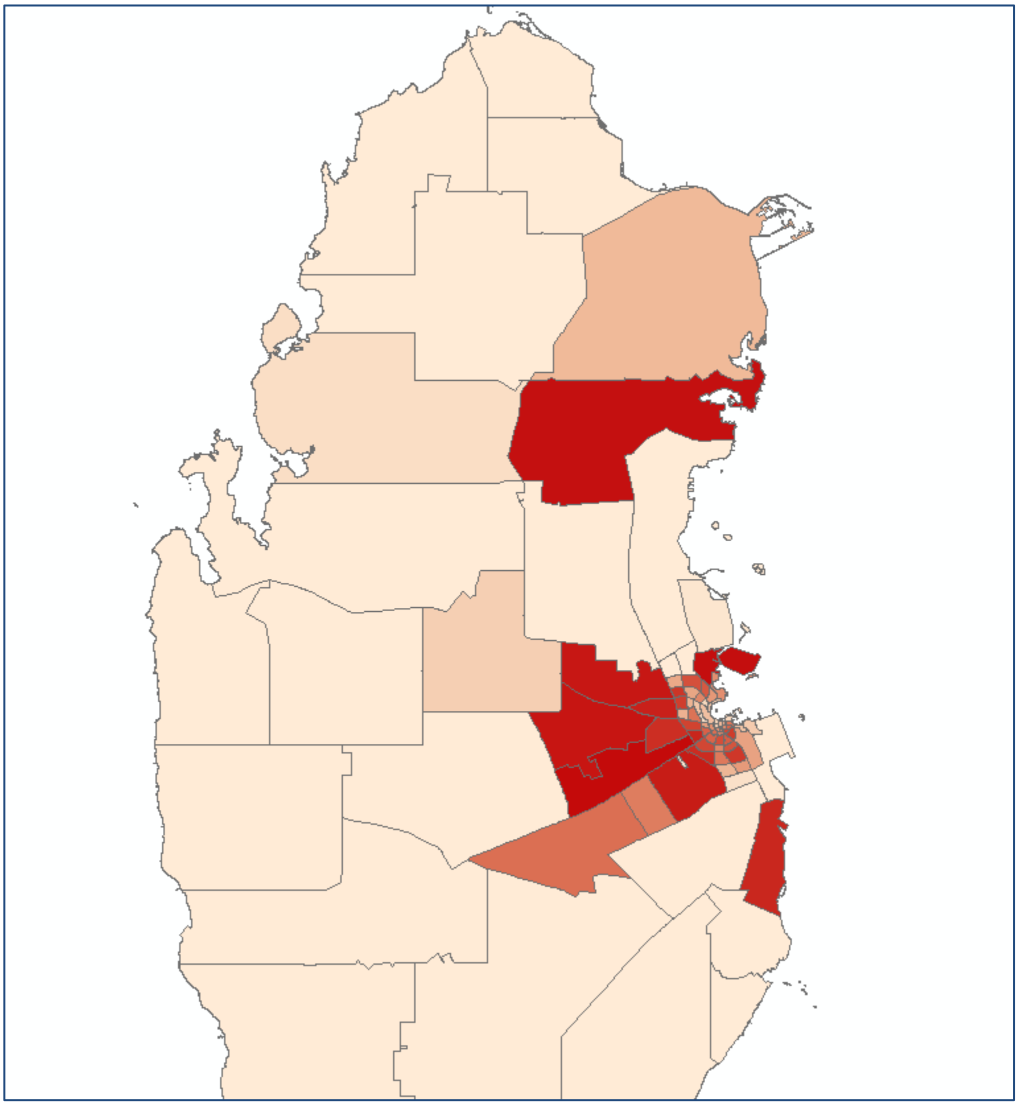

Figure 27. Complaints distribution after applying Priority factor

By keeping the potential locations (Facilities) as all complaints locations like option (1), and redefining Demand Points as all complaints demand locations multiplied by the priority factors, and keeping the number of facilities required as 5, the Network Analyst solver using the Streets Network dataset, optimized the new 5 locations that are maximizing the service coverage area within the shortest response time for zones with priority.

Table 11 summarize the location allocation optimization result, that shows that the new 5 optimized sub-facilities locations have a wider but acceptable range of demand distribution that it ranges between 14 - 26 %.

