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Intelligent WSN-Based Fire Alarm System for GAS depots in Sudan

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ABSTRACT

Automatic and intelligent fire detection system is important for early detection and promptly extinguishing fire. Fire is a danger leads to quick destroying of assets and human lives. Moreover, it can propagate in fast manner according to several factors such as wind direction, fired contents (gas, fuel), etc. The fire is giant phenomena which can be controlled in its early stages but this period does not take except few seconds, there after it turns into a formidable force where to be difficult to control. With the scientific progress, the man found himself before requirements that imposing obligation upon him to consider the velocity of fire discovery where the scientific progression has been exploited in the field of communications and information transfer towards developing means of fire alarm and linking these means with Automatic Firefighting System where the time element is one of the most important factors in the process of fighting and controlling the fire.

The area of this research is limited to south Khartoum in Elshagra GAS depots and briefly the problem concentrates in intelligent fire alarm and monitoring system because they have a problem to know where the fire location and sometimes the firefighting unit miss the location of fire, also they have not scientific scenarios for people and vehicles to exit by safest way, and one of the main reasons is the lack of firefighting resources, the research here applies the concept of resource sharing by enabling communication among the nearest firefighting units. Thus, enables them to remotely monitor the gas depots and knowing the exact situation in case of fire occurrence.

In this research, we survey previous studies to make our contributions of sensor networks to early fire detection and find the safest way to exit when there is alarm detected and also short path for firefighting unit to reach fired area.

The idea starts by sensing the signal coming from the sensors to define the fire location, direction and size. Then concentrate on how to reach the fire location and exit safe way for employee and people when there is a fire. The result of this research give strong justification that prove and verify our methodology with a clear contribution in Improved dijkstra algorithm for firefighting like Forced-Dijkstra and Geo-dijkstra. Furthermore, an evaluation of the above-mentioned algorithms has been done showing very promising and realistic results.

المستخلص

نظام الكشف عن الحريق التلقائي الذكي مهم جدا للكشف المبكر ، ومن ثم على الفور إطفاء الحريق لان الحريق خطر يتربص دائماً بالإنسان والمادة وهو مارد جبار ويمكن السيطرة عليه في مراحله الأولي إلا أن هذه الفترة لا تستغرق إلا بضع ثواني يتحول بعدها الي قوة هائلة يصعب فيها السيطرة عليه . ومع التقدم العلمي وجد الإنسان نفسه أمام متطلبات تحتم عليه النظر في سرعة إكتشاف الحريق فتم إستغلال التقدم العلمي في مجال الإتصالات ونقل المعلومات في تطوير وسائل الإنذار بالحريق،وربط هذه الوسائل بمنظومة الإطفاء التلقائي، حيث أن عنصر الزمن يعد من أهم العناصر المؤثرة في عملية المكافحة والسيطرة علي الحريق. موقع البحث يقع فى المنطقة جنوب الخرطوم بمستودعات الشجرة للغاز وبإختصار تكمن مشكلة المستودع فى وجود نظام إنزار ذكي وشاشات مراقبة وذلك لمشكلة أساسية فى المستودع هي عدم معرفة مكان الحريق وفى بعض الأحيان تصل عربة المطافى للموقع الخطأ وأيضا لاتوجد لديهم طريقة علمية لعمليتي إخلاء المستودع فى حالة الحريق , وتوجية عربة المطافى لموقع الحريق , وايضا ضعف الإمكانيات فى عملية الإطفاء يجعلنا نفكر فى مشاركة موارد الإطفاء للمناطق جنوب الخرطوم وذلك بإرسال إشارات عن طريق وسائل الاتصالات الحديثة وذلك لطلب المساعدة بسرعة كبيرة.ونكرر ان عامل الزمن هو من العوامل الاساسية والمؤثرة جدا فى مكافحة الحريق حيث الدراسات اثبتت ان ثواني كافية جدا لان تكون هناك خسائر كبيرة جدا فى الموارد والارواح. تكمن الفكرة فى تجميع الإشارات من الحساسات اللاسلكية وإجراء المعالجات علي المعلومات الواصلة منها للإستفادة منها فى تحديد مكان وحجم وإتجاه الحريق .ويتم التركيز أكثر على وجود اقصر المسارات للوصول لمكان الحريق , وأيضا الطريق القضير الآَمن لعملية إخلاء الموارد والبشر من مواقع الحريق. النتائج المتحصل عليها فى هذا البحث تحقق مساهمات علمية واضحة فى عملية تحسين خوارزمية (Dijkstra) فى عملية الإخلاء التي يمكن أن يكون فيها مسار الخروج القصير به حريق وعلية يجب التحول مرغمين لاقصر مسار اخر (Forced-Dijkstra) وبالنسبة لعملية وجود أقصر مسار لعربة الإطفاء حتي تصل موقع الحريق عادة يكون الطريق الطويل بدون دورانات فى الغالب الأفضل وذلك بالإعتماد على الموقع الجغرافي (Geo-Dijkstra). و لقد تم تقييم لهاتين الخوارزميتين وكانت نتائجهما محفزة و متوافقة مع الواقع.

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Loay Ahmed Hassan

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DEDICATION

...to the ones close to my heart ♥!

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LIST OF ABBREVIATIONS

ADC	Analog-to-Digital Converter
APSP	All Pair's Shortest Path
ASP	Active Server Pages
ASIC	Application-Specific Integrated Circuit
DPM	Dynamic Power Management
DVS	Dynamic Voltage Scaling
DSP	Digital Signal Processor
FPGA	Field-Programmable Gate Arrays
GEO	Geographical
GSM	Global System for Mobile
GUI	Graphical User Interface
IP	Internet Protocol
IS	Indian Standard
ISM	Industrial. Scientific. Medical.
LAN	Local Area Network
LCD	Liquid Crystal Display
MEMS	Micro Electro-Mechanical Systems
PHP	Personal Home Page
RAM	Random Access Memory
RF	Radio Frequency
SMS	Short Message Service
SSSP	Single Source Shortest Path
USB	Universal Serial Bus
WSN	Wireless Sensor Networks

CHAPTER ONE

INTRODUCTION

1.1 Preface

Fire disasters are considered the most important challenges in the Real World where the risk of fire disasters directly affect human, material and environmental [1]. The harm of the fire is not only affecting the individual but also it can be for the society in direct or indirect manner. Sometimes the impact of fire can be reflected on the activities of daily life such as Factories, Gas Reservoirs, Petroleum Refineries, Gas Stations and Power Plants and Industrial Facilities of various kinds [1].

These examples when exposed to such disasters, it will result in failure, "or complete paralysis" of energy resources, also Environmental pollution caused by these fires, extremely dangerous [1].

So, it became very necessary to respond very fast to such disasters by using automatic and quick recovery at least be real time alarms and guidance for firefighting unit as well as mention the safest exit ways towards the outside.

1.1.1 Research Motivation

The area of ‘Elshagra Warehouse’ that contain multi number of company (for more details see appendix A), will be taken in detailed study to determine exactly where the fire place and secure checkout for the lives and assets from ‘Elshagra Warehouse site’ in case of fire alarm. In meetings with senior officers in one of the companies he listed: the depot when there is a fire alert for warning; usually they do not know the fire location in many cases, moving the vehicle until we get inside the warehouse fire location exactly. So, it seems just a try and error methodology, although the response time is very sensitive in case of fire.

Mentioning an example, an explosion in a gas pipeline in the mobilization of (Aman) factory in 21.02.2016. Normally all companies activate the Alarm but the fire brigade vehicle went to a wrong company.

He complements that not specifying the fire location exactly with the required speed, the interior vehicle cannot reach the Fire site only after the occurrence of very large losses or after the Fire extinguishing by the company. This fully confirms the importance of the process of the (real time monitoring and accurate identification of the fire location).

1.2 Problem Definition:

In general, the following challenges represent the problem statements:

- Delay in fire discovery, provisioning of clear map for area of the fire., lack of information about the fire reasons (GAS or petroleum or electrical…etc.).

- In some cases, despite the availability of units to extinguish the designated location may not be enough in the catastrophic fires and explosions, which requires the participation of firefighting resources between the various sites near the fire premises.

- Difficulty of estimating the exact amount of fire, which determine the required firefighter to support fire.

- Identification of fire source and its direction to find the best path for firefighting. As well to send guidance safety messages for walker and drivers toward the safe and short path to the exit door.

1.3 Objectives

The objectives of this thesis divided into two, the general objectives and the specific objectives.

1.3.1 General Objectives

The general objective of this project is to design Intelligent WSN-Based GAS/liquid/Fire Alarm System for the area south Khartoum specifically “Elshagra GAS depots”, so as reduce the risk for human life’s and assets.

1.3.2 Specific Objectives

The specific objectives of this project are:

To locate the exact position of fire and the corresponding information such as fire area (by providing firefighting unit a visual clear map about fire area), level and starting point.

To find the shortest path in case fire disaster for survivors using enhanced algorithm for short path detection Wireless Sensor Network.

To propose autonomous guiding system for a robot car (fire fitting car) to recover from fire (how to reach fire).

To define the size of the fire (is it more than local civil defense ability to recover the local fire).

To propose guideline for and vehicle to exit (safe ways).

To build intelligent network for all area south Khartoum to share the fire units (sharing resources for fast response).

1.4 State of the Art

The related work was written based on scientific ten papers. The main things that made by the previous studies for this project that, many factors lead to leakage of gases and liquid and these cost millions of dollars in damages and many human lives every year. Common causes of leakages of gases include Hole pipe, human carelessness and bad culture, however in most cases the damage caused by leakages of gas/liquid to public safety and natural resources is intolerable and early detection and suppression of fire deem crucial.

Most of the papers insure that, early detection is only the way to minimize the damages and casualties. We present the design and evaluation of wireless sensor network for early detection of leakages gas/liquid and fast fire alarm system.

Also, some papers give a good idea for how to make the design of WSN, how to use GSM with WSN, how to use SMS for alarm and some different intelligent ideas.

1.5 Methodology

The project starts by study and analysis to the wireless sensor network and its characteristics, protocols, limitations, then start Splitting sensors in the prototype maps, define routing techniques, create link, and detect readings. Also by creating a cost table for the map representing shortest paths between two nodes by considering the terns in the ways between nodes because this turn has direct effect in the delay between nodes and also increase the cost. A GUI then will be programmed to give the end user a result about the fire area, size of fire, direction of fire and the map for firefighter to recover the fire fast. To be realistic with the way that methodology represent a full design for a system that gives fast alarm, simulator software with a number of GAS/liquid/fire sensors distributed as nodes in a detailed map of Elshagra GAS depots building. To visualize the location of fire then random selection for node to verify that is alarm coming from that node selected randomly, and if the selected node is more than two nodes, this means that the size of fire is big than the local civil defense and we must use special network for requesting the nearest location civil defense.

By trying different scenarios for the above factors, we can yield a good result for the system. Then we must choose the best technique for finding the shortest path and chose the best technique for finding safest shortest exit path for employee and vehicles, and also the shortest path for firefighting unit to recover fired company.

1.6 Scope and Limitations:

Prototype, limited number of sensors and simulation software to improve WSN system performance, define the fire source, size of fire and automatic firefighter request.

1.7 Expected Contribution

In the following details the expected contribution discus the contribution as general and also give specific contribution.

1.7.1 General Contribution

The thesis gives a complete system for alarm system starting from the small point which is an alarm in Elshagra warehouse to big point which is an alarm to the nearest institution from Elshagra warehouse to apply sharing resources feature for firefighting units through special network.

1.7.2 Specific Contribution

The thesis solves big problem for Elshagra warehouse starting from define where the fire starts by monitoring the area using WSN and give fast alarm to detect GAS/liquid/fire, guideline for save exit, call nearest outside firefighting help if the fire is big than the ability of local firefighting to cover.

1.8 Thesis Layout

This thesis composed of five chapters, chapter two gives a brief background, it also presents the related works. Chapter three represents the project methodology. It explains the simulation scenarios, Chapter four explores the results and discussion Chapter five concludes this thesis and show the future directions as recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction:

This chapter starts with an overview about fire disaster in section 2.2. Section 2.3 explains the fire growth and behavior. Section 2.4 represents the fired location identification and fast recovery to clarify the shortest path including dijkstra. Section 2.5 clarifies the use of WSN in firefighting while section 2.6 starts discus WSN specially the sensor node and component of sensor. Section 2.7 outline WSN characteristics. Section 2.8 about technical challenges factor. Section 2.9 represents the application of WSN. Lastly in Section 2.10 the related work was written based on scientific ten papers.

2.2 Fire Disasters:

As have been mentioned in chapter one Fire disasters are considered the most important challenges in the Real World where the risk of fire disasters includes Human, Material and Environmental disasters. Disasters also include the Individual and Society, where the impact on the activities of daily life is reflected directly and indirectly. Factories, Gas Reservoirs, Petroleum Refineries, Gas Stations and Power Plants and Industrial Facilities of various kinds when exposed to such disasters, it will result in failure of energy resources, also environmental pollution caused by these fires, output of the risks combustion extremely dangerous, so it became very necessary to respond to such disasters [1].

2.2.1 Tejanyen Warehouse Fire:

A strong example of a fire is a Tejanyen Warehouse - North China as shown in the following pictures Figure (2.1), that represent the size of the fire and the big loss due to that big fire.

Figure (2-1)Tejanyen Warehouse fire

Where injured more than 700 people, 114 people have been killed, and explosions triggered several other fires in the city, including damage Hundreds of Cars. This fire has made destruction unimaginably and the Chinese Authorities have arrested a Formal 12 Executive Managers, mostly from Roahaa Global Logistics Co., which owns Warehouse. The investigation shown that the Company does not have a license to deal with the dangerous chemicals that are stored in the warehouse without the License from the Chinese Authorities [2].

2.2.2 Fire Inside Sudan:

Sudan is a developing country and there are no possibilities in the Civil Defense to support a number of fires at one time, and even one fire there will be a very great difficulty to reach the place in time before the destruction happens, a real examples fires in Sudan as shown in the following next page pictures Figure (2.2), a Sidibe Cafeteria in Albulabl Khartoum Station and the GAS Tanker in the Khartoum University Street tunnel.

Figure (2.2) fire in Sidibe Cafeteria and GAS Tanker in Khartoum

Noticing that the arrival of fire-fighting services after total damage has been happen, due to the car congestion and late of fire alarm.

2.2.3 The Methods of Extinguishing Fires:

Hundreds of thousands of fires, both big and small, break out in workplaces around the country every year. While many are controllable and only a very small percentage result in fatalities, ensuring that staff and employers are trained in effective fire safety practices, such as extinguisher usage, is key to keeping these figures low. The following details is the main function in controlling the fire representing the methods of extinguishing fires [3].

2.2.3.1 Cooling the Burning Material

Cooling the burning material is the most common method used to extinguish fire. Water is widely available and the best cooling agent to use specially in fires involving solid materials. By evaporating in contact with fire, water also blankets the fire, cutting off the oxygen supply. However, you should never apply water to fires involving hot cooking oil or fat; water can cause the fire to spread [3].

2.2.3.2 Excluding Oxygen from the Fire

Smothering agents are substances used to extinguish a fire by cutting off the oxygen supply. Foam, which is the content of some fire extinguishers, can help to cool down and isolate the fuel surface from the air, eliminating combustion and being able to resist wind and draught disruption. However, never use foam on energized electrical equipment, because it is an electrical conductor. Other smothering agents include carbon dioxide, which is found in some fire extinguishers and is ideally used in electric equipment and sand, which is effective only on small burning areas [3].

2.2.3.3 Removing Fuel from the Fire

Another method of extinguishing a fire is to remove the fuel supply by switching off the electrical power, isolating the flow of flammable liquids or removing the solid fuel, such as wood or textiles. In woodland fires, a firebreak cut around the fire helps to isolated further fuel. In the case of gas fire, closing the main valve and cutting off the gas supply is the best way of extinguishing the fire [3].

2.2.3.4 Using a Flame Inhibitor

Flame inhibitors are substances that chemically react with the burning material, thus extinguishing the flames. Dry-chemical fire extinguishers work in this way, and can contain monoammonium phosphate, sodium and potassium bicarbonate and potassium chloride. Vaporizing liquids, such as Halon, also have a flame inhibiting action. However, most of these substances have been phased out due to high levels of toxicity [3].

2.3 Fire Growth and Behavior:

Before attempting to understand intelligent WSN fire alarm system, it is beneficial to possess a basic knowledge of fire development and behavior.

With this information, the role and interaction of these supplemental fire safety systems in the protection process can then be better realized [4].

Basically, a fire is a chemical reaction in which a carbon-based material (fuel), mixes with oxygen (usually as a component of air), and is heated to a point where flammable vapors are produced. These vapors can then come in contact with something that is hot enough to cause vapor ignition, and a resulting fire. In simple terms, something that can burn touches something that is hot, and a fire is produced fast [5].

Fires are the accidents which occur most frequently, whose causes are the most diverse and which require intervention methods and techniques adapted to the conditions and needs of each incident

Depending on the type of fire (nature of the material ablaze), meteorological conditions (wind) and the effectiveness of the intervention, material damage can be limited (a single car, building or production or storage warehouse installation), or affect wide areas (forest or agricultural fires, hydrocarbons, gas or other highly flammable products, storage or piping installations, harbor installations and rail or marine transport equipment). Explosions are in a different category [6]

Each type of fire is the object of specific technical prescriptions as regards prevention, intervention and the behavior of the population affected. It is also relevant to note that many fires have a criminal origin and that in times of armed conflict or crisis as well as of indirect wars (sabotage) human intervention also provokes major accidents.

For practical reasons refer to technical documentation, which should be known or available to all security and fire-fighting services, and to national and regional disaster alarm and information centers.

This is especially the case for rescue and fire extinction on motorways, buildings designed to be used by a great number of people (hospitals, hotels, cinemas, high-rise buildings, department stores, etc...); fires affecting chimneys, attires, cotton (bales, loose, explosive dust), fodder (fermentation), fires in high warehouses, silos or underground garages as well as forest fires. Everyone know the big loss that come with fire especially the human loss [6]

2.4 Fired Location Identification and Fast Recovery

This area talks about optimization techniques used for fast location identification and fast recovery by finding the short path to reach the locations. Shortest path is a fundamental problem in graph theory then we can define the shortest path problem as the problem of finding a path between two vertices [7] (source and destination). This problem solved by using different algorithms depending on the structure of the graph, we classify the shortest path algorithms into:

Single source shortest path (SSSP) algorithms: in this type of problem, we want to find the shortest path from the specific source node to specific destination node or all nodes. Dijkstra algorithm is more efficient to solve this type of shortest path problem especially when we do not have negative edge weight, however if we have it, the Bellman-Ford's algorithm used [8].

All pair's shortest path (APSP) algorithms: if we want to find the shortest path from all nodes to all nodes, then the Floyd-Warshall algorithm is more efficient to solve this type of shortest path problem. Another algorithm to solve this type of problem is called Johnson's algorithm, and this type may be faster than Floyd–Warshall on sparse graphs [9].

Another algorithm is available to solve shortest path algorithms, such as A* search algorithms, Viterbi algorithm, and others. In this thesis, we are focusing on Dijkstra algorithm.

2.4.1 Dijkstra Algorithm:

Dijkstra algorithm was designed in 1956 by Dutch computer scientist Edsger Dijkstra [10], and it is one of the most popular algorithms to find the shortest paths to our knowledge. When the nonnegative edge path is considered, then we can use this algorithm to solve the single-source shortest path problem for a graph. This algorithm is often used in routing and as a subroutine in other graph algorithms. By using this algorithm, we can find the shortest path between the specific vertex to all vertices in the graph.

Methodology: We can define the algorithm methodology as follow:

Choose the source node as a first permanent node, and assign it 0 costs.

Check all neighbor nodes from the previous permanent node

Calculate the cumulative cost of each neighbor nodes and make them temporary

Check the temporary nodes as follows

Choose a node with the smallest cumulative cost, and make it as a permanent node. Keep in mind; do not check the permanent again because this is a final cost for this node.

If we have more path to reach to the nodes, then the shortest cumulative cost paths were chosen

Repeat steps 2 to 4 to make all nodes as a permanent.

2.5 The Use of WSN in Firefighting:

The use of WSN in firefighting is wide Science and have different applications, WSN Provide information about the location of the fire and also Provide information about the extent of spread of the fire – where it is spreading and how quickly and so on, in the following we must try to detail WSN to understand the idea and its components.

2.6 Wireless Sensor Network

Recent technological improvements have made the deployment of small, inexpensive, low-power, distributed devices, which are capable of local processing and wireless communication. Such nodes are called as sensor nodes. Each sensor node is capable of only a limited amount of processing. But when coordinated with the information from a large number of other nodes, they have the ability to measure a given physical environment in great detail. Thus, a sensor network can be described as a collection of sensor nodes which co-ordinate to perform some specific action. Unlike traditional networks, sensor networks depend on dense deployment and co-ordination to carry out their tasks [11].

Previously, sensor networks consisted of small number of sensor nodes that were wired to a central processing station. However, nowadays, the focus is more on wireless, distributed, sensing nodes. But, why distributed, wireless sensing [12] When the exact location of a particular phenomenon is unknown, distributed sensing allows for closer placement to the phenomenon than a single sensor would permit. Also, in many cases, multiple sensor nodes are required to overcome environmental obstacles like obstructions, line of sight constraints etc. In most cases, the environment to be monitored does not have an existing infrastructure for either energy or communication. It becomes imperative for sensor nodes to survive on small, finite sources of energy and communicate through a wireless communication channel. Another requirement for sensor networks would be distributed processing capability. This is necessary since communication is a major consumer of energy. A centralized system would mean that some of the sensors would need to communicate over long distances that lead to even more energy depletion [13].

Hence, it would be a good idea to process locally as much information as possible in order to minimize the total number of bits transmitted.

2.6.1 Sensor Nodes:

Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a processing unit with limited computational power and limited memory, sensors or MEMS (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery [14]. Other possible inclusions are energy harvesting modules, secondary ASICs, and possibly secondary communication devices (e.g. RS-232 or USB).

The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. Other special components in routing based networks are routers, designed to compute, calculate and distribute the routing tables [15].

2.6.2 Components of Sensor Node

The main components of a sensor node as shown in the following Figure (2.3) the main component of sensor node are a microcontroller, transceiver, external memory, power source and one or more sensors [16].

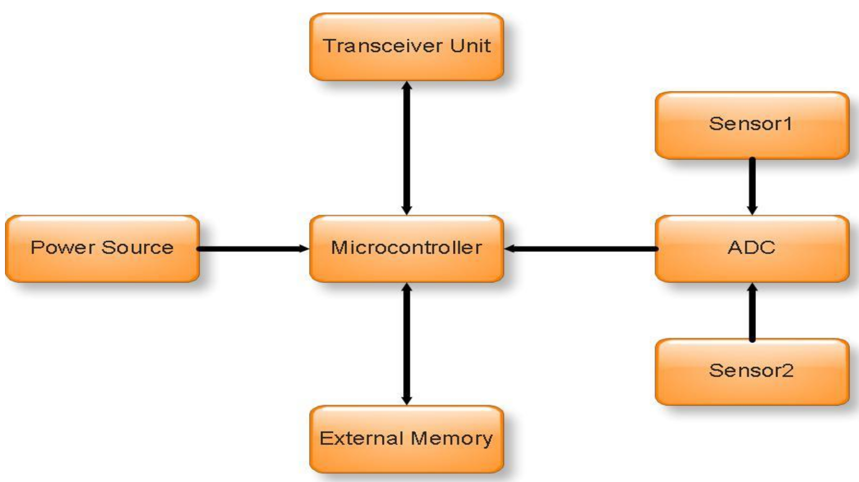


Figure (2.3) the main component of sensor node

2.6.2.1 Controller

The controller performs tasks, processes data and controls the functionality of other components in the sensor node. While the most common controller is a microcontroller, other alternatives that can be used as a controller are: a general-purpose desktop microprocessor, digital signal processors, FPGAs and ASICs. A microcontroller is often used in many embedded systems such as sensor nodes because of its low cost, flexibility to connect to other devices, ease of programming, and low power consumption. A general-purpose microprocessor generally has a higher power consumption than a microcontroller, therefore it is often not considered a suitable choice for a sensor node. Digital Signal Processors may be chosen for broadband wireless communication applications, but in Wireless Sensor Networks the wireless communication is often modest: i.e., simpler, easier to process modulation and the signal processing tasks of actual sensing of data is less complicated. Therefore, the advantages of DSPs are not usually of much importance to wireless sensor nodes. FPGAs can be reprogrammed and reconfigured according to requirements, but this takes more time and energy than desired [17].

2.6.2.2 Transceiver

Sensor nodes often make use of ISM band, which gives free radio, spectrum allocation and global availability. The possible choices of wireless transmission media are radio frequency (RF), optical communication (laser) and infrared. Lasers require less energy, but need line-of-sight for communication and are sensitive to atmospheric conditions. Infrared, like lasers, needs no antenna but it is limited in its broadcasting capacity. Radio frequency-based communication is the most relevant that fits most of the WSN applications [18]. WSNs tend to use license-free communication frequencies: 173, 433, 868, and 915 MHz; and 2.4 GHz. The functionality of both transmitter and receiver are combined into a single device known as a transceiver. Transceivers often lack unique identifiers. The operational states are transmitting, receive, idle, and sleep. Current generation transceivers have built-in state machines that perform some operations automatically [19].

