إقـــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Using a Simulation Model for Crisis and Emergency Management

(A Case Study on Coastal Municipalities Water Utility "CMWU")

استخدام نموذج محاكاة لإدارة الأزمات و الطوارئ

(دراسة حالة على مصلحة مياه بلديات الساحل)

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The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/**فراس نبيل غانم أبو نقيرة** لنيل درجة الماجستير في **كلية *التجارة*/ قسم إدارة الأعمال** وموضوعها:

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(دراسة حالة: مصلحة مياه بلديات الساحل)

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وبعد المناقشة التي تمت اليوم الاثنين 09 جمادي الأولى 1435 هـ، الموافق 2014/03/10م الساعة الواحدة ظهراً، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

أ.د. يوسف حسين عاشور	**مشرفاً ورئيساً**	....
أ.د. فارس محمود أبو معمر	**مناقشاً داخلياً**	....
أ.د. سامي سليم أبو ناصر	**مناقشاً خارجيًا**	....

وبعد المداولة أوصت اللجنة بمنح الباحث درجة الماجستير في **كلية *التجارة*/** قسم **إدارة الأعمال**.

واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله ولي التوفيق ،،،

مساعد نائب الرئيس للبحث العلمي و للدراسات العليا

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Using a Simulation Model for Crisis and Emergency Management

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Abstract

This research develops a highly efficient and effective simulation-based decision making tool which can be applied in real-time management situations. It basically simulates the using of mobile pumps to discharge and dispose flooded storm water from incident areas through efficient and effective resources reallocation to finish the assigned tasks as quickly as possible to minimize the loss of life, asset and property.

In this research Arena software package used to combine the using of discrete logic with continuous models to facilitate a solution for the flooding problem due to high storms and rain falls that struck Rafah city on 8 January 2013 and imitates the real time situation taking into account reducing the response time, service time and waiting time spent to finish the assigned tasks and hence output analyzer used to analyze and evaluate the effectiveness and efficiency of different suggested scenarios when responding to an emergency event and illustrates which is the best scenario for the decision maker to follow?

The model is flexible enough to fit with dynamic situation changes and has the ability to interface with other interactive models using GIS maps, national databases and user friendly interfaces in order to deal with high complex crisis and emergency flooding problems.

عنوان الرسالة:

استخدام نموذج محاكاة لإدارة الأزمات و الطوارئ

(دراسة حالة على مصلحة مياه بلديات الساحل)

ملخص الرسالة

هذا البحث قام بتطوير أداة فاعلة و كفوءة لصنع القرار بإستخدام المحاكاة والتي يمكن تطبيقها في حالات إدارية واقعية. حيث تم محاكاة استخدام المضخات المتنقلة لتصريف مياه الأمطار والتخلص منها في المناطق التي غمرتها المياه من خلال إعادة تخصيص الموارد بكفاءة وفعالية لإنهاء المهام الموكلة في أسرع وقت ممكن لتقليل الخسائر في الأرواح والممتلكات والأصول.

في هذا البحث تم استخدام الحزمة البرمجية أرينا حيث تم الجمع بين استخدام النماذج المنطقية المنفصلة مع النماذج المستمرة لتسهيل التوصل إلى حل لمشكلة الفيضانات بسبب العواصف و سقوط الأمطار التي ضربت مدينة رفح في يوم 8 يناير عام 2013 و ذلك بواسطة محاكاة الوضع الحقيقي القائم مع الأخذ بعين الإعتبار تقليل زمن الإستجابة و زمن الخدمة و زمن الإنتظار اللازم لإنجاز المهام المطلوبة وبالتالي تم استخدام برنامج Output analyzer لتحليل وتقييم فعالية وكفاءة السيناريوهات المقترحة المختلفة عند الاستجابة لحدث معين في حالات الطوارئ ويوضح ما هو السيناريو الأفضل حتى يتبعه صانع القرار؟

هذا النموذج لديه من المرونة ما يجعله قادراً للتكيف مع تغيرات الأوضاع الديناميكية كما لديه القابلية للإشتراك و التكامل مع مختلف النماذج التفاعلية التي تستخدم خرائط GIS و قواعد البيانات الوطنية و المجهزة بواجهات سهلة للمستخدمين في سبيل التعامل مع الأزمات و الطوارئ الخاصة بإدارة مشاكل الفيضانات عالية التعقيد.

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Finally, the deepest appreciation is expressed to my wife, for her silent sacrifice and endless support throughout this long journey.

Dedication

TO MY DEAR PARENTS . . .

WITH LOVE AND APPRECIATION

TO MY PATIENT WIFE . . .

TO THE FUTURE OF PALESTINE . . .

MY CHILDREN . . .

Mohammed, Farah and Yousif

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Abbreviations

3D	Three dimension
ABS	Agent Based Simulation
ANOVA	Analysis of Variance
CEML	Crisis and Emergency Modeling Language
CES	CMWU Emergency Service
CMWU	Coastal Municipalities Water Utility
D4S2	Dynamic Discrete Disaster Decision Simulation System
DES	Discrete Event Simulation
DS	Decision Support
DSS	Decision Support Systems
EMS	Emergency Medical Service
EOCs	Emergency Operation Centers
GIS	Geographic Information System
HSEM	Homeland Security and Emergency Management
KM	Knowledge Management
KW	Kilowatt
MCDM	Multiple Criteria Decision Making
MDA	Model-Driven-Architecture
PC	Personal Computer
Rpm	Revolution Per Minute
UI	User Interface
VBA	Visual Basic for Applications

Chapter one

Introduction

This chapter consists of the following sections:

1.1. Research background
1.2. Scope of the research
1.3. Problem statement
1.4. Research objectives
1.5. Importance of the research
1.6. Research methodology
1.7. Research framework

Chapter one
Introduction

1.1. Research background

Urban flooding is expected to increase due to climate changes and rapid urbanization. In order to minimize the risk of flooding and locate high risk flood areas, tools for flood management are needed. When flooding occurs overland flow tends to run on a complex terrain with many flow paths in close connection with the collection system. It is in a physical sense difficult to separate these two flow systems. Usually, a one way flow connection is applied, allowing water to enter the collection system but overflow from the drainage system is not routed on the surface (Nielsen et al., 2008).

In addition natural disasters (e.g., earthquakes, floods, fires) and technical faults (e.g., power outages) and their impact on critical infrastructures and population have caused a growing attention on how to manage crisis and emergency. Simulation allows creating a portfolio of virtual crisis and emergency management experiences to be used, for instance, for training institutional operators with the responsibility of solving the crisis (Nicola et al., 2011).

Thus Simulation techniques have been extensively used in modeling and analyzing complex systems in the past decades with the advances of computer technology. Simulation can outperform mathematically modeling in such instances because of its capability to get around stringent assumptions that must be made for analytical models to be tractable (Wu et al., 2007).

The complexity of most of real-world systems is very much related to their stochastic nature as well as to the interactions (at different levels) among their main factors and variables. Although traditional methodologies (i.e. analytical approaches and models) contribute confidence and knowledge about a real-world system they provide theoretical solutions whose validity is very much dependent on initial (and usually restrictive) assumptions.

Historically the most suitable way to come up with solutions to solve problems in real-world complex systems is a modeling & simulation (M&S) based approach. And thanks to unstoppable growth of digital computers, has simulation become a critical enabling technology for many scientific disciplines and social sciences (Longo, 2010).

The case study shed the light on a suburb with a residential area in Rafah City located in the south of Gaza strip. The residential area called El-Jenena and consists of single family houses and apartment buildings. During the end of the intensive rainfall in the 8th of January 2013 rainwater with rain intensity of 50 mm / day (Ministry of Agriculture, 2013) collected from an impervious area of 488216.81 m^2 calculated by using AutoCAD software package with 23824.9 m^3/hr runoff rate calculated using rational method detailed in chapter 4 of this research was lead to backwater effect which accumulates storm water to levels greater than houses plinths and its estimated to be around 30366.5 m^3 storm water according to the observed and measured water depths trapped in eight areas.

So it's important and essential to simulate these real-world systems to provide decision makers with useful tool to resolve this crisis and manage the emergency operations and resources efficiently and effectively by rationale the decisions taken to resolve problems.

1.2. Scope of the research

In 8^{th} of January 2013, Palestine notably Gaza strip encountered huge water storms which cause flooding in many areas all over the coastal cities. Civil Defense confirmed that Gaza emergency team carried out 550 rescue tasks during the high storms, pulling 54 cars were flooded, evacuate about 50 houses flooded by rain water in the Gaza Strip 25 houses of them in Rafah city containing 40 families and on the other hand CMWU emergency team used mobile diesel pumps to discharge about 30366.5 m^3 storm water as calculated in chapter 4 of this research from the case study area and about 208000 m^3 from all incident areas in Rafah (CMWU, 2013). Thus, relevant safety management, facilities maintenance, and emergency response must be provided in immediately. However, Palestine does not have prior extensive experience in the management of crisis and emergency operations in addition to the shortage in resources and capabilities in the light of poor piping and storm water collection systems infrastructure. Once a crisis or accident occurs in certain area, it would spread faster within the confined space, making the crisis relief very difficult. The severity of the crisis may increase. As the existed problem resolving system fails to manage the crisis and emergency events effectively and efficiently because of:

a. The inability to allocate the area hazard prioritization.
b. Using the first in first out procedure which is not fit to the reality.

Focusing on water storms and flooding crisis and emergency responses, this research will discuss the impact of various ratios of resources and time inputted during crisis relief on the degrees of crisis scopes, through computerized simulation model of crisis and emergency response of operations and system dynamics. This research takes the CMWU - Rafah regional area office as the research target.

1.3. Problem statement

The main problem addressed in this research is: what will be the impact of using a computerized simulation model to improvement and effectiveness of crisis and emergency management decision making in Costal Municipalities Water Utility?, as there's a long service time, response time and waiting time in finishing the assigned tasks of serving incident flooded areas which threaten human life property and assets.

1.4. Research objectives

The main objective of this research is to provide decision makers with useful tool to resolve the problem statement, so that this research is being carried out with several objectives and it is important to state them clearly; to ensure that the research is kept on track.

Following are the objectives of: **using a simulation model for crisis and emergency management.**

a. Build a simulation model for helping CMWU decision makers.

b. Provide a real time decision support system based on simulation to be a useful tool in improving operation efficiency.

c. Evaluate the efficiency and effectiveness of using the simulation model by CMWU decision makers.

d. Improve dealing with disasters, mitigating their effects, controlling and managing emergencies and improving operation efficiency on both large and small scale.

1.5. Importance of the research

The main target of this research is to build an interactive, computerized simulation model for testing and measuring how the scale of the flooded areas due to high storms, and enable decision makers to manage such situations efficiently and effectively, mitigating the effects of flooding on peoples, community property and assets as this model is the best fit and tailored to local Palestine capabilities and available resources in the light of poor infrastructure and piping systems as well as taking into account the nature of the surrounding environment and pave the way to researchers to develop integrated solutions to dealing with flooding crisis and emergency. The problem lies in dealing with situations has a difficulty to estimate by money because it’s deal with human. So this model will be a great assistance to emergency officials in managing emerging events in CMWU.

The model will be designed to simulate:

a. The deployment of emergency resources.
b. The response time, service time and wait time spent in completing the emergency tasks.

1.6. Research methodology

1.6.1. Research methodology

To answer the main question of this research, a case study based on a computer simulation approach was followed to study and evaluate the impact of response time in finishing the assigned emergency tasks efficiently and effectively. CMWU regional office in Rafah selected. The traditional emergency service work flow analyzed and evaluated using simulation approach. Some of the variables examined include: dispatch time, traveling to scene time, pumping time, pumping waiting time and variability in storm water levels accumulation and storm water discharging. Arena software package version (14.00) used in fitting and analyzing the collected data, and building the simulation model.

1.6.2. Sources of Data

Accumulated storm water volumes, surface runoff rate and service rate collected through mathematical calculations, direct observations and historical records. In addition, data on dispatch time, traveling time and pumping time collected for validation purposes. Secondary data sources supported theoretical background of this research.

1.6.3. Research Steps

As shown in figure (1.1) this research will be consisted of *five* steps to achieve its objectives. The first step handled problem formulation and objectives of the overall project plan. The second step specifying model which included extracts the essence of the system without including unnecessary detail. The third step building model included data collection experimental controls describe the procedures for performing a simulation and analysis of the model. The step four concerned in network simulation advances time in accordance with the movement of entities through the nodes and activities of the model. Finally step five using model through run simulations and the subsequent interpretation and presentation of the output data.

1.7. Research framework

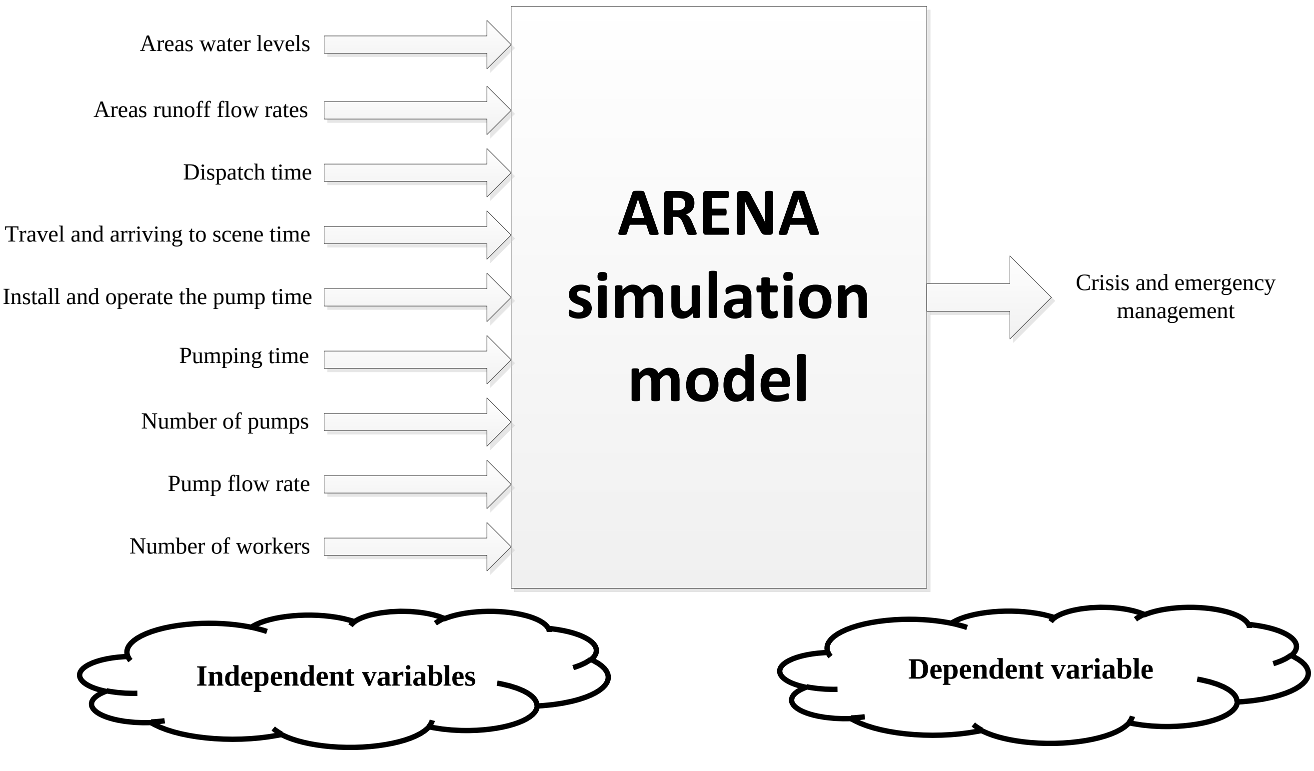

Figure (1.1): Research framework

Chapter two

Literature review

This chapter consists of the following sections:

Chapter two
Literature review

2.1. CMWU profile

The Coastal Municipalities Water Utility (CMWU) is a semi – public entity financially independent, responsible for the water supply services, wastewater treatment and storm water collection. The CMWU is funded to integrate all water and wastewater services into a unique service for better service and performance.

CMWU aims at providing safe and clean water services and environmental friendly wastewater services to the residents of Gaza strip, through the efficient operation, maintenance, and improvement of the utility assets and services. CMWU strives to meet the needs of the customers through innovative solutions.

CMWU role in the Gaza Strip is one of the most important organizational roles in the water and wastewater sector, especially in the light of the difficult circumstances the area undergo; lacking of the raw material, the tightened siege, and lack of financing for strategic and developmental projects. CMWU was established to improve the water and wastewater sector through unified and connected administration of planning, resources and performance in all the regions of the Gaza Strip. CMWU also aims at enhancing the municipalities' role through sustaining their censorship in this field in order to achieve the CMWU goals (CMWU, 2011).

2.1.1. CMWU main objectives

CMWU has some main objectives to achieve and attain its goals which are illustrated as follows:

a. Structuring the newly established utility by proposing its organization structure, staffing plan, payroll system, human resource management, strengthening the capital investment and planning systems.
b. Improving water quantity by reducing water losses and increasing the supply capacity.
c. Improving water quality via the maintenance and upgrade of the existing disinfection program and improving the performance of the existing wastewater works.
d. Improving the management systems of the water, wastewater, storm water and related emergency services with emphasis on operation and maintenance systems, financial management, customer services, billing and collection, human resources development (CMWU, 2011).

2.1.2. CMWU emergency services

CMWU playing a foundation and valuable role in helping civilians and victims through high storms and flooding by doing a lot of emergency works by emergency team work as follows:

a. Keep the waste water and storm water pumping stations working properly by executing all operation and maintenance procedures including all preventive and unscheduled maintenance operations.
b. Cleaning all storm water inlets, grating and channels from sediments and debris in the storm water collection system.
c. Work in cooperation with the municipality teams, civil defense forces, police, healthcare teams to facilitate victims evacuation by using mobile pumps to discharge flooding and storm water to the nearest safe areas away from the civilian existence.

2.2. Background of emergency management

Emergency management (or disaster management) is the discipline of avoiding risks and dealing with risks (Haddow et al. 2007). It has a comprehensive spectrum including mitigation of potential risks, response to ongoing disasters, recovery after disasters, preparedness to future emergency situations and communications before, during and after disasters and involves a broad class of knowledge and practices (Wu et al., 2008).

In emergency management, collaborative decision-making usually involves collaborative sense-making of diverse information by a group of experts from different knowledge domains, and needs better tools to analyze role-specific information, share and synthesize relevant information, and remain aware of the activities of others (Wu et al., 2013).

A disaster is an extreme event with a natural, technological or social cause that has consequences in terms of casualties, destruction, damage and disruption (Perry and Quarantelli, 2004). “Emergency” is a broader term that includes disasters, catastrophes (which some would define as major disasters) and smaller disruptive events. It can be defined as an imminent or actual event that threatens people, property or the environment and which requires a co-ordinated and rapid response (Alexander, 2005).

No country and no community are immune from the risk of crisis. However, it is possible to prepare for, respond to and recover from crisis and disasters and limit the destructions to a certain degree. Emergency management is a discipline that involves preparing for crisis and disaster before it happens, responding to crisis and disasters immediately, as well as supporting, and rebuilding societies after the natural or human made crisis and disasters have occurred. Emergency management is a continuous process. It is essential to have comprehensive emergency plans and evaluate and improve the plans continuously.

2.2.1. Crisis concept and crisis lifecycle

The umbrella term of crisis helps capture extraordinary phenomena such as pandemic viruses, volcanic ash clouds, oil spills, animal welfare diseases, hurricanes, tsunamis, urban riots, water contamination episodes, chemical explosions, policy failures and institutional fiascoes (McConnell, 2011).

Crisis is said to be bad, and can only result in negative consequences. In organizations as in life, crises come in as many strains as the common cold. The spectrum is so wide that it is impossible to list each type. As individuals, we realize that our daily life is fall with many kinds of unexpected situations; and if we do not prepare for what might encounter in accordance with the available information, our daily life would be more challenging and threatening (Al-Ghamdi, 2013).

The word crisis originates from the Greek word "krisis", which means judgment, choice or decision. The use of the term, however, varies depending on the context in which it is being used and the researcher's discipline (Preble, 1997). In the organizational literature, crisis is defined as follows:

An organizational crisis is a low-probability, high-impact event that threatens the viability of the organization and is characterized by ambiguity of cause, effect, and means of resolution, as well as by a belief that decisions must be made swiftly (Pearson and Clair, 1998).

Several different events must be taken into account for a precise crisis definition. A crisis is made up of precursors, the manifestation of the crisis and the restoration process. As Coombs wrote "a crisis does not just happen, it evolves" (Coombs, 2007).

According to Coombs, three influential classifications of the crisis lifecycle can be found in the literature (Coombs, 2007):

a. Four stages' crisis lifecycle by Fink (Fink 1986)
b. Five stages' lifecycle used by Mitroff (Mitroff 1994)
c. A basic three stages' model (Coombs 2007)

Fink's model is the earliest and he is one of the first to consider a crisis as an extended event. He divides a crisis in four stages:

a. Emergent clues or hints of a potential crisis.
b. Crisis breakout.
c. The effects of the crisis and the efforts to get through it.
d. Finding signals that make stakeholders sure that the crisis is over.

The model from Mitroff identifies five stages:

a. Signal detection.
b. Risk factors searching and reducing.
c. Crisis damage's prevention.
d. Recovery phase.
e. Crisis management's reviewing and critiquing to learn from it.

The essential difference of both models resides on the last phase. Fink concentrates on the progress of crises while Mitroff is concerned about the progress of crisis management efforts.

The last model is a three stage approach and it has been recommended by several authors (Coombs, 2007). The other stages from Fink and Mitroff are integrated to the phases of this model. Coombs labeled the three stages as precrisis, crisis event and postcrisis (Coombs, 2007):

a. **Precrisis:** Crises incubation period where a series of warning signals come out before the crisis event.
b. **Crisis event:** Sequence of events in an unstable or crucial time in which a decisive change occurs.
c. **Postcrisis:** Period in which the safety level is restored and learning and continuity mechanisms are initiated.

2.2.2. Crisis and emergency / disaster phases

Crises and emergencies as well as disasters can likewise be defined in many ways (Boin, 2005b; Boin & t'Hart, 2006; Eriksson, 2008). The concepts are overlapping and may sometimes be hard to separate**.**

Disasters are not new phenomena for human life and for the world itself. They can be seen as fundamental aspects of normal life. Disasters are often described as consequences of the ways societies structure themselves, economically and socially, the ways that societies and government interact, and the ways that relationships between decision makers are sustained (Kusumasari et al., 2010).

The crisis management capability can be discussed with regard to four phases: preventive measures, preparedness measures, responsive measures and recovery measures (McEntire, 2003).

In Afshar (2009), that the related activities are usually classified as four phases of Preparedness, Response, Recovery, and Mitigation. Figure 2.1 illustrates the order of these phases according to the onset of the disaster. Appropriate actions at all points in the cycle lead to greater preparedness, better warnings, reduced vulnerability or the prevention of disasters during the next iteration of the cycle.

Figure (2.1): Crisis and emergency phases

Some of the main activities during four phases of emergency management cycle are summarized below (Afshar, 2009):

Preparedness

a. Activities to improve the ability to respond quickly in the immediate aftermath of an incident.

b. Includes development of response procedures, design and installation of warning systems, evacuation planning, exercises to test emergency operations, and training of emergency personnel.

Response

a. Activities during or immediately following a disaster to meet the urgent needs of disaster victims.

b. Involves mobilizing and positioning emergency supplies, equipment and personnel; includes time-sensitive operations such as search and rescue, evacuation, emergency medical care, food and shelter programs, and bringing damaged services and systems back online.

Recovery

a. Actions that begin after the disaster, when urgent needs have been met. Recovery actions are designed to put the community back together.

b. Include repairs to roads, bridges, and other public facilities, restoration of power, water and other municipal services, and other activities to help restore normal operations to a community.

Mitigation

a. Activities that prevent a disaster, reduce the chance of a disaster happening, or lessen the damaging effects of unavoidable disasters and emergencies.

b. Includes engineering solutions such as dams and levees; land-use planning to prevent development in hazardous areas; protecting structures through sound building practices and retrofitting; acquiring and relocating damaged structures; preserving the natural environment to serve as a buffer against hazard impacts; and educating the public about hazards and ways to reduce risk.

Emergency management process needs the cooperation of all individuals, groups, and communities to be successful. When a major crisis happens such as flooding and storms in 8th January of the year 2013, many emergency management agencies work with governments and non-governmental organizations in an effort to decrease the impact of the crisis. Humanitarian organizations such as CARE USA, ACF, International Committee of the Red Cross and UNICEF among the organizations that work with CMWU in Gaza strip to provide humanitarian aids.

Based upon the national standards, local governments and agencies establish their operational emergency plans for responding to potential local incidents. The general purpose of such plans is to specifically define task assignments and responsibilities for emergency responding units and personnel in order to best alleviate suffering, save lives and protect property (Wu et al., 2008).

2.2.3. Emergency response system concept

The underlying philosophy of any emergency response agency is to respond as quickly as possible to minimize the loss of life and property due to the occurrence of an emergency. Time is of the essence to emergency response agencies (Altintas and Bilir, 2001). Emergencies are known to occur suddenly, unexpectedly, and they can be life threatening. Emergencies take place in various forms like fires, accidents (i.e. vehicular, industrial, etc.), and flooding due to heavy rainfalls. Emergency response work entails various non-routine tasks such as discharging and disposal of flooding water, rescuing someone or something trapped in a building due to these huge amounts of storm water, and salvaging property damage.

Emergencies undoubtedly result in great loss of life and property. As such they exert tremendous pressure on emergency response agencies and the management of emergency response in responding to such situations (Subramaniam et al., 2012).

In an emergency response system, when a crisis or disaster occurs and is reported, the responders (e.g., police, fire trucks with fire fighters, ambulances and medical responders) are dispatched to the disaster/crisis scene or other critical locations to save lives and assets. The scene could be extremely chaotic because of the excessive congestion caused by both the responders and injured or panicky people. When more responders get involved, other areas might also be affected and the traffic could become more congested. The major disaster event might also increase the number of other related emergency incidents and the response resources might become overwhelmed. It is not feasible to model such a stochastic and dynamic system mathematically, but it is possible to simulate it with operational rules and logic. The more accurate the information and rules used, the better the decisions are made (Wu et al., 2008).