Table 11

Option (2) Optimization Result (Priority Applied)

Facility	Zone	Number	Demand	%	Coordinates
Location 1	Al Khor	74	8177	14.07	228916, 435470
Location 2	Al Gharrafa	51	10136	17.44	223227, 396350
Location 3	Onaiza	65	13445	23.13	230972, 399065
Location 4	Old Airport	45	15012	25.82	233788, 389896
Location 5	Mouaither South	55	11365	19.55	221735, 389795
Total		(Factored)	58135	100	(AV. 11627)

Figure 28 shows the relationship in terms of distance between zones demand around with priority and the closest service sub-facility of the five new optimized locations. The linear relationship liens represent the travel distance from each assigned optimized facility to the demand point within its service boundary.

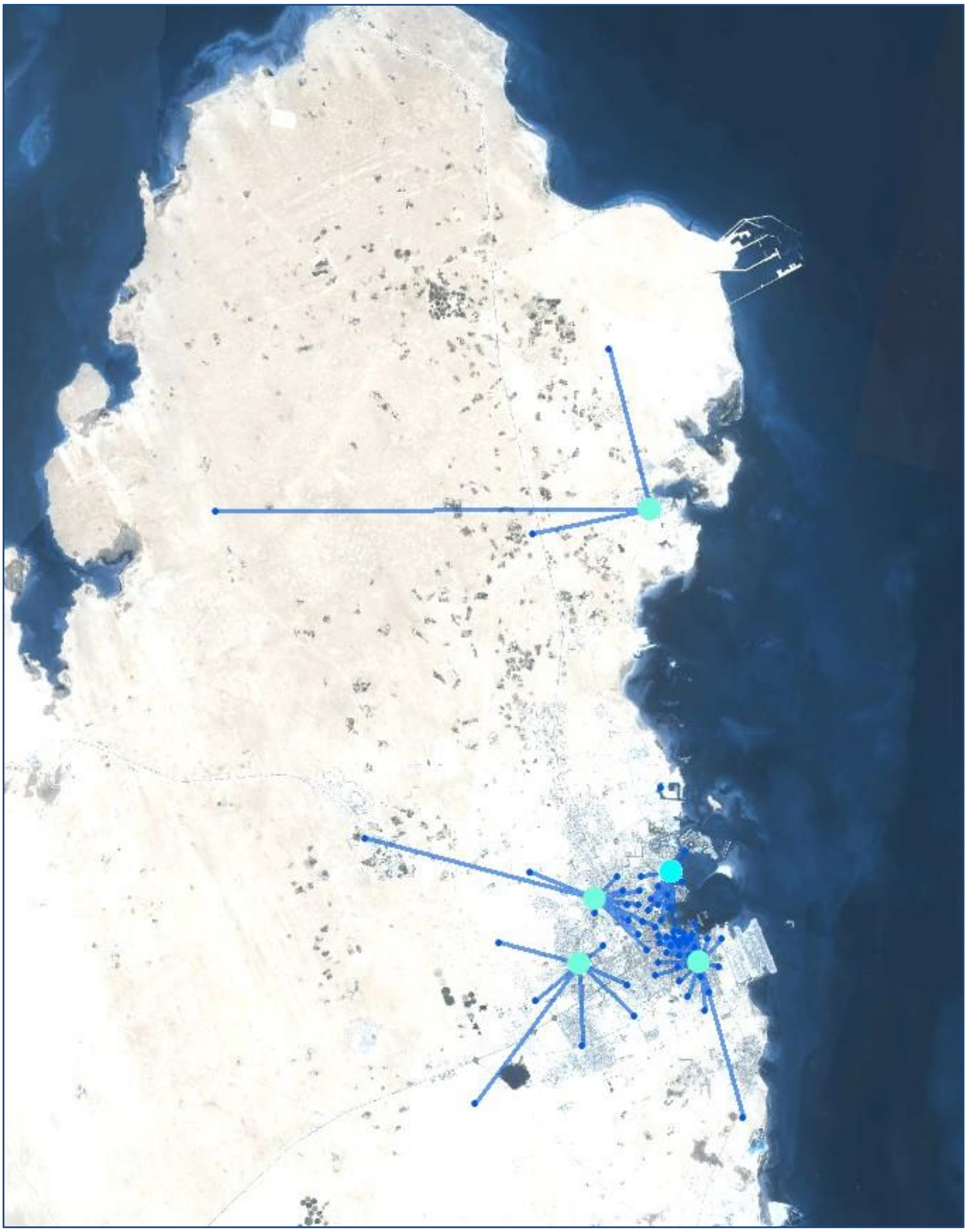

Figure 28. Optimal 5 locations by GIS using demand with priority

Average Total_Distance	2121.754629	Count Total_Distance	66
Max Total_Distance	5321.429725	Standard Deviation	823.454079

Figure 29. Distance report generated by ArcGIS for the new 5 optimal locations

Figure 29 captures the result analysis of the traveled distance of the fleet from the new five optimized locations to the assigned demand points with priority by GIS. The average distance reaches around 21 km which is very close to option (1). Also, the maximum distance reaches around 53 km which is around 10% less than Option (1) maximum distance. The average response time has increased by 5 min than option (1) to be 105 min, around 5% more. While distance standard deviation has dropped another 3 in compassion with option (1).