Most transceivers operating in idle mode have a power consumption almost equal to the power consumed in receive mode. Thus, it is better to completely shut down the transceiver rather than leave it in the idle mode when it is not transmitting or receiving [19]. A significant amount of power is consumed when switching from sleep mode to transmit mode in order to transmit a packet.

2.6.2.3 External Memory

From an energy perspective, the most relevant kinds of memory are the on-chip memory of a microcontroller and Flash memory—off-chip RAM is rarely, if ever, used. Flash memories are used due to their cost and storage capacity. Memory requirements are very much application dependent. Two categories of memory based on the purpose of storage are: user memory used for storing application related or personal data, and program memory used for programming the device. Program memory also contains identification data of the device if present [19].

2.6.2.4 Power Source

A wireless sensor node is a popular solution when it is difficult or impossible to run a mains supply to the sensor node. However, since the wireless sensor node is often placed in a hard-to-reach location, changing the battery regularly can be costly and inconvenient. An important aspect in the development of a wireless sensor node is ensuring that there is always adequate energy available to power the system. The sensor node consumes power for sensing, communicating and data processing [19]. More energy is required for data communication than any other process. The energy cost of transmitting 1 Kb a distance of 100 meters (330 ft.) is approximately the same as that used for the execution of 3 million instructions by 100 million instructions per second/W processor. Power is stored either in batteries or capacitors. Batteries, both rechargeable and non-rechargeable, are the main source of power supply for sensor nodes. They are also classified according to electrochemical material used for the electrodes such as NiCd (nickel-cadmium), NiZn (nickel-zinc), NiMH (nickel-metal hydride), and lithium-ion. Current sensors are able to renew their energy from solar sources, temperature differences, or vibration. Two power saving policies used are Dynamic Power Management (DPM) and Dynamic Voltage Scaling (DVS). DPM conserves power by shutting down parts of the sensor node which are not currently used or active. A DVS scheme varies the power levels within the sensor node depending on the non-deterministic workload. By varying the voltage along with the frequency, it is possible to obtain quadratic reduction in power consumption [19].

2.6.2.5 Sensors

Sensors are hardware devices that produce a measurable response to a change in a physical condition like temperature or pressure. Sensors measure physical data of the parameter to be monitored. The continual analog signal produced by the sensors is digitized by an analog-to-digital converter (ADC)and sent to controllers for further processing. A sensor node should be small in size, consume extremely low energy, operate in high volumetric densities, be autonomous and operate unattended, and be adaptive to the environment. As wireless sensor nodes are typically very small electronic devices, they can only be equipped with a limited power source of less than 0.5-2 ampere-hour and 1.2-3.7 volts [19].

Sensors are classified into three categories: passive, Omni-directional sensors; passive, narrow-beam sensors; and active sensors. Passive sensors sense the data without actually manipulating the environment by active probing. They are self-powered; that is, energy is needed only to amplify their analog signal. Active sensors actively probe the environment, for example, a sonar or radar sensor, and they require continuous energy from a power source. Narrow-beam sensors have a well-defined notion of direction of measurement, similar to a camera. Omni-directional sensors have no notion of direction involved in their measurements [19].

The overall theoretical work on WSNs works with passive, omni-directional sensors. Each sensor node has a certain area of coverage for which it can reliably and accurately report the particular quantity that it is observing. Several sources of power consumption in sensors are: signal sampling and conversion of physical signals to electrical ones, signal conditioning, and analog-to-digital conversion. Spatial density of sensor nodes in the field may be as high as 20 nodes per cubic meter.

2.7 WSN Characteristics:

The main characteristics of a WSN include:

1. Power consumption constrains for nodes using batteries or energy harvesting

2. Ability to cope with node failures

3. Mobility of node

4. Communication failures

5. Heterogeneity of nodes

6. Scalability to large scale of deployment

7. Ability to withstand harsh environmental conditions\

8. Ease of use.

2.8 Technique Challenges Factors

In spite of the diverse applications, sensor networks pose a number of unique technical challenges due to the following factors [20]:

2.8.1 Ad hoc Deployment:

Most sensor nodes are deployed in regions which have no infrastructure at all. A typical way of deployment in a forest would be tossing the sensor nodes from an aero plane. In such a situation, it is up to the nodes to identify its connectivity and distribution [20].

2.8.2 Unattended Operation:

In most cases, once deployed, sensor networks have no human intervention. Hence the nodes themselves are responsible for reconfiguration in case of any changes [20].

2.8.3 Untethered:

The sensor nodes are not connected to any energy source. There is only a finite source of energy, which must be optimally used for processing and communication. An interesting fact is that communication dominates processing in energy consumption. Thus, in order to make optimal use of energy, communication should be minimized as much as possible [20].

2.8.4 Dynamic Changes:

It is required that a sensor network system be adaptable to changing connectivity (for e.g., due to addition of more nodes, failure of nodes etc.). Thus, unlike traditional networks, where the focus is on maximizing channel throughput or minimizing node deployment, the major consideration in a sensor network is to extend the system lifetime as well as the system robustness [20]

2.8.5 Energy Efficiency:

Energy efficiency is a dominant consideration no matter what the problem is. This is because sensor nodes only have a small and finite source of energy. Many solutions, both hardware and software related, have been proposed to optimize energy usage [20].

2.8.6 Localization:

In most of the cases, sensor nodes are deployed in an ad hoc manner. It is up to the nodes to identify themselves in some spatial co-ordinate system. This problem is referred to as localization [20].

2.8.7 Routing:

Communication costs play a great role in deciding the routing technique to be used. Traditional routing schemes are no longer useful since energy considerations demand that only essential minimal routing be done [20].

2.9 Application of Wireless Sensor Network

As shown in the following Figure (2.4) applications of wireless sensor network Many applications were developed for wireless sensor network each has its limitation.

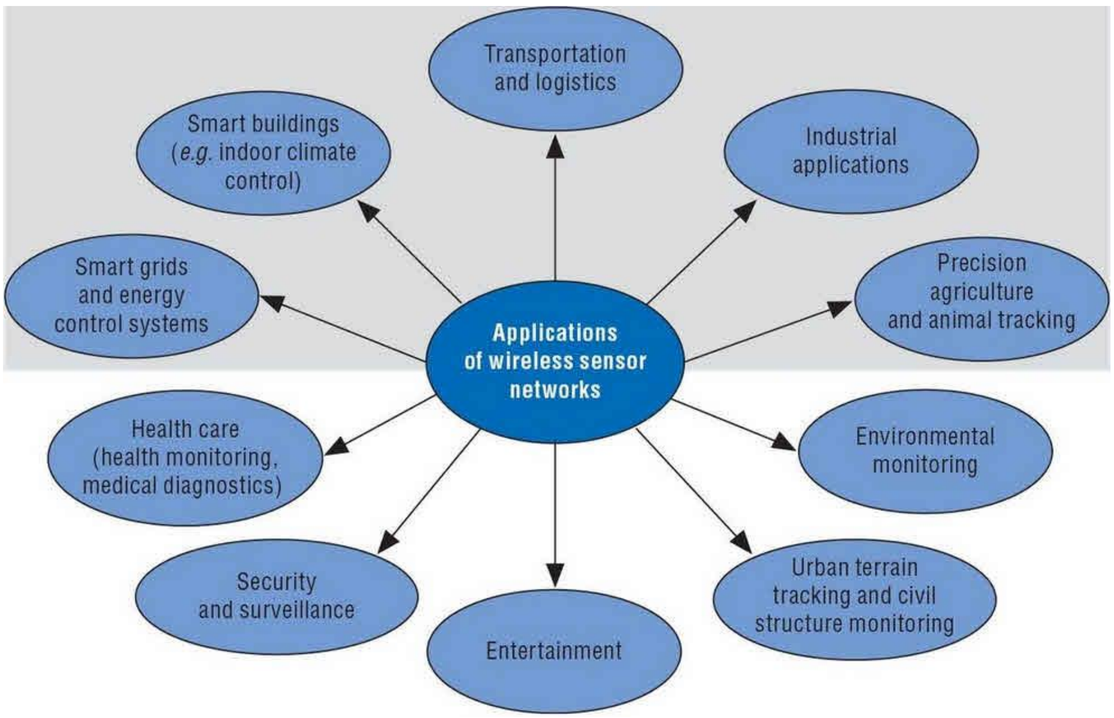


Figure (2.4) applications of wireless sensor network source: [21]

These networks are used in environmental tracking, such as forest detection, animal tracking, flood detection, forecasting and weather prediction, and also in commercial applications like seismic activities prediction and monitoring.

Military applications, such as tracking and environment monitoring surveillance applications use these networks. The sensor nodes from sensor networks are dropped to the field of interest and are remotely controlled by a user. Enemy tracking, security detections are also performed by using these networks.

Health applications, such as Tracking and monitoring of patients and doctors use these networks.

The most frequently used wireless sensor networks applications in the field of Transport systems such as monitoring of traffic, dynamic routing management and monitoring of parking lots, etc., use these networks.

Rapid emergency response, industrial process monitoring, automated building climate control, ecosystem and habitat monitoring, civil structural health monitoring, etc., use these networks.

This is all about the wireless sensors networks and their applications. We believe that the information about all the different types of networks will help you to know them better for your practical requirements. Apart from this, for additional information about wireless SCADA, queries, and doubts regarding this topic or electrical and electronic projects, and for any suggestions, please comment or write to us in the comment section below [21].

2.10 Related Work:

Based on scientific ten papers, that help me by reading and analyzing the gap to start my research with strong and good ideas to reach a result that give a clear contribution.

2.10.1 Fire Safety Assessment for Educational Building in India

P. M. Karake.et, both concentrate their paper work in Fire Safety Assessment for Educational Building in India, they go on the way to reduce the accidental fire by using fire proof materials and techniques and guidelines in (Indian Standard) IS codes. Where the spread of fire should be slow and it confined within space of origin without affecting adjacent places. And the building structure should be able to stand for some time so that occupants can evacuate. The paper study fire and safety for every Educational building.in my opinion their work is very important but in addition we must apply the fast fire alarm techniques. [22]

2.10.2 Forest Fire Monitoring System Based On ZIG-BEE WSN

P.S. Jadhav.et, prepare a system for Forest Fire Monitoring System Based on ZIG-BEE Wireless Sensor Network, they make design of a system for detection of temperature and humidity and smoke for the prevention of forest fires using wireless sensor networks to prevent a disaster (forest fire) that could lead to loss of a significant number of natural resources. The design includes hardware and software based on WSN protocol which includes Sensors such as temperature, smoke, humidity along with the processor LPC 2138 and ZigBee as a RF device.in my opinion they argue that wireless sensor network is very promising for fire rescue applications. [23]

2.10.3 Fire-Detectors Design Automated, Responsive FAS, SMS-Based

Omar Asif.et, works on making design of an automated, quick responsive fire-alarm system based on SMS, and the aim to alert the distant property-owner efficiently and quickly by sending short message (SMS) via GSM network, and they go on the way of using A Linear integrated temperature sensor detects temperature beyond preset value whereas semiconductor type sensor detects presence of smoke or gas from fire hazards. The sensor units are connected via common data line to ATMega8L AVR microcontroller. A SIM300CZ GSM kit based network module, capable of operating in standard GSM bands, has been used to send alert messages. In my opinion it is a cost-effective fire alarm system but SMS is not suitable alarm they need to add features like web server interconnect, fire area tracking and auto alarm etc. [24]

2.10.4 Wireless Sensor Network for Building Monitoring

Renjan Raj V.C, use wireless sensor network for building monitoring, mainly used to monitoring the building to access the earthquake damage and evaluate the structural behavior of the building. Additionally, adding fire sensor, smoke sensor, temperature sensor is adding the roof of the building to evaluate any damages that occurring the building, they use different sensor function connected to microprocessor and LCD for providing warning massages, in my opinion they install various equipment's and they help in minimize the damages for huge structures and loss human lives. [25]

2.10.5 An Effective Method for Crop Monitoring Using WSN

N. Sakthipriya, work on an effective method for crop monitoring using wireless sensor network applying wireless sensor technology in agriculture ,and this done by the scenario ,using board and mobile for receiving data ,to have several external sensors namely leaf wetness, soil moisture ,soil pH, atmospheric pressure sensors attached to it, as example when value of soil pH sensor is sent to the base station and in turn base station intimates the farmer about the soil pH via SMS using GSM modem. Obtaining the soil pH value in his mobile the farmer selects the necessary fertilizer and crop for his next season.in my opinion they propose a state of art wireless sensor technology in agriculture and they investigating environmental situations. [26]

2.10.6 Oil and Gas Process Monitoring THROUGH WSN: A Survey

ACHONU O. ADEJO.et, they make a survey on oil and GAS process monitoring through wireless sensor network, the survey yields that WSN technology introduces significant benefits in cost, ease of deployment, flexibility and convenience in relation to the wired, in my opinion the show WSN deployment in Condition monitoring, pipeline monitoring, etc. [27]

2.10.7 Forest fire detection wireless sensor node

George E. Sakra.et, describes a design of a wireless sensor node to be used for early forest fire detection, using the scenario it utilizes the WSN principle where each node is a sensing device with various sensors attached, powered by solar recharging and supports wireless data transmission. Each one of these nodes sends its collected data through the network to reach a sink node. The latter has a direct link with a base station. The base station analyses the received data and takes the decision accordingly to raise a fire alarm or not.in my opinion they detail the design as well as the experimental activities which demonstrated that this work is capable of early forest fire detection. [28]

2.10.8 A Survey on Intelligent Sensor Network and Its Applications

Feng-Cheng Chang.et, both make survey on intelligent sensor network and its applications and the concentrate on optimize the wireless sensor network (WSN) issues and this done by using different intelligent algorithms.in my opinion it's not easy to survey all application and algorithms specific research and they make few survey and few application scenarios in this paper. [29].

2.10.9 Design and Implementation of Automatic FAS based on WSN

Santosh P. Patange.et design an automatic fire alarm system based on wireless sensor networks, to provide early extinguishing of a fire disaster, and this done by large numbers of detectors which periodically measure smoke concentration or temperature are deployed in buildings. Those scattered detectors report their monitoring information to the surveillance center via the self-organizing hierarchical wireless sensor networks.in my opinion they are not lock to the system optimization which have an affect system, and put system optimization for future work. [30]

2.10.10 Intelligent Fire Sensing Using Wireless Sensor Network

Pradeep Kumar.et, work on Intelligent fire sensing using wireless sensor network, and they perform the design, research and development of a wireless multisensory network which mixes sensors with IP cameras in a wireless network in order to detect and verify fire in rural and forest areas. central server selects the closest wireless cameras to the multisensory, based on a software application, which are rotated to the sensor that raised the alarm, and sends them a message in order to receive real-time images from the zone. The camera lets the fire fighters corroborate the existence of a fire and avoid false alarms.in my opinion its good work but have more cost and complicated design. [31].

CHAPTER THREE

METHODOLOGY

3.1 Introduction:

In this chapter the methodology of the research was written including computer model and mathematical model. Section 3.2 starts with how the research work and give the plan. Section 3.3 details the general framework. On the other hand, section 3.4 discusses the general proposed system, through full system diagram and while section 3.5 concentrates on specific proposed system to visualize fire locations clearly in the map. Section 3.6 talks about the hypothesis for Validation of geo-dijkstra algorithm, lastly section 3.7 deals with the issue of finding the shortest path between two nodes so as minimize the arrival time for the firefighting units which leads to minimizing the loss.

3.2 Research Plan:

As can be seen from Figure (3.1) General flow chart that describe research plan that describe how research deal with information to produce and record the results.

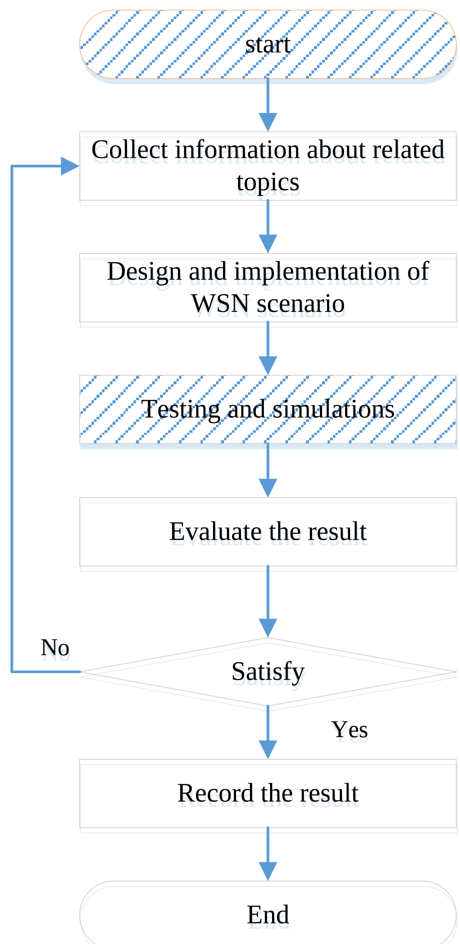


Figure (3.1) General flow chart that describe research plan

As has been shown in the above figure, the steps of the research are stated very clearly starting with accurately information collection about the related topics, make design and implementation of WSN. Proposing suitable algorithms, and finally, making simulation with its corresponding results in addition to evaluation and validation of the proposed algorithms according to several scenarios.

3.3 The General Framework:

In the following next page Figure (3.2) shows the framework of the research which shows the framework of the research with three main processing units, that gives readers the main idea starting with hardware design, like sensors map and links between them, then going through how the system act using optimization techniques to give fast response and real time output monitoring in a clear result, lastly interconnects between outside units that represent independent units of the main side to give help as sharable for firefighting by connecting them through communication facilities. The aim of sharing the events among civil defense authorities is to make very fast alarm and getting fast response from the remote side in recovering the fire, below the details of the three-main processing unit of the framework.

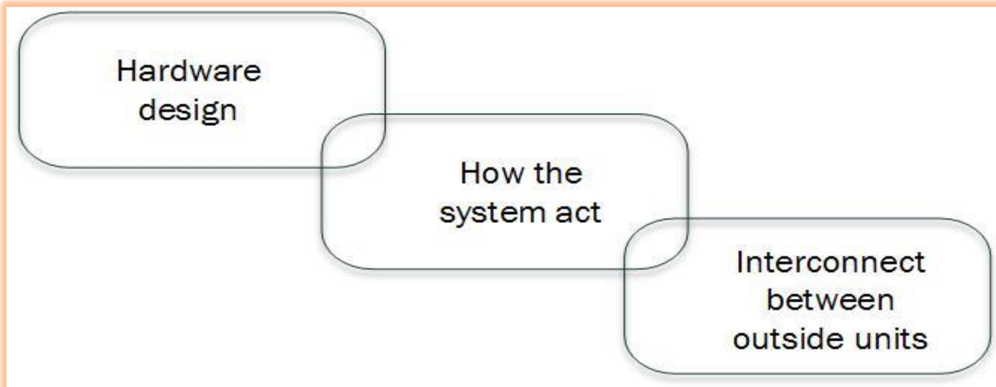


Figure (3.2) shows the framework of the research

Hardware design: which including the design of WSN as a hardware and topology of site interconnection peering in mind (electronic site map, location of sensors or digital map).

How the system act: include the decisions and how the system act?

Interconnect between outside units: connection with outside units for sharing the resources of firefighting using WAN technology.

For more and specific details Figure (3.3) shows how the devices in above general framework will be connected.

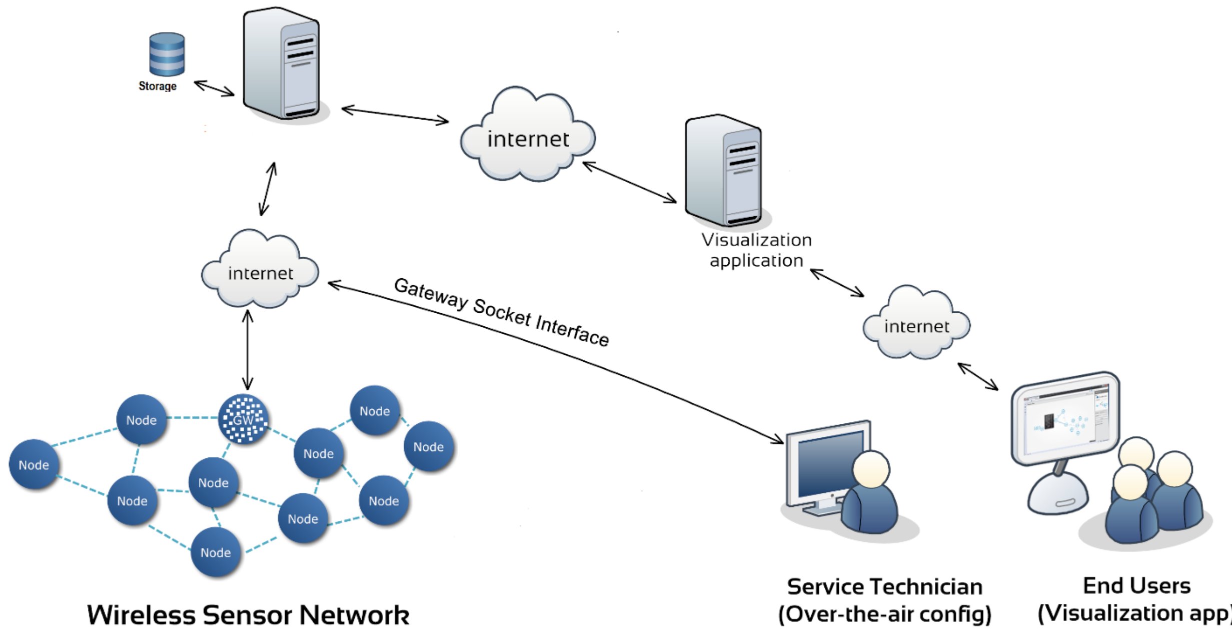


Figure (3.3) how devices connected for monitoring using WSN

3.4 General Proposed System:

In this area of the research the methodology discussed and the design gives the clear and correct results in different scenarios and ideas.

Firstly, before going on, mention the research locations by define geographical locations and details existing system of work in Elshagra GAS depots and companies with in it, also the current status of the companies described due to defense when there is a fire alarm and this include civil defense plan 2016, where they have manual system for dealing with fire when there is a fire alarm. For more details, place refer to appendix A.

3.4.1 General Full System Diagram:

Figure (3.4) next page represents the full system diagram and the figure shows the compatibility, integrity and scalability of the system that give an acceptable and attractive system for fire alarm including different ideas and more intelligent design with multi-level monitoring, where monitoring level is started inside the location, in near company, in stakeholder mobile and HQ civil defense. And also, as it can be seen the system is divided into three tiers: -

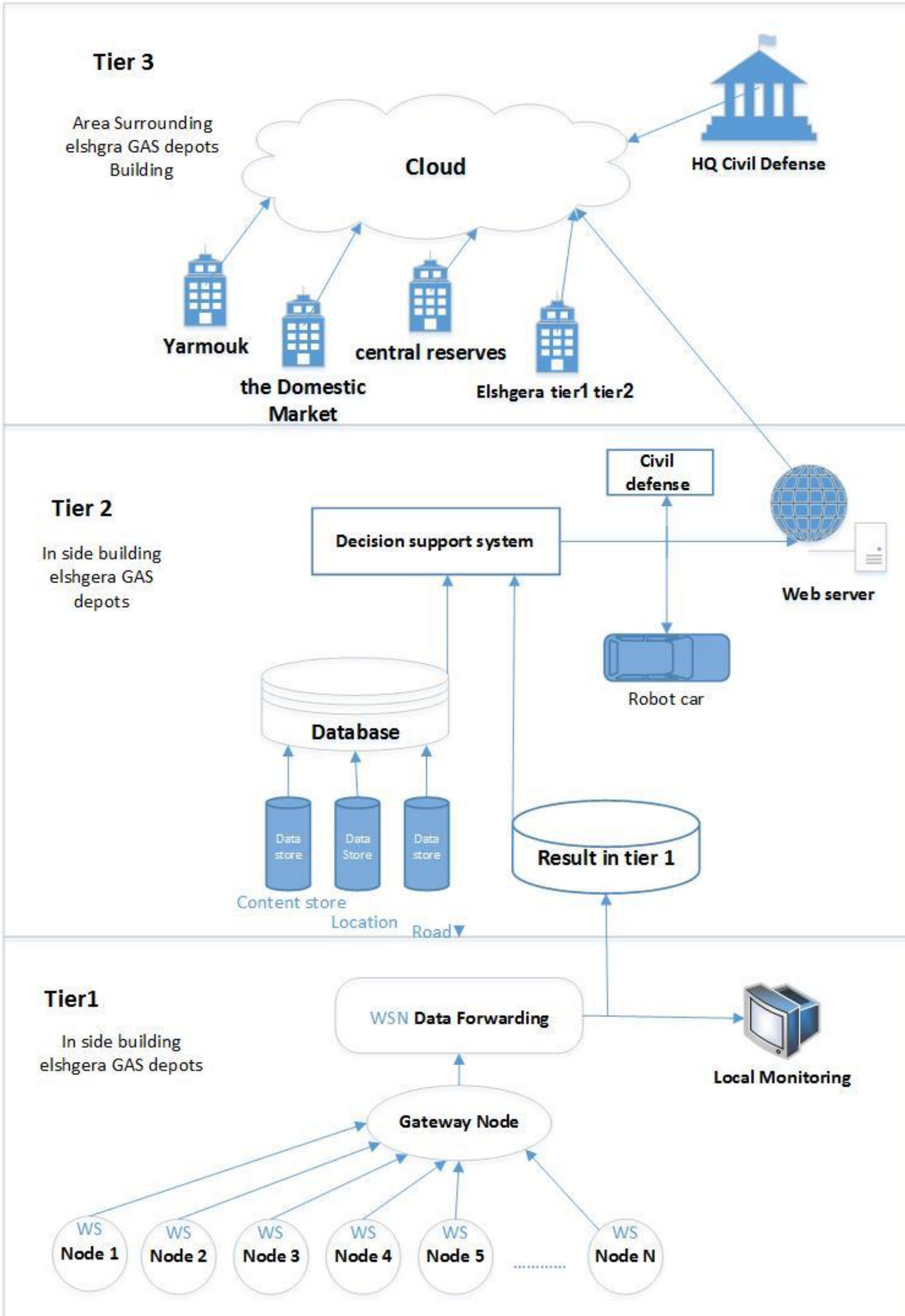


Figure (3.4) General full system diagram

3.4.1.1 Tier 1

The infrastructure that include the design and map of sensors inside the building of Elshagra GAS depots as example representing the way of communication, that typically connect all sensors in one company direct to the gateway node. As the same time, also other company's sensor nodes connected to the same gateway node, and for redundancy some time used two gateways. In this tier the information about WSN collected and forwarded to tier 2.