Abrahamsson et al. (2010) identified four main challenges to the analysis and evaluation of emergency response systems; the use of value judgments for evaluation, the complexity of emergency response systems and the context in which they operate, the validity of the information upon which analysis and evaluation is based, and the limiting conditions under which the system was operated and is being evaluated.

So the success of the management of an emergency depends on resources, systems, and personnel. Resources are required at the planning, response and recovery phases, and they need to be identified according to the responding agencies and the types of emergencies encountered. In addition to resources, good systems such as the development of an emergency operation plan, an incident command system, and a warning system to facilitate the emergency management activities should be in place. The systems essentially specify the roles, functions, and responsibilities of each responding agency in responding to emergency situations. The emergency response personnel serve as the link between the resources and the systems because they are trained to use the resources and practice the systems in various emergency situations. In other words, during emergencies, these trained personnel are the ones who are on the ground and on the site handling matters at hand (Subramaniam et al., 2012).

2.2.4. Emergency response performance

Even though the field of emergency response has attracted a number of researchers to examine the domain conceptually (Coleman, 2005; Ford and Schmidt, 2000), however, no standard definition of emergency response is available. Ford and Schmidt (2000) view emergency response as efforts to minimize the potential for, and subsequent impacts of, disasters on life and property. Coleman (2005) refers to it as putting emergency preparation into action. Despite these varied conceptual understandings, emergency response can generally be seen as consisting of activities conducted during the time from when an emergency event is initially detected to the time when the emergency situation is stabilized by the emergency agencies to minimize the impact on human suffering.

One important component of emergency response is the time taken to respond, which has been identified as a measure of emergency performance (Al-Ghamdi, 2002; Altintas and Bilir, 2001; O'Meara, 2005; Pons and Markovchick, 2002; Pons et al., 2005). Al-Ghamdi (2002) asserted that performance measurement is recognized as an index of output or production. Because the time taken to respond by CES (Costal Municipalities Water Utility services) team is a form of work output, the response time is clearly a form of performance measurement. Within the context of emergency response, the rate taken to complete various mitigating activities varies. For example, there is time taken to respond immediately to distress calls, time taken to reach the emergency scene, time to execute the operation, time to leave the emergency scene, time to reach back to the base, etc. The assumption here is that the shorter the time taken to respond by emergency responders, the better their performance is in the accomplishment of their job. In other words, time is key to responding because it determines the extent of mitigation in emergency situations; the more time taken to respond, the more damage is incurred to life and property and vice versa.

In the present research, the main focus is time taken in all emergency response stages. This is defined as the time taken by emergency responders to finish the assigned tasks from the moment they receive a distress call. How soon emergency responders are able to finish the task is important because it determines the rate taken of the whole emergency activities (assuming that reaching the emergency scene is not hindered by uncontrollable factors such as weather or traffic conditions).

2.2.5. CMWU emergency services (CES) work flow

The CMWU emergency services (CES) personnel are a generic type of responders who are capable of treating and stabilizing victims at the scene and/or discharging huge storm and flooding water to be available to other supporting emergency responders transporting them to medical facilities for more definitive treatment. So the main focus in this research is to learn the CMWU emergency services responder's (CES) operations first.

In normal situations, CES vehicles and equipment's are responsible for responding to the emergency calls (i.e., 2145242 calls) which have potential emergency needs in their designated service areas. The calls are not served on a first-come-first-serve basis but with preemption and are processed by dispatchers, and there are may be an effort to do some prioritization. Normally the nearest available CES vehicle or equipment is dispatched. When a vehicle is dispatched, it starts traveling from its current location to the scene. On arriving at the scene, the responder assesses the victim's situation and determines the appropriate actions to take. In severe situations, the responder treats and stabilizes the area by installing mobile diesel pump according to surrounding environment and pumping the storm and flooding water to the nearest manhole or storm water channel to be a safe to civil defense forces and EMS to transports him/her to an appropriate hospital or shelter. In less critical situations, the EMS responder may just treat the patient at the scene and leave him/her for further medical care to be delivered by other support responders.

The CES responders can respond to most critical needs. After appropriate treatment and water discharge, the CES vehicle becomes available and travels back to the base. From that point, it can be dispatched again to respond to another emergency call either while enroute back to the base or after returning to the base. Some variations may be made to fit the special needs in various places. For example besides CES units, they also dispatch fire company resources to assist in responding when CES services become overwhelmed. This approach can help improve the response service quality but it involves other issues such as mutual aid agreement.

During a major disaster event, the other normal emergency calls within the area should also be covered as much as possible. In case of a disaster, all available CES units are divided into two groups. One group is designated to deliver stormwater/wastewater services to normal emergencies and the other group is designated to respond to the major crisis/disaster.

CES has more complex operations in the disaster/crisis response system compared with other responders including fire, police and hazmat. When they are dispatched, they simply travel to the destination and stay there to perform their assigned tasks individually and/or collaboratively. For example, firefighters are trained for basic life support and they can be the first responders to the scene and work as emergency medical technicians to stabilize victims at the scene; hazmat teams might be needed at the scene to deal with the contaminated materials first before other responders can get into the scene.

2.2.6. Emergency operations centers (EOCs)

A variety of public, private, non-profit and volunteer organizations come together to provide shelter, food, ice, and other essential needs within the communities affected. These actions, for the most part are supported by those who are working behind the scenes to supply the resources required in order to be effective. They don't garner the headlines, conduct extensive in depth interviews, or even seek acknowledgment of their efforts. They simply come to one place so that they can bring all the pieces together to meet the needs of their friends, families, and neighbors. These individuals staff the central coordination point for any disaster, the Emergency Operations Center (EOC) (Ryan, 2013).

EOCs are facilities that provide technical assistance to emergency responders at the scene of an incident. EOCs, which are permanently located in areas expected to be safe from hazard exposures, provide support for the performance of emergency response functions at the incident scene. An EOC is important because the resources needed to respond to an incident are often widely dispersed, so the specific resources needed to respond to a particular type of incident at a given location cannot be predicted with certainty in advance. Moreover, many organizations participate in the incident response and each organization must have a capability for obtaining and processing timely information about the incident. This capability is established by collocation of essential personnel with telecommunications and information processing equipment in an EOC that will provide an effective division of labor while maintaining coordination of action. Lessons learned in previous incidents suggest that considerable decision making authority should be allocated to organizations close to the incident site because of their superior knowledge of local conditions. However, greater technical knowledge and resources generally are available at higher levels. Thus, close coordination is needed among organizations at all levels.

An EOC must be designed with enough space to house to support the emergency response functions that take place within it. Moreover, it must provide a layout that places its staff in close proximity to the equipment, information, and materials they need (Lindell et al., 2006).

2.3. Previous research overview

2.3.1. Simulation studies

The research of (Sivalingam et al., 2013) titled *“Optimal Staff Scheduling Using Discrete Event Simulation in Indian Hospital”* proposes a method to analyze the patient flow in the outpatient department of an Indian hospital in order to reduce the patient waiting time. A discrete event simulation model of the outpatient department was developed to examine the patient flow. This research identified some of the suitable doctor schedule by integrating the simulation model into optimization program in order to reduce the patient waiting time without adding additional resources.

The research of (Aleisa and Savsar, 2013) titled *“Modeling of Firefighting Operations through Discrete Event Simulation”* reports the results of applying discrete event simulation on firefighting operations in the State of Kuwait. The objective was reduce response times to reach fires in all districts to below five minutes. The Simulation of output runs were analyzed using ANOVA. The results were validated at 95% confidence level. Simulation turned to be an excellent tool for testing a major change without disturbing firefighting operations.

The research of (Eskandari et al., 2011) titled *“Improving The Emergency Department Performance Using Simulation And MCDM Methods”* Which it’s focused on the examination of processes in emergency department of a governmental hospital in Iran and identifying bottlenecks that lead to long waiting times. Simulation was used first to identify bottlenecks of the process and second to evaluate different scenarios developed for overcoming these bottlenecks in order to decrease waiting time of the patients in the emergency department.

The research of (Liong & Loo, 2009) titled *“A Simulation Study Of Warehouse Loading And Unloading Systems Using ARENA”* simulate and model the loading and the unloading systems in a warehouse that involves ready packed as well as products that need sealing has been conducted using ARENA. Therefore four improvement models have been experimented with in order to find a strategy that will optimize the residence time of any customer’s lorry without affecting the other processes. This study has not only overcome the overtime problem but also reduces the waiting time of the customers by almost two hours, i.e. reduces the waiting time by more than 70%.

The research of (Wu et al., 2008) titled *"Agent-based Discrete Event Simulation Modeling for Disaster Responses"* summarizes key features of the design and implementation of a comprehensive disaster simulation system. The simulation system has several unique features compared with other existing systems. The architecture incorporates hybrid discrete event and agent based simulation capabilities and has embedded GIS capabilities. In addition strategies for streamlining computations allow for the system to operate in real time on a standard desk top or portable personal computer. This single platform has the potential to provide realistic decision support for planning and mitigating catastrophic events.

The research of (Wu et al., 2007) titled *"System Implementation Issues Of Dynamic Discrete Disaster Decision Simulation System (D4S2)-Phase I"* concentrated on building a comprehensive, interactive, multi-module computer simulation system – D4S2 – for testing how the type and scale of the event, situational variables and command decisions affect responders' efficiency and effectiveness in dealing with complex and evolving disasters, and stated that such a system can be of great assistance to emergency officials in managing emerging events. Discrete event simulation is a superior tool for modeling complex, large-scale systems. When combined with agent-based models, it becomes even more powerful because it bears more flexible scalable operational rules and it is easier to interface with other modules that can introduce more reality and dynamics into the system. This research outlined the goals and implementation issues of Phase I. The issues include basic system work flow, agent based modeling and rules, client interfaces, and instance generation. The fundamental system has been tested through some experiments done for the City of Pittsburgh downtown area. The results showed several reasonable outcomes so that the system has been verified to some extent.

2.3.2. Emergency and crisis management

The research of (Nicola et al., 2012) titled *"An MDA-based Approach to Crisis and Emergency Management Modeling"* presented an approach to build models concerning crisis and emergency scenarios, which is based on the CEML language and the related meta-model consisting of a set of modeling constructs, a set of relationships, and a set of modeling rules. Then, it proposes some methodological guidelines, consisting of system architecture; to allow CEML models to be part of the input data required by-simulation environments. Finally, it proposes a modeling methodology based on collaborative design patterns, i.e., reusable solutions to recurrent modeling problems, tailored to model interaction and communication exchange arising during the crisis.

The research of (Reda et al., 2011) titled *"A Hierarchical Model For Emergency Management Systems"* focused on two objectives The primary objective of this research was to make some suggestions of how to implement intelligent systems for disaster management, as in the larger approach of emergency management including disaster risk reduction. A special attention is paid for systems that assure support for decisions of the operators and assistance for repair the technical defects that occur during technological processes. To respond crisis situations, the personnel often analyze great volume of process data and are obliged to filter quickly not useful information, to find the principal cause of a situation in which alarms appear, to implement an action to remediate the situation.

The second objective of the research was the definition of the framework of a complex multilayered emergency management system named HSEM, which is a comprehensive model that includes risk assessment, disaster prevention, mitigation and preparedness. Instead of focusing on a single disaster it is used to reduce disaster comprehensively. It worked on multilevel, multidimensional and multidisciplinary to improve the disaster reduction and response. This model is considered a dynamic model that is able to maintain multi-interdependency between events, actions, actors, context and the other factors involved in the process.

The research of (Longo, 2010) titled " *Emergency Simulation : state Of The Art And Future Research Guidelines"* presented that Modeling & Simulation can be profitably used for preventing disasters, mitigating their effects, controlling and managing emergencies and improving evacuation efficiency on both large and small scale. Additional efforts are still required to put together ideas for better use and integration (i.e. standardization) of M&S, 3D virtual environments (gaming technologies), artificial intelligence techniques and Geographic Informative Systems.

The research of (Lauge' et al., 2009) titled *"The Dynamics of Crisis Lifecycle for Emergency Management"* presented that Crisis management should not only rely on the steps and actions carried out when a crisis occurs. It must be a learning process instead. Failing to understand the characteristics of Crisis Lifecycle's phases could result in ineffective response when managing crisis.

The research of (Toby J. Kash and John R. Darling, 1998) titled *"Crisis management: prevention, diagnosis and intervention*" focused on the fact that companies that prepare for crisis events are better able to handle them more efficiently and successfully. It is quite feasible to address crisis situations ahead of time by issues analysis and scenario creation. Acknowledging a crisis, and communicating affectively with constituent groups, will reduce image and reputation damages. However, the primary success comes from prevention, preparation and intervention.

2.3.3. Decision support systems

The research of (Fogli and Guida, 2013) titled *"Knowledge-centered design of decision support systems for emergency management"* focuses on the design of decision support systems for emergency managers in charge of planning, coordinating and controlling the actions carried out to respond to a critical situation. A novel knowledge centered design methodology is proposed and demonstrated through the application in a concrete case study in the field of pandemic flu emergency management. Knowledge-centered design is based on a rational and structured approach to the elicitation and modeling of the knowledge concerning the target environment, the application domain, the intended users, their tasks, and the specific activities that the decision support system is expected to provide. The research aims at overcoming some of the limitations of user-centered and activity-centered design in the specific context of decision support systems. As knowledge-centered design is based on an iterative process that goes through four main phases, namely: target environment identification, domain understanding, user characterization, and functional analysis. The research illustrates each phase in detail and discusses the application in the proposed case study.

The research of (Alvear et al., 2012) titled *"Decision support system for emergency management: Road tunnels"* presents a decision support system (DSS) for emergency management in road tunnels. Based on a specific methodology, the system provides the operator with decision recommendations to deal with the emergency in real time. Furthermore, the system uses predictive tools to estimate the severity of the accident or incident, as well as rescue and evacuation times. This information is very useful during the first stages of an emergency when information is scarce, incomplete and inaccurate, yet the tunnel operator is required to make the right decisions under a high level of stress. The DSS reduces the decision circle and allows the operator to make critical decisions based on dynamic alternatives. The system has been tested in various hypothetical emergency cases based on the Tunnel of Lantueno in the A-67 Highway, Spain. The application cases show that the DSS provides reasonable and consistent results.

The research of (Druzdzel and Flynn, 2003) titled *"Decision Support Systems"* stated that Decision support systems are powerful tools integrating scientific methods for supporting complex decisions with techniques developed in information science, and are gaining an increased popularity in many domains. They are especially valuable in situations in which the amount of available information is prohibitive for the intuition of an unaided human decision maker and in which precision and optimality are of importance. Decision support systems aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge, aiding the process of structuring, and optimizing decisions.

2.4. Comments on previous research

Previous research shed the light on the importance of discrete event simulation model in scheduling and optimizing the work flow to reduce waiting time without the need to additional resources as well as its valuable role in reducing and minimizing the response time to reach the incident areas. In addition simulation playing a foundation role in identifying the bottlenecks of the processes and evaluate different scenarios to overcoming these bottlenecks in order to decrease waiting time. DES is a powerful tool that it is easier to interface with other modules and introduces reality and dynamics into the systems

The emergency and crisis previous research reveal that the personnel who deal with the crisis should analyze great volume of process data and are obliged to filter quickly not useful information to reach the remedial solution faster. So crisis management should not rely on the steps and actions carried out. It must be a learning continuous process instead, and failing to understand the crisis life cycle's phases could result in ineffective response when managing crisis. Consequently companies that prepare for crisis events are better able to handle them more time by issues analysis and scenario creation through acknowledging a crisis and communicating effectively with constituent groups which leads to reducing image and reputation damages.

The DSS previous research illustrate that decision support systems are important for emergency managers in charge of planning, coordinating and controlling the actions carried out to respond to a critical situation. As The DSS's reduce the decision circle and allow the decision makers to make critical decisions based on dynamic alternatives. DSS's are powerful tools integrating scientific methods for supporting complex decisions with techniques developed in information science. Decision support systems aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge, aiding the process of structuring, and optimizing decisions.

The main difference of this research from the previously mentioned research is that it is concerned and focused on the emergency and crisis management in flooding management problem using a combined discrete logic with continuous simulation model to mimics and imitates the emergency response time spent, service time and waiting time in discharging flooding storm water which threaten humans, property and assets by building ARENA model which provides an interactive DSS tool to help emergency managers to minimize the time and cost of the assigned tasks done by emergency team.

Chapter three

Simulation, modeling and decision support systems

This chapter consists of the following sections:

Chapter three
Simulation, modeling and decision support systems

3.1. Introduction

Many real world problems in management and optimization are very complex and mathematically intractable so that simulation is the appropriate tool for system analysis and performance evaluation. Computer simulation requires developing a program that mimics the behavior of a system as it evolves over time and records the overall system performance. As the technology of computer hardware and software advances, simulation has emerged as an essential tool in academic research. Simulation has been applied to various sectors, such as manufacturing and business (Jahangirian et al., 2010), services and supply chain management (Bandinelli et al., 2006), etc. In fact, the simulation method has the advantage of being applicable whatever the complexity of systems. Despite, the simulation is rarely used in many companies of the underdevelopment countries.

3.2. Concept of simulation and modeling

3.2.1. Definition of simulation

Simulation can be defined as “a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software” (Kelton et al., 2010). Simulation allows management to test performance models that might be extremely expensive, risky, and time consuming instead of experimenting with actually workers, equipment, and materials. Additionally, mangers can analyze the effects of a specific decision in a variety of situations. Thus, simulation software enables management to evaluate alternative design options when implementing new strategies. However, the main attraction of simulation is its ability of easily building and carrying out models along with generating statistics and presenting animations of the results (Montazer et al., 2003). According to Altiok and Melamed (2001) systems simulation is an analytical framework to create a simpler yet adequately realistic representation of a system the behavior of which needs to be better understood.

Kelton et al. (2010) defined simulation as a method used to create a model with the characteristics of a real system on a computer with the appropriate software. Simulation is a powerful problem-solving technique that is concerned with statistical sampling theory and analysis of complex and probabilistic physical systems (Kelton et al., 2010).

From the practical viewpoint, simulation is the process of designing and creating a computerized model of a real or proposed system for the purpose of conducting numerical experiments to give us better understanding of the behavior of that system for a given set of conditions (Kelton et al., 2010).

3.2.2. Definition of modeling

Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the real system and incorporate most of its salient features. So, it should not be so complex that it is impossible to understand and experiment with it. A good model is a judicious tradeoff between realism and simplicity. Simulation practitioners recommend increasing the complexity of a model iteratively. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software. Mathematical model classifications include deterministic (input and output variables are fixed values) or stochastic (at least one of the input or output variables is probabilistic); static (time is not taken into account) or dynamic (time-varying interactions among variables are taken into account). Typically, simulation models are stochastic and dynamic (Andradottir et al., 1997).

3.3. Simulation modeling

Computer simulation is defined by Kelton et al. (2010) as the methods for studying a wide variety of models of real-world systems by numerical evaluation using software designed to imitate the system's operations or characteristics, often over time. Simulation is a popular, versatile and powerful tool because it is capable of realistically modeling considerably complicated and dynamic operational systems (Wu et al., 2008).

3.3.1. Simulation study

In a simulation study as shown in figure (3.1), human decision making is required at all stages, namely, model development, experiment design, output analysis, conclusion formulation, and making decisions to alter the system under study. The only stage where human intervention is not required is the running of the simulations, which most simulation software packages perform efficiently.

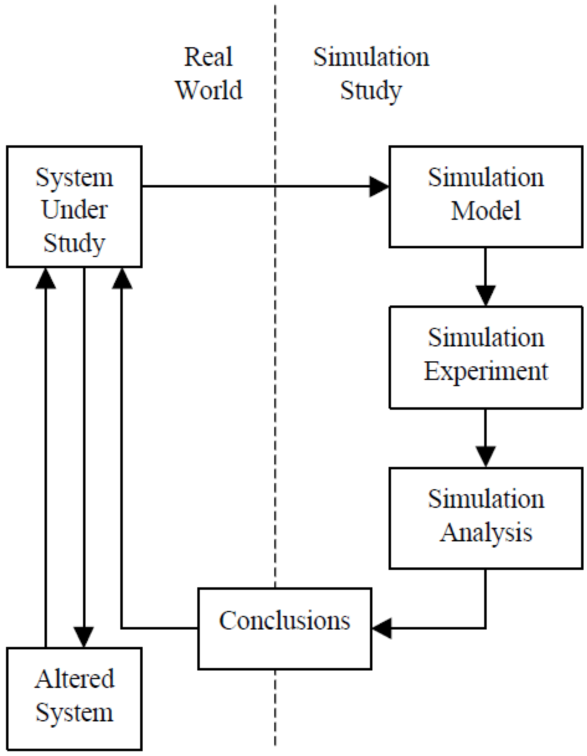

Figure (3.1): Simulation study schematic
Source: (Andradottir et al., 1997).

Briefly, steps involved in developing a simulation model, can be explained designing a simulation experiment, and performing simulation analysis (Andradottir et al., 1997): Identify the problem, determine the objectives and overall project plan, collect and process real system data, formulate and develop a model, validate the model, select appropriate experimental design, establish experimental conditions for runs and perform simulation runs, documentation and reporting and implementation.

3.3.2. Benefits of simulation modeling and analysis

Simulation modeling and analysis is one of the most frequently used operations research techniques. When used judiciously, simulation modeling and analysis makes it possible to (Andradottir et al., 1997):

a. Obtain a better understanding of the system by developing a mathematical model of a system of interest, and observing the system's operation in detail over long periods of time.
b. Study the internal interactions of a complex (sub)-system.
c. Test hypotheses about the system for feasibility.
d. Compress time to observe certain task over long periods or expand time to observe a complex task in detail.
e. Study the effects of certain informational, organizational, environmental and policy changes on the operation of a system by altering the system's model; this can be done without disrupting the real system and significantly reduces the risk of experimenting with the real system.

f. Allow training & learning at a lower cost.
g. Experiment with new or unknown situations about which only weak information is available.
h. Identify bottlenecks of system (material, people, etc.)
i. Improve system through model building.
j. Use multiple performance metrics for analyzing system configurations.
k. Understand & verify analytic solutions.
l. Employ a systems approach to problem solving.
m. Visualize operations through animation.
n. Develop well designed and robust systems and reduce system development time.

3.3.3. Pitfalls to guard against in simulation

Simulation can be a time consuming and complex exercise, from modeling through output analysis that necessitates the involvement of experts and decision makers in the entire process. Following is a checklist of pitfalls to guard against (Andradottir et al., 1997).

a. Unclear objective.
b. Using simulation when an analytic solution is appropriate.
c. Invalid model.
d. Simulation model too complex or too simple.
e. Erroneous assumptions.
f. Undocumented assumptions. This is extremely important and it is strongly suggested that assumptions made at each stage of the simulation modeling and analysis exercise be documented thoroughly.
g. Using the wrong input probability distribution.
h. Replacing a distribution (stochastic) by its mean (deterministic).
i. Using the wrong performance measure.
j. Bugs in the simulation program.
k. Using standard statistical formulas that assume independence in simulation output analysis.
l. Initial bias in output data.
m. Making one simulation run for a configuration.
n. Poor schedule and budget planning.
o. Poor communication among the personnel involved in the simulation study.

3.3.4. Disadvantages of simulation

Despite its advantages, simulation may not be a perfect tool for system analysis. This is because many real systems are affected by uncontrollable and random inputs, many simulation models involve random, or stochastic, input components, causing their output to be random too. Although modelers think carefully about designing and analyzing simulation experiments, simulation output may still be uncertain. This uncertainty might be solved by making a lot of oversimplifying assumptions about the system. Unfortunately, though, such an oversimplified model will probably not be a valid representation of the system. In general, modelers would prefer an approximate answer to the right problem rather than an exact answer to the wrong problem (Bahtiyar, 2005).

3.3.5. Different kinds of simulation

There are many different ways to classify simulation models, but a useful way is along these three dimensions:

a. **Dynamic or static:** Time plays a natural role in dynamic models but does not in static ones. Most operational models are dynamics and Arena was designed to best fit with this kind of models (Kelton et al., 2010).

b. **Discrete or continuous:** In a discrete model changes occur only at specified points in time while in a continuous model the state of the system changes continuously over time. A discrete model can be a manufacturing system where parts arrive and leave following a specific timetable; a water reservoir with water flowing in and out is a perfect example of a continuous model. In the same model can be present elements of both discrete and continuous change: these models are called mixed continuous-discrete models (Kelton et al., 2010).

c. **Deterministic or stochastic:** Models with no random inputs are called deterministic models while stochastic models operate with at least some random inputs. Due to the randomness of the inputs, even the outputs of a stochastic model are uncertain and the analyst has to consider this carefully in designing and interpreting the results of this kind of projects (Kelton et al., 2010). A model can have both deterministic and random inputs in different components. It is often a must to allow for random inputs in order to make the model a valid representation of reality. Random inputs can be generated through specifying probability distributions from which observations are sampled (Kelton et al., 2010).

3.3.6. Discrete event simulation (DES)

Discrete event simulation models the discrete processes in which changes of the system states occur at isolated points of time (Goldberg, 2004).

DES is used to model systems that change states dynamically, stochastically, in discrete intervals (Gunal, 2012). DES models are useful for quantifying the effectiveness of certain operating policies for systems with flexible workers. In addition they are also ideal for study of short-term transient effects that may not be discernible with analytic models (Brown, 2012).

The components that flow in a discrete system, such as people, equipment, orders, and raw materials, are called entities. There are many types of entities, and each has a set of characteristics or attributes. In simulation modeling, groupings of entities are called files, sets, lists, or chains. The goal of a discrete simulation model is to portray the activities in which the entities engage and thereby learn something about the system's dynamic behavior. Simulation accomplishes this by defining the states of the system and constructing activities that move it from state to state. The beginning and ending of each activity are events. The state of the model remains constant between consecutive event times, and a complete dynamic portrayal of the state of the model is obtained by advancing simulated time from one event to the next. This timing mechanism, referred to as the next-event approach, is used in many discrete simulation languages (Banks, 1998).