4.2.4.4 Option (2) : Service Area Analysis

Table 12 summarizes how Option (2) new 5 optimized sub-facilities performs in terms of time. The simulation show that option (2) facilities fleet can attend 99.6% of the complaints within the KPI target of 3 hours, which is 2% higher than option (1), 14% more than DOM score and 20% more than the actual score.

Table 12

Coverage Percentage of Option (2) New 5 Optimized Facilities

Coverage of..	***within..***	**<60 mins**	**<120 mins**	**<180 mins *KPI***	**>180 mins**
Complaints	Numbers	20921	51144	57900	58135
	Percentage	35.99%	87.98%	99.60%	100%

Figure 30, presents the service area boundaries based of option (2) facilities. It is clear that Option (2) capability is remarkably higher than all other options. At option (2), facilities are covering all of Doha, Al Rayyan, Al Khor, and most of Umm

Salal municipality with 2 hours only. Also by the priority optimized sub-facilities municipalities like Al Shamal, Al Wakra, and Al Sheehaniya become reachable within the KPI target. This is extraordinary that some of those locations were not even within the 5 hours boundary line at DOM centralized option.

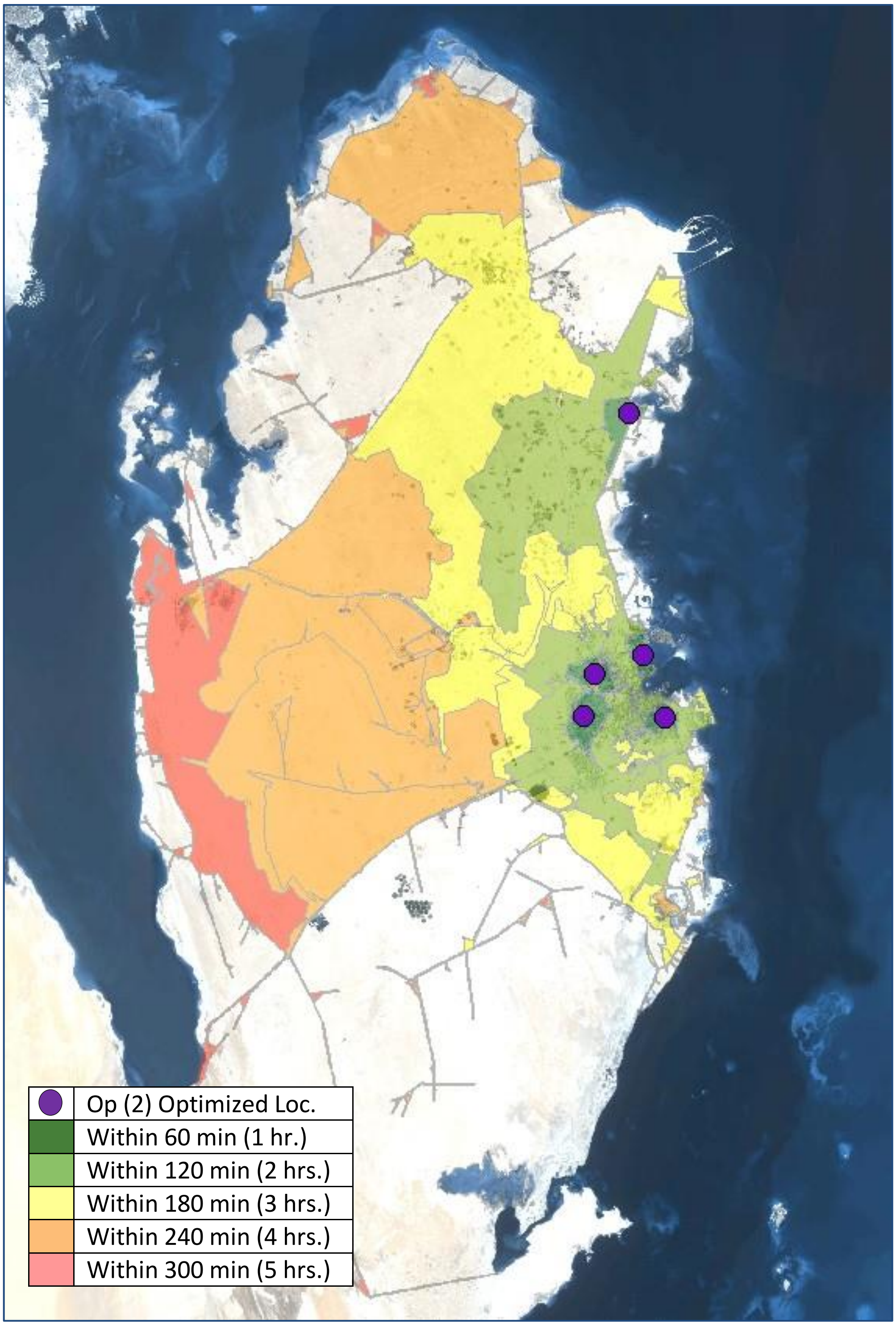

Figure 30. Service area of option (2) 5 priority optimized facilities in terms of time

4.2.5 Results Compression Summary

In this chapter, the existing DOM system performance has been evaluated using the Network Database of DOM complaints. Furthermore, three GIS models have been developed. First, a model for the existing DOM facility where the performance of the current DOM got evaluated in terms of service distance and response time. The other two models are for the two proposed options, where Option (1) considers the regular demand capacities as obtained from DOM drainage network database, while Option (2) considers a priority factor for demand capacity locations in order to generate more desirable result.

Table 13

Comparission of Existing and Optimized Results

Model	**Service Area Analysis**			**Closest Facility Distance Analysis**				
Parameter	<60 min (%)	<120 min (%)	<180 min (%)	Max. (km)	Av. (km)	Standard Deviation	Res. Time (min)	Av. Zones per facility
Actual (no GIS)	12	29	80	*113	42	-	*210	*91
Central by GIS	16.33	35.18	86.52	98.86	38.49	17.60	192	78
Option (1)	37.19	70.52	97.50	57.19	19.73	11.41	99	15.6
Option (2)	35.99	87.98	99.60	53.21	21.22	8.23	106	13.2

* Actual Values

CHAPTER 5: CONCLUSION