3.4.1.2 Tier 2

Contains the database stored about the map of road, locations and the content of store and assets. The decision support system that deals direct with the database and the result of tier1, to process all available data in real time that help in producing accurate information for web server and firefighting units.

3.4.1.3 Tier 3

The interconnection of all units of firefighting in area south Khartoum to apply the function of sharing the resources, by making an intelligent network for alarm system to inform all area surrounding the location of

Elshagra GAS depots (" Yarmouk, central reserves, the Domestic Market, the Industrial Zone Savola"). Also, this conductivity gives direct and real time connection to inform Civil defense head quarter and stockholders about the situation of fire through fixed monitoring, or mobile monitoring applications, as shown in the following figure (3.5).

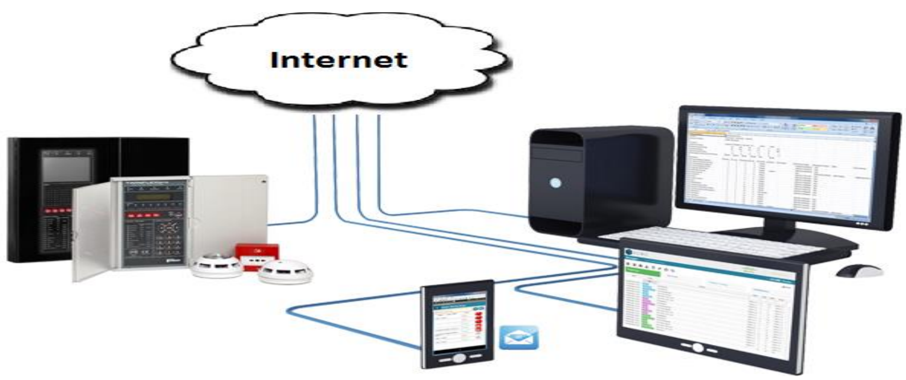


Figure (3.5) monitoring through internet

3.4.2 Full System Functional Flow Chart

The following Figure (3.6) represent the full system functional flow chart that simulate what is done in this research.

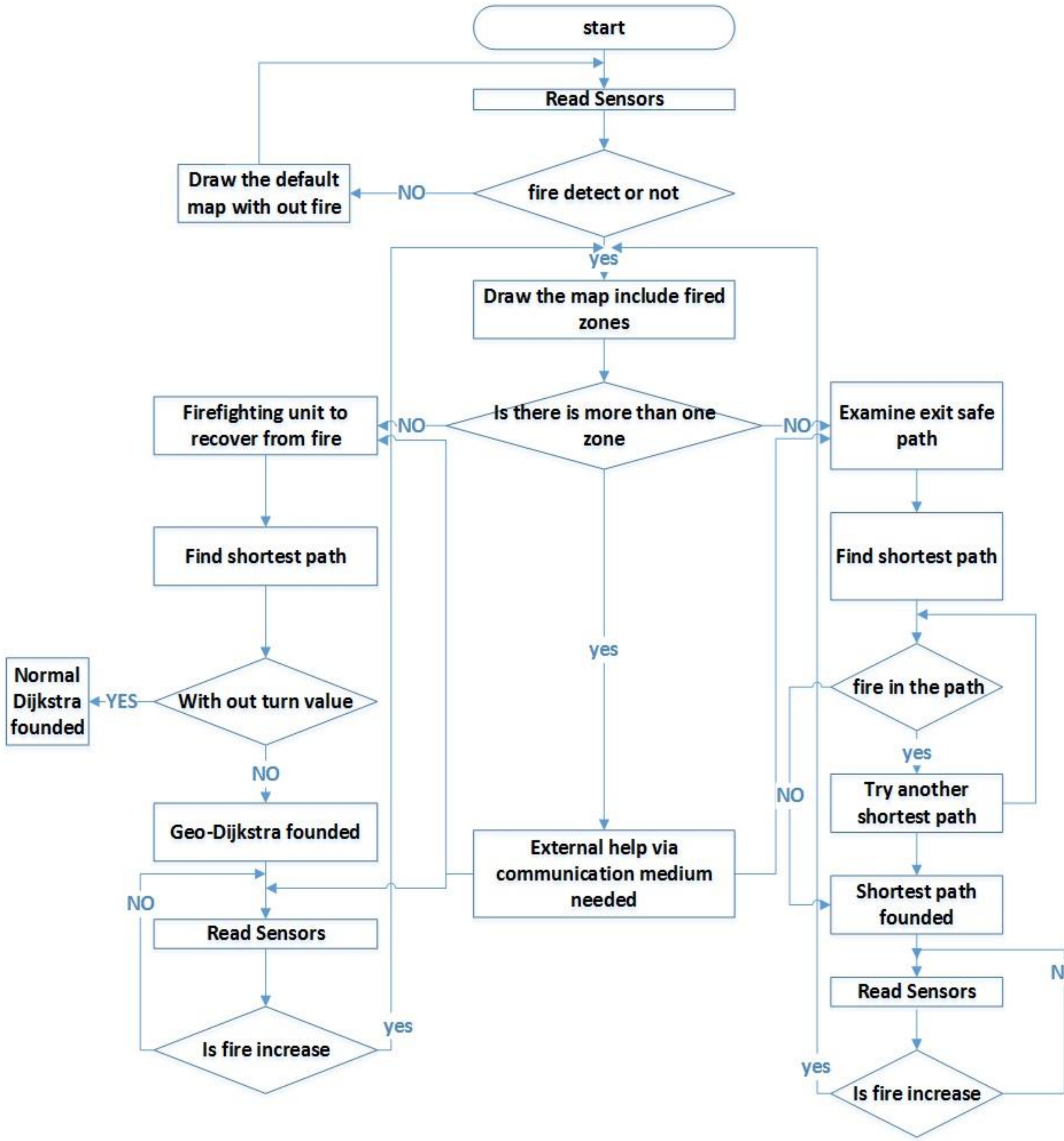


Figure (3.6) functional flow chart

3.4.3 General Pseudo Code for Full System Diagram.

For more details of the full system functional flow chart place refer to appendix B to see the General pseudo code for Full system diagram.

3.5 Specific Proposed System:

The methodology of this project is divided into three stages, that represent the software using simulation to output the result in chapter four by verifying some of the objectives, where others that mentioned in above general proposed system will be discussed in chapter 5 as recommendation for future work.

3.5.1 Visual-Based Fire Detection and Expectations:

TO visualize fire location clearly in the map, this stage done by programing technique and ideas to visualize the fire source and size on the map that represent all area of the project (Elshagra GAS depots building – as shown in Figure (3.7)).

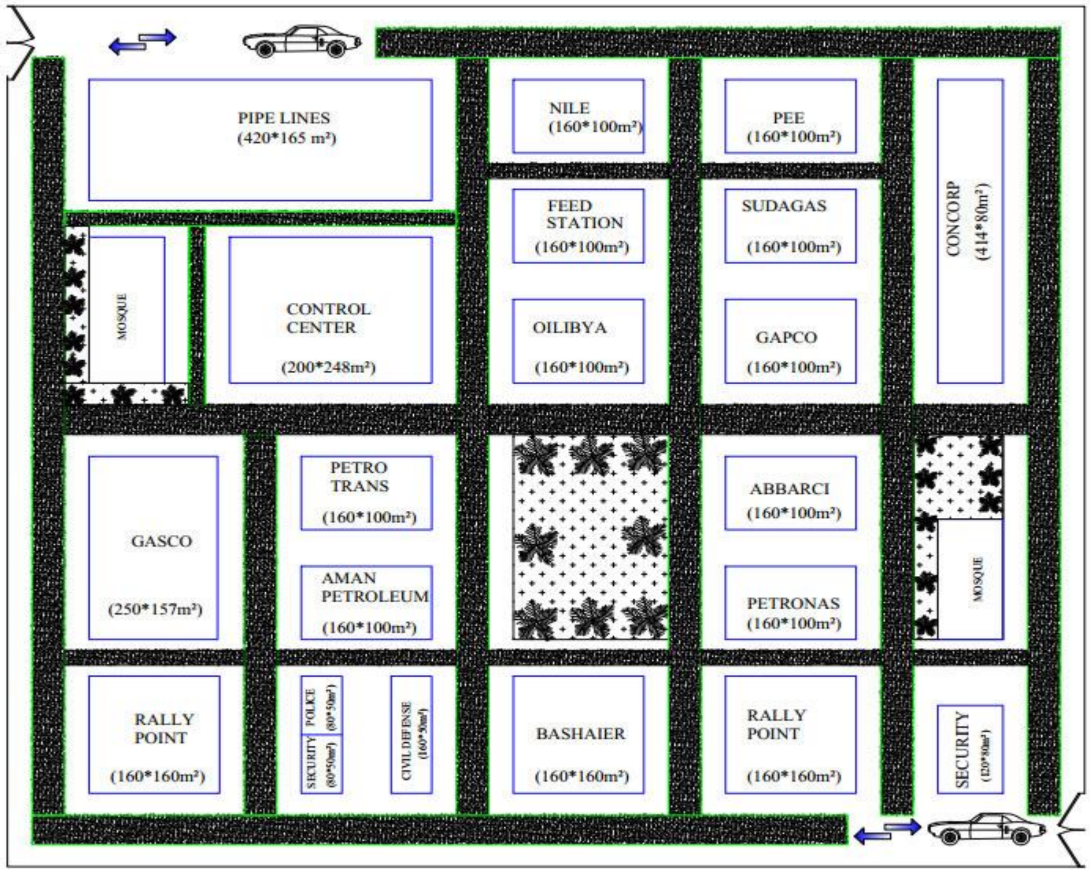


Figure (3.7) Elshagra GAS depots building

3.5.1.1 The Idea:

As explained previously the area covered in this project contains many sensors distributed as explained in tier-1, the sensors will detect the occurrence of fire as they will send a signal to a control center or a unit, that will help process the data from the sensors (i.e. the sensors helps in data collection) while the control center uses the collected data so as to reach useful decisions.

The idea behind the program is to imitate the live response that occurs when one of the fire alarm sensors signals is picked, then handle the signal and use it to determine the fire location, the fire size, and also can be broadcasted this information to different stake holders.

3.5.1.2 The Goal:

1. The program should imitate the signal coming from all the sensors indicating whether a fire occurred or not (True or false, i.e. 1 or 0).

2. The program should indicate zones are (or not) affected by fire based on the feedback from each of the sensors.

3. The program should indicate the size of the fire (based on the number of the zones affected).

4. The program should display a clear physical map of the fire location clearly indicating areas that are affected by fire.

5. The fire warning should be easy to broadcast, so the program should be easily accessed by different stakeholders inside/outside the LAN.

6. The program output result should be easily understood.

3.5.1.3 The Plan:

1. Use PHP as it can do the following

a) display the output in an html format that can easily be viewed inside or outside the LAN by many different stake holders.

b) it allows flexibility to dynamically manipulating html and displaying of images and other responses.

c) The size and speed of PHP will allow viewing the program with minimum available bandwidth compared to java, .net or ASP for example.

2. Use check boxes to indicate (true, false) coming from the sensors, when implementing the program in real life, this can be easily changed to implement signal coming from a live sensor.

3. Divide the covered area into 7 zones, each zone will be covered by a one sensor, as shown in Figure (3.8).

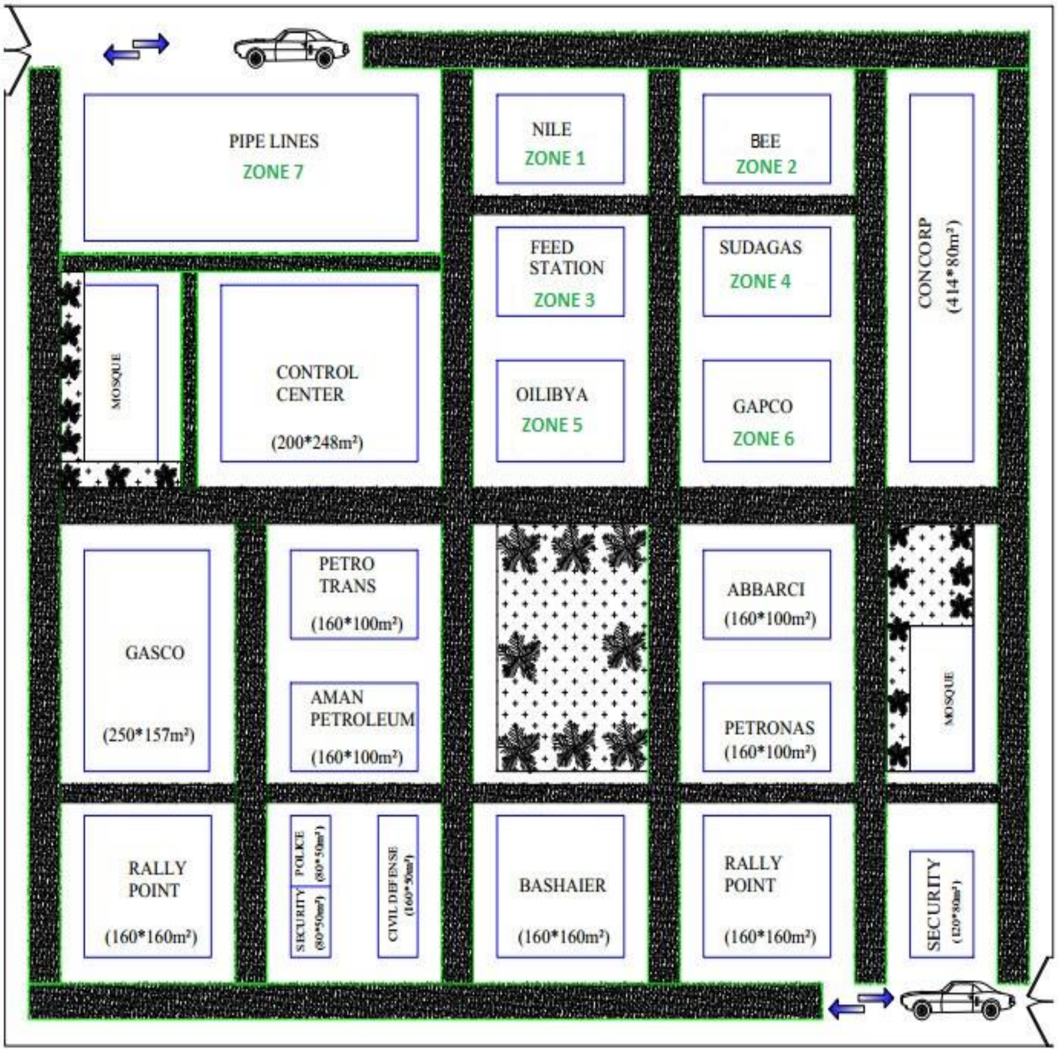


Figure (3.8) the areas divided into zones from zone1…to zone7

1. Provide a map representation that shows the fire affected.

2. The program should indicate it is a large fire if more than one zone is affected, if this is implemented an additional feature can be added to call external help in this case.

3.5.1.4 Flow Chart:

The following

Figure (3.9) represents general flow chart for visualize the fire source in the map, which represent the fire locations in side the company and then from same sensors informs by visualizing that there is a fire in the company for more information please refer to appendix b to see the Pseudo code.

Figure (3.9) general flow chart for exact fire location

The following figure (3.10) next page shows the flow chart in details, which start by defining the exact fire location in the company, and by the same sensors define the fired company location in the map.

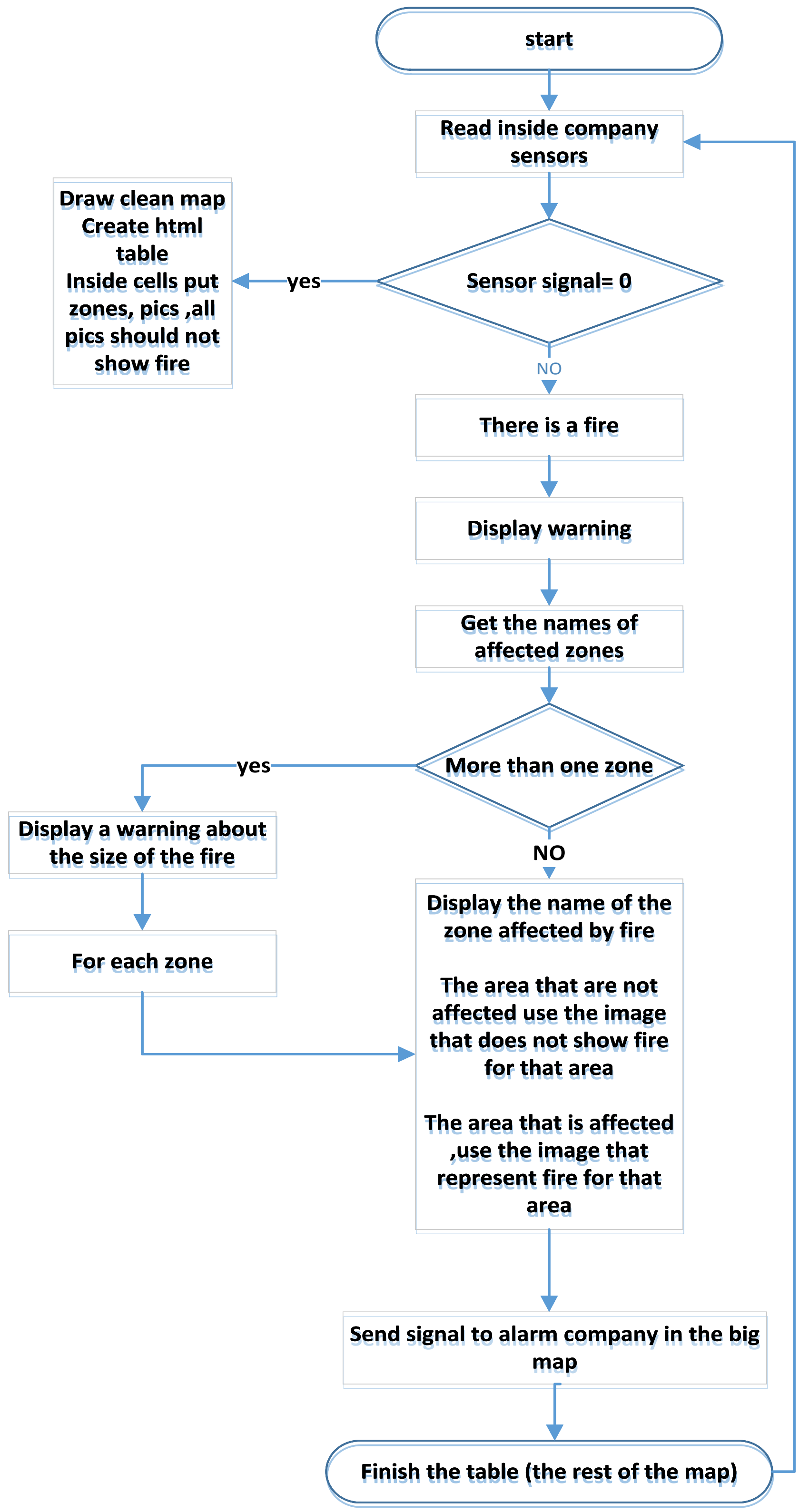


Figure (3.10) visualize fire locations in the inter and exterior map

3.5.2 Hypothesis for Validation of Geo-Dijkstra Algorithm: -

As an illustrative example for validation Geo-dijkstra algorithm, that find the shortest path between two nodes we take a small real area in south Khartoum as shown in the following Wikimapia plan Figure (3.11).

Figure (3.11) area south Khartoum example for validation Geo-dijkstra algorithm

In the above figure, it’s clear that we have two ways between two nodes, the red one is passing through three turns while the green one passes through one turn.

A practical test was done by moving a car through the two paths’, in a time that there is no cars congestion to calculate the time of internal red path and the time of external green path as shown in the following Figure (3.12) next page. It is clear the green path take less time than the red path because of turn which effect the time to be more and another meaning also direct long path effect the time to be less.

In our research scope, there is no car congestion and its suitable to use this scenario of validation for Geo-dijkstra algorithm peering in mind the case of full congestion change the result and the internal red path become the best and take less time than external green path. For detailed prove please refer to section 4.5 which explains the details of the prove based on mathematical rules with an illustrative calculation.

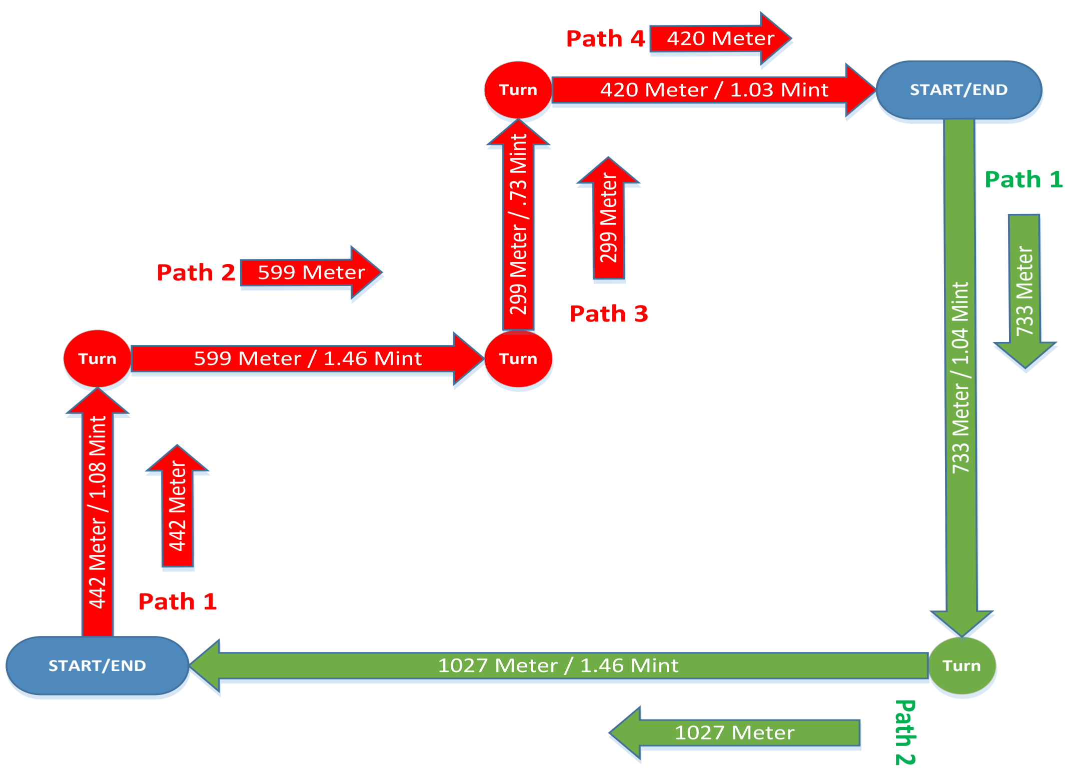


Figure (3.12) block diagram for above Wikimedia plan

Above Figure (3.12) was a block diagram for the above Wikimapia map and the distance/time relationship was calculated clearly as shown in table (3.2) below.

Table (3.1) distance and time value for figure 3.10

Path	Following path sequences	Distance/meter	Time/minute
Green path	Path1+turn+path2	1760	2.50
Red path	Path1+turn+path2+turn+ path3+turn+path4	1760	4.30

In the above table, also the distance between the source and destination is equal for both of the green and red paths, the more turns add more time for the red path and also the time is less for the green path because it has only one turn. Also, you can say that long direct distance adds less time because mechanically the car speed became high in long direct distances, and that's due to the use of the fastest gear (4 and 5) if compared to the use of the slowest gear (1 and 2) while the car is entering and leaving the turn.