3.3.7. Agent-based simulation (ABS)

A computer agent is an autonomously controlled entity that can perceive its own operations as well as the surrounding environment, compile the predefined rules to make operational decisions, and act based on these decisions. An agent-based simulation model contains a collection of such autonomous decision-making agents and it is preferable in simulating the actions and interactions of the individuals in a network which can affect the entire system (Bonabeau, 2002).

ABS is a simulation method for modeling dynamic, adaptive, and autonomous systems. It is employed to discover systems by using ‘deductive’ and ‘inductive’ reasoning. At the core of an ABS model, there are ‘autonomous’ and ‘interacting’ objects called agents. Agents are like entities in a DES model; however, agents are social and interact with others and they live in an environment and their next actions are based on the current state of the environment. In addition, an agent senses its environment and behaves accordingly based on simple rules defined. Agents may have explicit goals to maximize or minimize, may learn and adapt themselves based on experience (which needs memory, e.g., using dynamic attributes). The definition of agent behaviors ranges from simple ‘if-then’ statements to complex models, for example cognitive science or artificial intelligence (Gunal, 2012).An ABS model has three elements: agents, which have attributes (static or dynamic levels, e.g. variables) and behaviors (conditional or unconditional actions, e.g., methods); interactions, which define relationships between agents; and environment that are external factors that affect agents and interactions.(Borshchev & Filippov, 2004; Sobolev et al., 2008).

3.4. Arena simulation package

Rockwell Software’s Arena is a powerful package. Its popularity can be traced to its ability to provide useful results without requiring too significant a learning curve. One of Arena’s most beneficial traits is that users across the whole spectrum of skill-levels can use the product to generate useful results. This robustness is achieved by expanding upon an evolved version of the SIMAN language, meaning that Arena has been built upon the shoulders of an already successful product. Arena allows users to choose from various modules that are presented in various templates ranging from basic logic pieces to complex items such as conveyers and transporters. Each module represents a combination of SIMAN code that has been pre-packaged to allow the user to drag and drop pieces of code into the model without having to work with the code itself. In fact, an entry-level user can design, develop, and execute somewhat complex Arena models without having to type a single line of code. Arena also provides generated reports at the end of simulation runs that can be modified however the user sees fit (Kelton et al., 2004).

Despite being straightforward enough for a beginner user to use, Arena allows experienced users to model at sophisticated levels of detail. Each of the modules is basically a combination of various pieces of SIMAN code that have been packaged together for the more popular coding scenarios. Arena also provides a blocks template that contains the individual pieces of logic that make up the pre-packaged modules. For example, as shown in figure (3.2) a process module in the basic process template contains logic to seize and release a resource along with logic to delay the process for a specified duration in the interim. In the blocks template a user can find each of these logic pieces, such as seize, as individual pieces that can be added to the model. This allows a user to combine any of these logic pieces as they see fit in order to achieve the modeling logic needed. In addition to the basic SIMAN blocks that can be used to write the model logic at a basic level, Arena also allows users to include pieces of code in other languages such as Microsoft's Visual Basic for Applications (VBA). For example, every time an entity passes through a VBA module, a corresponding piece of VBA code can be executed. This is very useful in that it allows the use of ActiveX object libraries common in most PC desktop applications so that Arena can interact with other programs and vice versa. Arena does provide read and write modules in the advanced template that allow models to read and write to Excel, Access, or regular text files, but the addition of embedded VBA code allows an unlimited amount of communication between applications (Kelton et al., 2004).

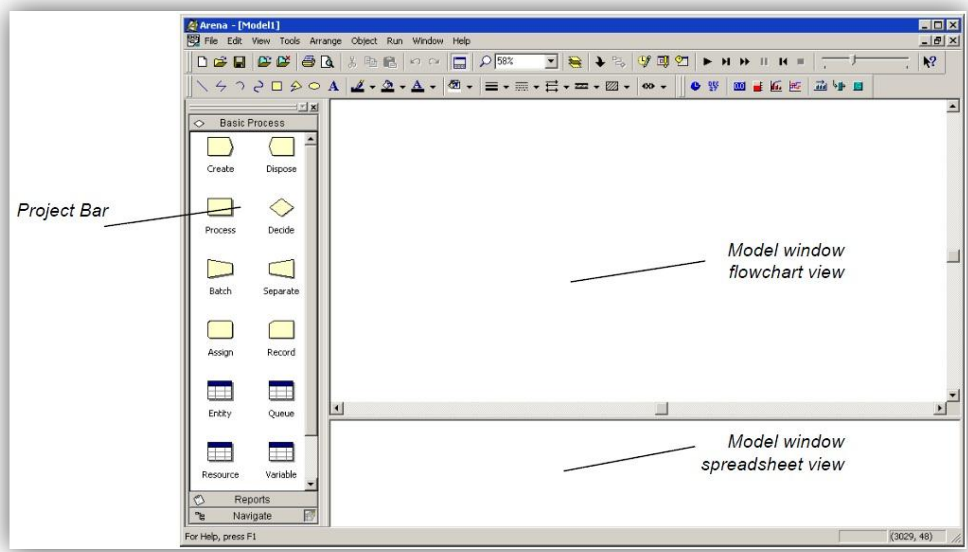

Figure (3.2): Arena software interface

3.4.1. SIMAN

The core technology of Arena is the SIMAN simulation language. The modules contained in the Arena template were created using SIMAN's modeling blocks as their components. SIMAN blocks are made available to all Arena users in the SIMAN template. SIMAN modules provide the user with increased flexibility and increased control of detailed system logic. Those users who have become accustomed to writing SIMAN code directly in a text editor are able to do so within Arena. In this case, Arena provides an option for directly recognizing this code, which is contained in a file external to the Arena graphical modeling environment (Takus & Profozich, 1997).

3.4.2. Arena details

Arena's main interface is a working space common among Windows-based environments along with a template window that allows users to drag and drop modules onto the working space. Table (3.1) contains generalized definitions to the most common simulation terms encountered. A model is basically the simulation scenario itself that encapsulates everything going on in the simulation. An entity however is an actual dynamic piece that proceeds through the model while interacting with various processes. Many processes require the access of resources, and can be used to model just about any real world activity. The resources themselves are whatever an entity may need to interact with during a process. Variables and expressions are model-specific parameters that are independent with any entity or resource, although they can be accessed for information anywhere in the model.

Table (3.1): Basic Arena Definitions

Term	Definition
Model	A combination of processes and process flows that represents a real-world scenario. A typical model would include many different aspects of various scenarios.
Entity	The fundamental driver of a simulation that represents what is using or accessing the various processes. Entities travel throughout the simulation model and are generally the dynamic pieces of the model that change throughout time.
Process	A capture-all term that is used to define various stops along an entity's path that require the interaction with resources. Processes are used to model activities.
Resource	A resource is any external service or item that an entity needs to interact with during a process. A resource is seized and released as needed.
Attribute	Attributes are pieces of information that are related to the various entities.
Variable	A variable is a model wide parameter that is not related to any one particular entity or process. Variables can be updated through a simulation run as needed.
Expression	An expression is similar to a variable in that it does not pertain to any one entity or process, but differs in that it is generally used to model mathematical relationships or statistical expressions.

3.5. Decision support systems

3.5.1. Decision support in general

The term Decision Support is very loosely defined and it means different things to different people in different contexts (Bohanec, 2001). DS may also link with Operations Research where scientific methods or quantitative models are used to analyze and predict the behavior of systems that are influenced by human decisions (Ecker & Kupferschid, 1991). The term DS contains two words, "decision" and "support". The word "decision" is a choice or selection between two or more objects and the word "support" refers to supporting or helping people in making decisions. The decision support is a part of decision making processes which means aiding people to make good decisions by understanding and analyzing the effects of all the alternatives.

3.5.2. Decision support system concept and elements

The initial concept of Decision Support System (DSS), even though it was coined before the PC era, focused on the use of interactive calculation in semi-structured decision-making (Alter, 2002). The decision support systems are a distinct class of information systems. Clement (1995) identified four factors which determine the difficulty degree of the decision-making process. The first, and altogether the most important factor is the complexity of the problem. The human factor has a limited capacity of perceiving and solving complex problems and, therefore, builds simplified mental models of real situations. Even if these models are applied in the best way possible, any simplification may lead to defective decisions. The second factor is given by the uncertainty degree of the problem, and the third is the fact that, in most cases, several different objectives are set. A certain decision may be right in the short run, but may prove wrong in the long run and vice versa. In order to make good decisions, the decision maker must be well informed, must have access to high-quality models (from simple, implicit models to sophisticated mathematical models) and to "adequate" information. A decision support system may make all these conditions achievable (Hellstom & Kvist, 2003).

Considering the activities that the DSS supports, the elements of the decision-making model as shown in the figure (3.3) are (Demarest, 2005):

a. A decision maker – an individual or a group responsible for making a particular decision.

b. A set of inputs of the decision-making process – data, numerical or qualitative models for interpreting data, previous experiences with similar data sets or decisional situations and diverse rules of a cultural or psychological nature, or constraints associated to the decision-making process.

c. The decision-making process proper – a set of steps, which are more or less clearly defined, for transforming input data into output data as decisions.

d. A set of output data of the decision-making process, including the decisions proper and (ideally) a set of evaluation criteria for the decisions which take into account the needs, problems or objectives at the root of the decision-making process.

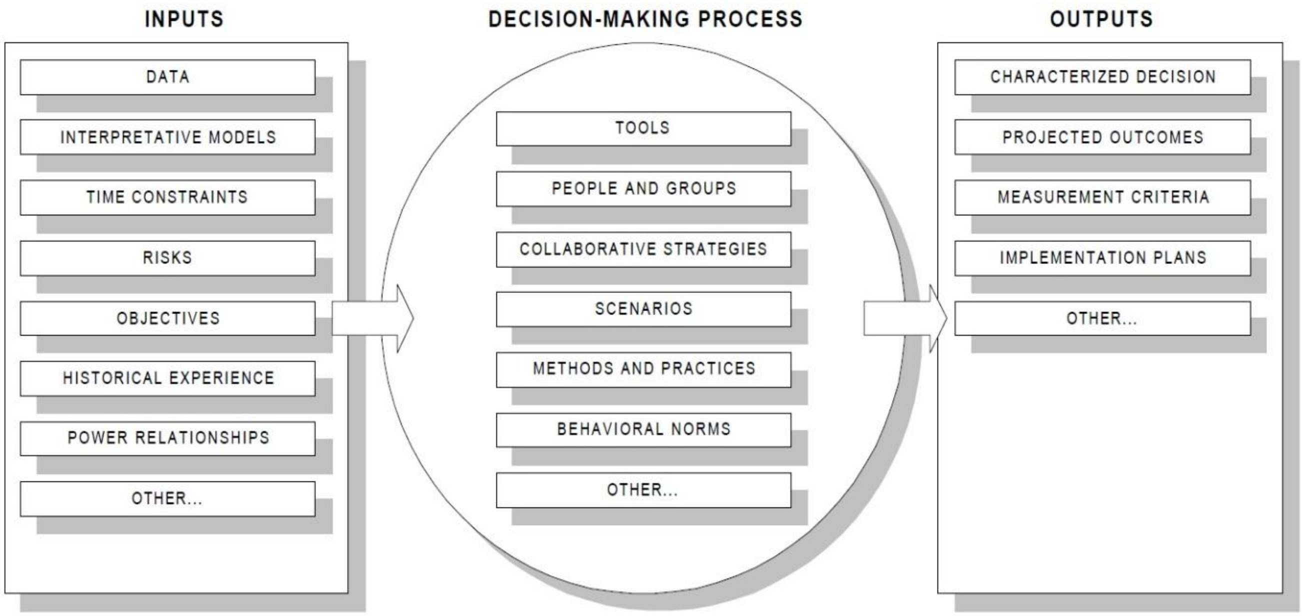

Figure (3.3): A Prototypic Decision-Making Model
Source: (Demarest, 2005)

3.5.3. Categories of DSSs

Based on different viewpoints many classifications of DSSs were proposed in the last decade (Power, 2003). One approach to categorize DSSs is based on different interactive behavior between users and systems to support decision making. They are either passive or active (Carlsson et al., 1998).

a. ***A passive D*****SS** is a system that aids to support decision making by simplifying and reducing non-structured problems to well-defined tasks that can be predefined in a system without any ambiguity. Most of traditional DSSs are passive and not adequate for real and complex applications.

b. ***An active DSS*** is a system that is able to respond to changes or exceptions and is able to exhibit goal-directed behavior by taking the initiative, in order to solve decision problems.

Another approach for classifying DSSs is according to the dominant component in the system. In (Power, 2002) there are five generic types of DSSs identified:

a. **A communications-driven DSS** is a system that supports decision making with the emphasis on communications and collaboration. It aims to cooperative and collaborative decision making based on one or more groupware.

b. **A data-driven DSS** is a system that supports decision making with the emphasis on accessing to and manipulating a time series of internal data or external data. For example GIS (Geographic Information Systems) are data driven.
c. **A document-driven DSS** is a system that supports decision making with the emphasis on retrieval and management of unstructured documents in a digital format.
d. **A model-driven DSS** is a system that supports decision making with the emphasis on accessing to and manipulating decision models that are normally constructed by statistical, financial, OR (Operation Research) or simulation methods.

e. **A knowledge-driven DSS** is a system that supports decision making with the help of a knowledge base. Normally this kind of DSS combines KBS (Knowledge based system) and other methodologies for decision making.

3.5.4. Components of decision support systems

A DSS is composed of four fundamental subsystems as depicted in the figure (3.4): Data management, model management, user interface and knowledge management subsystems.

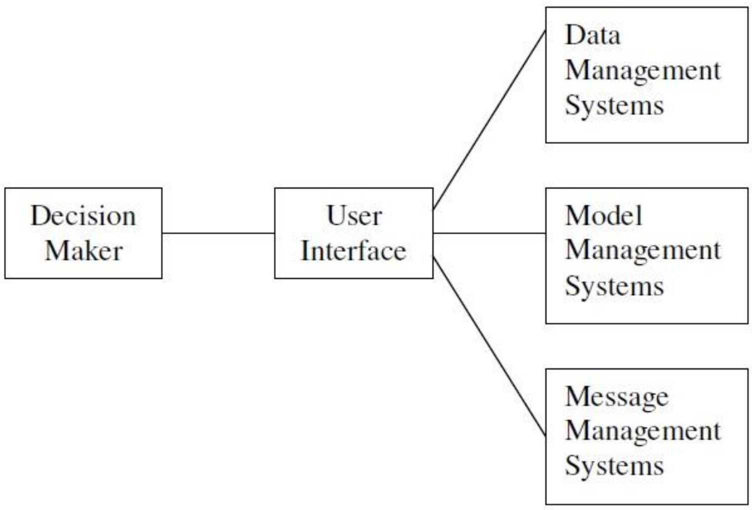

Figure (3.4): Components of DSS
Source: (Ackoff, 1989)

a. **Data management system:** A DSS uses one or more data stores to provide relevant information to the decision support system. Some of them are maintained by the DSS itself and some are external data sources. Some database are primarily used and maintained by another information system with its own database management system and some DSS applications may have no separate DSS database. The data is entered into the DSS as needed.

b. **Model management system:** The model base gives decision makers access to a variety of models and assist them in decision making. It can include the model management system software that coordinates the use of models in a DSS.

c. **Dialogue subsystem or user interface:** It allows users to interact with the DSS to obtain information. The user supplies information to the DSS and commands the DSS using this subsystem. In addition, the user is considered as part of the system. The user interface is the hardware and software that facilitate communication and interaction between the user and the computer.

d. **Knowledge management subsystem:** This is an optional subsystem and can support any of the other subsystems or act as an independent component. Also it provides knowledge for the solution of the specific problem (Mallach, 1994).

3.5.5. Challenges of DSSs

A sound DSS must be able to address the following important challenges.

a. **Uncertainty** is one of the most daunting challenges in an open and dynamic environment for decision making. Not only the imperfection of information, but also the uncertain nature of correlations between decisions and outcomes, causes uncertainty. Therefore, a good DSS must be able to work under uncertainty

b. **Adaptivity** Another daunting challenge is the perpetual change in the environment. Therefore, DSSs have to scale up and adapt to changing knowledge, workflow, and operational setting (Druzdzel and Leong, 2005). Particularly, an adaptive DSS should be flexible enough so that a decision making process can be quickly reconstructed or modified without high cost. From the perspective of system engineering, all components of the system should be loosely coupled, in order to increase their reusability (Yang, 2007).

c. **Knowledge management** KM (*Knowledge Management*) is a discipline concerned with the representation, processing, distribution and improving of knowledge by humans, machines, organizations and societies. KM in DSSs appears to be more and more important because decision making is a knowledge intensive activity with knowledge throughout the whole decision making process: problem identification, data (or evidence) gathering, diagnosis or predication and so on. The more proficient decision makers are in KM, the more competitive they are within the global knowledge society (Holsapple, 2001). Due to the heterogeneity of information resources the effectiveness and efficiency of knowledge management can only be ensured when it relies on the establishment of a common and formal language. The difficulty here is to select a formal representation language which makes a tradeoff between expressiveness and tractability, because the more expressive a formal language is, the less tractable it is, and vice-versa.

i. Expressiveness is a schema-level or conceptual level issue for modeling decision processes, models and other relevant knowledge in a better way. The background knowledge behind decision making problems in certain application domain must be expressible.

ii. Tractability is a data-level or individual level issue for providing better data exchange, query and integration (Yang, 2007).

d. **Collaboration** To enable decision making to be efficient DSSs must offer a platform for collaboration with teamwork of all participating agents in the decision process. A decision maker needs to collaborate with these agents in getting the knowledge they need and solving decision problems they have, with careful coordination, cooperation, negotiation and even synchronization of activities. From this perspective, the collaboration must be designed into systems from the start and cannot be patched in later (Grosz, 1996).

e. **Intelligence** One of the decisive factors to estimate the support capabilities of a DSS is its intelligent behaviors. Such intelligences are embedded in the whole decision making process and in all of the system components, for example knowledge management, algorithms, reasoning and so on.

f. **Explanatory** The explanatory power of a DSS refers to its ability of explaining its action. Two characteristics are related to this challenge: transparency and flexibility (Nakatsu, 2006).

i. Transparency refers to the ability of DSSs that the decision maker or other users are allowed to have an insight into the underlying mechanism for decision support. A black box for such mechanisms is not desired.

ii. Flexibility refers to the viewpoint of the UI (*User Interface*) of DSSs, because DSSs are highly interactive by the fact that DSSs do not replace humans but rather support them by augmenting their limited computational and cognitive capability. Therefore, a *user-friendly* and flexible user interface is very important. UIs are not rigid, but open and flexible for a wide variety of end-user interactions according to their divergent demands, for instance interaction via dialogue, argumentation and so on (Druzdzel and Flynn, 2003).

Chapter four

Research methodology and design

This chapter consists of the following sections:

Chapter four
Research methodology and design

4.1. Introduction

The main purpose of this chapter is to explicate the research methodology with sufficient details for the case study being analyzed including problem formulation, data collection and manipulation, model conceptualization, verification and validation of the simulation model, in addition to the design of the experiment and the alternatives or opportunities that are to be simulated in order to facilitate the analysis of the outputs and achieve the objectives of this research.

4.2. Case study description

The case study was carried out in a suburb with a residential area in Rafah City located in the south of Gaza strip. The residential area called El-Jenena and consists of single family houses and apartment buildings. Rainwater collected from an impervious area of 488216.81 m^2 calculated using AutoCAD software package is lead to an open catch basin of only 14163.6 m^3. The basin is connected to the downstream system by a single pipe with a capacity varies between 600 mm diameter to 1.25 m diameter. The capacity of the basin will be exceeded and flooding in the area will occur at certain rain events In the vicinity of the catch basin there is a local depression in the terrain where water may pond.

During the end of the intensive rainfall in the 8th of January 2013 the capacity in the pipes was exceeded resulting in backwater effect from the downstream system. The backwater effect generated a water flow resulting in flooded roads within 15-20 minutes.10 minutes later; the water level reaches the plinths of several houses. After 30 minutes with backwater effect, the water exceeds the edge of the catch basin.

The causes of the flooding events were analyzed and there major sources contributing to the flooding were identified. It was concluded that the cause of the flooding was a combination of:

a. Heavy rainfall.
b. Hydraulic insufficiency of the drainage system.
c. The fact that family houses and apartment buildings were built in a local depression in the terrain where the overland flow tends to accumulate.

A traditional approach to the flooding problem would be to modify the drainage infrastructure. But the modification needed to achieve adequate capacity is so extensive that it would not be carried out in the near future. Furthermore, due to the topography of the area, the building would eventually be flooded for events exceeding the design criteria so there's an essential need to develop a simulation model for resolving and managing the problem efficiently and effectively.

4.3. Research methodology and design

The use of computer simulation modeling as a tool has grown significantly as more powerful information technology and computers have become much cheaper and more widespread. Many industries are changing their design and evaluation process based on the use of simulation. Computer simulation modeling remains, however, a computerized mathematical tool, of which there are two basic types, according to Sinreich and Marmor (2005):

a. **Prescriptive models:** These models provide a prescription for how to set the decision variables in order to achieve optimal performance of a predefined objective function.

b. **Descriptive models:** These models provide a detailed report on the system's operational behavior based on its description.

Regardless of the computer software program used, there is a general process by which simulation modeling is conducted. Here, is a briefly outline of the process illustrated in figure (4.1).

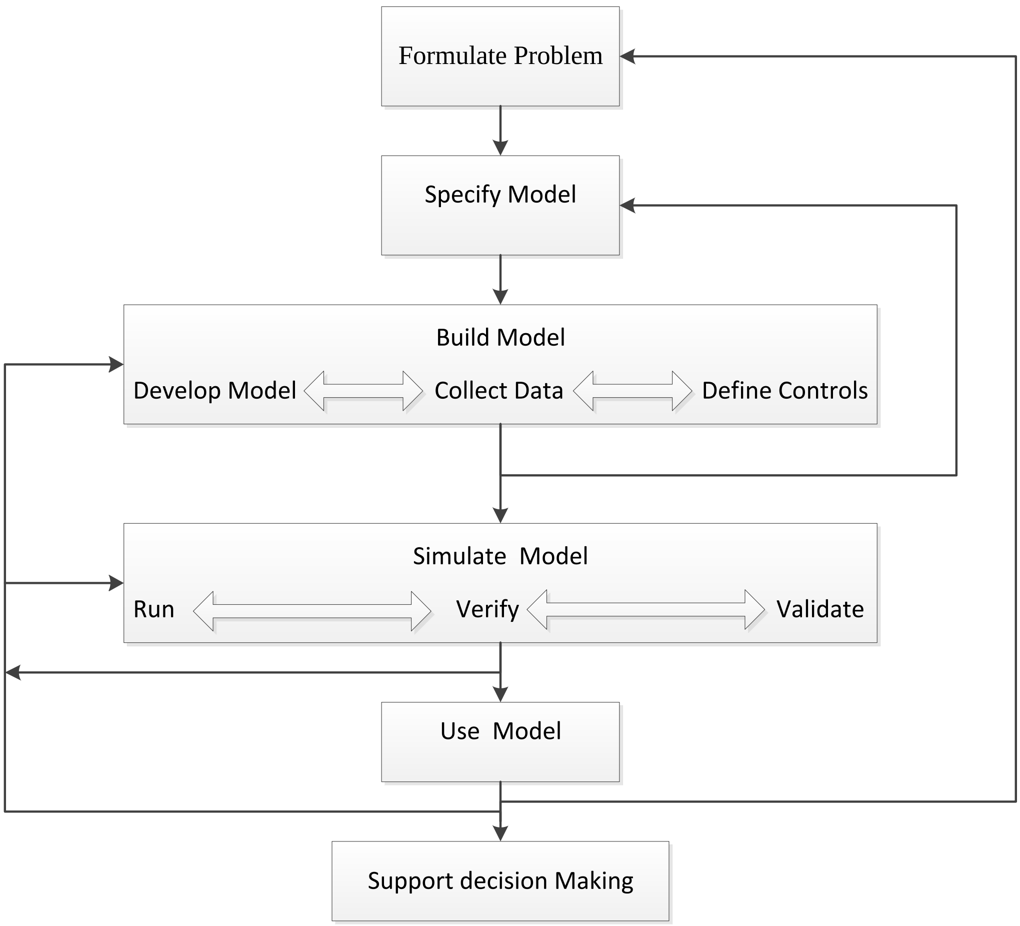

Figure (4.1): Modeling and simulation process

a. **Formulating the problem:** will require to understand the problem context, identify project goals, specify system performance measures, set specific modeling objectives and define the system to be modeled. A series of questions are posed to help and support in this process. These include:

   i. What operations and functions produce the systems output?
   ii. What procedural elements exist in the systems operation?
   iii. What interactions occur between functional units of the system?
   iv. What information is available to characterize the operations, functions, and procedures of the system?

   It is important to note that modeling objectives are statements of desired results in terms of performance measures.

b. **Specifying model:** requires using both art and science in conceptualizing. One must extract the essence of the system without including unnecessary detail. Good models have sufficient detail to be easily understood yet reflect in the most realistic sense the reality of the environment or organization being modeled.

c. **Building model:** is a three-step process: develop the simulation model, collect the data, and define the experimental controls. First, the model is developed with the structural and procedural elements that represent the system. Data is collected to add this to the system. Finally, experimental controls describe the procedures for performing a simulation and analysis of the model. These establish the initial state of the network.

d. **Simulate model:** the build model step must have been completed at least once. A network simulation advances time in accordance with the movement of entities through the nodes and activities of the model. Before the model can be used to support decision making, it must be shown to run in accordance with its own specifications. In other words, attempt to ascertain whether the model is behaving as it is intended to. Finally, seek validation that it is a reasonable representation of the system attempting to model. All of these sub-steps may be performed concurrently.

e. **Using model:** requires the making of run simulations and the subsequent interpretation and presentation of the output data. It may be used to draw inferences or test hypotheses, and therefore statistical methodology should be employed here.