Ashghal Drainage operations and maintenance (DOM) services must be available and distributed in a way that allows reliable and timely response to drainage complaints from demand spots. However, many factors, including fleet location sites and population growth, can influence DOM service coverage and response time. As such, Ashghal planners are continuously looking for methods for evaluating, refining and optimizing existing services. This project has discussed the GIS simulation for determining optimal locations of DOM facilities and evaluating the response time that can be achieved.

5.1 Project Findings

In order to reach this project's goal, DOM service considered as location allocation problem. GIS simulation for DOM planning and development was successfully developed and implemented to; (a) evaluate the performance of the service, (b) analyze and solve the optimality required to improve the service, and (c) compare the optimized outcome with the existing records.

The overall service performance of the existing DOM central facility can be rated as acceptable. A comparison of the existing system with a proposed GIS based showed that their performance has shown that the average response time can be dropped to 100 minutes which the half of the current performance, the reflects that the existing DOM system is not calibrated and not planned well.

It can be concluded that GIS can be used to model, simulate, assess, evaluate and compare the performance of a DOM service facilities.

5.2 Project Contributions

The major contribution of this project is that it is taking it place on Ashghal Asset Affairs budget line for next year of 2018. And soon the implemented proposed model will be available for performance evaluation. It has been observed also that the existing DOM model can be improved just with re-allocation the available fleet and without increasing the cost or equipment.

5.3 Future Work

Future studies could include the fleet type optimization based on the complaint type distribution around Qatar. Also, it could include the upcoming new drainage networks and consider the population factor there as upcoming demand points. One other thing, studies could include dynamic multi-complaints cases where some complaints may become idle without response until a fleet get free which affects the response time of DOM. Something else, it could include season effect like winter and summer, or even time effect like morning, afternoon, evening, and night. These important parameter may help in getting more accurate results and a better optimized solution.

Last but not least, a development plan could be studied for facility requirements like Jetters filling points, vehicle technician, IT system, rest areas,.. etc. which may affect the overall DOM level of service.

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