In chapter4 practically we see the Hypothesis results and the calculations for the value of near and far turns.

3.5.3 Improved Dijkstra Algorithm for Firefighting:

The following methodology is for stage three, which represent how to find the shortest path between two nodes (i.e. between the firefighting unit and fired company and Also it can be the short path between exit door for companies that want safe exit passage for employees and vehicles whenever there is fire alarm, putting in mind when exit you may face fired area force you to change the path even if it's the shortest path) using forced-Dijkstra algorithm.

3.5.4.1 The Idea:

To use enhanced techniques of Wireless Sensor Network routing such as shortest path detection, by putting sensor nodes as it is in the map of Elshagra building and find the shortest path between two nodes by writing matlab code using inbuilt matlab function Dijkstra, finding optimized path to:

1. Firefighting unit to recover area from fire

2. exit Shortest path optimization due to fire occurrence

1. Firefighting Unit to Recover Area from Fire

And this done in the following scenarios, form the block diagram for the area of the research Elshagra GAS depots Figure (3.13) next page, shows how to obtain the cost table in time approximate factor for the movement between nodes, putting in mind the value of turn by adding and removing.

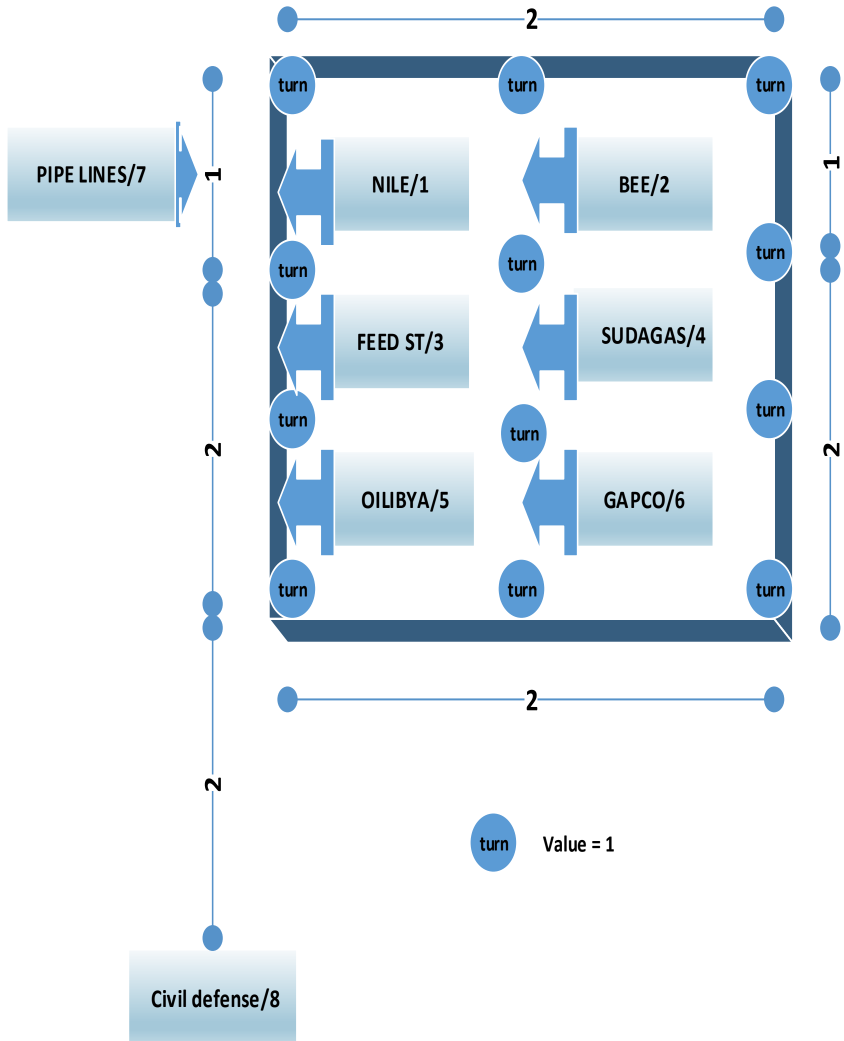


Figure (3.13) block diagram with distance time factor between companies

In the above figure, we represent the block diagram of the companies to make the system node diagram, and this by calculate the movement between nodes putting in mind the value of turn, if the movement from civil defense to the fired company need turn. Another calculation was done without value of turn to improve that turn as by number of turn or by long distance then turn influence the cost in time value.

For example, movement between civil defense and OILIBYA

Path cost equal (2+1=3)

another example, movement between civil defense and GAPCO

Path cost equal (2+turn+1+turn+1= 6) and so, on.

As shown in node diagram below Figure (3.14), the edge and paths calculated from above system diagram with turn value.

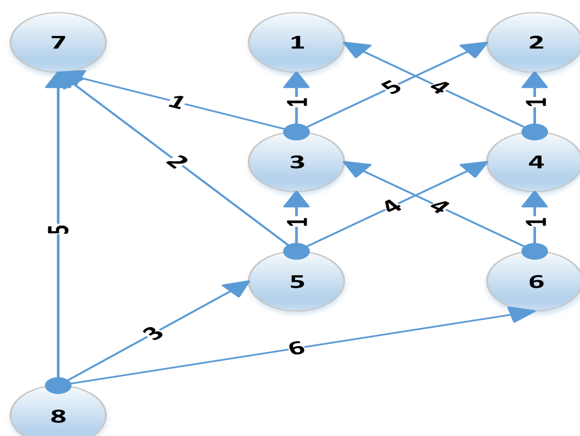


Figure (3.14) node diagram with turn value

The movement from node to node in above figure telling the truth about the movement between companies putting in mind the turn values.

Also, as shown in node diagram below Figure (3.15), the edge and paths calculated from above system diagram without turn value.

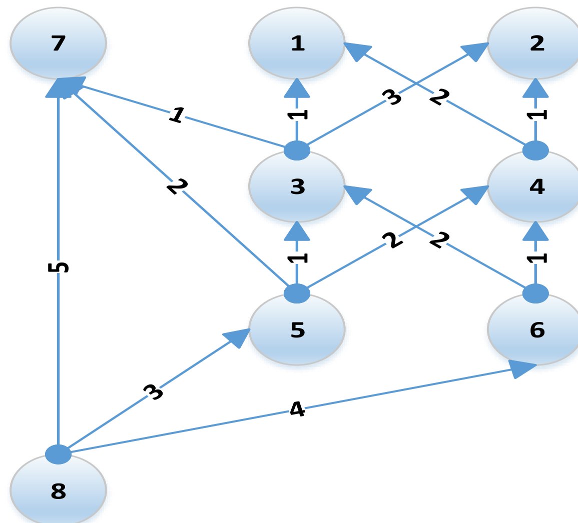


Figure (3.15) node diagram without turn value

In this case the movement between nodes without turn values, and this produces less edge cost compared to that take in mind turn values.

When using above two nodes figures it's easy to obtain the cost table without turn and with adding the turn cost value, then the following next page table (3.2) obtained:

Table 3.2 cost table and turn values (TURN VALUE=1)

Source TO destination node	Number of turn	Cost without turn	Cost with turn value
FEED ST → NILE	0	1	1
FEED ST → BEE	2	3	5
FEED ST → PIPE	0	1	1
SUDAGAS → NILE	2	2	4
SUDAGAS → BEE	0	1	1
OILIBYA → FEED ST	0	1	1
OILIBYA → SUDAGAS	2	2	4
OILIBYA → PIPE	0	2	2
GAPCO → FEED ST	2	2	4
GAPCO → SUDAGAS	0	1	1
Civil defense → OILIBYA	0	3	3
Civil defense → GAPCO	2	4	6
Civil defense → PIPE	0	5	5

From above table easily program the matlab code to find the shortest path between two nodes or civil defense and any of the companies to recover from fire when there is a fire alarm and the result be in a red arrow from source to destination. For this solution, we have the following options with different scenarios and the result obtained in chapter 4 to verify:

1. Validation of our dijkstra algorithm mathematical calculations and graph relations result.

2. Optimized path between Firefighting unit and Non-Direct Path, fired company

3. Optimized path between Firefighting unit and Direct Path to fired company, both simple and complicated scenario.

2. Exit Shortest Path Optimization due to Fire Occurrence:

Find the safes passage to rescue employees and vehicles and this done in three scenarios by finding normal shortest path between two nodes (i.e. exit door and the company that want exit employee and vehicles) as shown in the following Figure (3.16).

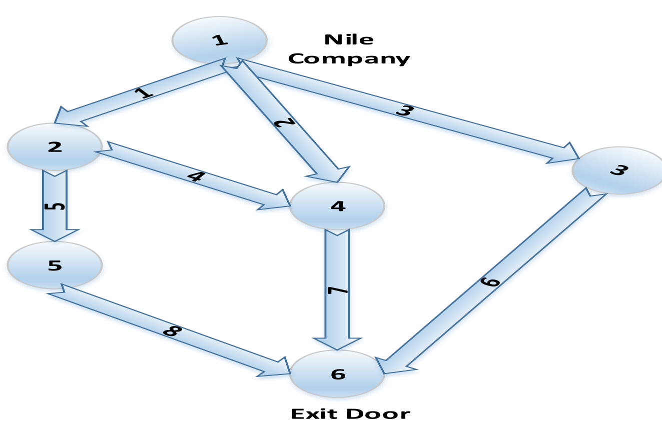


Figure (3.16) system node between Nile company and exit door

Pervious page Figure represents the system nodes for finding shortest path between two nodes, node 1 represent NILE company and node 6 represent the exit door, and we put the edge cost only as example not a real cost because we want to prove only the shortest path is not the short path but short path and safe way. The result is shown clearly in three scenarios clearly in chapter 4.

3.5.4.2 The Goal:

The program should:

1. display companies in Elshagra building (as nodes) and the connection between them (as edge) and the cost that represent the distance between nodes putting in mind turn value.

2.display the shortest path between two nodes with red arrowed line.

3.response automatically to another short path if the middle node of the selected short path removed by fire.

4.be generalized for any number of nodes, so it can be used for any other building with small modification in the code.

3.5.4.3 The Plan

Use matlab 2016 to verify the objective that find the short and safest way to exit when fire alarm detected. And this done by finding the shortest path putting in mind you must use another way than this short path if there is a fire on the path of it to give you the safest path and may be its not the short one.

Also, finding the shortest path for firefighting unit to reach the location of fire. And this also done by finding the shortest path between two nodes, putting firefighting unit location one of the two nodes and any company as the second node.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction:

This chapter represents the results and discussions of the simulated work, a simulation was made using matlab programming environment and PHP software programming, both was successfully implemented and tested giving very promising results. Section 4.2 and Section 4.3 deals with the results of visualizing the fire source in real time and gives the size and direction of the fire. It also shows the full map for the area of the fire (i.e. Elshagra GAS depots). Section 4.4 and section 4.5 details mathematical calculations of the distances between the source (firefighting unit) and the destination (fired location) with their corresponding graph result. These graphs are for the validation of the newly proposed Geo-dijkstra according to simplified situation so as to prove the successfulness of the functionality of this algorithm considering the effect of turns. From section 4.6 in this section the original dijkstra algorithm has been improvised so as to choose the shortest path in an adaptive way according to the number of turns, the improvised Invented algorithm has been called a GEO-Dijkstra.

Section 4.7 concentrate on the issue of the safest exit way for drivers and walkers. In this section the algorithm focus on finding the shortest path between fired company and exit door and here the result Invented Forced-Dijkstra, where the short path is not the similar to shortest path selected by original dijkstra but it may be a longer as well as safer path. The above-mentioned algorithms (GEO-Dijkstra, Forced-Dijkstra) have been evaluated and validated through several scenarios. The validation results are satisfied.

4.2 Visual Simulation of Elshagra Gas Depots Buildings using PhP

In this section, the area of this project is done as prototype for upper side of Elshagra Gas depots building, and the area used by the model of software to visualize the fired company in real time and quick response divided into seven zones from (zone 1 to zone 7) where the seven zones is representing in order these companies (NILE, BEE, FEED ST, SUDAGAS, OILIBYA, GAPCO, PIPE LINES) as seen in the next page Figure (4.1). this simulation has been designed using PhP so as to reflect the real situation from safety and risks point of views.

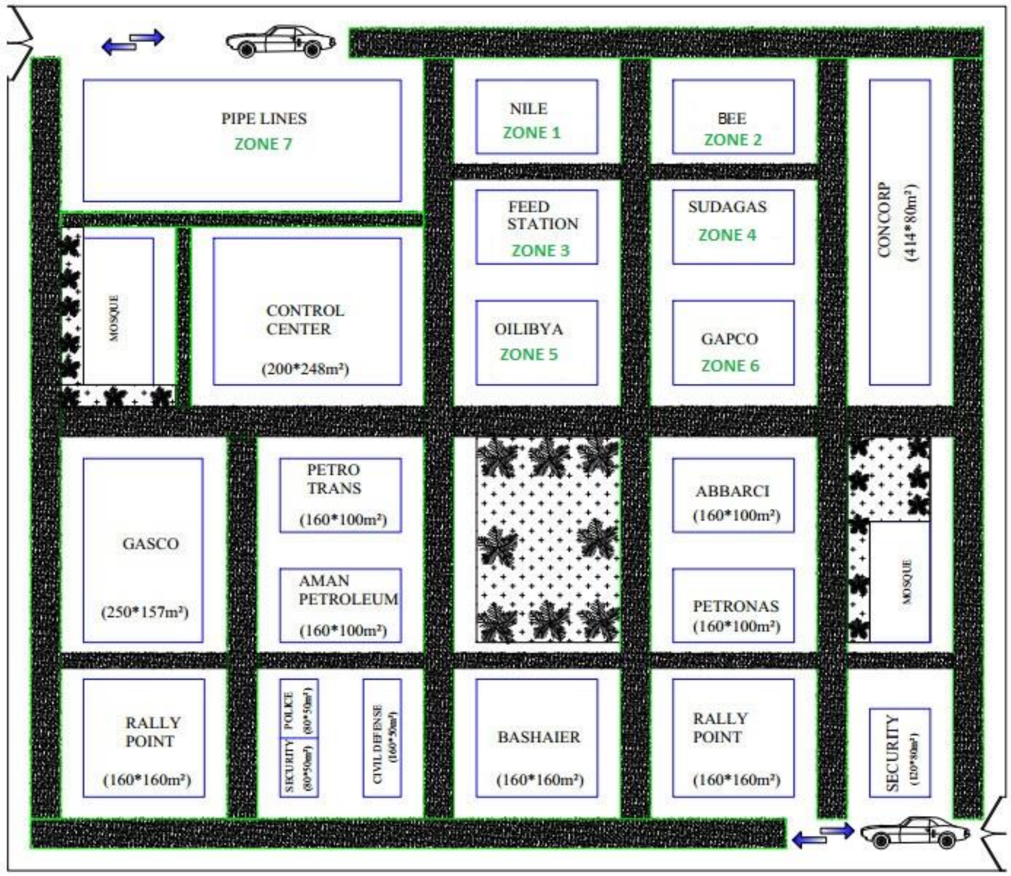


Figure (4.1) seven zones used as prototype for visualize fired company

In more details for the source of fire, we take as example GAPCO company (zone 6) inner side to visualize the exact fire source and we defied it to twenty zones as shown in the following Figure (4.2) in the next page.

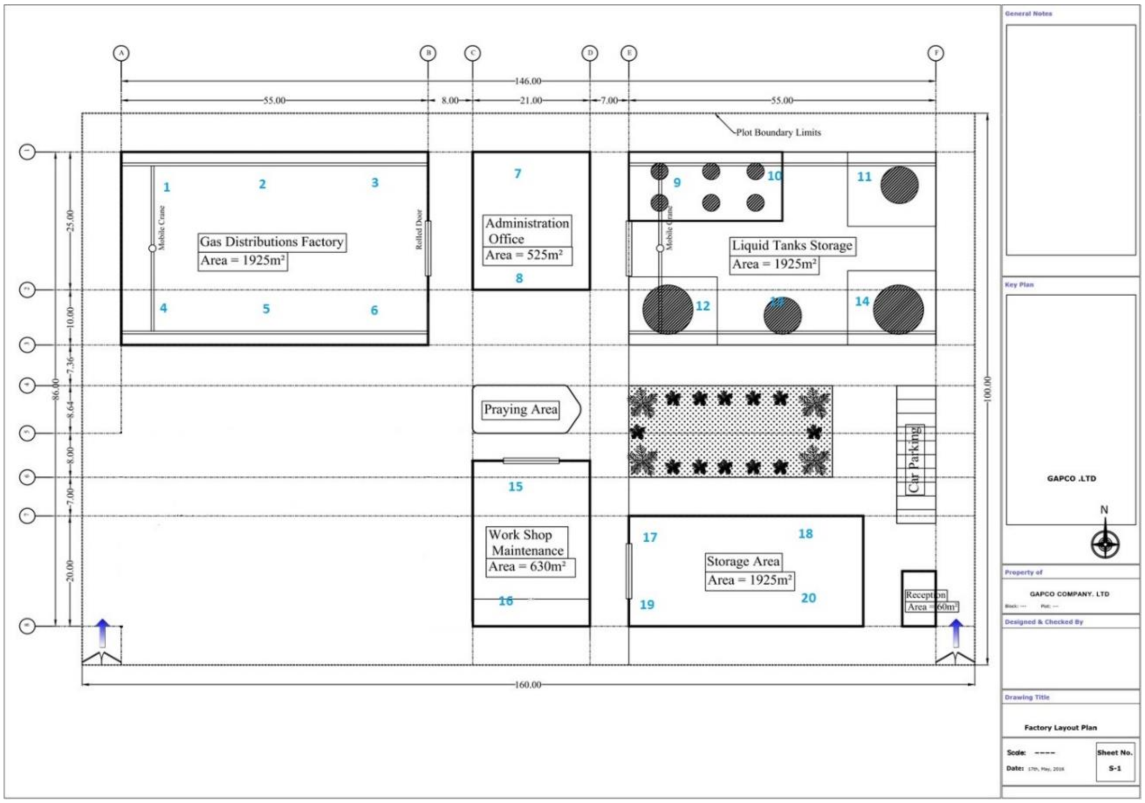


Figure (4.2) exact location in GAPCO Company

As we see in above figure which contain the sub_zones of zone 6 (GAPCO company) by the following details:

1. Sub_zones (1 to 6) for the locations of Gas Distribution Factory

2. Sub_zones (7 to 8) for the locations of Administration office

3. Sub_zones (9 to 14) for the locations of Liquid Tanks Storage

4. Sub_zones (15 to 16) for the locations of Work Shop Maintenance

5. Sub_zones (17 to 20) for the locations of Storage area.

And from monitoring point of views the location is defined as example for GAPCO Company (zone 6), and for location in GAPCO (sub_zone 6.1, sub_zone 6.2, sub_zone 6.3………. sub_zone 6.20).

A simulation module has been designed and implemented practically so as to achieve the following summarized results, however, the details of those results will be on the following sections:

1. Simulation for randomly reading from sensors in different zones to give fast response alarm.

2. Visualization in the map for fired companies with red color and beep alarm sound.

3. Define the size of fire in terms of number of zones.

4. Define the direction of fire in term of zone fired and next zone according to the wind direction in addition to other factors. The outcomes of this module were clearly shown in the map. Firefighting authorities can check the map massages to see fire location, size and direction. These results guide the authorities to determine the capability of the in-campus firefighting unit regarding the issue of recovering from the fire. If they are not

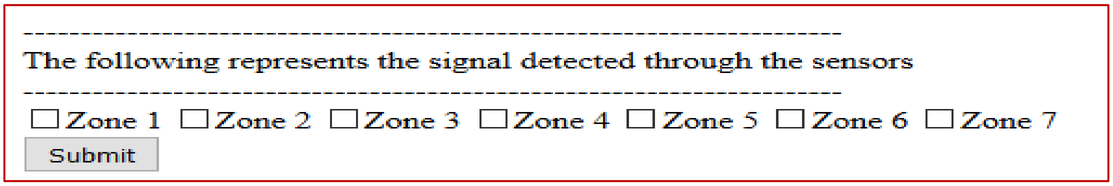
capable the nearest firefighting units will know and react very quickly since the map will be updated automatically according to what is happing in the real-time. i.e. if large fire is detected (when fire in two or more zones), the neighboring firefighting unit will come immediately peering in mind the capability of the in-campus firefighting unit is not more than on company.

4.3 Visualize the Fire Source and Size as a Company:

While running, the simulation using PHP software the following give some detailed output scenarios for visualization and size of fire as pictures represent the area of the fire with red color and beep, as a real-time monitoring, beside full map for that area.

4.3.1 Scenario1: Default Monitoring without Fire Alarm:

default picture without fire alarm as shown in the following Figure (4.3) peering in mind the default and safe situation (everything is ok):



Check the map for exit

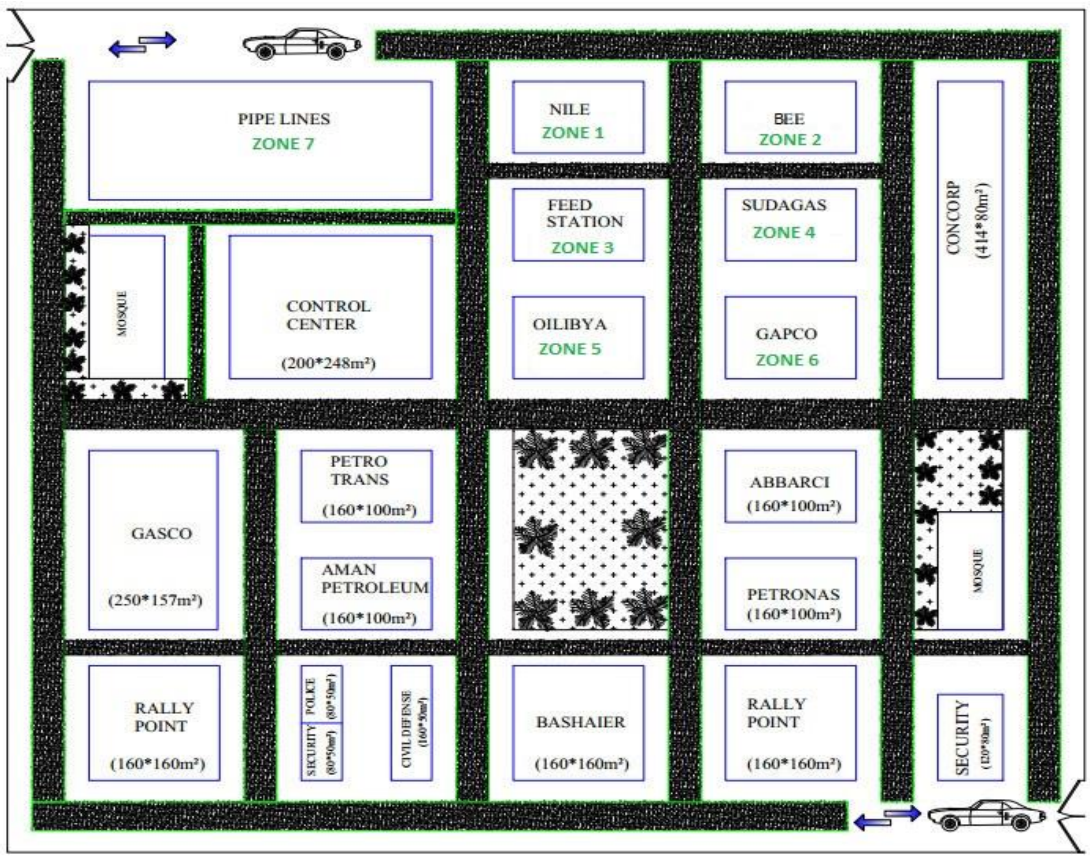


Figure (4.3) output result that represent default map of Elshagra building

The above figure shows the output result of PHP program that represent the default picture of Elshagra building where there is no fire. Furthermore, to make it simple only the upper side of the map is considered as can be clearly shown in the figure which are highlighted in green color.