Finally, modeling and simulation is used to **support the decision-making process.** We emphasize here that the model does not *make the decision*, but rather assists in informing the decision.

4.3.1. Problem formulation and specifying model

Costal Municipalities Water Utility (CMWU)- Rafah regional office faces challenge during winter season as It's play a foundation and central role in helping residents in flooded areas due to heavy rainfalls and storms using resources like emergency team members and mobile diesel pumps to discharge and dispose these water away from the flooded areas, so there is a long waiting time in serving these areas which extended to 2 days on average in certain cases and consequently the long waiting time periods raise the probability of risk and danger to residents, property and assets in the flooded areas.

So the longer waiting time the longer the service time which lead to bad results and effects, thus CMWU – Rafah regional office needs a technique to manage crisis and emergency incidents through manage and distribute the available resources to minimizing response time waiting time and service time as much as possible.

4.3.2. Simulation study objectives

The main goal of the simulation study is to build a real time decision support system based on simulation to be a useful tool in improving operation efficiency and evaluate the efficiency and effectiveness of using the simulation model by CMWU managers and decision makers to deal with disasters, mitigating their effects, controlling and managing emergencies.

4.3.3. Data collection and input data analysis

Data was collected via observation of the emergency team daily operation, reviewing the historical recorded files.

The data required to develop the model as follows:

a. The accumulated water volumes in the areas.
b. The needed dispatch (CES responders and pumps) time.
c. The time required to travel and arriving to scene.
d. The time required to install and operate the pump.
e. Stay and Deal with the Situation time.
f. Number of pumps.
g. Pump flow rate.
h. Number of emergency team members.

To estimate the accumulated volumes of storm water first it's important to shed the light on the concept of runoff which is calculated by the simplest and the widely used method which called rational method to predict the peak run-off rate. The rational method is perfectly acceptable for calculating storm drain and inlet peak discharges as well as calculating street surface flow peak discharges (Chow et al., 1988). It depends on calculating the flow as the product of rainfall intensity; drainage area, and a coefficient, which reflects the combined effects of surface storage, infiltration, and evaporation (McGhee, 1991).

The calculated peak discharge at the design point is a function of the average rainfall rate during the time of concentration to that point. With these underlying assumptions, the peak discharge can be calculated as:

$Q = C\, i\, A$

Where; Q is the Peak discharge in cubic meter per second, *C* is the Run-off coefficient which represents the ratio of run-off to rainfall for the drainage area considered, *i* is the average rainfall intensity in mm per hour for a period of time and *A* is the drainage area in square meter, contributing run-off to the point of consideration.

Sogreah, et al.(1999) calculated the run-off coefficients for different surface types in Gaza Strip as it given in table (4.1) :

Table (4.1): Run-off coefficient for different surface types in Gaza strip (Sogreah, et. al., 1999)

Development coefficient	Coefficient
Pavement, Road/Parking	0.90
Commercial / Public lots	0.70
Residential Communities	0.60
Parks / Unimproved Areas	0.30
Irrigation Areas	0.20
Natural Zones	0.05

The USAID wastewater master plane for Gaza city modified the intensity duration relationship (PECDAR, 2000), as follows:

Modifying the figure for the intensity duration relationship for 5 year return periods is shown in table (4.2). The derived intensity duration equation for 5 years return period was given as:

I (mm/min) = $6.2\, T^{0.65}$

Resulting in 26 mm rain in one hour. This equation is more applicable to the rainfall intensity in Gaza Strip and it used in the calculations of this research.

Table (4.2): The intensity duration relationship for various return periods in Gaza. (Sogreah, et al., 1999)

Return Period: 5 years – a: 6.18 – b: 0.649										
Duration	5 min	15 min	30 min	1 hr	2 hr	3 hr	6 hr	12 hr	18 hr	24 hr
Rainfall (mm)	10.9	16	20.4	26	33.2	38.2	48.8	62.2	71.7	79.4

The area (A) or catchment area is calculated via computer software package called AutoCAD and was estimated to be approximately 488216.81 m^2 as shown in figure (4.2):

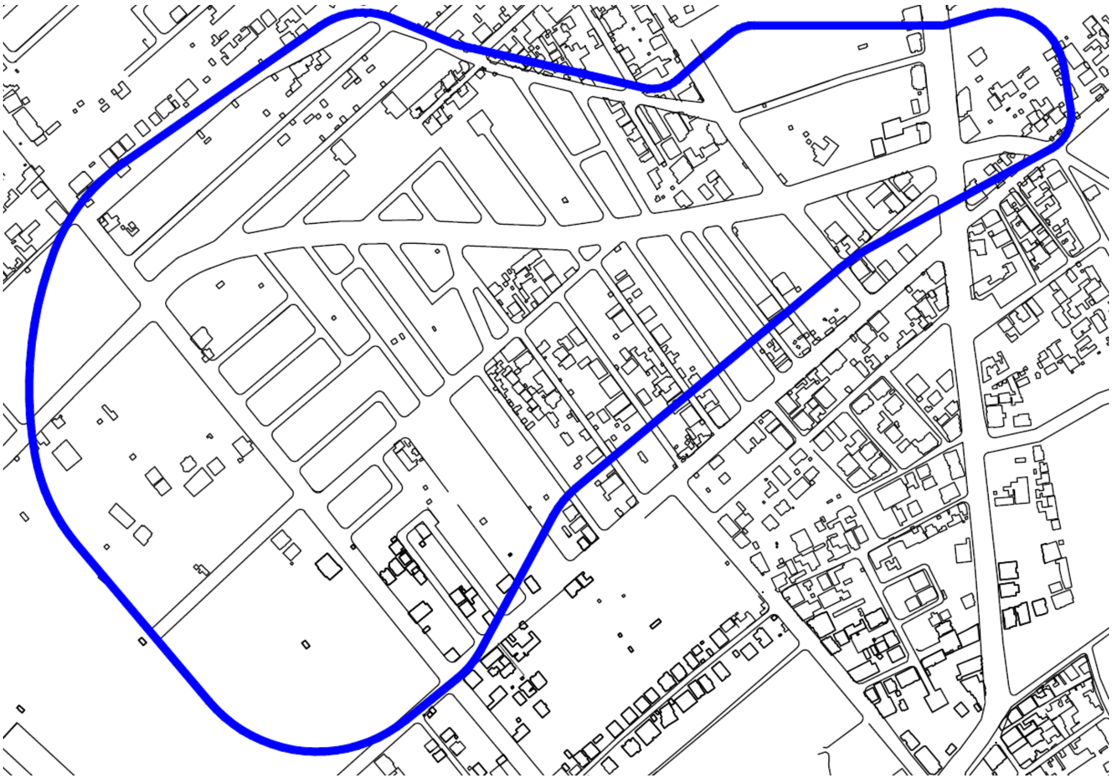

Figure (4.2): The catchment area

So from table (4.1) the Run-off coefficient C = 0.6 because the area is considered as residential communities, and from table (4.2) the return period 5-years and duration 6 hours rainfall (mm) = 48.8 and its very consistent with the number depicted in the ministry of agriculture report in the 8th of January 2013 as rain fall (mm) per day = 50.

So Q = $0.6 \times \frac{(\frac{48.8}{6})}{100} \times 488216.81 = 23824.9 \ m^3/hr$

So during 6 hours rainfall the Q = 142949.88 m^3

And as discussed before in the case study description the catchment basin capacity to collect the storm water only 14163.6 m^3 which implies that there is 128786.2 m^3 of backwater threaten the residential area.

Taking into account the amount of water losses through infiltration and water entered the sewage network through gutters and inlets, and by observing and measuring the level of water depths in 8 incident areas the accumulated water volumes well be as shown in table (4.3):

Table (4.3): Water depth, volumes of incident areas

Area NO.	Area (m2)	Water depth (m)	Volume (m3)
A1	1405	1.5	2107.5
A2	799	1.5	1198.5
A3	355	1.5	532.5
A4	842	1.5	1263
A5	9382	2	18764
A6	2322	1.5	3483
A7	688	2	1376
A8	821	2	1642
Total	**16614**		**30366.5**

The approximated inflow rate for each area as indicated in table (4.4) estimated according the weighted average of the incident area from the whole runoff rate $23824.9\ m^3/hr$.

As well as the flooding time calculation done by dividing the accumulated volume by the approximated inflow rate for each area.

Table (4.4): Inflow rates and flooding time of incident areas

Area NO.	weighted area	inflow rate	flooding time (hr)
A1	0.084567232	2014.8	1.046006489
A2	0.048091971	1145.7	1.046006489
A3	0.021367521	509	1.046006489
A4	0.050680149	1207.4	1.046006489
A5	0.564704466	13454	1.394675319
A6	0.139761647	3329.8	1.046006489
A7	0.041410858	986.6	1.394675319
A8	0.049416155	1177.3	1.394675319
Total			**1.1767573**

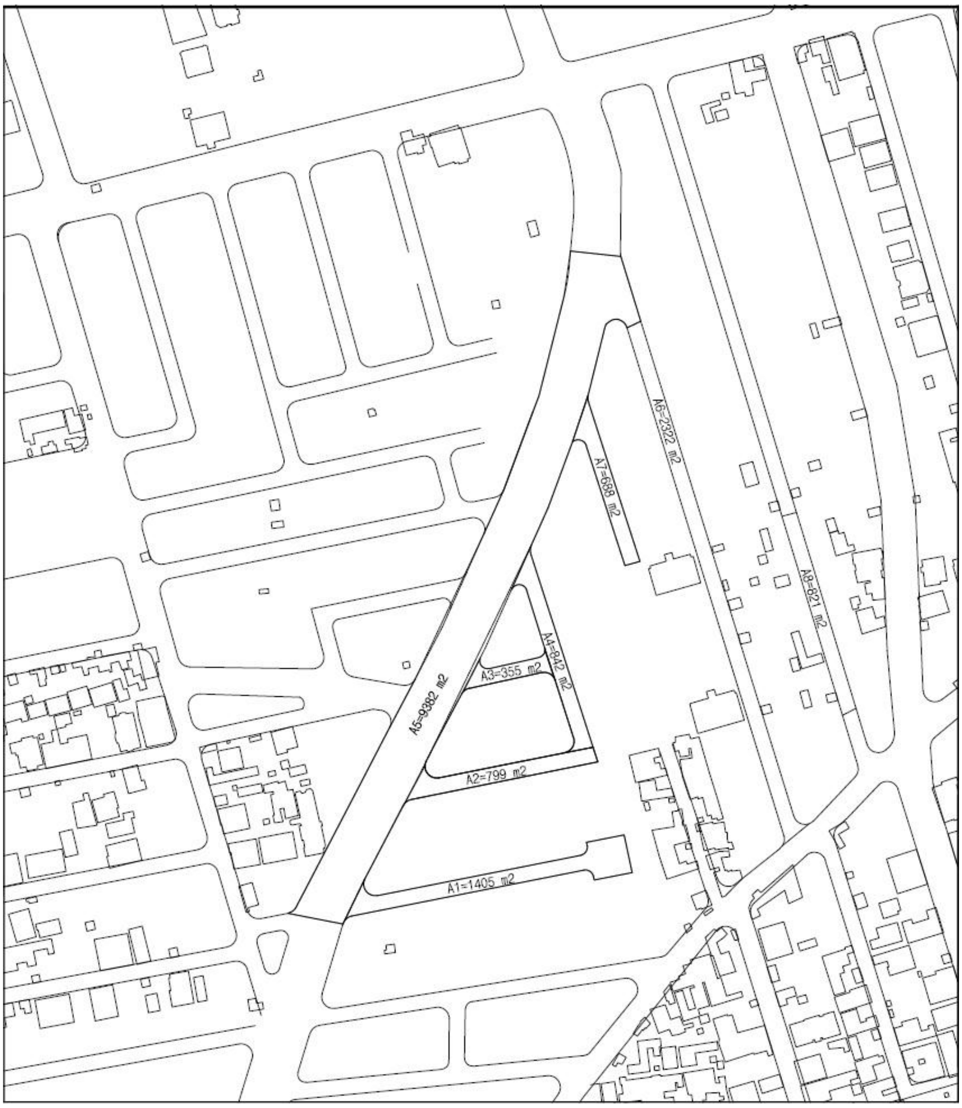

Figure (4.3): The incident areas

The distributions of the delay and service times for the processes in discharging accumulated storm water systems shown in figure (4.4), figure (4.5) and figure (4.6) were fitted using the input analyzer tool based on the observation and measurements. The distributions and the parameters are given in table (4.5).

Table (4.5): Distribution of the processes

Name	Distribution	Expression
Dispatch time	Triangular	TRIA(10 , 15, 20)
Travelling to scene time	Triangular	TRIA(15 , 20, 30)
Install and operate the pump	Triangular	TRIA(10 , 15, 30)
Stay and Deal with the Situation time	-	-area Level (areanumber) / Rate (areanumber)

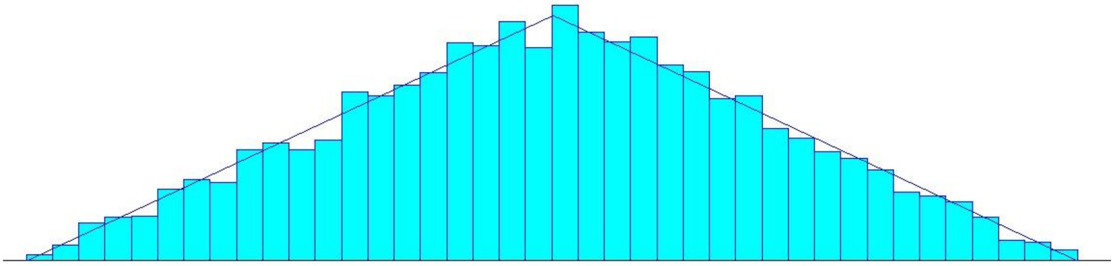

Figure (4.4): Dispatch time distribution

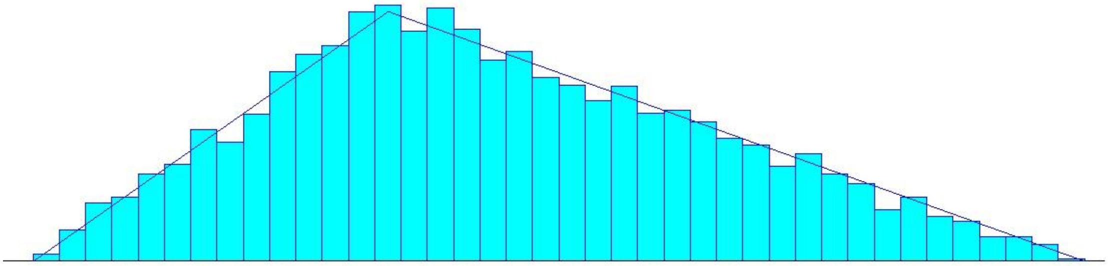

Figure (4.5): Travelling to scene time

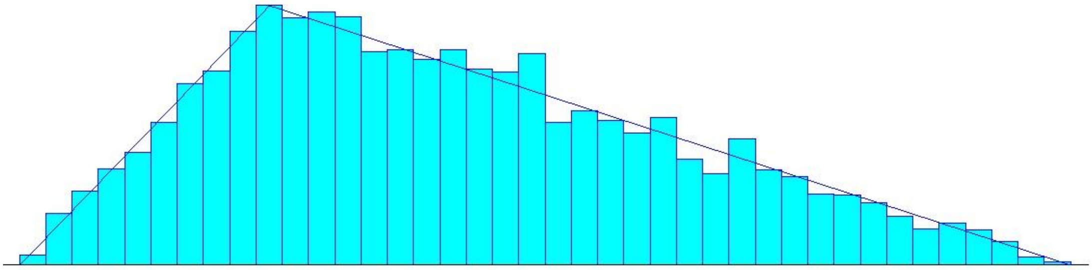

Figure (4.6): Install and operate the pump

And the available resources are depicted as shown in table (4.6):

Table (4.6): Available resources

Resource	Quantity
Mobile pump Q: 250 m^3/hr, H: 20 m Q: Flow rate H: Pumping head	4
Worker	5

The figure (4.7) indicates the photo of the mobile diesel pump used in discharging the flooded water in the incidents areas.

Figure (4.7): Mobile diesel pump

And the table (4.7) indicates the diesel engine and the pump specifications.

Table (4.7): Diesel engine and pump specifications

Diesel engine specifications	
Type	DEUTZ diesel engine
Model type	TD226B-4D
Prime power	60 KW
Speed	1500 rpm
Fuel consumption at prime power	16,1 L/hour
Pump specifications	
Flow rate (Q) :	250 m^3/hr
Head (H):	20 m

4.3.4. Overview of the model

The flow chart express the work flow in the crisis and emergency management in CMWU from the moment of receiving incoming emergency call to the moment finishing the assigned tasks as shown in figure (4.8).

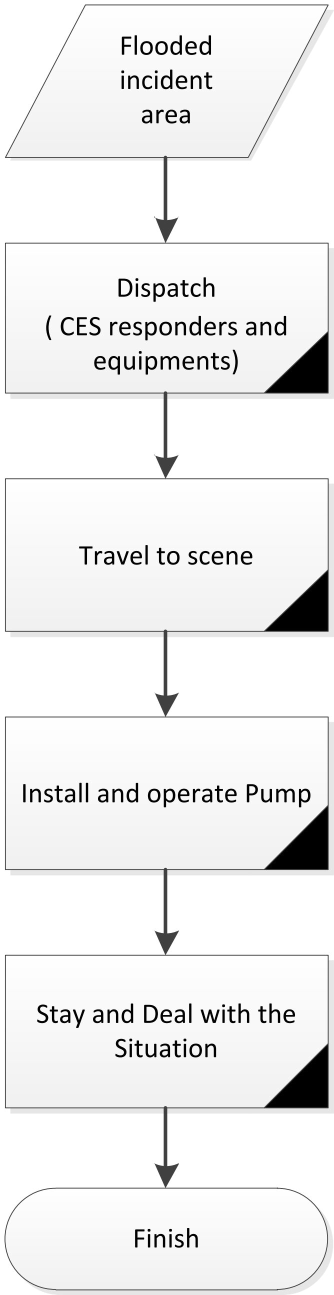

Figure (4.8): Crisis and emergency management model flow chart

4.3.5. Arena model overview

When modeling a continuous-change process the two primary elements of interest are the value that's changing and its rate of change over time. Arena provides two types of variables called levels and rates to represent these values. For each pair (a level and a rate), Arena applies the defined rate of change to approximate a continuous change in the value of the level. The discrete-event portion of the model (i.e., the modules used to flowchart a process) also can assign new values to levels and rates.

In this model the system activities may be discrete or continuous, the portion modeled as a continuous process is the actual inflow and outflow from the incident areas and the remaining activities in the model represented as discrete processes.

First step in building the model is defining the continuous-change levels and rates for the system in the Levels and Rates modules. As the model used to simulate eight similar processes filling operations at each of eight areas so there's useful to use arrays for the levels and rates.

As shown in the figure (4.9) the entries of the levels module was a single level named area Level and defining eight level variables numbered 1 through 8 by establishing a starting Number of 1 and a 1-D Array Index of 8. They'll be named area Level (1) through area Level (8). During the simulation run these will be treated independently.

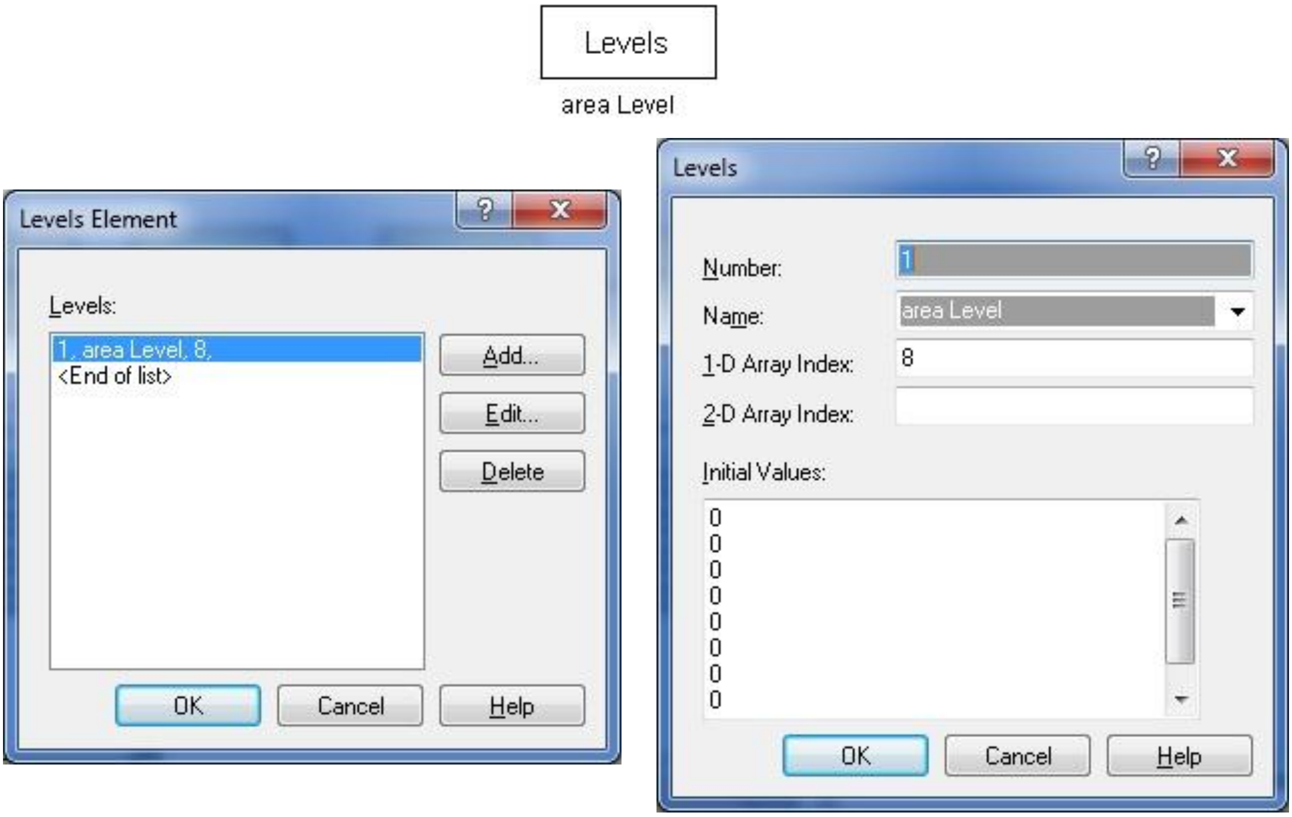

Figure (4.9): Levels element

The Rates module contains similar entries. As shown in the figure (4.10) these also will be numbered as rates 1 through 8 to match area Level variables and also will referenced in the model as Rate (1) through Rate (8).

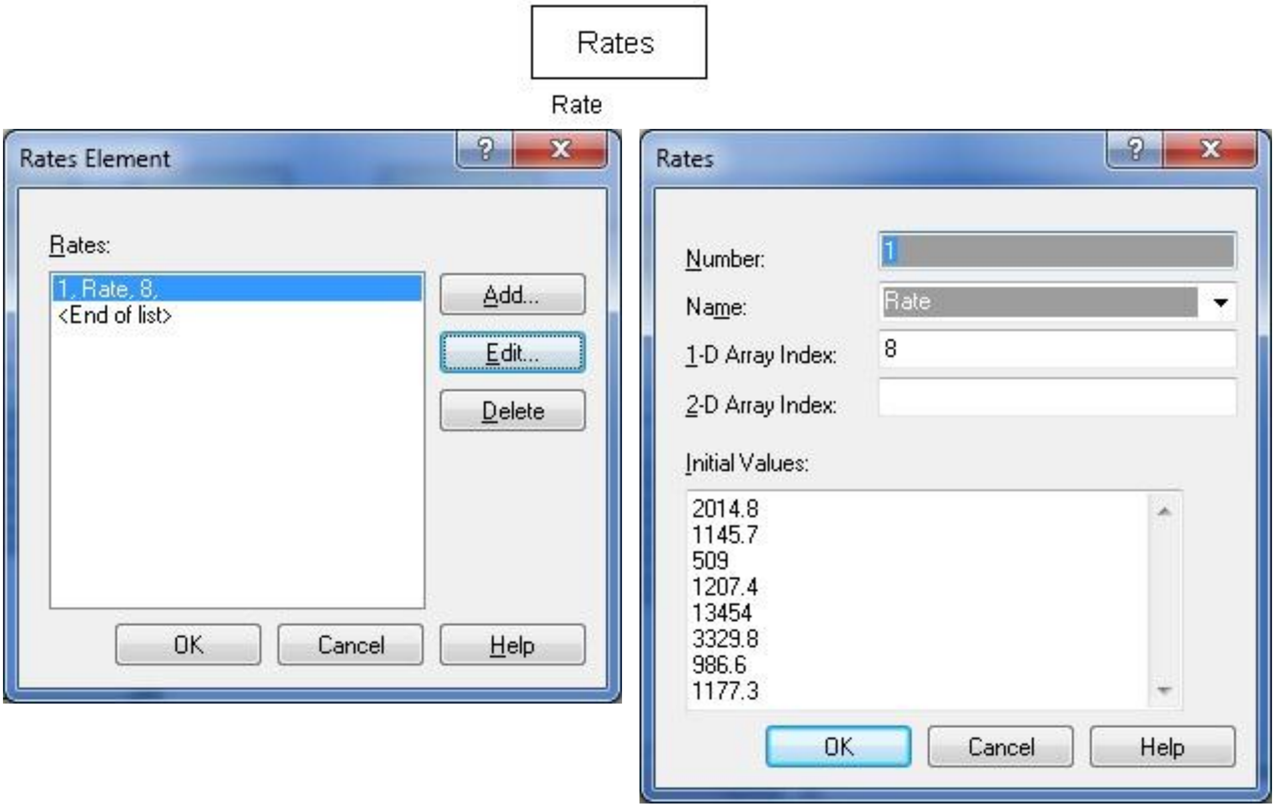

Figure (4.10): Rates element

The continuous module from elements panel as shown in the figure (4.11) establishes settings that are needed to configure Arena's continuous calculations. The number of Dif. Equations defines how many differential equations are to be evaluated for the model. In constant-rate systems each level/rate pair should be counted among differential equations so that Arena will calculate new values via the continuous time updates. For this model this field leaved at default value (blank), which will set the number of these equations equal to the number of level/rate pairs defined by levels and rates modules. The minimum step size and maximum step size fields dictate to Arena how often it should update the continuous calculations. In the method field leaved as default Euler which is appropriate integration algorithm to be used when the rates remain constant between continuous-time updates as in this model.

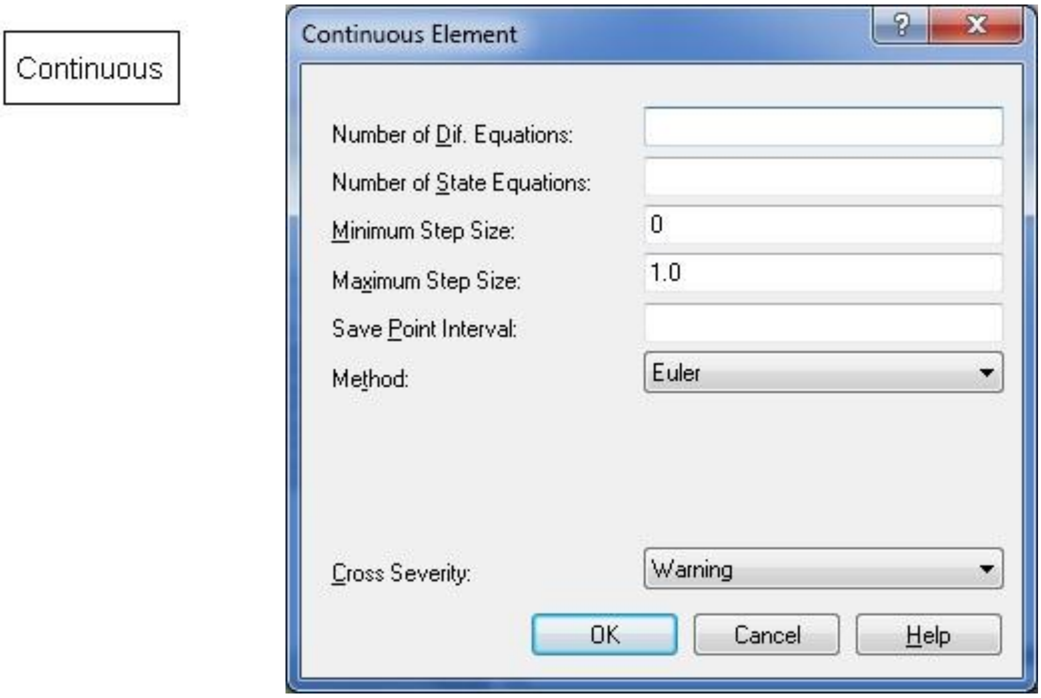

Figure (4.11): Continuous element

To determine when the area levels are full the Detect module should be used which watching for continuous area level at each area to exceed their corresponding capacity values as shown in figure (4.12) and figure (4.13). This will create an entity when area level full. The Detect module looks at all eight of continuous-level variables by defining station range from 1 to 8. For Detect module with a station range, Arena watches the values of the crossing variables through the simulation run. The Arena index variable J is used to indicate places in the module where the range values should be used. So Arena watches all eight area level variables versus all eight capacity values.

Variable - Basic Process

	Name	Rows	Columns	Data Type	Clear Option	File Name	Initial Values
1	capacity	8		Real	System		8 rows

Figure (4.12): Variable-basic process

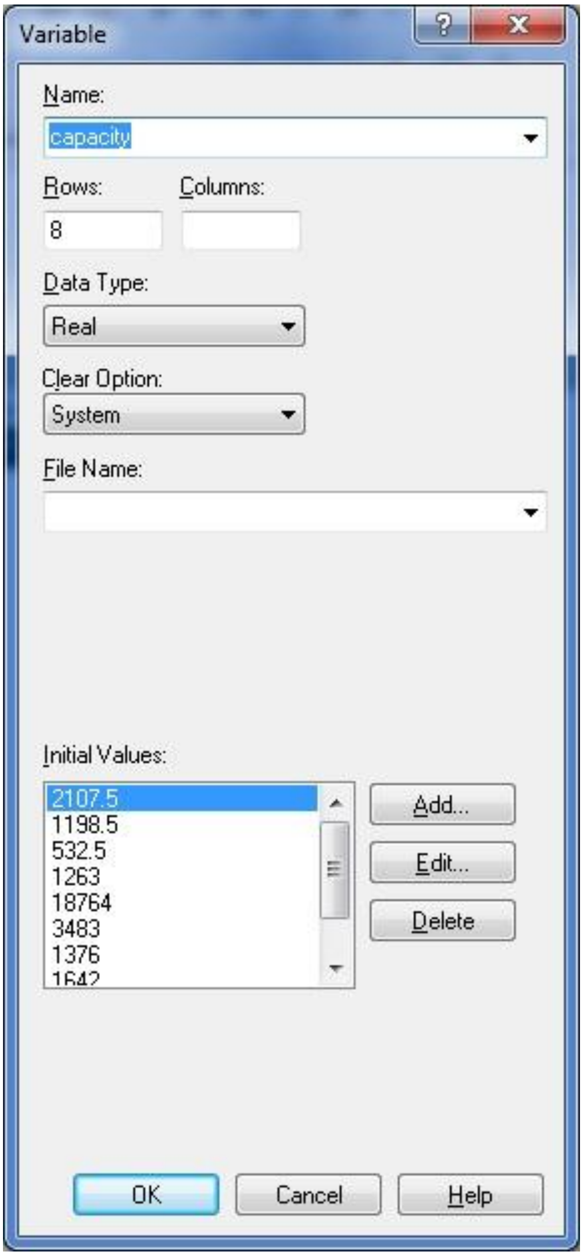

Figure (4.13): Capacity variable

Whenever one of the area levels passes its threshold value in the crossing direction (positive) an entity is created and leaves the Detect module as shown in figure (4.14). Arena also assigns the index that was detected (e.g., 1 if area level (1) passed capacity (1) in the positive direction) to the special attribute Entity.Station, of the newly created entity. This attribute is one of those that are automatically provided by Arena for each entity. It is used in continuous modeling with the Detect module to allow the convenience of watching a number of level variables with a single module.

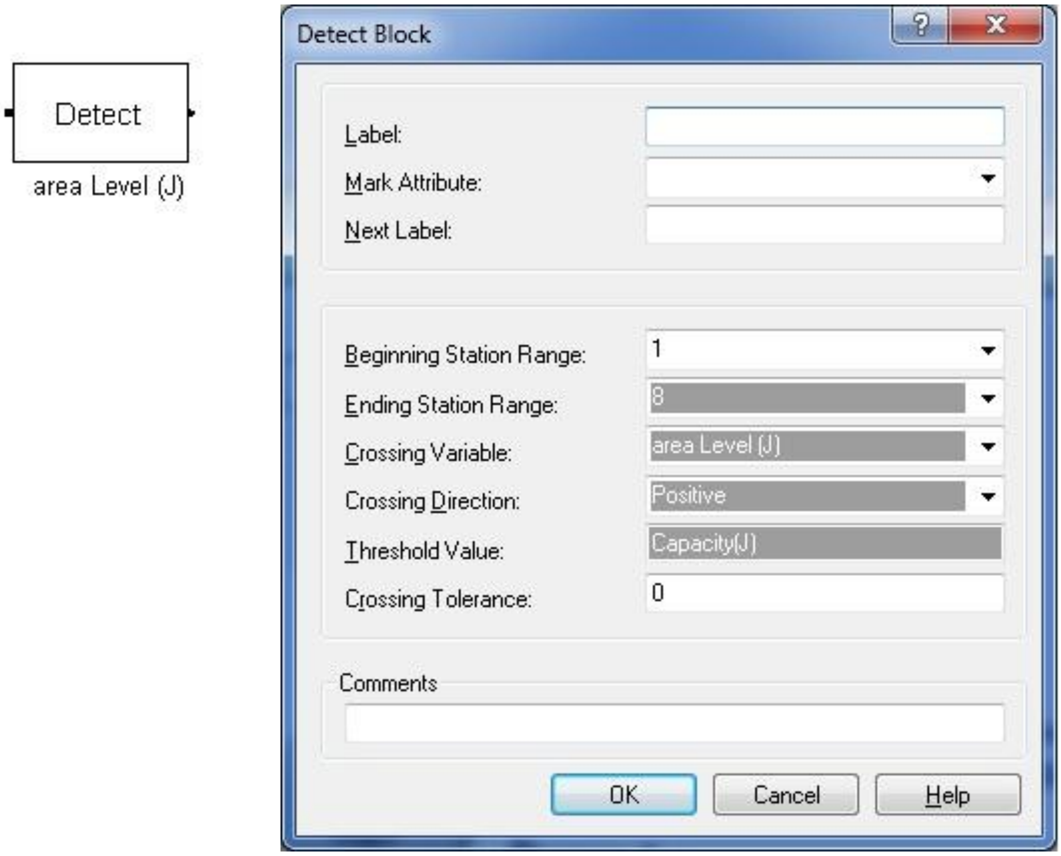

Figure (4.14): Detect block

Adding a Station module from Elements panel as shown in figure (4.15) and figure (4.16) needed to define eight stations. They are required to allow the Detect module to search across the station range.

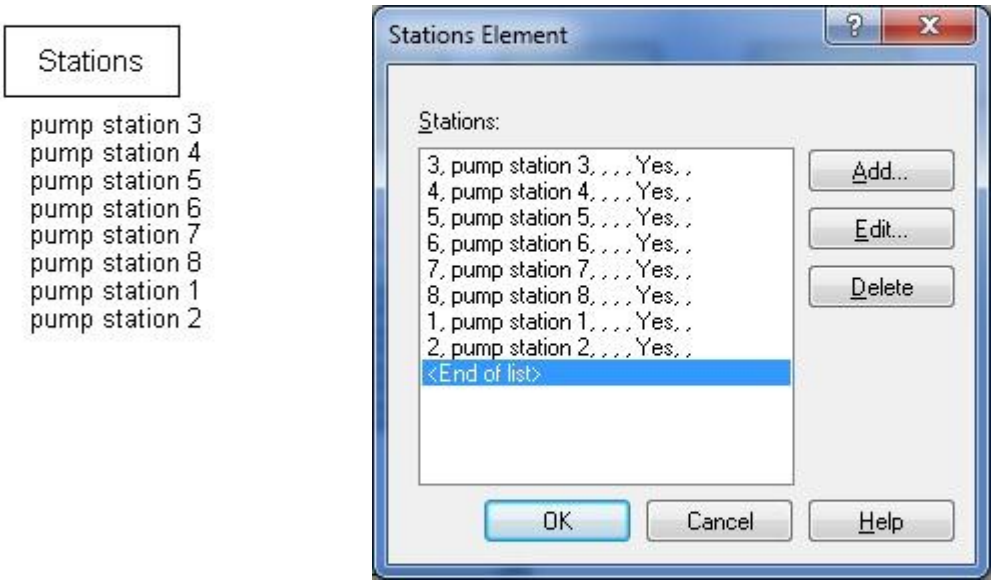

Figure (4.15): Stations element

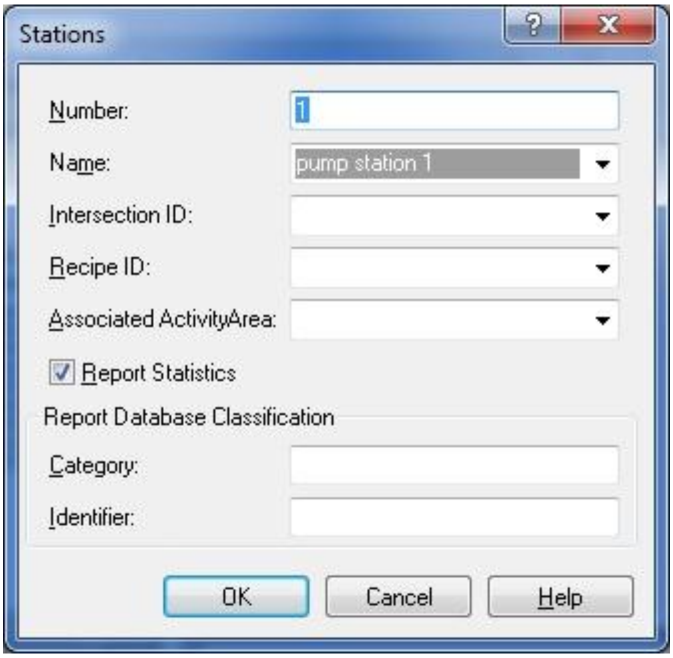

Figure (4.16): Stations

When an entity created by Detect module it enters the Assign module (stop water accumulation), the attribute areanumber assigned to Entity.Station as shown in the figure (4.17).

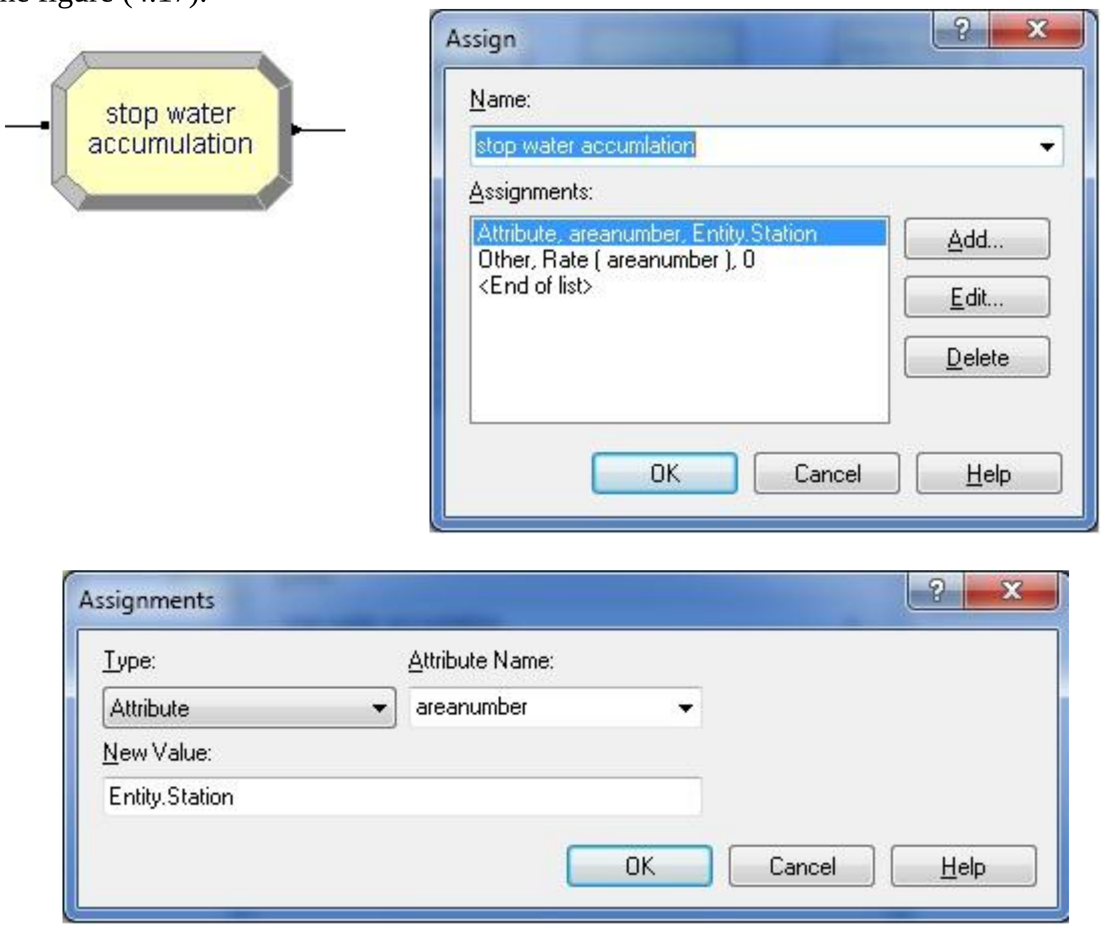

Figure (4.17): Areanumber assignment

And assign Rate (areanumber) to zero as shown in figure (4.18) which stopping flow of the desired area level.

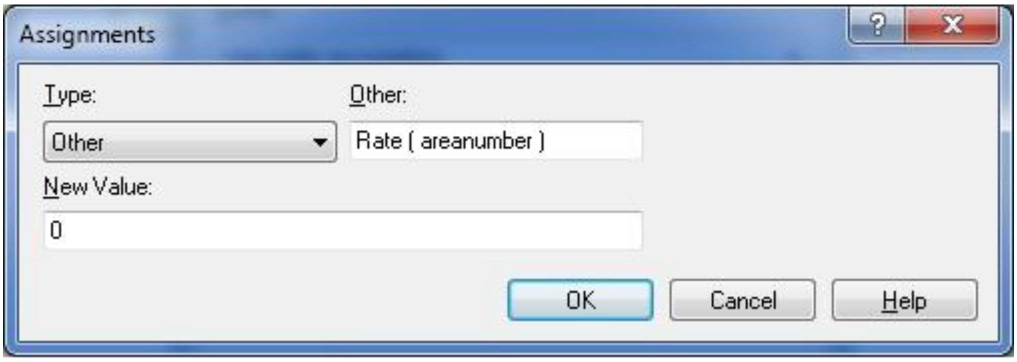

Figure (4.18): Rate (areanumber) assignment

After that the entity leaves this module to enter the dispatch CES module which is model the delay time spent in emergency team preparation and use triangular distribution TRIA(10 , 15, 20), as 10 minutes the minimum , 15 minutes is the most likely and 20 minutes is the maximum as shown in figure (4.19).

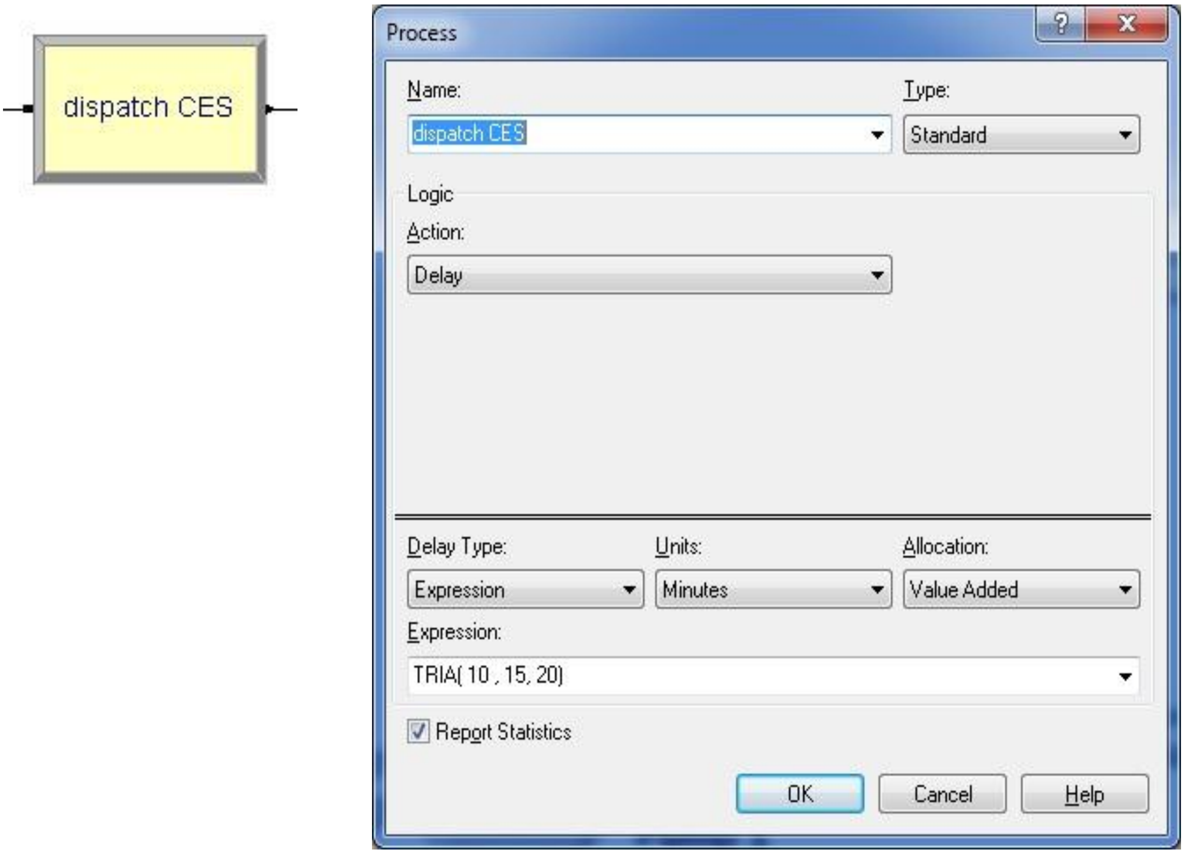

Figure (4.19): Dispatch CES process

Then the entity enters the travel to scene module which models the traveling time using triangular distribution TRIA(15 , 20, 30) as 15 minutes the minimum , 20 minutes is the most likely and 30 minutes is the maximum as shown in figure (4.20).

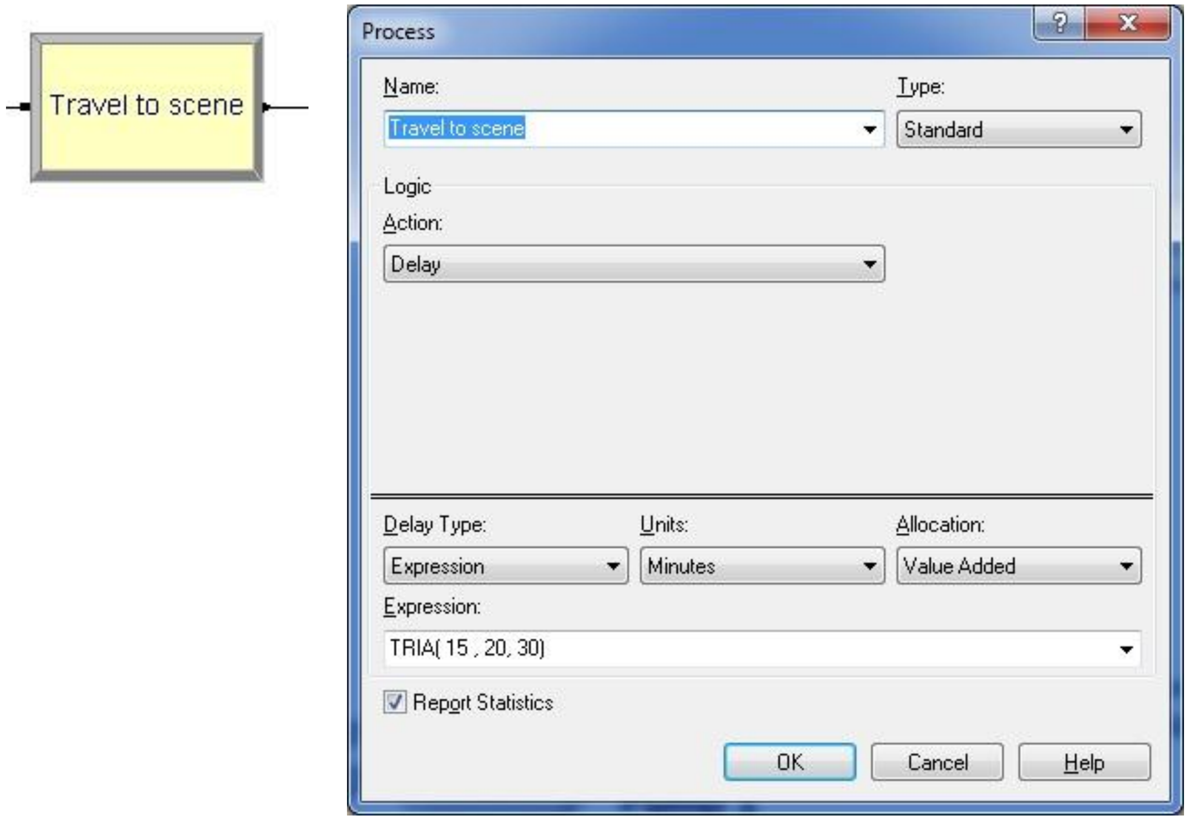

Figure (4.20): Travel to scene process

After that the entity passed through time to install and operate pump module which models the installing pump time using triangular distribution TRIA(10 , 15, 30) as 10 minutes the minimum , 15 minutes is the most likely and 30 minutes is the maximum as shown in figure (4.21).