4.3.2 Scenario2: Fire in One Zone (Zone1)

output when there is a fire alarm in zone 1 as shown in the following Figure (4.4):

WARNING

Fire is detected in the following zones
zone1

Check the map for exit

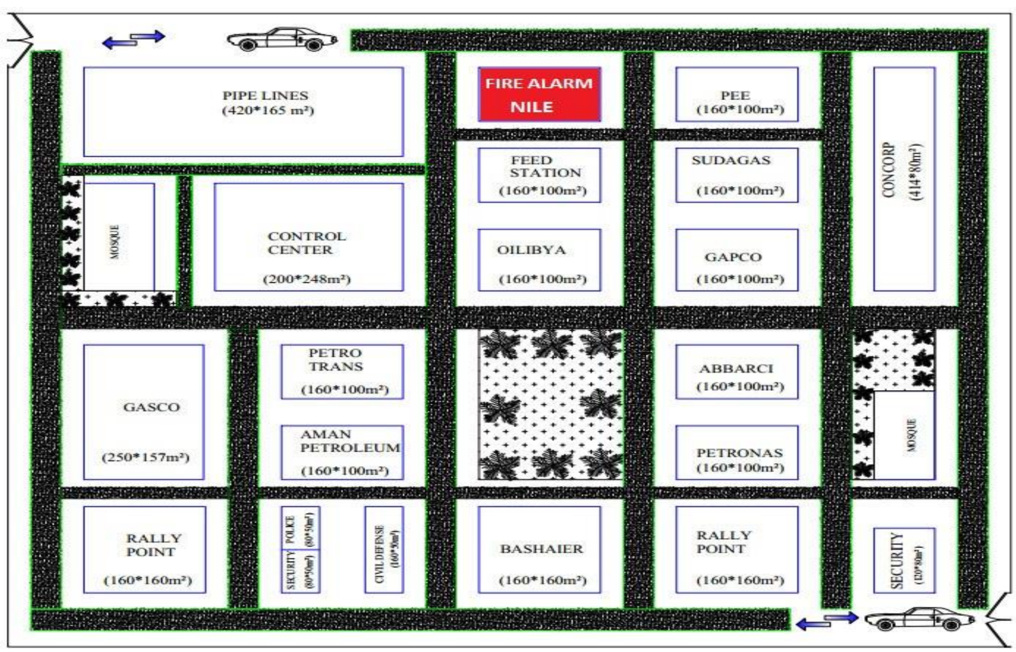


Figure (4.4) output result when there is a fire in zone 1 (NILE company)

The above figure shows an output result from PHP program to give fast response fire alarm and visualized map with the location of fire, where the location of fire is in the NILE company and the size of fire one zone represented in zone1.

4.3.3 Scenario3: Fire in two Zones (Zone1, Zone2)

output when there is a fire alarm in zone 1 and zone 2 as shown in the following Figure (4.5):

WARNING

Fire is detected in the following zones
zone1
zone2

Fire Size Estimation:

This is a large fire detected, external help will be called, GSM will be sent. Check the map for the exits

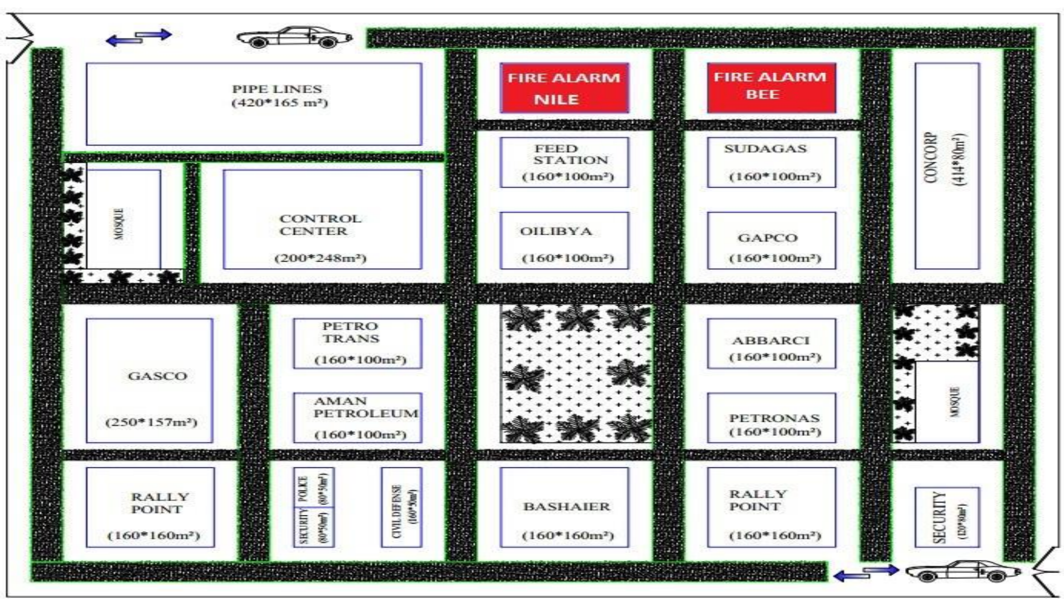


Figure (4.5) output result when there is a fire in NILE and BEE companies

The above figure shows an output result from PHP program to give fast response alarm and visualized map with the location of fire, where the location of fire is in the NILE and BEE companies and the size of fire two zones represented in zone1and zone 2, so this is large fire and the massage of calling external help appear here as shown clearly above.

4.3.4 Scenario4: Three Zones Fired (Zone1, Zone2, Zone7)

output when there is a fire alarm in zone 1, zone 2 and zone 7 as shown in the following Figure (4.6):

```
WARNING
-------------
Fire is detected in the following zones
zone1
zone2
zone7
---------------------------------
Fire Size Estimation:
---------------------------------
This is a large fire detected, external help will be called, GSM will be sent. Check the map for the exits
```

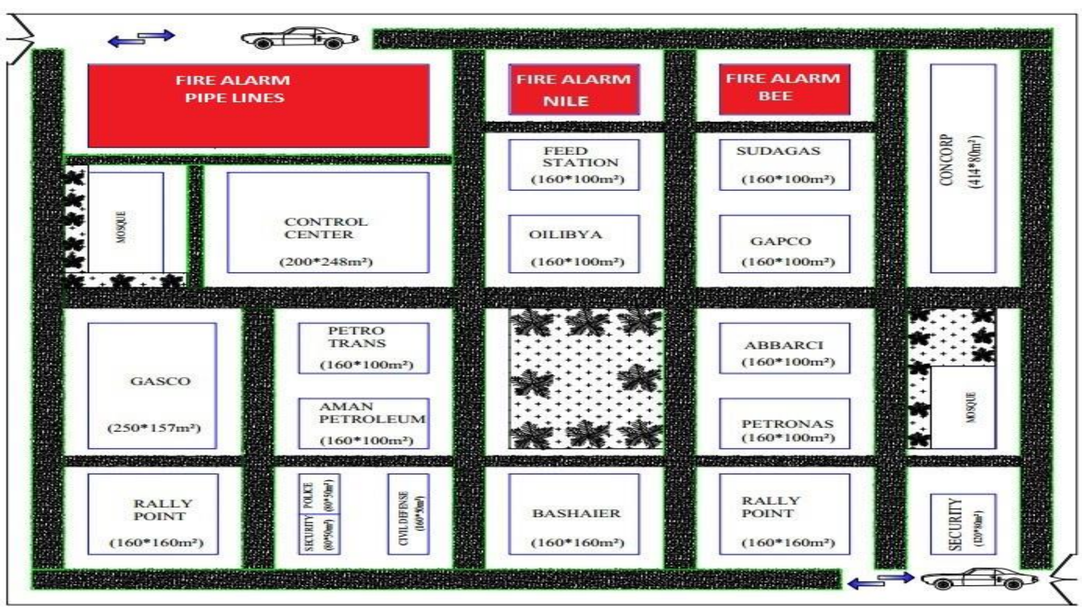


Figure (4.6) result when there is a fire in (NILE, BEE and PIPE LINES)

The above figure shows an output result from PHP program to give an alarm and visualized map with the location of fire, where the location of fire is in the NILE, BEE and PIPE LINES and the size of fire, three zones represented in zone1, zone 2 and zone 7. And also, help massage appear in this scenario.

The output of all above scenarios can be seen from any related civil defense office what so ever it is local, neighbor, or regional and this as a fast response monitoring system.

4.4 Determining the Exact Fire Location within the Fired Company:

Also, while running, the simulation using PHP software the following give some detailed output scenarios for visualization and size of fire as pictures represent the exact fire location inside the company (GAPCO) as real-time monitoring, beside full map for that area.

4.4.1 Scenario1: Default Monitoring without Fire Alarm:

default picture without fire alarm as shown in the following page Figure (4.7) peering in mind the default and safe situation (everything is ok):

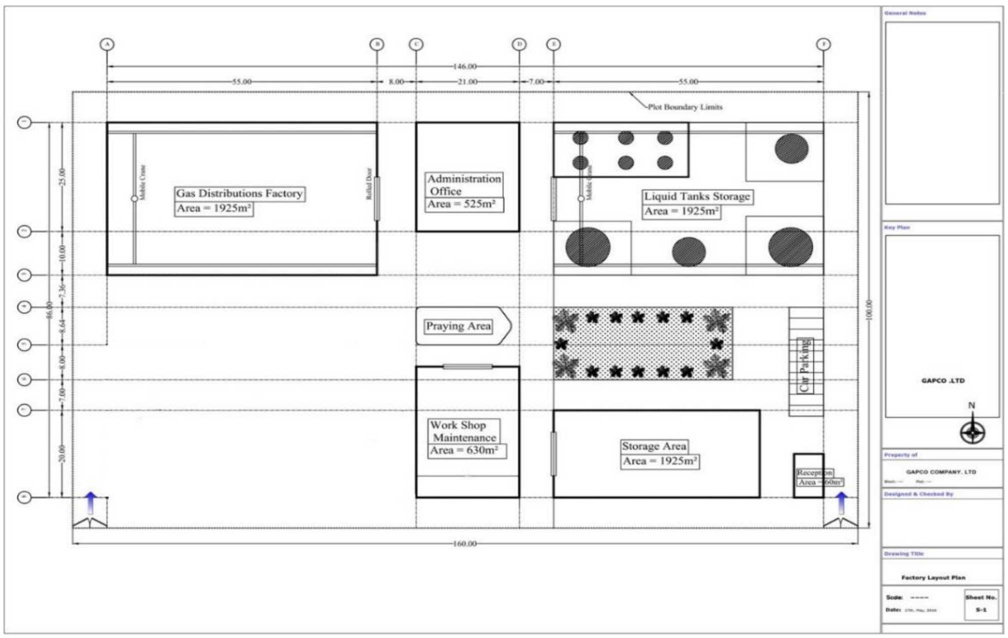


Figure (4.7) output result that represent default map of GAPCO company

4.4.2 Scenario2: Fire in One sub_zone (6.4) GAPCO Company

output when there is a fire alarm in one sub_zone within (GAPCO Company) as shown in the following Figure (4.8):

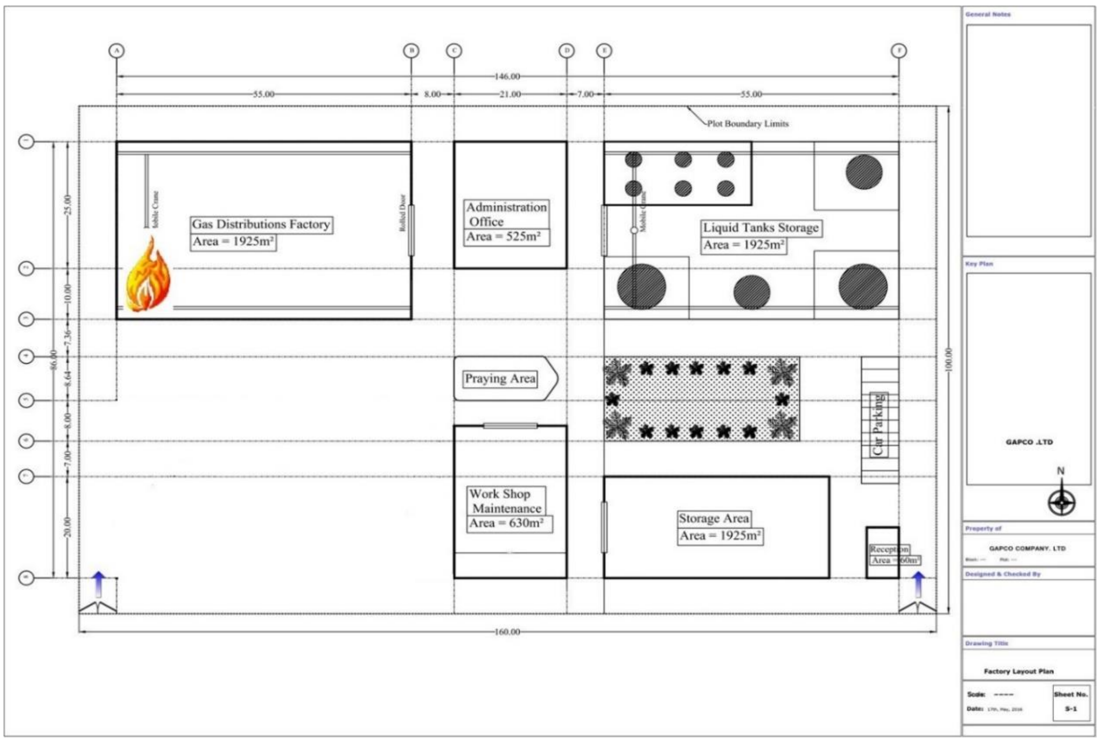


Figure (4.8) sub_zone 6.4 fired location

In above figure the fire start at location 4 which its sub_zone for GAPCO company (zone 6), then we can say exactly the fire in sub_zone 6.4 which is small location in Gas Distribution Factory for the GAPCO company.

4.4.3 Scenario3: Extension of the Fire in More than Five sub_zones.

output when there is a fire alarm in more than five sub_zone within (GAPCO Company) as shown in the following Figure (4.9):

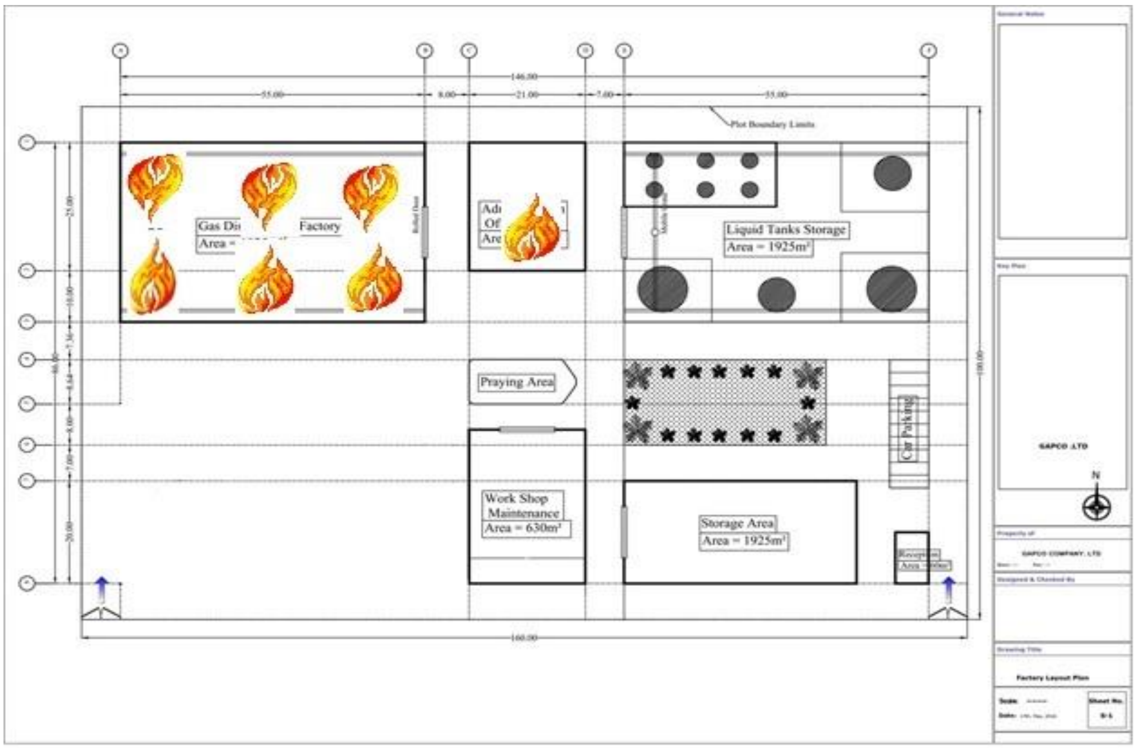


Figure (4.9) more than five sub_zones within GAPCO Company

In the above scenario, we see 7 sub_zones fired and this result a total fire of Gas Distribution Factory, then half of the administration office fired.

4.4.4 Scenario3: Extension of the Fire to Cover all sub_zones.

output when there is a fire alarm in all sub_zones within (GAPCO Company) as shown in the following Figure (4.10):

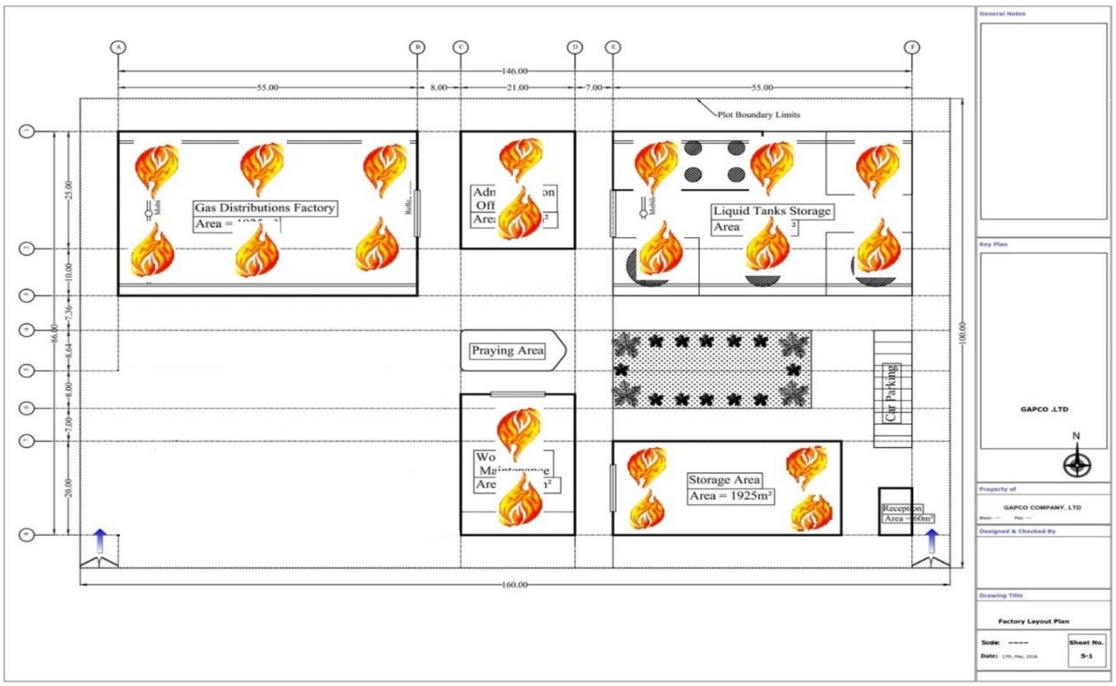


Figure (4.10) fire to cover all sub_zones within GAPCO Company

In the above figure, all sub_zones location in GAPCO company fired resulting afire in all of the company contents.

4.5 Validation of Geo-Dijkstra Algorithm using Mathematical Calculations.

By referring to the following Figure (4.11) that mentioned before in section 3.6, the following calculations results give approximately the increase of the cost of the near turns if compared it to the far turns. This scenario has been physically applied so as to show the trip by car from location A which is near to Alzakat Building to location B near to Alsahafa Locality (Alsahafa-Khartoum). As can be seen for the map the distance between location A and B are equal using both of the red and green path's.

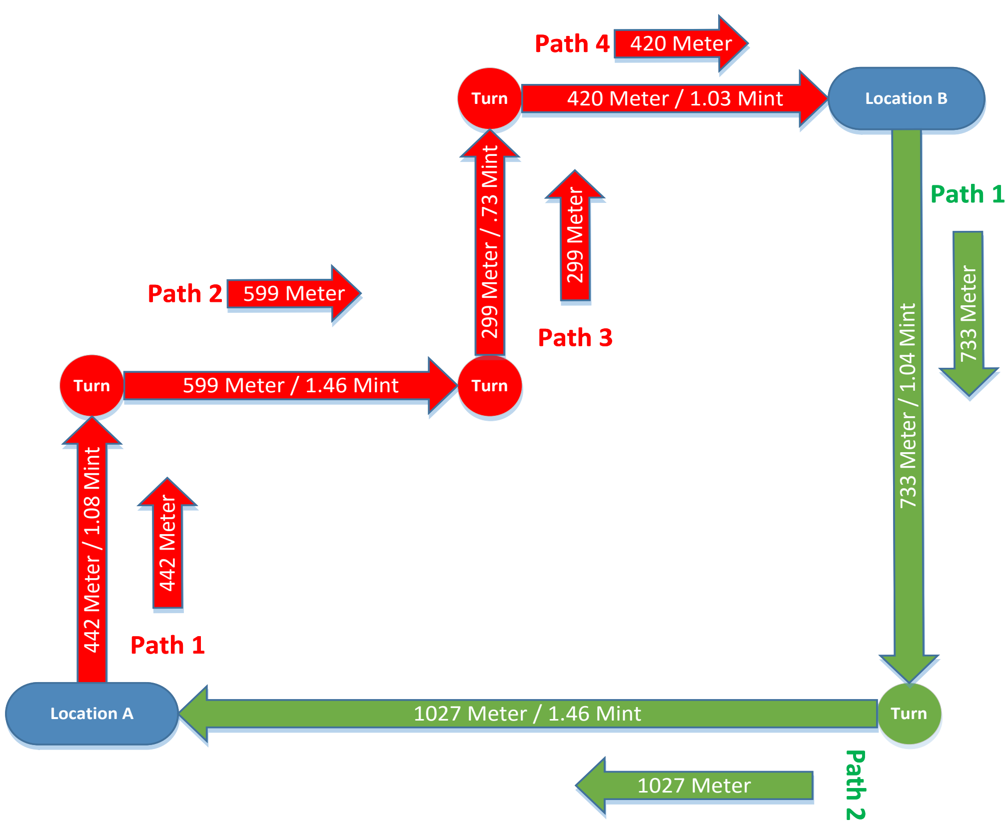


Figure (4.11) block diagram of an area that used for validation of turns

As can be seen from the figure above its clearly seen that the two different paths are equal from distance point of view, firstly the green path that includes one turn through the way from location B to location A, secondly the red path which includes three turns from location A to location B. The following mathematical calculations telling and simulate the fact, to prove the effect of turns on the arrival time for two equal distances one with turns more than the other (as has been shown by figure 4.3 a mathematical calculation has been done for the real car trip from location A to location B (Red Path) and from location B to location A (Green Path).

For the green path, take the speed value form one turn

Where,

Average Speed = $\frac{\boldsymbol{Distance\ Traveled}}{\boldsymbol{time\ of\ travel}}$

Green Path Speed (one turn path) = $\frac{\mathbf{1027+733}}{\mathbf{1.04+1.46}} = \frac{\mathbf{1760}}{\mathbf{2.5}}$ = 704 m/minute

Hypothesis: time required for the Green path with one turn to pass through 1000 meter.

Green Path (one turn) $\frac{\mathbf{1000}\ \boldsymbol{meter}}{\mathbf{704}\ \boldsymbol{meter/minute}}$ = 1.4 minute

Green Path Speed (without turns) = $\frac{\mathbf{1027}}{\mathbf{1.04}}$ = 987.5 m/ minute (by considering the longer trip from the above calculation)

Hypothesis: time required for the Green path without turns to pass through 1000 meter.

Green Path (without turn) $\frac{\mathbf{1000\ meter}}{\mathbf{987.5\ \ meter/minute}}$ = 1.0126 minute

Then, value of turn = G-Path with one turn – G-Path without turn

Turn value = 1.4 – 1.0126 = 0.3874 minute

For the red path, by using above law and calculate the average to find the speed through three turns.

Red Path Speed (three turn path) =

$\frac{\mathbf{442+599}}{\mathbf{1.08+1.46}} = \frac{\mathbf{1041}}{\mathbf{2.54}}$ = 409.84 m/ minute

$\frac{\mathbf{599+299}}{\mathbf{1.08+0.73}} = \frac{\mathbf{898}}{\mathbf{2.19}}$ = 410.04 m/minute

$\frac{\mathbf{299+420}}{\mathbf{0.73+1.03}} = \frac{\mathbf{719}}{\mathbf{1.76}}$ = 408.59 m/ minute

Red Path Speed Medium

$$\frac{\mathbf{409.84+410.04+408.59}}{\mathbf{3}} = \frac{\mathbf{1228.43}}{\mathbf{3}} = 409 \text{ m/ minute}$$

Hypothesis: time required for the Red path with three turn to pass through 1000 meter.

Red Path $\frac{\mathbf{1000\ \mathit{meter}}}{\mathbf{409\ \mathit{meter/minute}}}$ = 2.4 minute

Hypothesis: time required for the Red path without turn to pass through 1000 meter.

In the best-case the time required for the Red path without turns to pass through 1000 meter.

$$\frac{\mathbf{1000\ \mathit{meter}}}{\mathbf{987.5\ \ \mathit{meter/minute}}} = 1.0126 \text{ minute}$$

Then, value of turn = R-Path with three turn – R-Path without turn

2.44 – 1.0126 = 1.3874 mint as three nearest turns value

One turn value = $\frac{\mathbf{1.3874}}{\mathbf{3}}$ = 0.462 minute

In short, based on the above mathematical calculations, it's clearly observed that more turn more time consumed between the two locations. Furthermore, it seems that by sense the far turns consume less time than the adjacent turns.