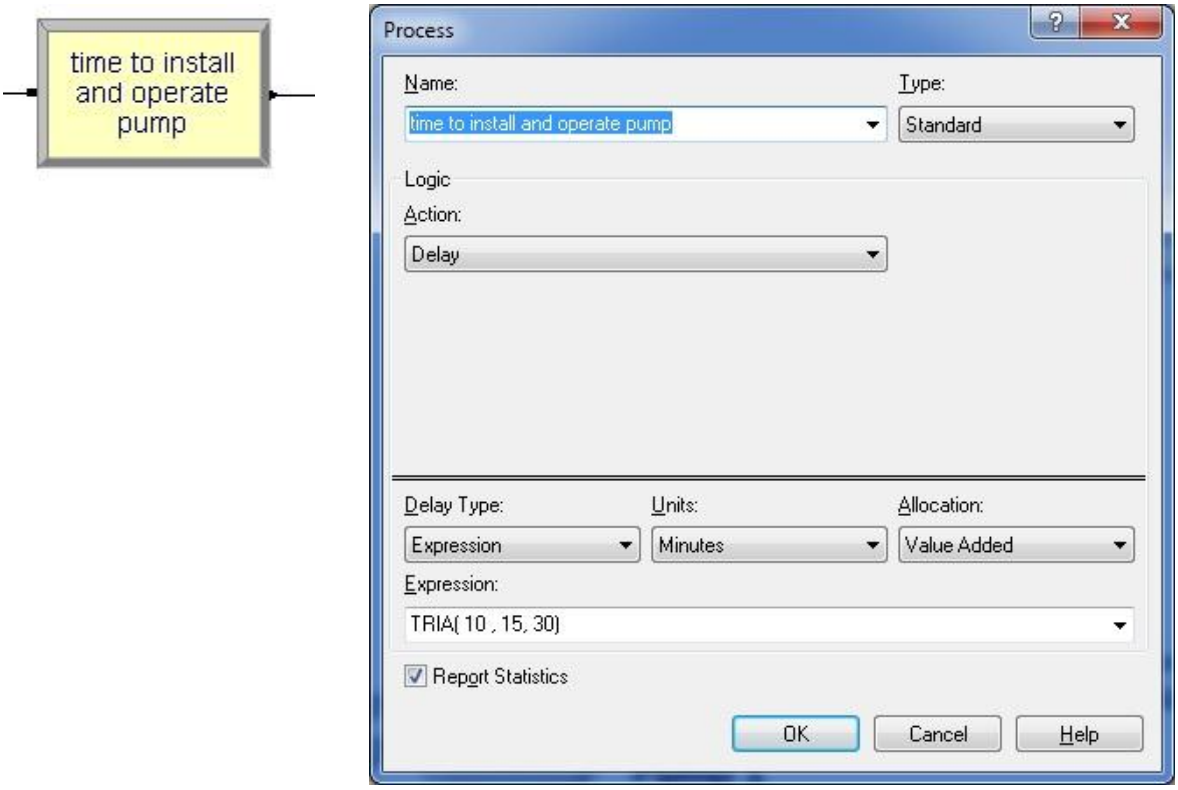

Figure (4.21): Time to install and operate pump process

Then the entity enters the assign pump flow rate module to set the pump flow rate and here 250 but in minus sign to decrease the area level as shown in figure (4.22).

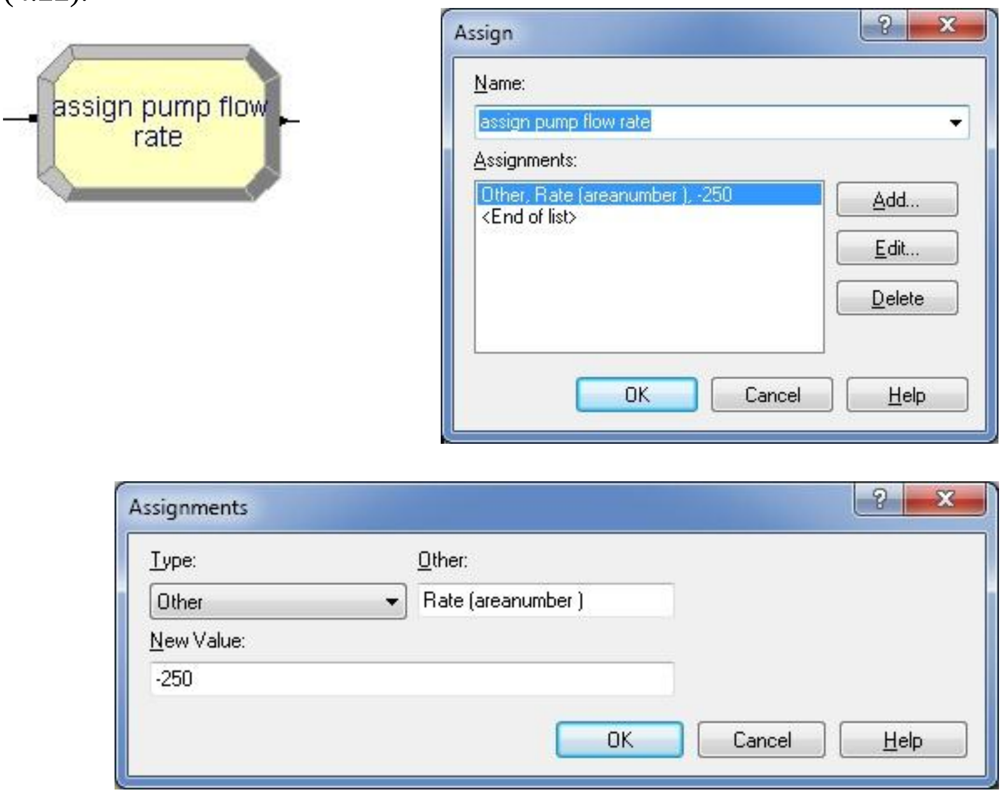

Figure (4.22): Assign pump flow rate

So the entity arrive to pumping time module which starts pumping accumulated water levels in different incident areas, and this module is the most important module in the model which it's contain the available resources with its capacities as shown in the figure (4.23) as well as the expression of time needed in the pumping process.

Set - Basic Process

	Name	Type	Members
1	pumps	Resource	4 rows
2	emrgency team	Resource	5 rows

Figure (4.23): Set-basic process

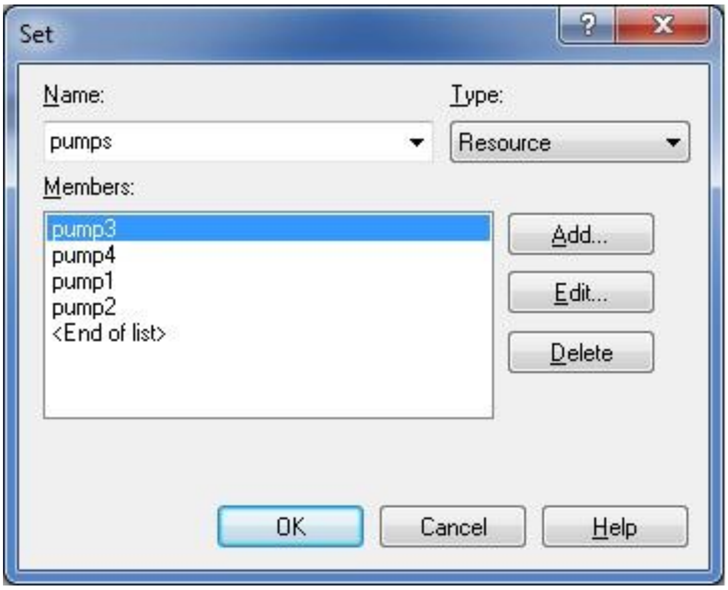

Figure (4.24): Pumps set

The resources defined as sets the first resource set was called pumps and have 4 pumps named as follows pump1,pump2,pump3 and pump4 as shown in the figure (4.24), on the other hand the second resource set was called emergency team and have 5 workers named as follows worker1,worker2,worker3,worker4 and worker5 as shown in the figure (4.25).

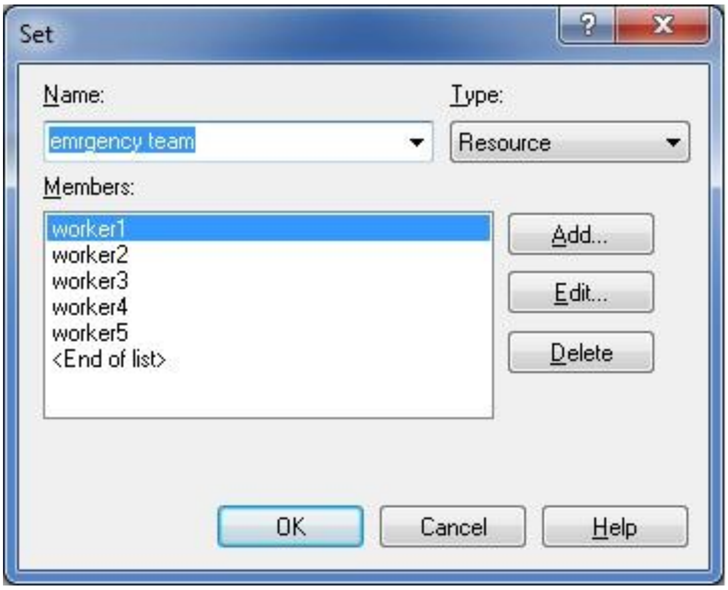

Figure (4.25): Emergency team set

The selection rule when the entity seizes the resources is Largest Remaining Capacity for pumps and Smallest Number busy for emergency team as shown in the figure (4.26) and figure (4.27).

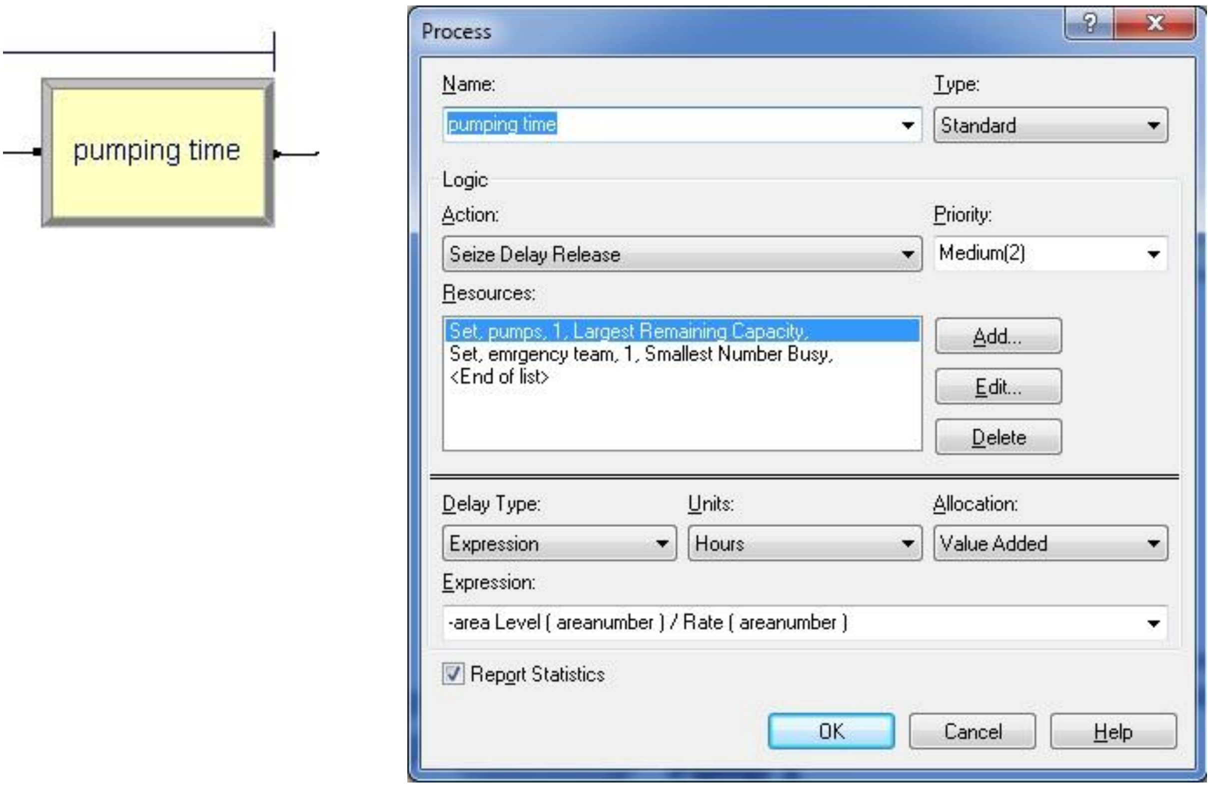

Figure (4.26): Pumping time process

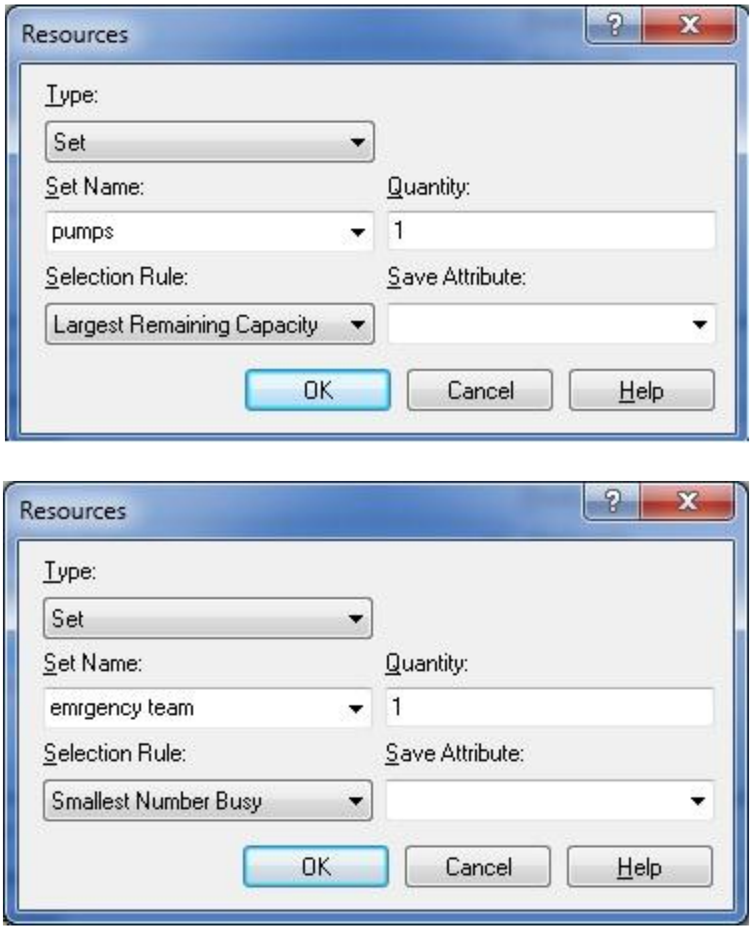

Figure (4.27): Resources selection rule

The time expression is: -area Level (areanumber) / Rate (areanumber) to determine the needed time to pumping water from the desired area.

Resource failures are primarily intended to model random events that cause the resource to become unavailable. Start failure definition will be available in either the resource or the failure data module. The failure data module can be found in the advanced Process panel.

New row added in the spreadsheet of the module and called pump failure as shown in figure (4.28).

Failure - Advanced Process

	Name	Type	Up Time	Up Time Units	Down Time	Down Time Units
1	pump failure	Time	TRIA(5 , 8 , 10)	Hours	TRIA(0.25 , 0.3, 0.5)	Hours

Figure (4.28): Failure-advanced process

And the type of failure set Time-based and setting the Up Time: TRIA(5,8,10) hours, and setting Down Time : TRIA(0.25,0.3,0.5) hours.

Resource - Basic Process

	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	StateSet Name	Failures	Report Statistics
1	pump1	Fixed Capacity	1	0.0	0.0	0.0		1 rows	✓
2	pump2	Fixed Capacity	1	0.0	0.0	0.0		1 rows	✓
3	pump3	Fixed Capacity	1	0.0	0.0	0.0		1 rows	✓
4	pump4	Fixed Capacity	1	0.0	0.0	0.0		1 rows	✓
5	worker1	Fixed Capacity	1	0.0	0.0	0.0		0 rows	✓
6	worker2	Fixed Capacity	1	0.0	0.0	0.0		0 rows	✓
7	worker3	Fixed Capacity	1	0.0	0.0	0.0		0 rows	✓
8	worker4	Fixed Capacity	1	0.0	0.0	0.0		0 rows	✓
9	worker5	Fixed Capacity	1	0.0	0.0	0.0		0 rows	✓

Figure (4.29): Resources with failures

In resource data module failures column for pump1 to pump4 used to add failures by selecting failure rule to wait as shown in figure (4.29) and figure (4.30).

	Failure Name	Failure Rule
1	pump failure	Wait

Figure (4.30): Failure rule selection

On the other side frequencies are used to record the time-persistent occurrence of an Arena variable, expression or resource state as shown in figure (4.31). In this model represent the number of failures of each pump in the pumps resource set.

Statistic - Advanced Process

	Name	Type	Frequency Type	Resource Name	Collection Period	Report Label	Output File	Categories
1	Statistic 1	Frequency	State	pump1	Entire Replication	Statistic 1		0 rows
2	Statistic 2	Frequency	State	pump2	Entire Replication	Statistic 2		0 rows
3	Statistic 3	Frequency	State	pump3	Entire Replication	Statistic 3		0 rows
4	Statistic 4	Frequency	State	pump4	Entire Replication	Statistic 4		0 rows

Figure (4.31): Frequency statistics

After finishing the task the entity enters the stop pumping assign module to set Rate (areanumber) to zero which is setting the flow rate to zero from the desired area according to the areanumber attribute as shown in figure (4.32). Finally the entity leaves the model through dispose module which is called finish as shown in figure (4.33).

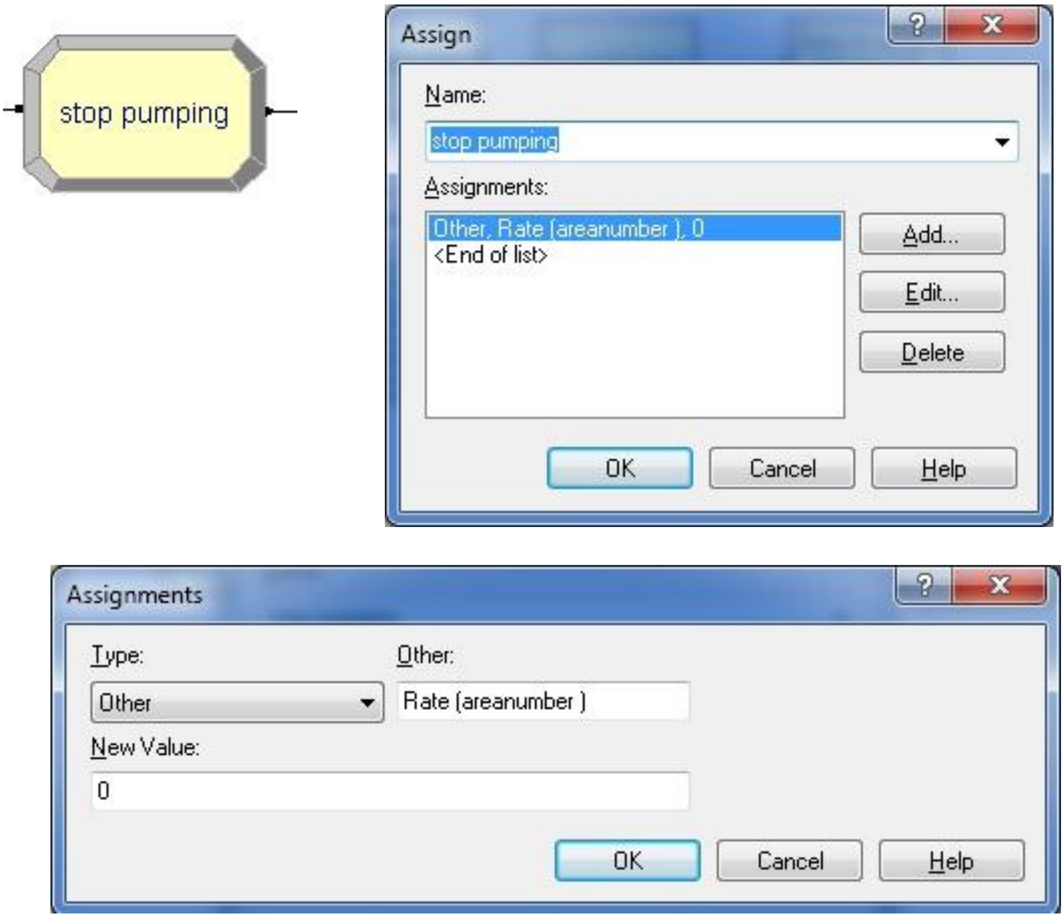

Figure (4.32): Stop pumping assignment

Figure (4.33): Dispose module

After building the model there's need to some graphics and indicators to show and visualize the progress of water accumulation in the incident areas by using Volume counter and flow rate counter as the value may be positive (Inflow) which indicates that water in accumulating case and the smoothly discharge rate (Outflow) which indicates that water in discharging case by pre-assigned rate pump flow rate as shown in figure (4.34).

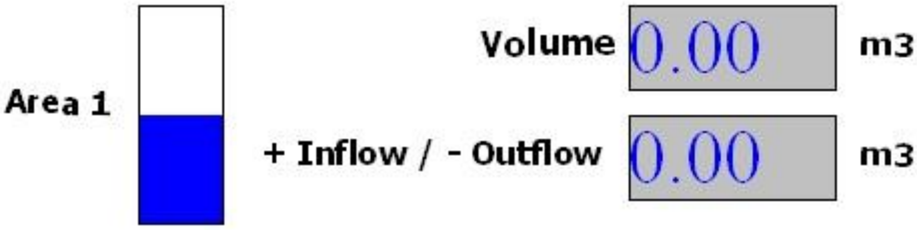

Figure (4.34): Levels and indicators

After selecting level indicator from the tool bar Level (J) as J ranges from 1 to 8 entered in the Expression field area, and full capacity volume entered in Maximum value field which repeated each area level indicator as shown in figure (4.35).

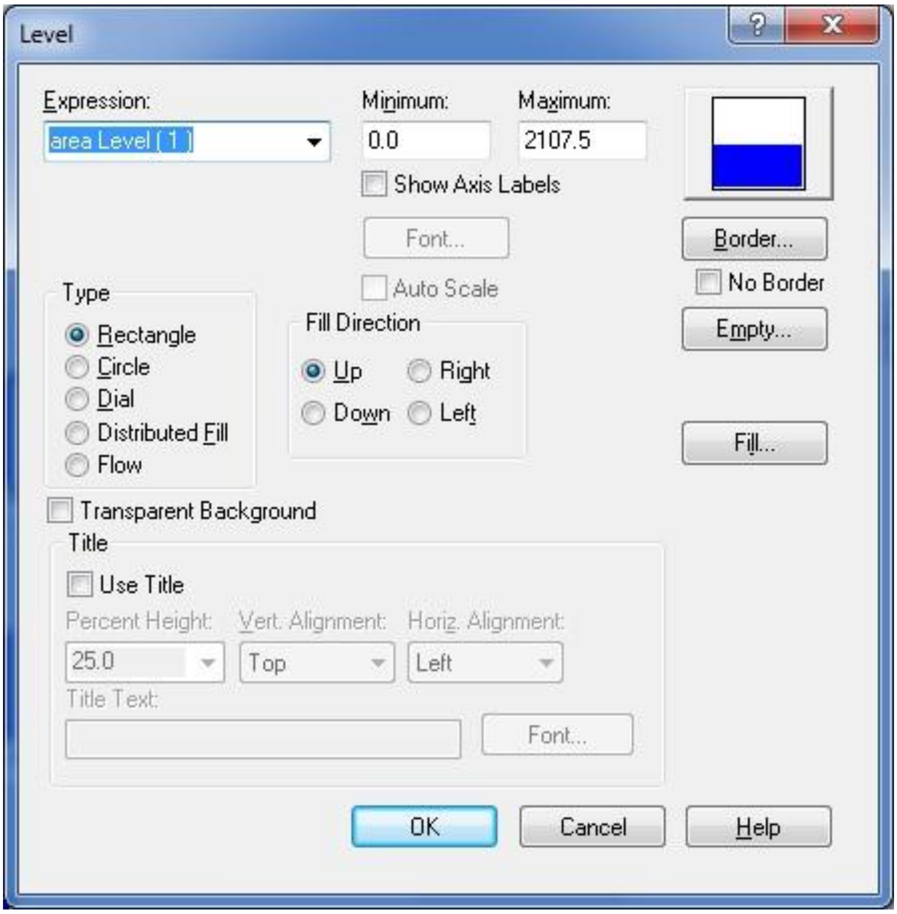

Figure (4.35): Level animation settings

And as for Variable counters the expression area Level (J) for Volume and Rate (J) entered for +inflow/-outflow rate as J ranges from 1 to 8 as shown in figure (4.36).