4.6 Validation of Geo-Dijkstra Algorithm Graph and Relations Result.

By referring to Figure (4.7) in section 4.4, and using its data in a matlab code for the validation of improved dijkstra (geo-dijkstra) algorithm. Then applied that values to be coded for finding the shortest path between the two-path's due to time unit cost, and this shown in the following result Figure (4.12).

By referring to the above mathematical calculations in section 4.4 which proves that the effect of turns leads to delay in arrival, moreover, the cost of the near turns is larger than the cost of the far turn. In this section to make it simply for human calculation a hypothesis for the cost of the near turn is considered to have the value of 2 while the cost for far turns is taking the value 1

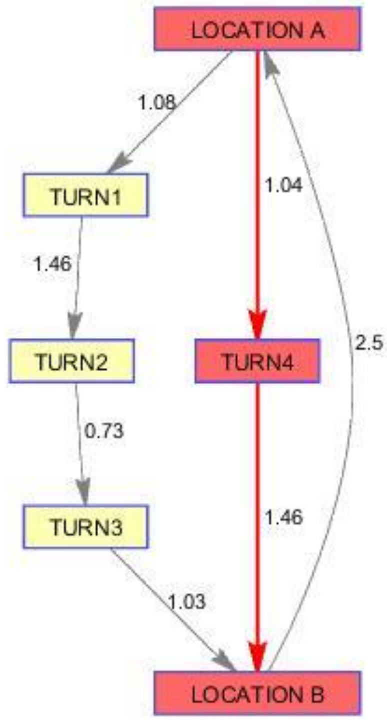


Figure (4.12) shortest path between the two-path's due to time unit cost

As this effort proved by calculations above, also the matlab code result Figure (4.12) above prove that the short path is the path passing one turn in a 2.50 minute, where the other path passing through three turn take 4.30 minute and the time difference is shown also clearly in the following matlab graph result Figure (4.13) in the next page.

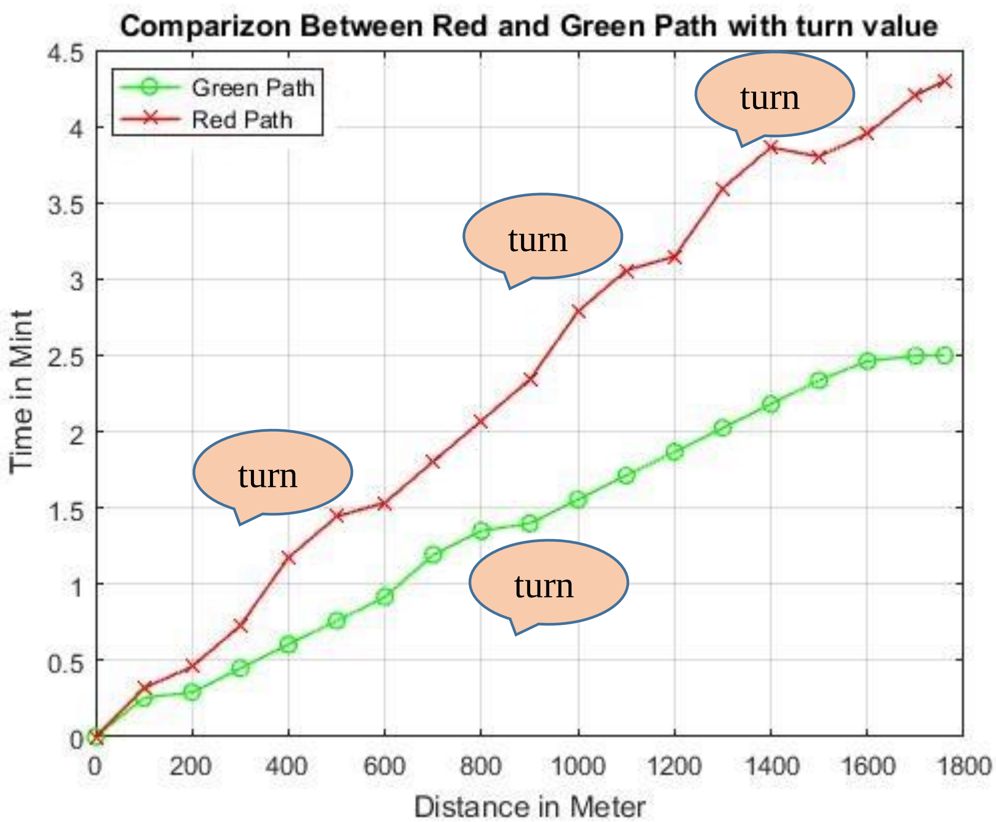


Figure (4.13) comparison between Red Path and Green Path with turn value

The figure above in the previous page has been drawn according to the data of the following **table** (4.1).

Table (4.1) Green and Red Path Movement Points

Green Path		Red Path	
x-axis Distance in Meter	y-axis time in Minute	x-axis Distance in Meter	y-axis time in Minute
0	0	0	0
100	0.25625	100	0.31875
200	0.2925	200	0.4595
300	0.44875	300	0.72825
400	0.605	400	1.175
500	0.76125	500	1.44375
600	0.9175	600	1.5345
700	1.19375	700	1.80325
800	1.35	800	2.072
900	1.39875	900	2.34075
1000	1.555	1000	2.7875
1100	1.71125	1100	3.05625
1200	1.8675	1200	3.147
1300	2.02375	1300	3.59375
1400	2.18	1400	3.8625
1500	2.33625	1500	3.80129
1600	2.4625	1600	3.95325
1700	2.49625	1700	4.20534
1760	2.5	1760	4.3

For the purpose of validating the proposed algorithm (Geo-dijkstra) considering the effect of turns as simple as possible in Figure (4.13), in the same distance, the green path has one turn taking less time for passing between the two nodes, while the red path has three turn and as we see in the figure more time for passing between the two nodes. then the Figure clearly shows the time difference between green path and red path Table (4.1) data plotting graph compare between red and green path with turn value.

For more details, if there is no turn in both red and green paths the time for passing by the two ways is equal and less in time than both time taken by red path and green path, this shown clearly compared with the graph simulate the movement of green path with one turn and the red path with three turns in the following Figure (4.14).

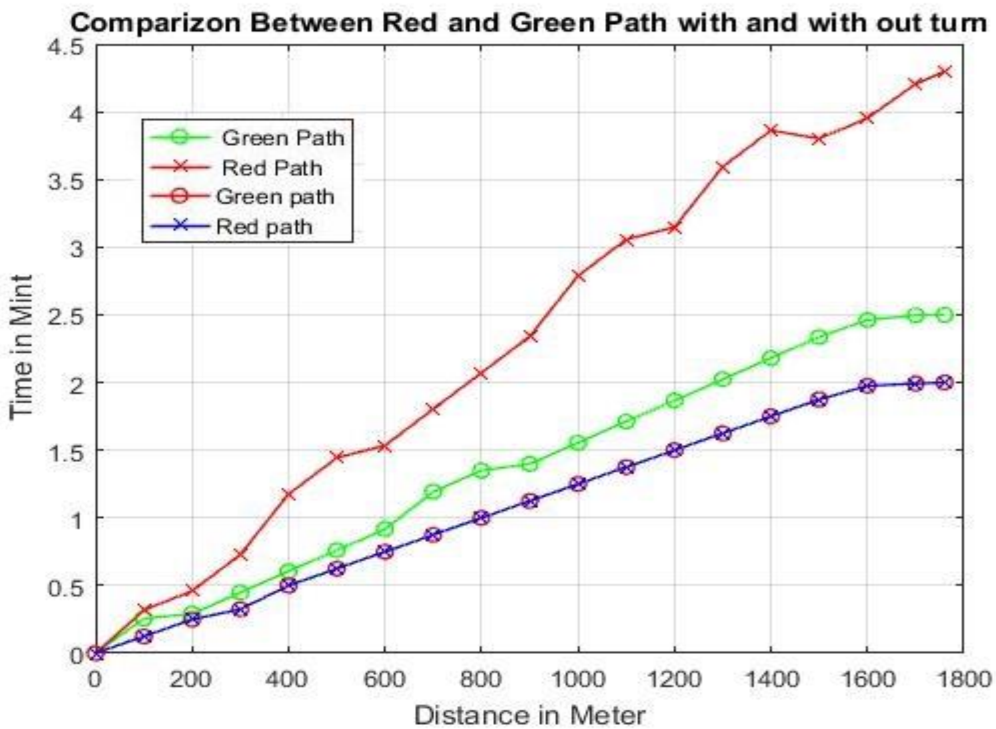


Figure (4.14) both relations with and without turns

In above figure, clearly you can see the difference between green path that have one turn and red path that have three turns and both compared assumption of having no turns. From the figure, it's clear that more turn more time and less turn mean less time, where in above figure the upper red line represent path with three turns, then the green path that represent path with one turn and the last typical lines represent both red and green path without turn and this yields less time than both above with one and three turns.

4.7 Shortest Path Between Firefighting Unit and Fired Company

When the fire occurs in Elshagra GAS depots, and the real time fast fire alarm system inform firefighting (in-campus and off-campus (neighboring)) units about the location, size and fire direction as well as the shortest path to the fired company(s). this enables the firefighting unit(s) start moving to the target company to recover from fire by using the shortest path which has been determined by the improvised dijkstra. The following scenarios discus simple and complicated examples to find the shortest path in Elshagra location with turns and without turns.

4.7.1 Optimized Path Between Fighting unit and Non-Direct Path Fired Company.

In the following sub sections efforts concentrate on applying scenarios for clarify the shortest path between two nodes that not in direct path, as simple design and complicated design due to number of nodes and turns, where the less number is simple scenario and more number of nodes and turns represent the complicated scenario. In here the existence of both simple and complicated scenario is to test the algorithm capabilities for choosing the optimum path considering the number of turns as well as the distance.

4.7.1.1 Simple Scenario Without Turn Value

The result that shown below in Figure (4.15a), is a normal dijkstra algorithm to find the shortest path between FIRE FIGHTING UNIT and BEE company using matlab code, the cost of edge without putting turn value in mind. While Figure (4.15b), represents the result simulated in the real map.

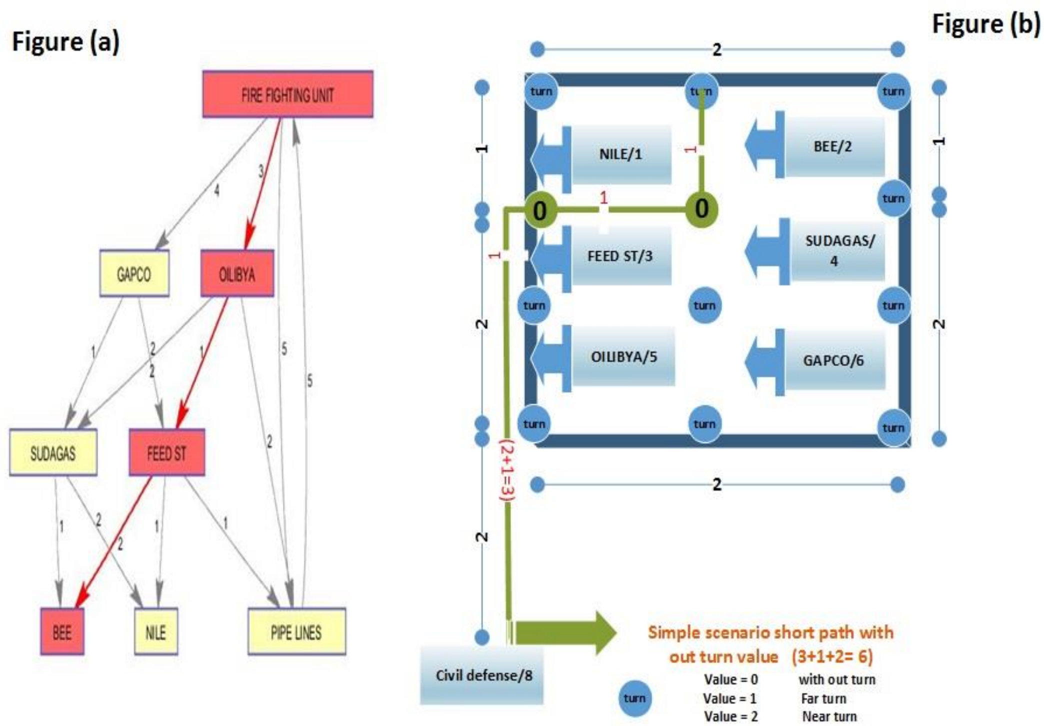


Figure (4.15) short path between (Firefighting to BEE) without turn value

As can be noticed from the above figure if compared with the matlab code result in figure (a) it gives accurate movement from source (Firefighting Unit) to destination (BEE). Where in above Figure (a), the result takes the shortest path from (FIREFIGHTING Unit to OILIBYA to FEED ST to BEE). and the total cost through this path = 6-time unit without turn value. And if we simulate in real map with green line figure (b) it will show typical movement with same cost value which also equal 6-time unit.

4.7.1.2 Simple Scenario with Turn Value:

the result shown below in Figure (4.16a), we suggest to call it GEO-Dijkstra algorithm where the path of shortest path in scenario1 without turn, was changed to a clear different path when putting turn values. While Figure (4.16b), represents the result simulated in fact map showing the new path and the previous path from senario1 just for proving both have different paths.

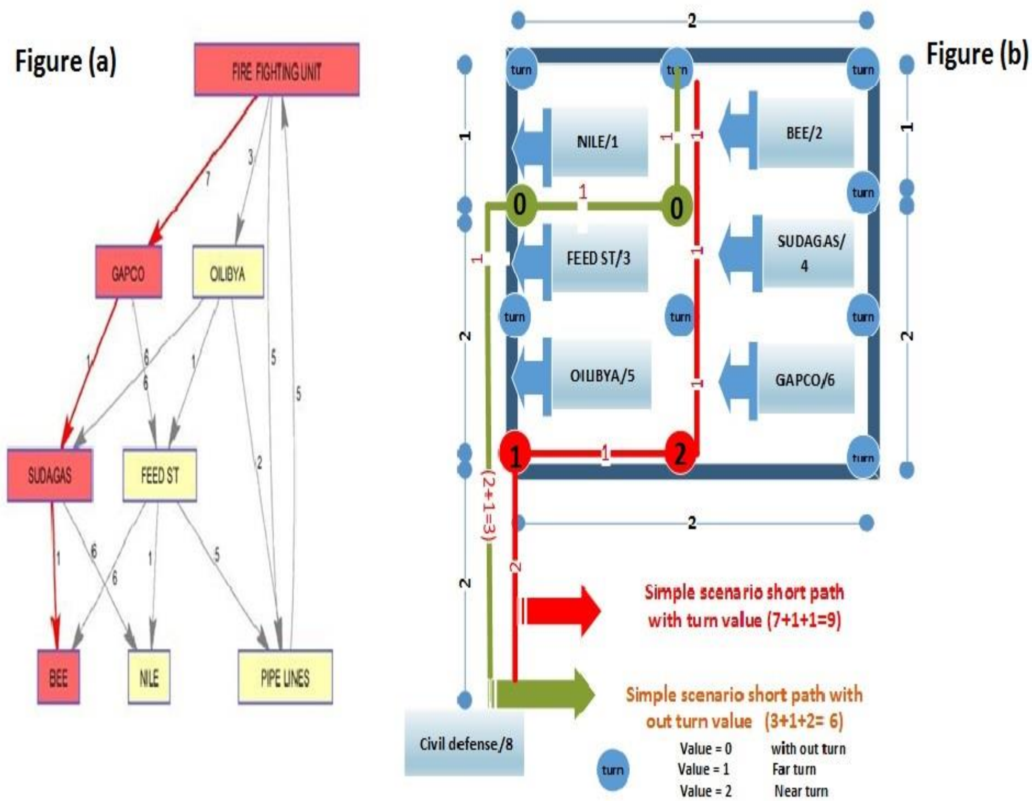


Figure (4.16) short path between (Firefighting to BEE) with turn value.

Where in above figure (a), the result takes the shortest path from (FIREFIGHTING Unit to GAPCO to SUDAGAS to BEE) and the total cost through this new path is also 9-time unit with turn value. And if we simulate in real map Figure (b) we see the difference between both with turn value (Red Path) and without turn value (Green Path) and its clearly different ways, the cost is changed from 6 to 9, because we add to the path the value of turns.

4.7.1.3 Complicated Scenario Without Turn Value:

To insure the correct functionality of the proposed algorithm (GEO-Dijkstra), it is urgently need to study in deep the behavior of the normal dijkstra algorithm and compare it with proposed algorithm which deal with the cost of turns. The result shown below in Figure (4.17a) is a normal dijkstra algorithm to find the shortest path between FIRE FIGHTING UNIT and CONCORP company in a complicated scenario using matlab code, the cost of edge without putting turn value in mind.

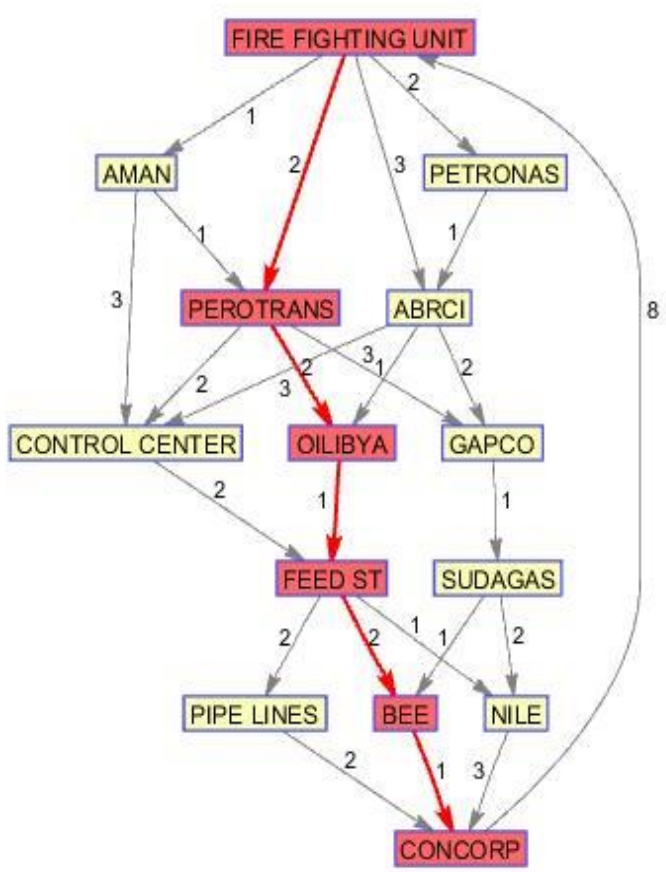


Figure (4.17a) complicated scenario without turn (firefighting to Concorp)

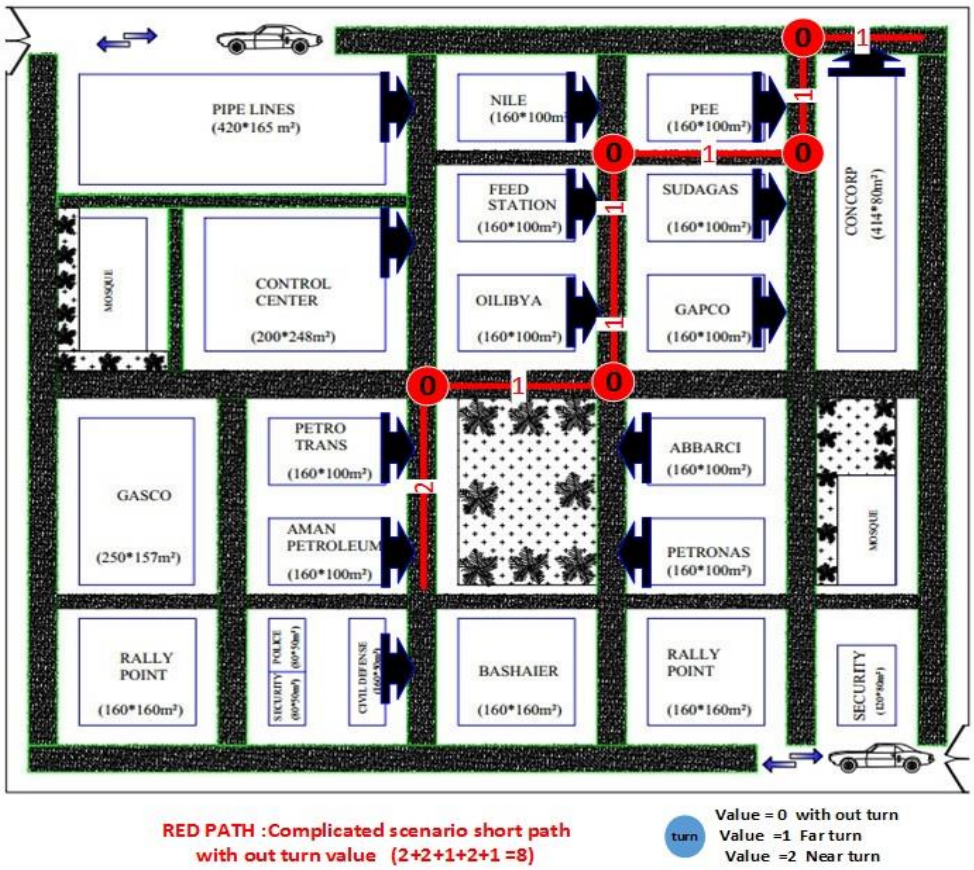


Figure (4.17b) complicated scenario without turn result simulated in fact map

While Figure (4.17b) above represents the result simulated in real physical map. Form the above two figures, if we compare the output of the matlab code in figure (a) with figure (b) it gives accurate movement from source (Firefighting Unit) to destination (CONCORP).

Where in above figure (a), the result takes the shortest path from (FIREFIGHTING Unit to PETROTRANS to OILIBYA to FEED ST to BEE to CONCORP.), and the total cost through this path is 8-time unit with turn value.

Figure (b) above simulate in fact the movement from FIREFIGHTING UNIT to CONCORP company and the value of turn equal zero as we say without turn value. Notice this output of the improvised algorithm is typically the same as the output of the normal dijkstra algorithm.

4.7.1.4 Complicated Scenario with Turn Value:

The result shown below in Figure (4.18a) we suggest to call it GEO-Dijkstra algorithm where the path taken after adding the value of turn is changed due to turn values. In another meaning the result shown below is a GEO-Dijkstra algorithm to find the shortest path between FIRE FIGHTING UNIT and CONCORP company in a complicated scenario using matlab code, the cost of edge with putting turn value in mind.

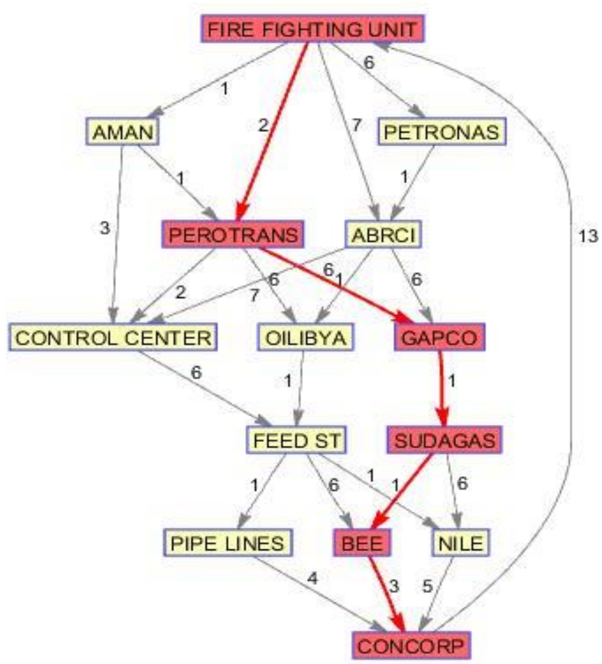


Figure (4.18a) short path (Firefighting to Concorp) with turn value.