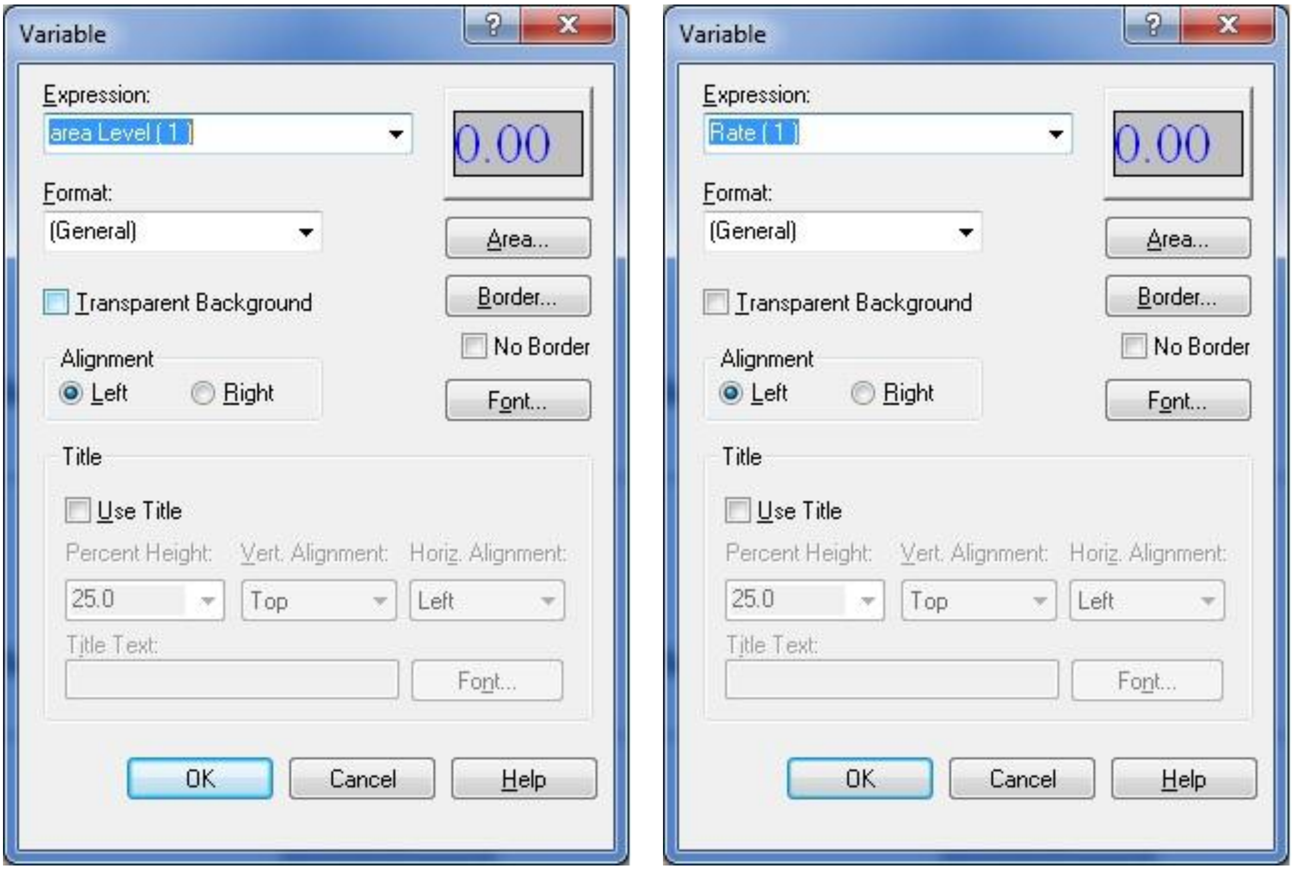

Figure (4.36): Level and rates variable settings

ActiveX Control figure used for pump from Arena symbol factory library and the suction and discharge pipes used form the same library as shown in figure (4.37), and these expressions entered in DiscreteValue1 property as shown in figure (4.38):

a. NR(pump1) for pump1
b. NR(pump2) for pump2
c. NR(pump3) for pump3
d. NR(pump4) for pump4

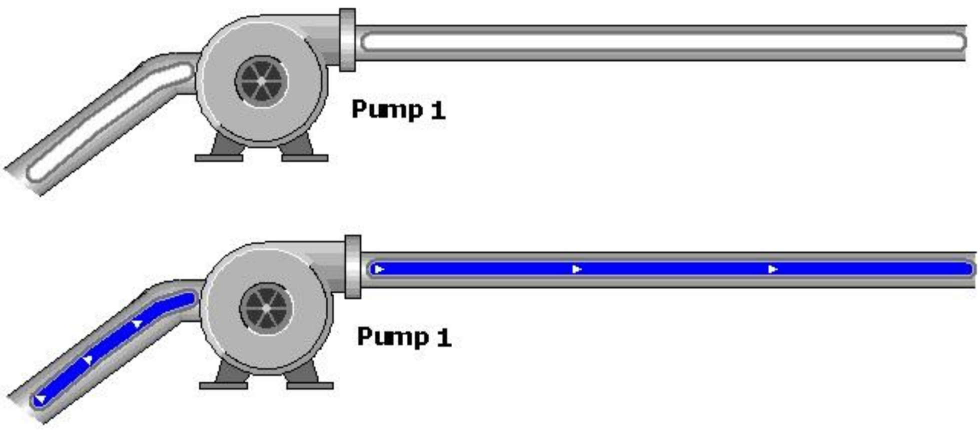

Figure (4.37): Pump on/off animation

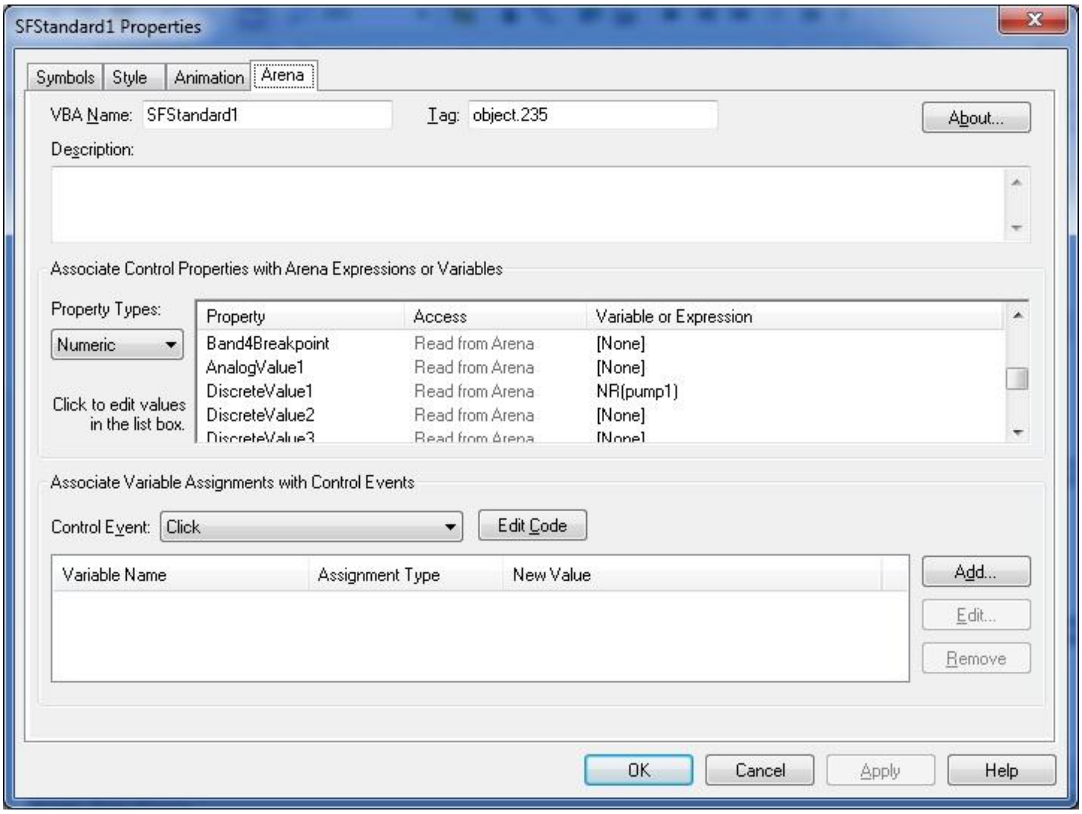

Figure (4.38): pumps animation settings

And the same for the workers in the emergency team as shown in figure (4.39) and the following expressions entered in DiscreteValue1 property as shown in figure (4.40):

a. NR(worker1) for worker1
b. NR(worker2) for worker2
c. NR(worker3) for worker3
d. NR(worker4) for worker4
e. NR(worker5) for worker5

Figure (4.39): Emergency team on/off animation

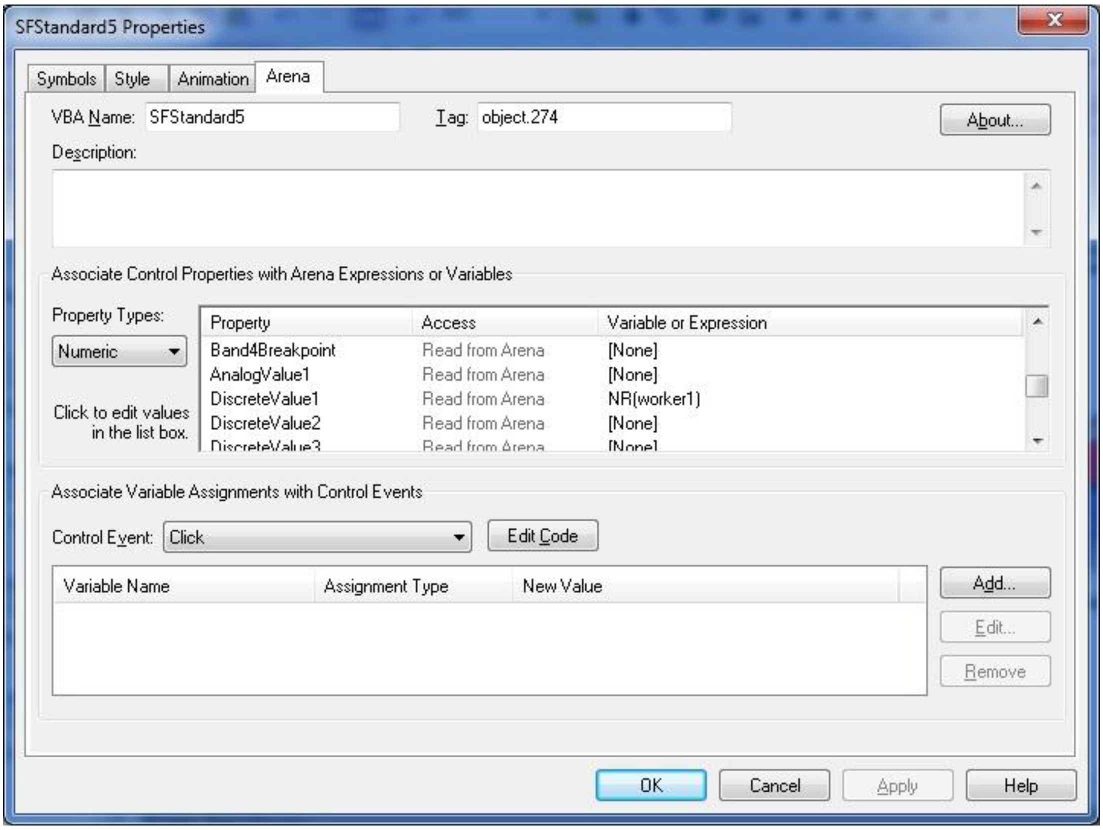

Figure (4.40): Emergency team animation settings

But to model the sectional view of the pipe to be able to visualize the water flow level indicator from tool bar used by select type flow and the following expressions entered in the Rate Expression field as shown in figure (4.41):

a. NR(pump1) for pump1
b. NR(pump2) for pump2
c. NR(pump3) for pump3
d. NR(pump4) for pump4

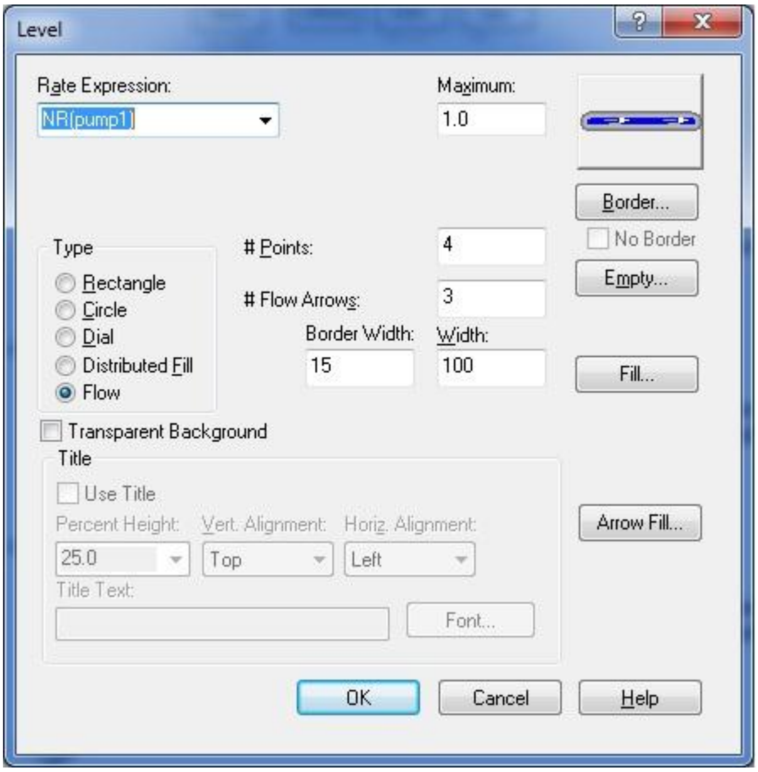

Figure (4.41): Water flow in pipes animation

There's three counters used to indicate the number of busy pumps, number of busy workers and the number of waiting areas as shown in figure (4.42).

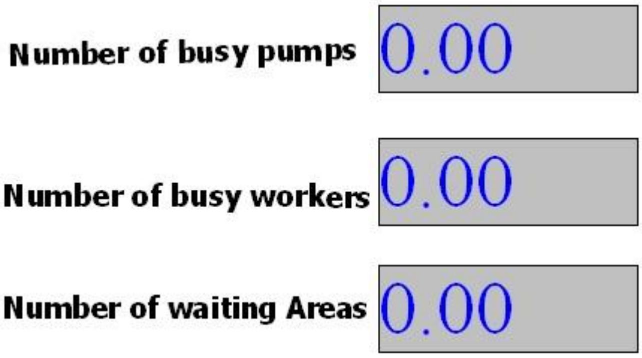

Figure (4.42): Status counters

And the expressions as mentioned in table (4.8) entered in the Expression fields as shown in figure (4.43):

Table (4.8): Status counters expressions

Counter	Expression
Number of busy pumps	SETSUM(pumps,5)
Number of busy workers	SETSUM(emrgency team,5)
Number of waiting areas	NQ(pumping time.Queue)

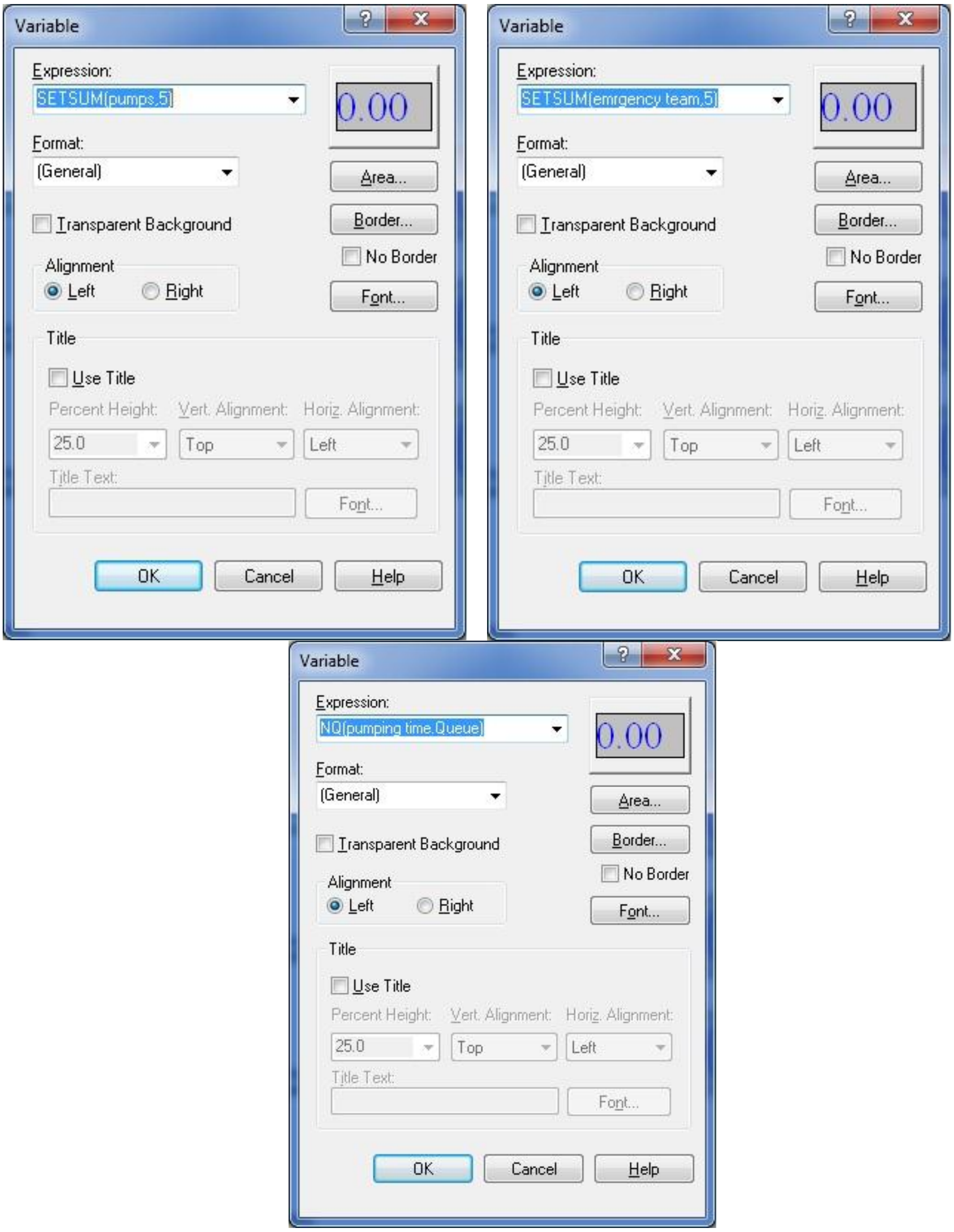

Figure (4.43): Status counters settings expressions

A few overall parameters were established for the model. These are specified in the Run Setup dialog box. The "Number of Replications" field was set to 30. This designates that the model will be run for 30 iterations and statistics will be gathered for each run. These multiple replications will reduce the variance and increase the reliability of the averages in the output. All statistics were initialized at the beginning of each replication. The base time units for the system were set to hours, and all expressions and statistics throughout the model are in terms of hours unless otherwise indicated. The replication length is set at 80 hours as shown in figure (4.44).

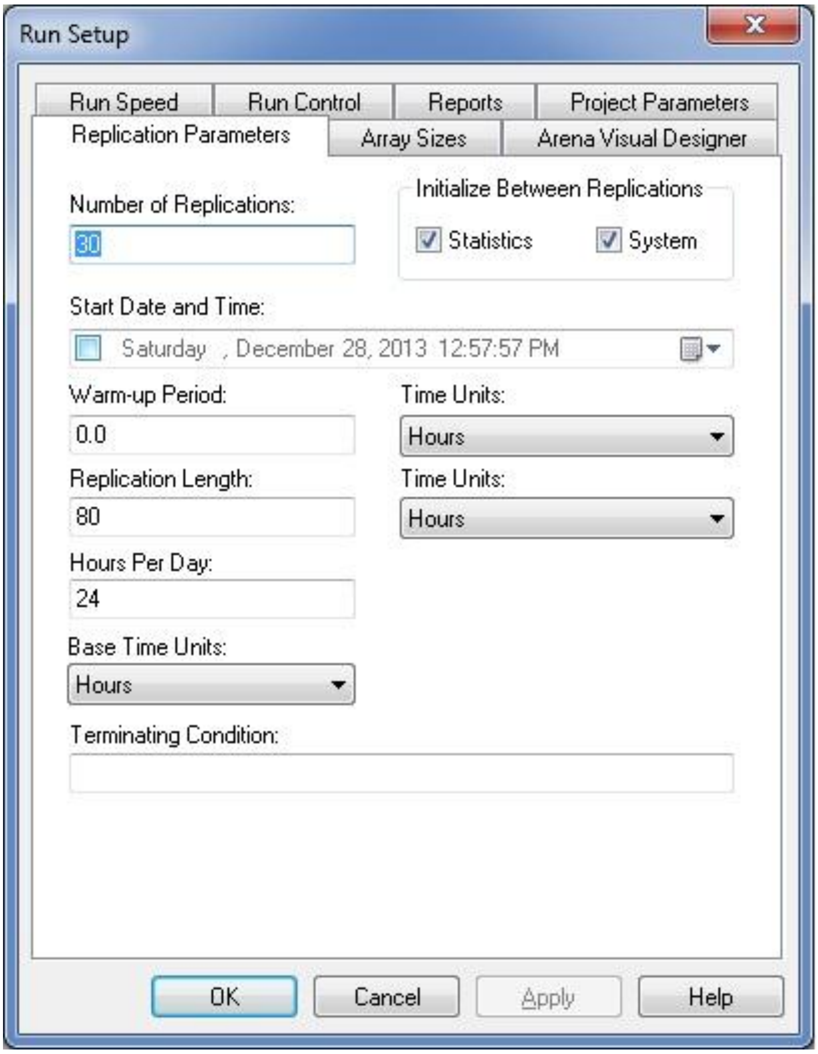

Figure (4.44): Run setup dialog box

4.3.6. Model verification

Verification is the process of ensuring that the Arena model behaves in the way it was intended according to the modeling assumptions made (Kelton et al., 2010). The model was developed in segments, and as each segment was added, the model was reviewed to verify that it was free of error and that it functioned as intended. Two techniques were utilized in the process or verification.

The first technique was to slow the system and generate input entities such that there was a sufficient delay between each to allow for viewing the activity of all entities in the system. As the model ran, the entities were visually tracked to verify that each traveled through the system as intended. To enhance this visual verification of the model, animation was used to enable a clear visualization of the increasing and decreasing of accumulated water levels in the different areas. The resources representing the pumps and workers were animated to show the busy or idle status for each.

A second technique used to verify the model was to use functions within Arena to display system information as the model was running. Using this technique, as the system was running, the user could track the number of busy pumps in the system, the number of the busy workers, and the number of waiting areas. This was useful in demonstrating that working sequence for pumps and workers assignments were functioning as intended.

4.3.7. Model validation

Validating a simulation model is the process of ensuring that it behaves the same as the real system (Kelton et al., 2010). Since this model is an approximation or representation of the real crisis and emergency system, it can never be absolutely validated. The goal in validation is to ensure the accuracy of the model results and to gain the confidence from the subject matter experts that the model is accurate for decision making purposes.

Since the simulation created was developed based on an existing real system, and some output data from the real system was historically recorded as mentioned in table (4.9) and table (4.10), it was possible to compare model results to real system results as shown in figure (4.45), figure (4.46) and figure (4.47).

Table (4.9): Model results

Model results	Average	Minimum value	Maximum value
Dispatch CES	0.2519	0.1727	0.3302
Pumping time	15.302	2.13	75.056
Time to install and operate pump	0.3068	0.1698	0.487
Travel to scene	0.3659	0.2581	0.4835

Table (4.10): Real system results

Real data	Average	Minimum value	Maximum value
Dispatch CES	0.23	0.15	0.32
Pumping time	15.5	2.2	76
Time to install and operate pump	0.27	0.16	0.45
Travel to scene	0.32	0.20	0.45

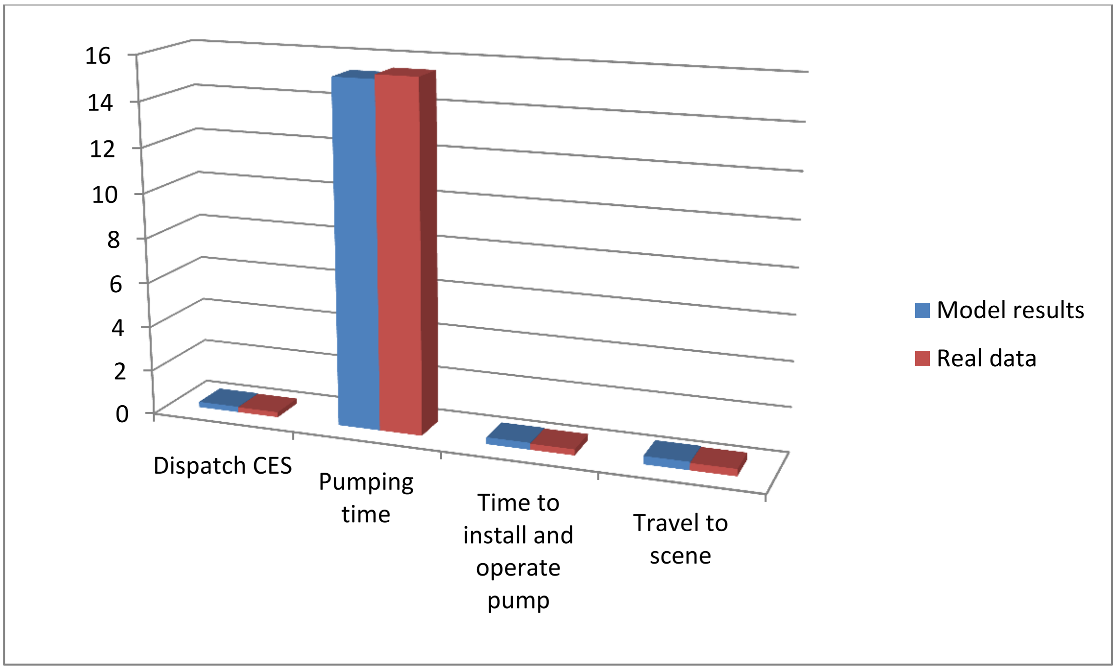

Figure (4.45): Average values comparison between model results and real data

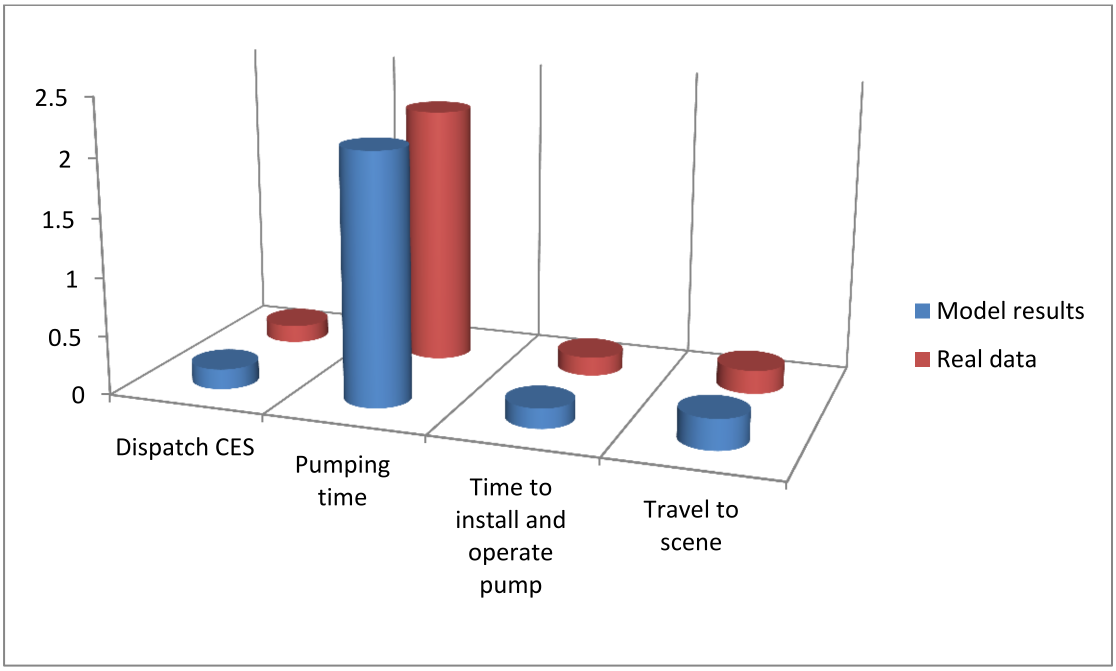

Figure (4.46): Minimum values comparison between model results and real data

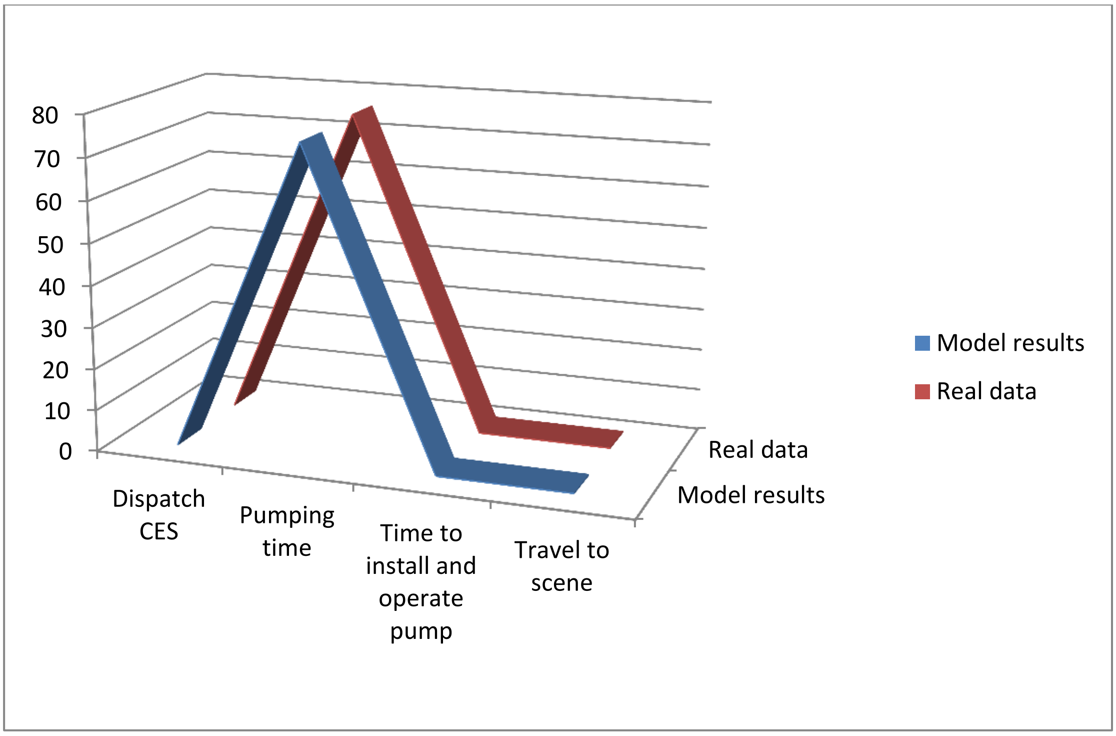

Figure (4.47): Maximum values comparison between model results and real data

Chapter five

Research analysis and findings

This chapter consists of the following sections:

Chapter five
Research analysis and findings

5.1. Introduction

This chapter deals with the analysis of the results of the simulation and with documenting the findings of the research. In order to properly understand the output from an Arena model, and make a comparison between different scenarios and point out to the best scenario that enable decision makers to manage crisis and emergency efficiently and effectively.