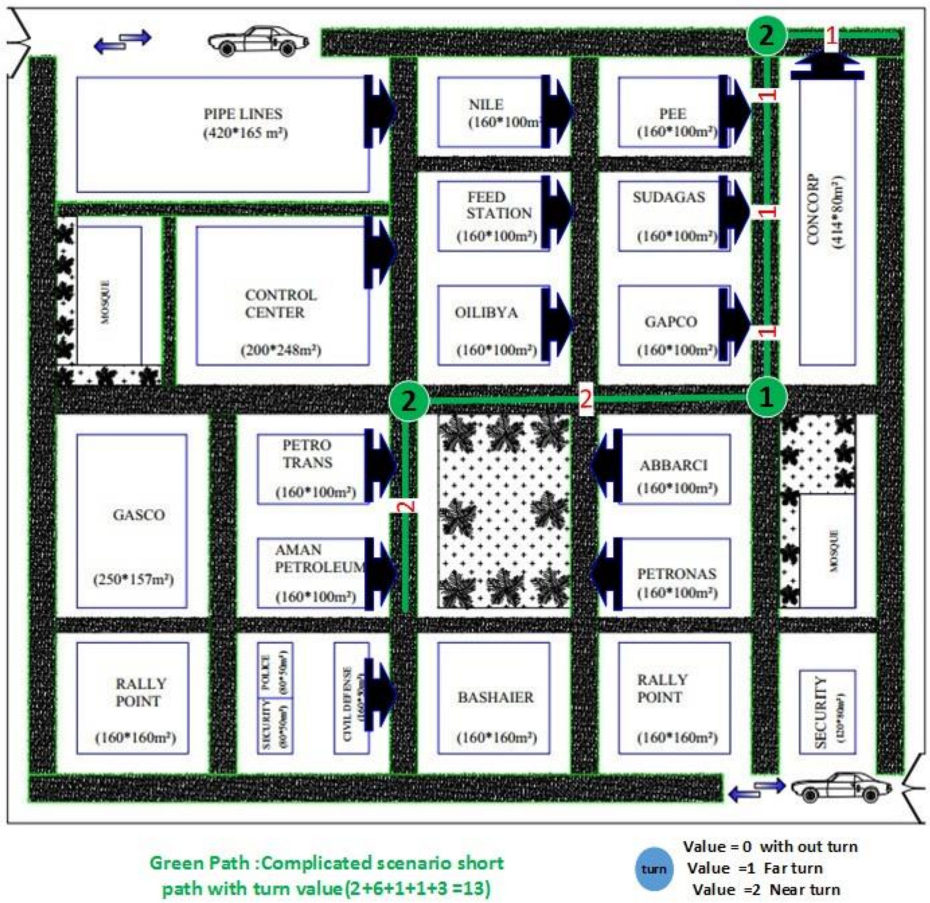


Figure (4.18b) short path (Firefighting to Concorp) with turn value

While Figure (4.18b) above represents the result simulated in real physical map. Form the above two figures, if we compare the output of the matlab code in figure (a) with figure (b) it gives accurate movement from source (Firefighting Unit) to destination (CONCORP).

Where in above figure (a), the result takes the shortest path from (FIREFIGHTING Unit to PETROTRANS to GAPCO to SUDAGAS to BEE to CONCORP.), and the total cost through this path is 13-time unit with turn value. Figure (b) simulate in fact the movement from FIREFIGHTING UNIT to CONCORP company with the value of turn.

It is very important to notice that the proposed algorithm has taken different path with similar total distance, but it has some sort of intelligence of choosing the path with less number of turns and even if the number of turns are equal it has the capability of choosing the path with turns that enable the firefighting car to move faster (i.e. taking less arrival time).

4.7.2 Optimized Path Between Firefighting Unit and Direct Path to Fired Company.

In the following sub sections, also efforts concentrate on applying scenarios for clarify the shortest path between two nodes in direct path, as simple design and complicated design due to number of nodes and edges, where the less number is simple scenario and more number of nodes and edges represent the complicated scenario

4.7.2.1 Simple Scenario Without Turn Value:

The result shown below in Figure (4.19) is a normal dijkstra algorithm to find the shortest path between FIRE FIGHTING UNIT and NILE company, the cost of edge without putting turn value in mind.

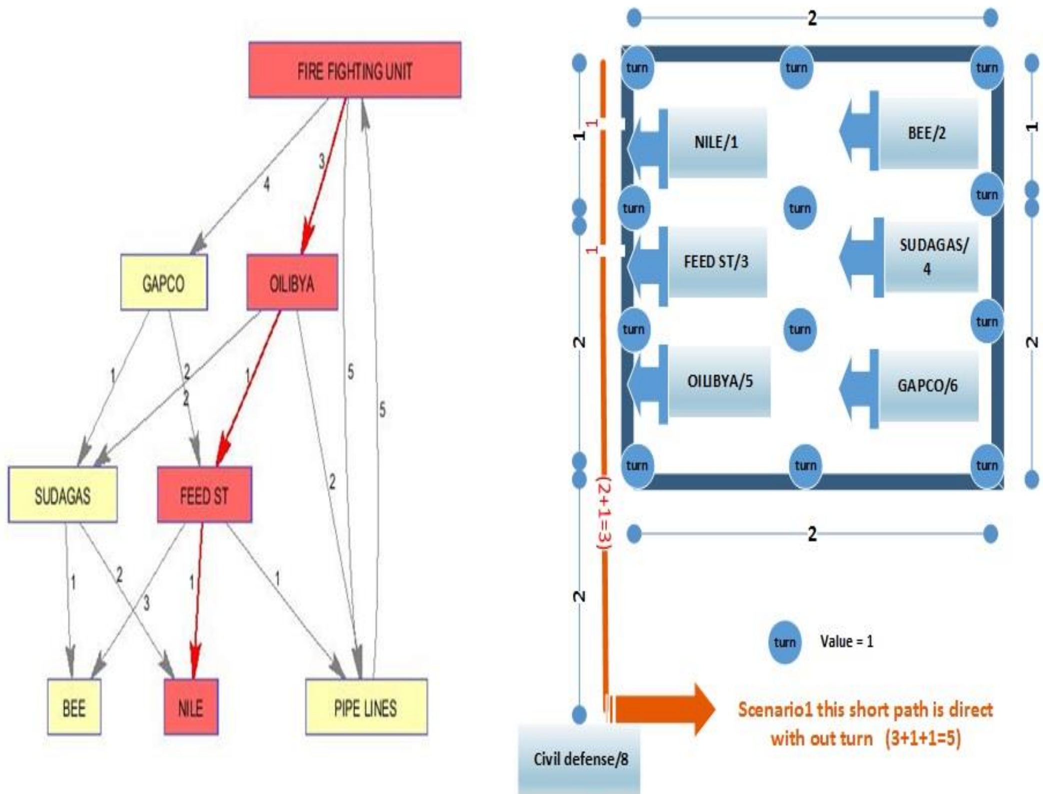


Figure (4.19) short path between (Firefighting to NILE) without turn value

Where in above figure, the result takes the shortest path from (FIREFIGHTING Unit to OILIBYA to FEED ST to NILE). and the total cost through this path = 5-time factor without turn.

4.7.2.2 Simple Scenario with Turn Value:

In this scenario, no way to add turn value because the result in scenario 1 is a direct way without turn, then the following Figure (4.20) also output same result in scenario 1 because of the location in direct way without turn value.

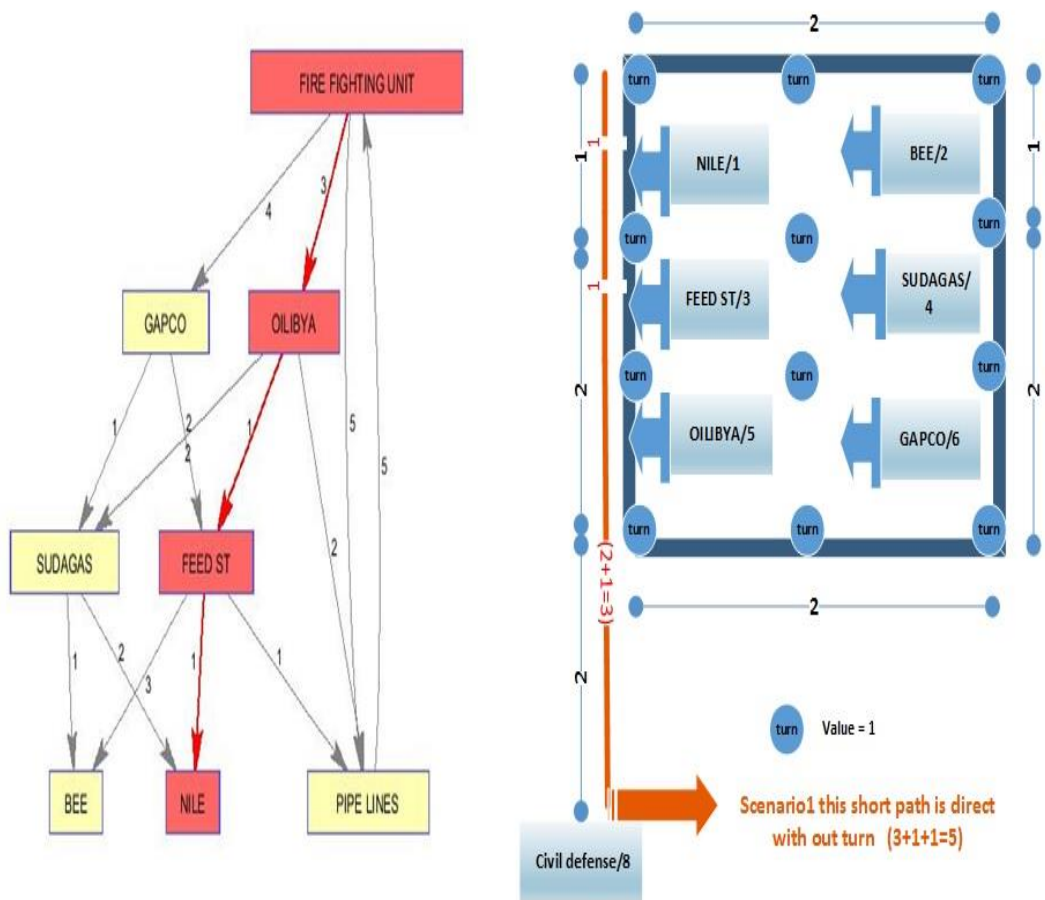


Figure (4.20) short path between (Firefighting to NILE) without turn value

Where in above figure, the result takes the shortest path from (FIREFIGHTING Unit to OILIBYA to FEED ST to NILE). and the total cost through this path = 5-time factor without turn. And this means that direct way without turn is the fastest way and fast response.

4.7.2.3 Complicated Scenario Without Turn Value:

The result shown below in Figure (4.21) is a normal dijkstra algorithm to find the shortest path between FIRE FIGHTING UNIT and PIPE LINE in a complicated scenario using matlab code, the cost of edge without putting turn value in mind.

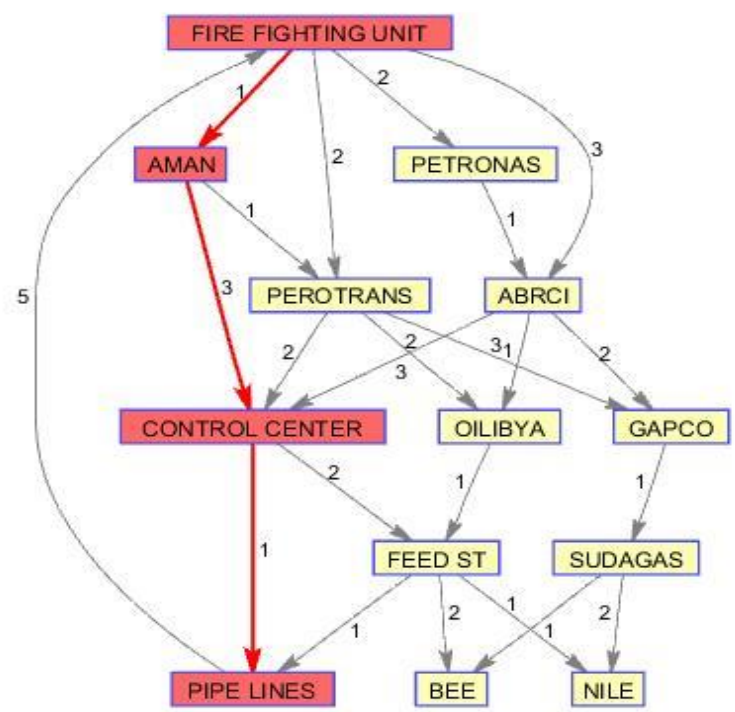


Figure (4.21) normal dijkstra for finding shortest path between FIRE FIGHTING UNIT and PIPE LINE

Where in above figure, the result takes the shortest path from (FIREFIGHTING Unit to AMAN to CONTROL CENTER to PIPE LINES.), and the total cost through this path is 5-time unit without turn value.

The following Figure (4.22) simulate in fact the movement from FIREFIGHTING UNIT to PIPE LINES without value of turns.

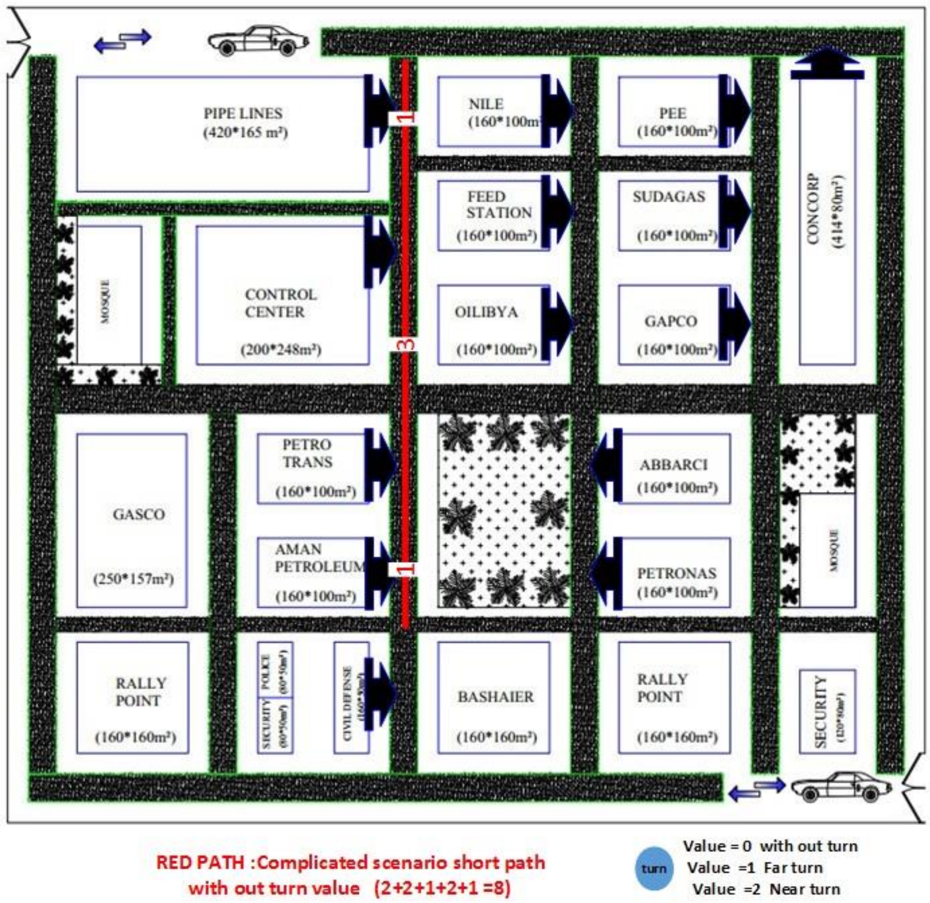


Figure (4.22) simulation in fact from CIVIL DEFENSE to PIPE LINES without turn

Where in above figure, the result takes the shortest path from (FIREFIGHTING Unit to AMAN to CONTROL CENTER to PIPE LINES) and the total cost through this new path is 5-time unit without turn value.

4.7.2.4 Complicated Scenario with Turn Value:

The result shown below in Figure (4.23) represent the path taken after adding the value of turn.

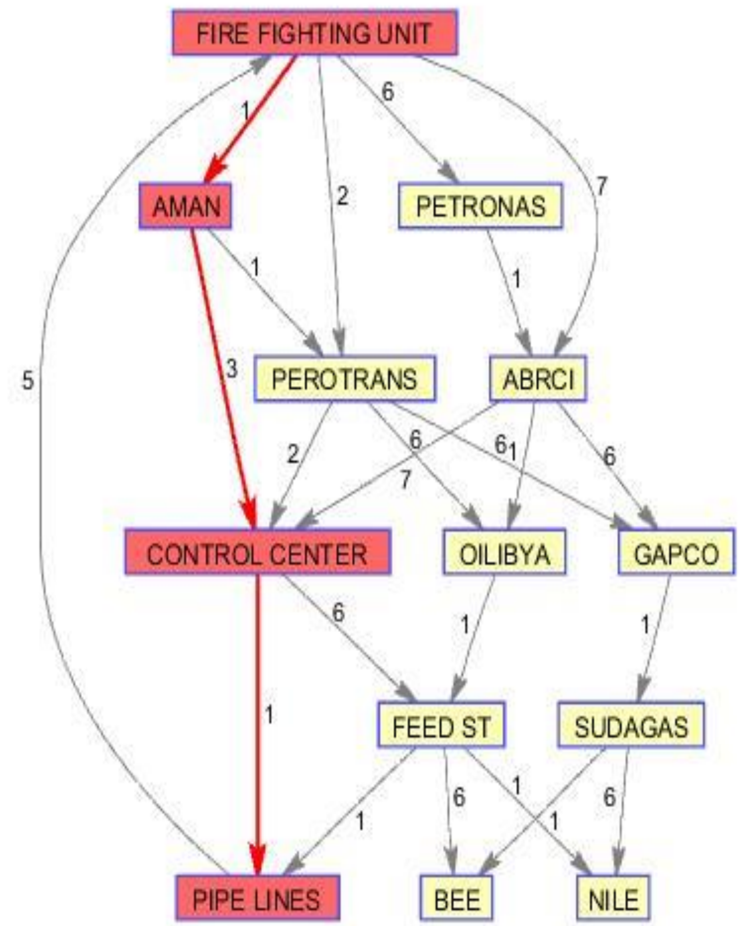


Figure (4.23) simulation in fact from CIVIL DEFENSE to PIPE LINES with turn

Where in above figure, the result takes the shortest path from (FIREFIGHTING Unit to AMAN to CONTROL CENTER to PIPE LINES.), and the total cost through this path is 5-time unit without turn value.

The following Figure (4.24) simulate in fact the movement from FIREFIGHTING UNIT to PIPE LINES with value of turns.

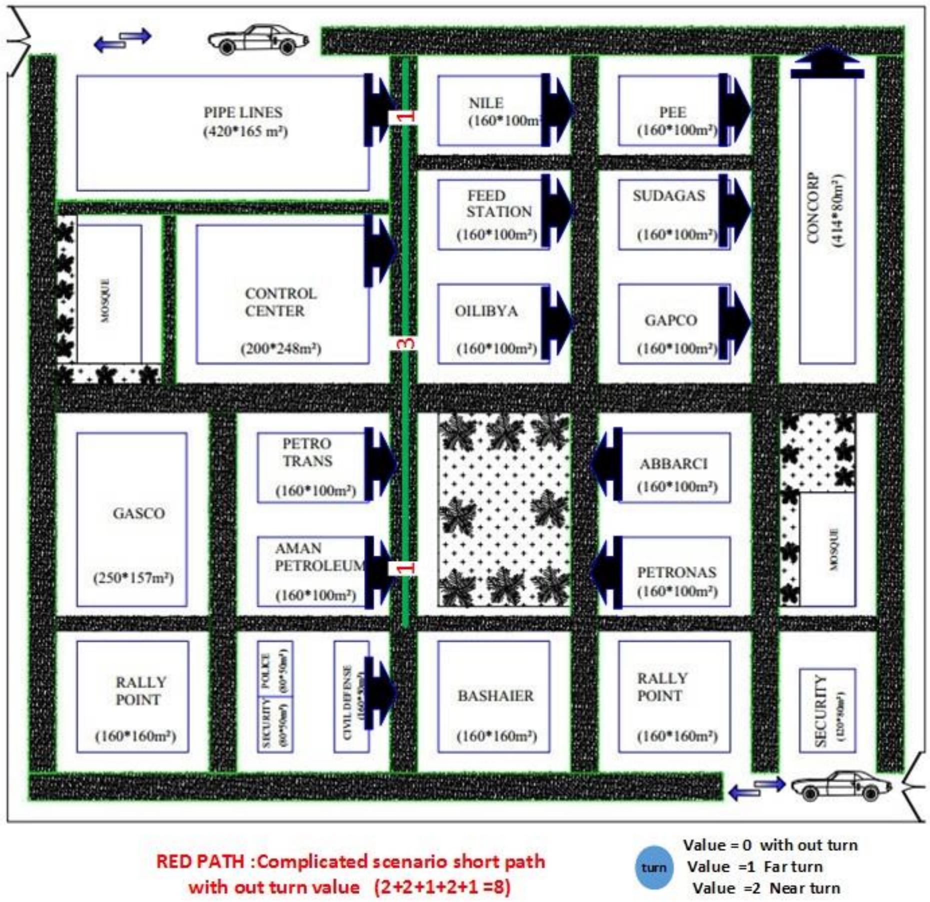


Figure (4.24) simulation in fact from CIVIL DEFENSE to PIPE LINES with turn

Where in above figure, the result takes the shortest path from (FIREFIGHTING Unit to AMAN to CONTROL CENTER to PIPE LINES) and the total cost through this new path is 5-time unit with turn value.

From above direct path scenarios it is very important to notice that the direct path most of time is the best as if its longer than paths that have turns, the cases shown satisfy that direct path was the best path.

4.8 Testing the Geo-Dijkstra with in Two Equal Paths

To prove our dijkstra for taking the wright shortest path suggestion make two equal paths, and as in the following result Figure (4.25) dijkstra take by default any one of both two equal paths.

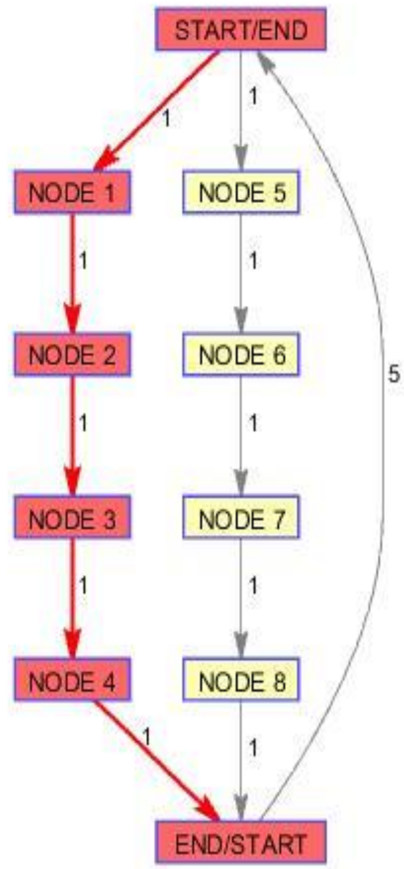


Figure (4.25) one path selected by dijkstra form two equal path

In above figure dijkstra take the path through (node1 to node2 to node3 to node4) choosing one of the two equal paths as shortest path.

Clearly to prove the validity of dijkstra for the selection of shortest path, assume high cost in the chosen path above (i.e. from STRAT/END to node1 = 100). And the result output will be in the following Figure (4.26).

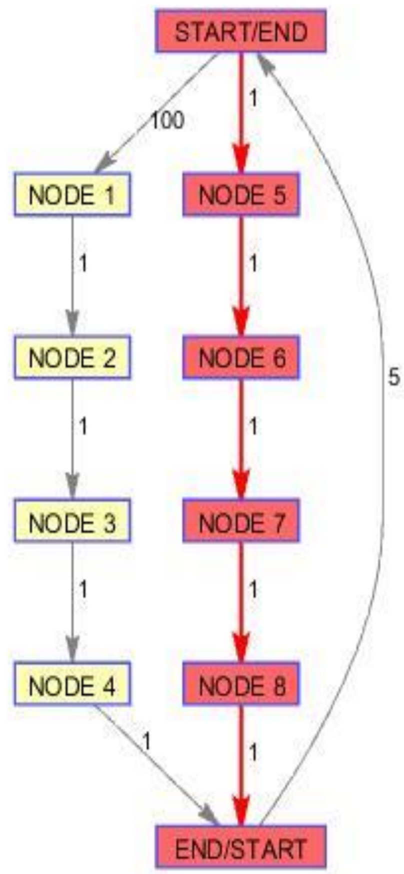


Figure (4.26) dijkstra take second path because of high cost in first

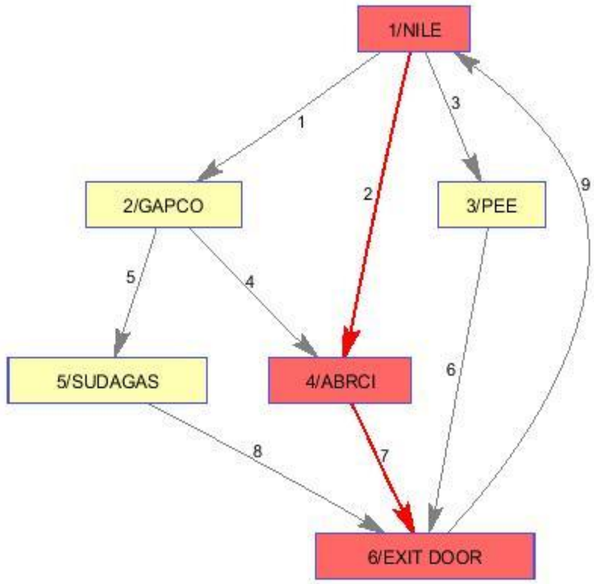
As we see in above figure the dijkstra take another path that represent the shortest path, and this prove the validity of dijkstra for the selection of the shortest path.

4.9 Determining the Safest Path Towards the Exit Door

For employees and vehicles whenever there is fire alarm, and this done by three scenarios because when employee and vehicles try exit they may face a fire node forcing them to take another shortest path.

4.9.1 Scenario 1: Normal Dijkstra Shortest Path

In this scenario **Figure** (4.27) next page shows 6 node system diagram represent five companies and one exit door and 8 edges represent the time factor cost as example between nodes to find the shortest path and fast response.




```
Command Window
Biograph object with 6 node and 9 edge

dist  =
        9
path =
        1   4   6
Enter the node you want to remove: 4
```

Figure (4.27) shortest path to exit door through node 4

In the above result figure, the shortest path for Nile company employee and vehicle to exit is going through the shortest path nodes from (1 4 6) where node1 is Nile company and node 4 is the middle node ABRCI company and the last node 6 for Exit Door. And we show in result figure above also the question (enter the node you want to remove:) was answered by putting node 4 to remove and that enforce the system to choose another shortest path, and this in real represent there is a fire in node 4 (ABRCI) so, vehicle and employee must change the path to another shortest path.

4.9.2 Scenario 2: Forced Dijkstra When Fire in Node4

In this scenario **Figure** (4.28) shows the node diagram without node 4 to find the shortest path between Nile company and Exit Door. And we called this case **Forced-Dijkstra** because system take long path to exit because of fire in the real shortest path

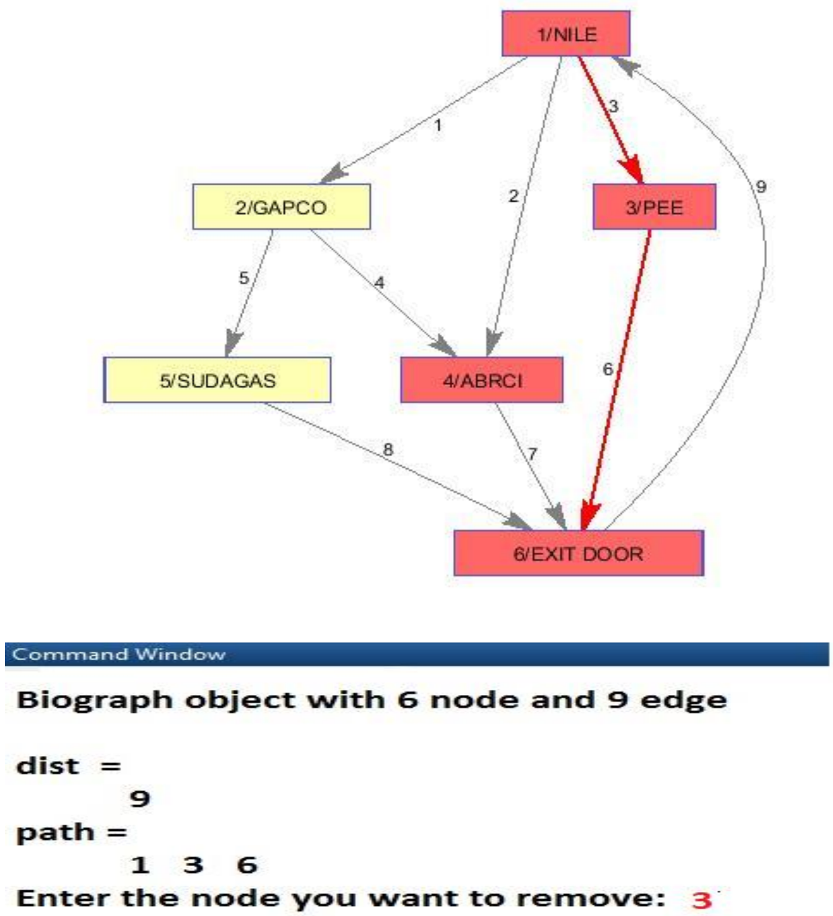


Figure (4.28) shortest path to exit door through node 3

In the above result figure, the shortest path for Nile company employee and vehicle to exit is going through the shortest path nodes from (1 3 6) where node1 is Nile company and node 3 is the middle node BEE company and the last node 6 for Exit Door. And we show in result figure above also the question (enter the node you want to remove:) was answered by putting node 3 to remove and that enforce the system to choose another shortest path, and this in real represent there is a fire in node 4 (ABRCI) and node 3 (BEE) so, vehicle and employee must change the path to another shortest path.

4.9.3 Scenario 3: Forced Dijkstra When Fire in Node 3, Node 4

In this scenario **Figure** (4.29) shows the node diagram without node 4 and node 3 to find the shortest path between Nile company and Exit Door. And we called this case **Forced-Dijkstra** also because system take long path to exit because of fire in the real shortest path.

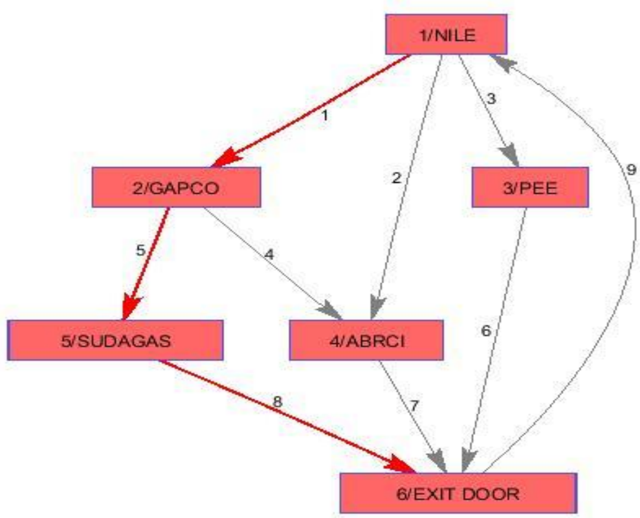


Figure (4.29) shortest path to exit door through node 2 and node 5

In the above result figure, the shortest path for Nile company employee and vehicle to exit is going through the shortest path nodes from (1 2 5 6) where node1 is Nile company and node 2 is the middle node GAPCO company and node 5 also middle and the last node 6 for Exit Door. And we show in result figure above take the longest path to exit door and this coming by force (Forced-Dijkstra) to tale the long path as shortest path to Exit, because of fire in node 3 and node 4.

In best cases if we built our considerations according to expectation to the fire size, direction and propagation speed the result will be more suitable and accurate for exit safe way as enhanced Forced-Dijkstra.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions:

In this thesis, a cost- effective and autonomous solution for intelligent fire alarm system using WSN has been presented. The aim of the propose system is the fast recovery of fire with an accurate estimation of fire location, size, direction. Moreover, according to the size the proposed system has the ability to determine whether the risk of the fire can be recovered by the in-campus firefighting unit or there is a need for logistic support by the nearby firefighting unit or by the headquarter of the civil defense. The system provides online real information that reflect what is exactly happing inside the fired location(s).

Also in this system, the original dijkstra has been improvised to achieve the goal of fast arrival of the firefighting units via the shortest path considering the mechanical movement. It is very important to notice that the proposed algorithm (geo-dijkstra) has some sort of intelligence of choosing the path with less number of turns and even if the number of turns are equal it has the capability of choosing the path with turns that enable the firefighting car to move faster (i.e. taking less arrival time) which leads reduction of the effect of fire in lives and assets due to the importance of quicker response time (i.e. 2 minutes late may lead to pig lost).

A full system design for intelligent fire alarm system using WSN, to give compatible full design alarm system with monitoring for the areas south Khartoum, although, the methodology of this research has considered the big picture of the proposed system with the details of every stage, however the following activities have been completed successfully:

Software module which has the capability of visualizing fire location in the map, in addition to giving estimation of the fire size as well as the fire estimated direction. The output of this module can be seen from any related civil defense office what so ever it is local, neighbor, or regional which help the civil defense authority to get the right decisions for the fire recover in very quick time.

Finding the shortest path between two nodes using dijkstra. Firstly, to guide Firefighting Unit through shortest path to recover fired location(s), and the shortest path without turn value is differing than short path with turn value which clearly show an effect of turn and this improvised dijkstra called GEO-Dijkstra. Secondly to find the safest path to exit door, the shortest path is calculated and we suppose there is a fire in this path, then improvised dijkstra here forced to find another short path which called here Forced-Dijkstra.

In more details, firstly the methodology of this project was started by PHP programed scenarios, to imitate the WSN sensor and sending signals to the map contains companies scattered in different zones, when the signal come to the zone, company location appears red alarm of fire as a clear monitoring for the fired zone. And when the fire is in more than one zone the system visualizes and detects that it's a big fire that need help form external firefighting unit assuming that they are connected together.

Lastly the proposed algorithm has been evaluated according to different scenarios (please refer to section 4.6) and it gives very promising and satisfied results.

5.2 Recommendations for The Research:

The following recommendations are offered for related research:

1. Fire risk forecasting

2. Automated Firefighting plan.

3. Physical Testing of Implementation

4. Using additional sensors for example GAS leakage valve sensor where sensing and if GAS leaking close the valve.

5. help form external firefighting unit using any interconnection technology so as to monitor the fired location in real time and by all branches of the civil defense authorities.

6. Built-in Data base to guide firefighting unit for using suitable fighting component according to the stored assets inside the fired locations.

7. Graphical User Interface for the system.

8. WSN Security from fake signals.

9. Using WSN to provide valuable information to firefighters and fire investigators

10. Extend the work so it can deal with robotics to help in recovering of fire.

11. Develop an android based application according to the proposed programs in this thesis (i.e. the walkers and drivers must have full information about what the situation and they can be guided through their smart phone to the safer exit).

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APPENDIX A

RESEARCH LOCATIONS AND FIREFIGHTING PLAN

A1: Introduction:

This appendix mentions the research locations by define geographical locations and details existing system of work in Elshagra GAS depots and companies with in it, also we describe the current status of the companies due to defense when there is a fire alarm and this include civil defense plan 2016.

A2: The Research Locations and Firefighting Plan:

In this area, we discuss the geographical locations of the research area and define the existing system that work when there is a fire alarm.

A3: Elshagra Gas Depots the Geographical Location:

It includes Geographical limitation for the warehouse to determine the nearby and entrances and paths for Ambulances and Police Vehicles, where (Elshagra) warehouses located south of Khartoum and bounded from south by the (Yarmouk) stores for Military manufacturing, from north residential area (Gabra), from west the Residential area of (Al Shagra) and from east some Industrial workshops.

The following Figure (a.1) show in details the location of Elshagra GAS depots:

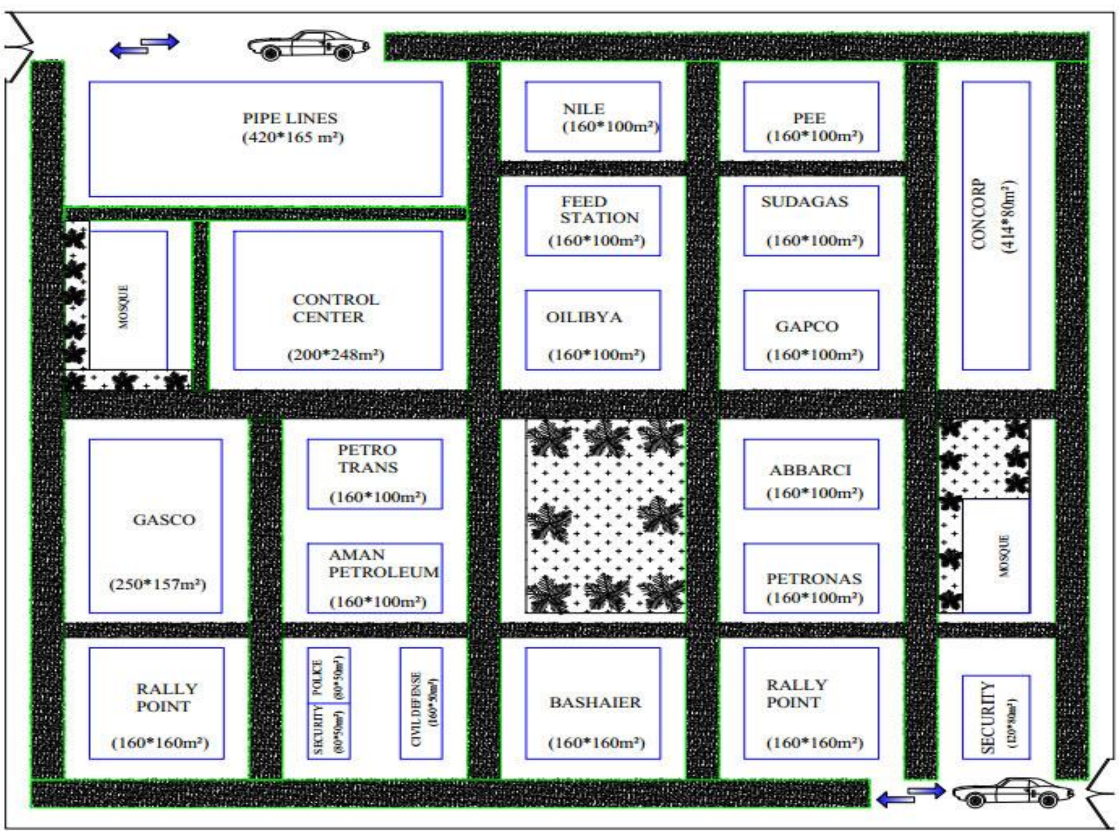

Figure (a.1) Elshagra GAS depots

(Al Shagra) warehouses are the largest warehouses in Sudan contain more than Ten Companies each with an area of (100 * 160) square meters, moreover the presence of police, Office of the security and integrity, there are assembly points used for different purposes.

A4 Companies' Description Within (Elshagra) Warehouse

As we mentioned above that company's area is (100 * 160) square meters as seen in the following Figure (a.2).

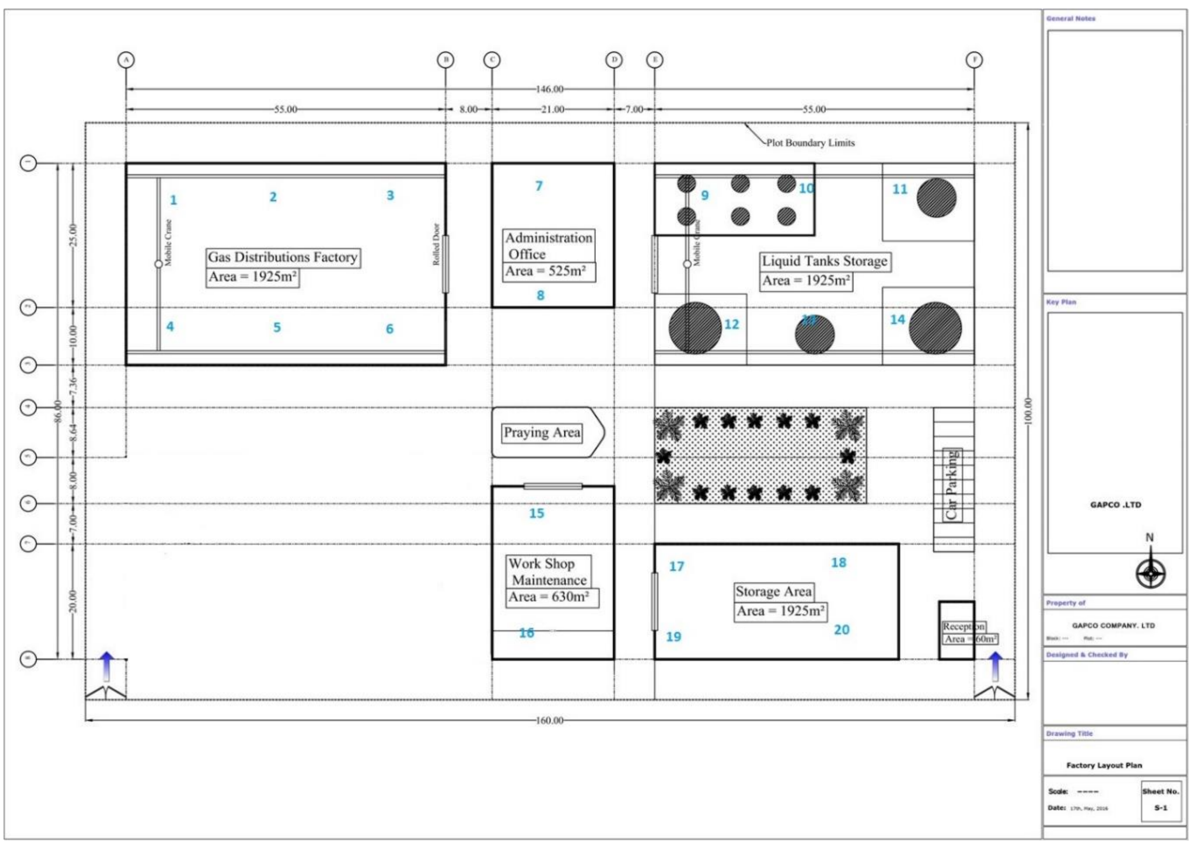

Figure (a.2) GAPCO company with in Elshagra GAS depots

And the work done almost similar in GAS and other petroleum products storage and are also mobilizing gas pipeline in a small mobilize factory within each company separate, above figure representing (GAPCO) as an Example for the Project Design and that will be applied to all companies in the Warehouse.

A5: The Coordination of Firefighting Systems in South Khartoum.

The following Figure (a.3) represent the location of Elshagra GAS depots and the nearest locations that give help when big fire is detected in Elshagra building.

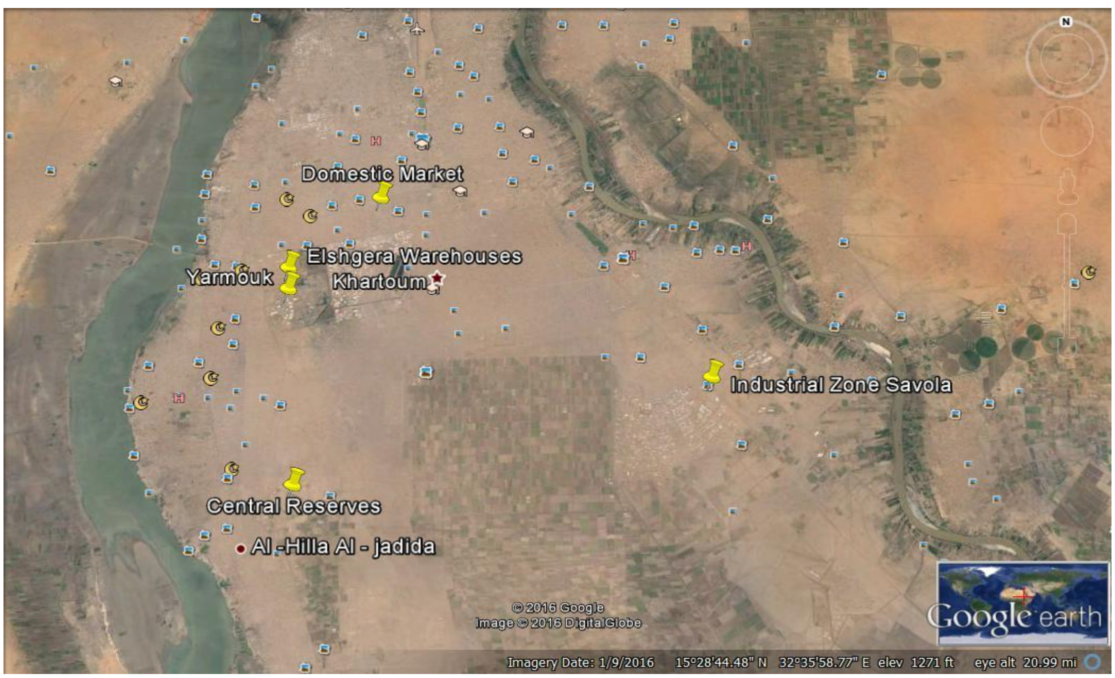

Figure (a.3) Elshagra GAS depots and the nearest locations

And this to apply the ability of sharing resources of firefighting unit in the area south Khartoum from the nearest location to the fired location as we suggest in the project.

The following Table (a.1) represent the distance between these companies which help in calculating signal propagation between locations when GSM signal is sent to inform other location to give help for fighting big fire.

Table (a.1) distance between south Khartoum locations

Location	Latitude	Longitude	Distance from Elshagra location
Elshagra Warehouses	15°30'4.52"N	32°30'33.62"E	0 kilometers
Industrial Zone Savola	15°27'41.72"N	32°38'51.61"E	17 kilometers
Yarmouk	15°29'38.48"N	32°30'33.79"E	1 kilometers
Central Reserves	15°25'45.05"N	32°30'44.20"E	9 kilometers
Domestic Market	15°31'29.87"N	32°32'22.62"E	6 Kilometers

A6: Current Status of the Companies in Terms of Fire Insurance:

There is great interest in safety for all Companies and there are Annual Emergency Plan confirms interest in Civil Defense Department (Petroleum Sector).

The next Plan is for 2016 describes how to handle well-integrated and fully reflect that the Alarm operations are manually applied.

A7: Civil Defense Plan for Petroleum Sectors 2016

Civil defense plan depends on boost implementation of the plan, which contains the following

A.7.1 Manpower:

- Civil Defense Force (Petroleum Sector).
- Secure Government Facilities Police Force.
- Petroleum Security.

- Modules Safety, Companies and workers Units.

A.7.2 Machinery, Vehicles and Materials Fire Fighters:

- Civil Defense Vehicles within the site.

- Deportation cars Available on Site.

- Water tanks for Civil Defense and companies.

- Fire extinguishing materials for Civil Defense and companies.

A.7.3 Communication Devices:

Using Telephones to inform civil defense unit about the fire, and also call petroleum Sector insurance by telephone, all this confirms the importance of the project.

A.8 How Companies Deal When Fire Detected

When fire detected in one of the depots companies, they have fixed scenario and job for each employee work in the depots and they distribute tasks for Four Groups to perform the following functions in sequence:

- The First Group performs the following functions:

1- Fire Siren.

2- Cut the power supply.

3- Activate the Companies Cooling Systems.

- The Second Group performs the following functions:

1- Open the Doors.

2- Lock the main Street.

3- Direct the Cars to the Assembly Points.

4- Employees evacuate for the Assembly Points.

- The Third Group performs the following function:

1. Fire-Fighting.

- The Fourth Group performs the following function

1. Evaluation and control.

The Plan listed above confirms the importance of the project to carry out the implementation of Alarm operations quickly and the urgent for the project in the current Emergency plan and its contribution to solve many of the problems in very high speeds.

APPENDIX B

PSEUDO AND ALGORITHMS

B.1: General Pseudo Code for Full System Diagram:

1. Any sensor detects there is GAS leakages or fire (fire discovery).
2. Define the location and source of fire (where fire start).
3. Send signal to the local monitoring there is a fire (monitor of the defined company).
4. Send signal to mobile sensor (robot car).
5. Send same local above signal to the Unit fire inside the warehouse
6. Guideline for vehicle and people to exit.
7. Send signals to open door automatically.
8. Define the speed of fire going fast or decline.
9. Define the size of fire if big than Unit fire inside the warehouse.
10. If no
11. End
12. If yes
13. Send signal (GSM) to the near fire units (sharing resources).
14. Triger the light traffic in the way of Fire engines of near institutions.
15. Send signal to the Fire presidency (HQ) through the cloud to inform (by monitoring) there is a fire in defined area.

16. Send SMS to general manager of companies there is a fire in defined location in Elshagra depots.

B.2: Visual-Based Fire Detection and Expectations Pseudo Code:

//Divide area into 7 zones

//create 7 images to represent each area

// make sure that the images can be put in an html table and they show the exact map before //dividing the files.

// store the value in an array

Var Images = array (image1, 2, ---7)

Var current file = nameof this php file;

Create html

Sensors (checkboxes 1,2..7)

Var (zone1, zone2…zone7)= sensor (1,2,…7)

// the page will be refreshed manually in the program using a button

// the var currentfile will help the program stay in the same page

// to represent an activation when fire occur

If post (page is refreshed){ //beginning of if #1

If (not empty (sensor)){ // if #2

Write("Warning" new line "Fire is detected")

var Counter=0;

foreach sensor detected (put its name in a var = selected, for example selected =zone1){

```
//begin a loop
        Counter ++;
 Var   needle = selected+.jpg (for examplezone1.jpg)
 // this will be used to search for image
For each image in Images array {            //for each #2
Search  Images(array, for  needle)
 If image is found
 Replace image with another image in the array
//For example replace zone1.jpg with zone1fire.jpg
}      // end of of for each#2
   Display selected   // area for example zone1
 // this  way this loop will display all zones selected
}                    //end of for each loop
}                                   //end of if #2
If (counter >1){   // this means more than one zone is selected
Write ('This is a large fire detected, external help will be called, GSM will be sent. ';)
}         / /  end of if counter above
          }                                   //end of if#1
// Draw an html table
Begin table
Begin row
// the following will happen for each of the cell
Begin cell
Put the value of images stored in the Images array above in cell
```

// note that the value above may indicate fire (e.g. zone1fire.jp) or not (e.g. zone1.jpg)

Close cell

Close row

Close table

B.3: Forced-Dijkstra Pseudo Code

pseudos' code one for the program for the three scenarios:

- Pseudo for the three scenarios'

% code to find shortest path during fire

% Define the connectivity matrix a & b manually

% Enter node names manually

% display the node & find shortest path scenario 1

% ('Enter the node you want to remove: - ');

% display the node & find shortest path for scenario 2

% ('Enter the node you want to remove: - ');

% display the node & find shortest path for scenario 3