5.2. Arena model data results analysis

The model was set to run for 30 replications. Each replication represents 80 hours of CMWU emergency team operations. The high number of replications provides for more reliable results. Key metrics from the model are shown in tables below.

Table (5.1): Value added time per entity

Variable	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
dispatch CES	0.2520	0.01	0.2140	0.2764	0.1727	0.3303
pumping time	13.0773	0.02	12.9999	13.1466	0.00	73.3208
time to install and operate pump	0.3068	0.01	0.2631	0.3479	0.1699	0.4870
Travel to scene	0.3659	0.01	0.3346	0.4224	0.2581	0.4836

As shown above the average pumping time per entity is 13.0773 hours with half width confidence interval 0.02 so the average pumping time equals 13.0773 ± 0.02 hours.

Table (5.2): Wait time per entity

Variable	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
pumping time	2.2249	0.07	2.0388	2.6863	0.00	6.9736

The average wait time as mentioned in table (5.2) is 2.2249 hours per entity with half width interval 0.07 so the wait time will be 2.2249 ± 0.07 hours.

Table (5.3): Total time per entity

Variable	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
dispatch CES	0.2520	0.01	0.2140	0.2764	0.1727	0.3303
pumping time	15.3022	0.06	15.1832	15.7236	2.1300	75.0560
time to install and operate pump	0.3068	0.01	0.2631	0.3479	0.1699	0.4870
Travel to scene	0.3659	0.01	0.3346	0.4224	0.2581	0.4836

As shown in table (5.3) the pumping time ranges from 2.1300 to 75.0560 hours and hence the average value equals 15.3022 hours ± 0.06. The average response time equals 0.9247 ± 0.01 hours.

As response time = dispatch CES + travel to scene + time to install and operate pump.

Table (5.4): Accumulated time

Variable	Average	Half Width	Minimum Average	Maximum Average
dispatch CES	2.0159	0.04	1.7116	2.2111
pumping time	104.62	0.14	104.00	105.17
time to install and operate pump	2.4547	0.06	2.1045	2.7831
Travel to scene	2.9273	0.06	2.6767	3.3794

On the other hand the accumulated average pumping time for all the eight areas equal 104.62 ± 0.14 hours.

Table (5.5): Accumulated wait time

Variable	Average	Half Width	Minimum Average	Maximum Average
pumping time	17.7990	0.56	16.3104	21.4906

The accumulated wait time equals 17.7990 ± 0.56 hours.

Table (5.6): Wait time and number waiting

Variable	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Waiting time	2.2249	0.07	2.0388	2.6863	0.00	6.9736
Number waiting	0.2225	0.01	0.2039	0.2686	0.00	4.0000

The number waiting equals 0.225 ± 0.01 and this is a small number which indicates that the system is on the track.

Table (5.7): Resources utilization

Variable	Average	Half Width	Minimum Average	Maximum Average
Pump1	0.2758	0.13	0.0825	0.9458
Pump2	0.3658	0.14	0.0811	0.9430
Pump3	0.2960	0.12	0.0833	0.9459
Pump4	0.3702	0.14	0.0847	0.9457
Worker1	0.2960	0.12	0.0826	0.9459
Worker2	0.3417	0.14	0.0826	0.09457
Worker3	0.3614	0.14	0.0825	0.9458
Worker4	0.3087	0.13	0.0808	0.9430
Worker5	0.00	0.00	0.00	0.00

As mentioned in table (5.7) the model shows a utilization rate for pump1 27.58%, pump2 36.58%, pump3 29.6% and pump4 37.02%.

On the other side the model shows a utilization rate for worker1 29.6%, worker2 37.02%, worker3 36.14%, worker4 30.87% and worker5 0.00% which indicates that no need to hire the fifth worker and the needed workers only 4 workers to do the assigned tasks.

Table (5.8): Resources total number seized

Variable	Average	Half Width	Minimum Average	Maximum Average
Pump1	2.3000	0.42	1.0000	4.0000
Pump2	2.0333	0.40	1.0000	4.0000
Pump3	1.9333	0.35	1.0000	4.0000
Pump4	1.7333	0.29	1.0000	3.0000
Worker1	1.9667	0.36	1.0000	4.0000
Worker2	1.7667	0.31	1.0000	3.0000
Worker3	2.2000	0.41	1.0000	4.0000
Worker4	2.0667	0.40	1.0000	4.0000
Worker5	0.00	0.00	0.00	0.00

As mentioned in the table (5.8) pump1 seized 2.3 times, pump2 seized 2.033 times, pump3 seized 1.933 times and pump4 seized 1.733 times according to the largest remaining capacity for each pump.

The model shows the total number seized of worker1 1.9667 times, worker2 1.7667 times, worker3 2.2 times, worker4 2.0667 times , worker5 zero times according to the smallest number busy for each worker.

5.3. Scenario analysis

Arena Process Analyzer was used to compare between scenarios, and there are four scenarios according to the number of pumps as the first scenario suggests using four pumps, the second scenario suggests using three pumps, the third scenario suggests using two pumps and the fourth scenario suggests using one pump to finish the assigned tasks.

As mentioned in the table (5.9) the best scenario according to the pumping time per entity, wait time per entity and number waiting is the first scenario which is suggests using four pumps and four workers to do the assigned tasks because the waiting time is very essential in dealing with such situations which touches the life nerve of the community.

Table (5.9): Pumping time responses

Scenario No.	Controls				Pumping time responses		
	Pump1 (Number)	Pump2 (Number)	Pump3 (Number)	Pump4 (Number)	Total time per entity (Hours)	Wait time per entity (Hours)	Number waiting (Number)
1	**1**	**1**	**1**	**1**	**15.302**	**2.225**	**0.222**
2	1	1	1	0	15.692	3.481	0.348
3	1	1	0	0	17.307	6.172	0.617
4	1	0	0	0	29.031	19.642	1.964

So the waiting areas is 0.222 area which is small number compared to numbers in other scenarios and the waiting time equals 2.225 hours which is the smallest waiting time compared to numbers in other scenarios.

As mentioned in the table (5.10) the pumps utilization of the first scenario is 27.6% for pump1, 36.6% for pump2, 29.6% for pump3 and 37 % for pump4 respectively.

Table (5.10): Pumps utilization responses

Scenario No.	Controls				Pumps utilization responses			
	Pump1 (Number)	Pump2 (Number)	Pump3 (Number)	Pump4 (Number)	Pump1	Pump2	Pump3	Pump4
1	**1**	**1**	**1**	**1**	**0.276**	**0.366**	**0.296**	**0.370**
2	1	1	1	0	0.300	0.455	0.466	0.000
3	1	1	0	0	0.481	0.633	0.000	0.000
4	1	0	0	0	0.939	0.000	0.000	0.000

Comparing the results of pumps utilization responses with the following results of the pumps number seized in table (5.11) in the first scenario 27.6% pump1 utilization used to serve 2.3 incident areas, 3.66% pump2 utilization used to serve 2.033 incident areas, 29.6% pump3 utilization used to serve 1.933 incident areas and 37% pump4 utilization used to serve 1.733 incident areas.

Table (5.11): Pumps number seized

Scenario No.	Controls				Pumps number seized			
	Pump1 (Number)	Pump2 (Number)	Pump3 (Number)	Pump4 (Number)	Pump1	Pump2	Pump3	Pump4
1	**1**	**1**	**1**	**1**	**2.300**	**2.033**	**1.933**	**1.733**
2	1	1	1	0	2.400	2.900	2.700	0.000
3	1	1	0	0	3.700	4.300	0.000	0.000
4	1	0	0	0	8.000	0.000	0.000	0.000

And as for workers table (5.12) indicates that workers utilization of the first scenario is 29.6% for worker1, 34.2% for worker2, 36.1% for worker3 and 30.9% for worker4 respectively.

Table (5.12): Workers utilization responses

Scenario No.	Controls				Workers utilization responses			
	Pump1 (Number)	Pump2 (Number)	Pump3 (Number)	Pump4 (Number)	worker1	worker2	worker3	worker4
1	**1**	**1**	**1**	**1**	**0.296**	**0.342**	**0.361**	**0.309**
2	1	1	1	0	0.466	0.300	0.455	0.000
3	1	1	0	0	0.481	0.633	0.000	0.000
4	1	0	0	0	0.939	0.000	0.000	0.000

Table (5.13): Workers number seized

Scenario No.	Controls				Workers number seized			
	Pump1 (Number)	Pump2 (Number)	Pump3 (Number)	Pump4 (Number)	worker1	worker2	worker3	worker4
1	**1**	**1**	**1**	**1**	**1.967**	**1.767**	**2.200**	**1.733**
2	1	1	1	0	2.700	2.400	2.900	0.000
3	1	1	0	0	3.700	4.300	0.000	0.000
4	1	0	0	0	8.000	0.000	0.000	0.000

Comparing the results of workers utilization responses with the above mentioned results of the workers number seized in table (5.13) in the first scenario 29.6% worker1 utilization used to serve 1.967 incident areas, 34.2% worker2 utilization used to serve 1.767 incident areas, 36.1% worker3 utilization used to serve 2.2 incident areas and 30.9% worker4 utilization used to serve 1.733 incident areas.

So each pump used to serve and dispose storm water from more than one area and each worker used to operate the pump and seized more than one time with total number of eight served incident areas which including 25 houses containing 40 families (CMWU, 2013). And the last outcome 4 pumps with 4 workers used to serve eight incident areas including 25 houses containing 40 families with least response and service times compared with the other scenarios.

As shown in figure (5.1) the best scenario according to the total pumping time scenario number1.

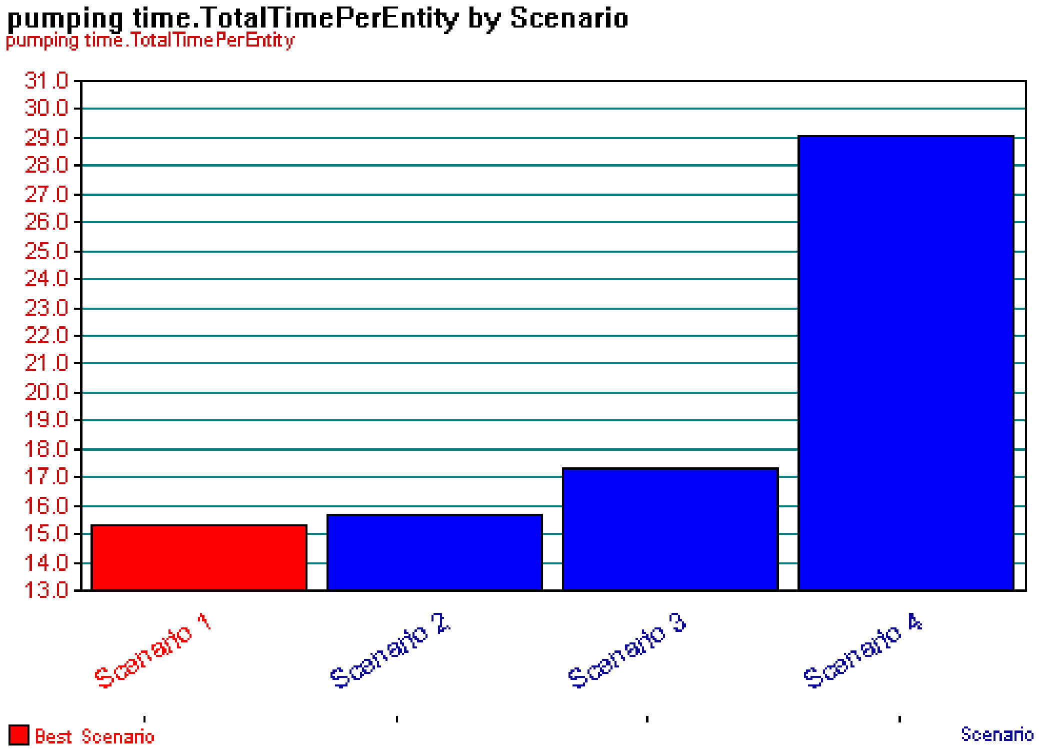

Figure (5.1) Best scenario according to total pumping time

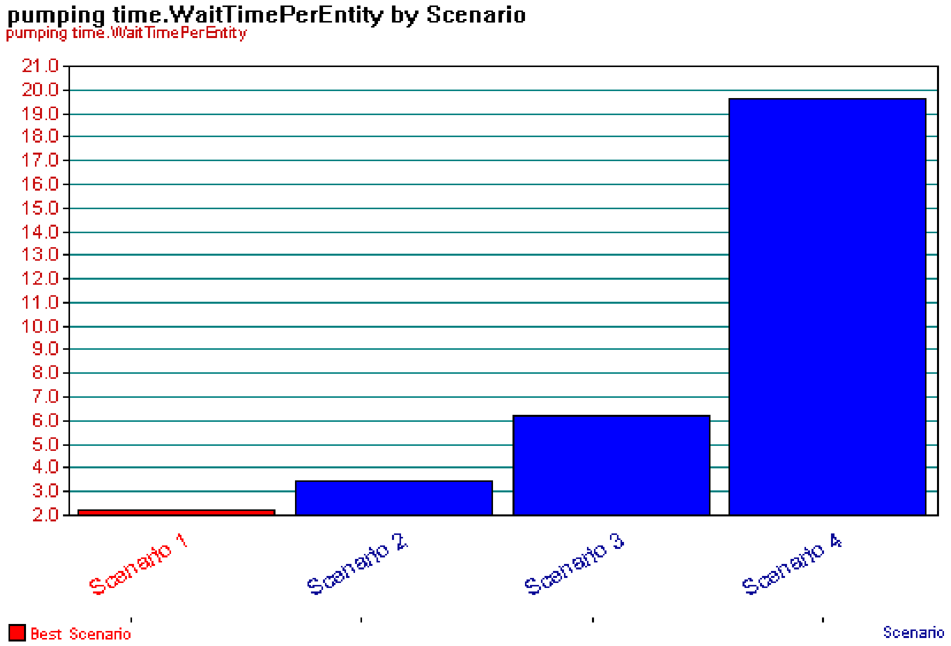

Figure (5.2) Best scenario according to waiting time

As shown in figure (5.2) the best scenario according to waiting time number1, and the same result according to the number waiting as shown in figure (5.3).

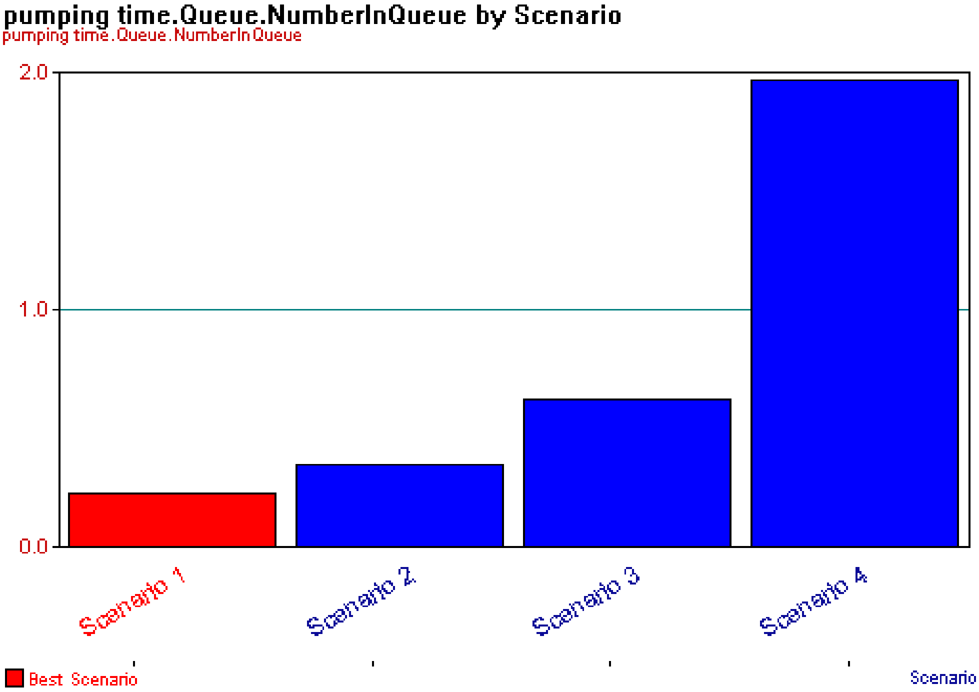

Figure (5.3) Best scenario according to number waiting

So the best scenario that the decision makers should follow is scenario number1 which supposes using four pumps and four workers with no need to the fifth worker which reduces the hiring cost of the additional worker.

Chapter six

Conclusions and recommendations

This chapter consists of the following sections:

6.1. Introduction
6.2. Conclusions
6.3. Recommendations
6.4. Future research directions

Chapter six
Conclusions and recommendations

6.1. Introduction

The main objective of this research aims to help decision makers to manage crisis and emergency that may reduce the effects and consequences of crisis and disasters on people, property and assets. This chapter will consolidate the main results of the previous chapters in the light of research problem and objectives. Research recommendations will be directed towards using Arena simulation model to manage crisis and emergency effectively and efficiently.

6.2. Conclusions

Simulation is an effective tool for modeling complex systems such as the crisis and emergency management system without imposing overly simplified assumptions. It incorporates the stochastic nature of such systems so as to make the models more robust and convincible in practice. Discrete event simulation (DES) is a widely adopted method to model system operations in a discrete time manner.

This research concentrates on discrete event simulation method; the simulated entities operate in an efficient discrete-event framework. So the model can be modified more easily and flexibly without affecting the simulator much. This model aims to providing a decision support tool for management to make robust simulation-based decisions in real-time. The evolutionary procedure decomposes the entire process horizon into smaller time intervals and then simulates each interval in sequence, allowing system updates in the small intervals. This scheme enables a simulation system to import stochastic situational changes during the simulated events such that it incorporates another layer of reality. The crisis and emergency management problem is used to realize the evolutionary real-time decision making procedure and verify the decision support system's effectiveness and efficiency.

The test results show that the simulation model is very well and as intended so the system is capable of producing good management decisions dynamically within specified time allowance. Through the case study, also gain an important insight into the crisis and emergency management problem. As the first objective of using a simulation model for crisis and emergency building a simulation model for helping CMWU decision makers, this model will be a flexible interactive visualized tool which enables CMWU decision makers to deal with flooding problems efficiently by finishing the assigned tasks by reallocation and equally distribution of the available resources to reduce cost and efforts needed and effectively by succeeding in helping people life, property and assets and this established through the comparison between different scenarios and choosing the best suitable scenario according the scale and complexity of the crisis and emergency problem. The second objective is to provide a real time DSS based on simulation in improving operation efficiency and this is represented clearly through the combined simulation discrete and continuous to deeply and really express and represent the real system as intended. The third objective which is the evaluation of the efficiency and the effectiveness of using the simulation model and this is achieved through providing a pool of alternatives and scenarios with different resources ratios distribution with the selection of the best fit scenario to finish the assigned tasks based on the minimizing of areas waiting times and reducing response and service times. Finally the fourth objectives which is improving dealing with disasters, mitigating their effects, controlling and managing emergencies and improving efficiency in both large and small scale attained by enabling managers to manage the crisis and emergency efficiently and effectively side by side increasing the knowledge and the ability to deal with such situations and reducing the effects and consequences of crisis and emergencies as much as possible.

As a short concluding remark, the work presented in this research makes a significant contribution to the simulation modeling as well as the crisis and emergency management research.

6.3. Recommendations

Emergency managers have been using protocols, standards, manuals, tables, charts, and/or even expert opinions for more than thirty years to make effective decisions before, during and after crisis. Those qualitative rules were developed based on experience and practices and can provide substantial insights into the problems.

On the other hand, quantitative and computerized models are more precise and reliable for studying large-scale dynamic systems so they are great tools to aid in making timely and high-quality decisions. So this shed the light on the importance of using the simulation model to manage crisis and emergency and the recommendations as follows:

a. Coastal municipalities water utility decision makers should use this model to helping them in managing crisis and emergency issues.

b. Using this simulation model by managers in Palestinian municipalities and local government institutions to manage crisis and emergency.

c. Modify this model to build a more flexible, integrated system for large-scale emergency management by:

    i. Interface the model with other interactive modules including a geographic information system (GIS) and real-time information systems to facilitate the synergic decision making process.

    ii. Add a client/control visual basic interface to interact with the model and prepare the data needed for running the simulation.

iii. Link the various components such as a GIS, a client/control interface together by a relational database to share data.

6.4. Future research directions

Further research could focus on and go deeper into building integrated simulation-based decision support system and improving the model functionality by using GIS maps, national databases and visual basic interfaces in order to deal with complex emergency problems in various fields.

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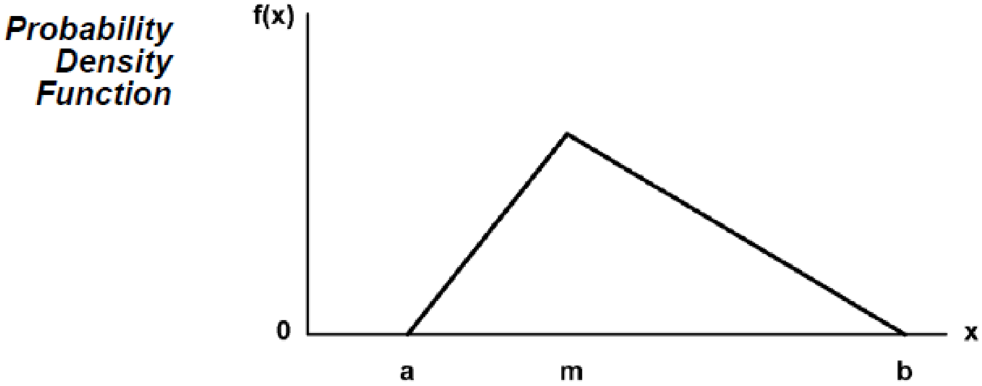
Appendix (A):
Probability distributions used in this research

Triangular (*a*, *m*, *b*): TRIANGULAR (Min, Mode, Max) or TRIA (Min, Mode, Max)



$$f(x) = \begin{cases} \dfrac{2(x-a)}{(m-a)(b-a)} & \text{for } a \leq x \leq m \\ \dfrac{2(b-x)}{(b-m)(b-a)} & \text{for } m \leq x \leq b \\ 0 & \text{otherwise} \end{cases}$$

Parameters : The minimum (a), mode (m), and maximum (b) values for the distribution specified as real numbers with a < m < b.

Range: [a, b]
Mean: (a + m + b)/3
Variance: $(a^2 + m^2 + b^2 - ma - ab - mb)/18$

Applications: The triangular distribution is commonly used in situations in which the exact form of the distribution is not known, but estimates (or guesses) for the minimum, maximum, and most likely values are available. The triangular distribution is easier to use and explain than other distributions that may be used in this situation (for example, the beta distribution).

Appendix (B):
Simulation Model