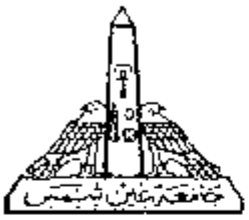

Ain Shams University

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Optimal Utilization of Cairo Regional Underground Railway Lines (CRURL)

By

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Chapter (1)
Introduction

1-1 General

Underground Metro (UM) represents the most reliable and safe mean of transportation in the crowded cities and important world capitals.

Cairo governorate represents one of the oldest metropolises which suffer from unplanned growth due to the high rate of both birth and immigration.

Several studies have been prepared to decide the best solutions for overcoming the serious problems facing the inhabitants of the regional Greater Cairo.

Certainly, traffic and transportation congestions are the most complicated problems.

Encouragement of shifting towards public transport has been the recommended issues. As well as it must give priority to high capacity modes over lower capacity ones. Consequently; Greater Cairo Undergound Railway Network (GCURN) could be considered the main mode of public transport.

This research deals with improving UM operation scientifically, accurately and practically to compile with the continuous increasing of passenger's demands to achieve safety and economy.

GCURN transport over 2 million passengers / day with an average speed 90 km/hr without any intersections with roads in isolated routes either by tunnels or bridges.

This thesis aims to propose solutions and recommendations to overcome the two following problems:-

- Continuous delays due to the unorganized sequence of the train's headway with passenger's demands which results in traffic jam inside the train & on the platform.

- operating the trains with its complete composition at off peak hours which results in reducing passenger's occupancy for every meter operating square than the international standard specifications causing unreasonable financial losses.

Appendix A gives some examples of Underground Metro all over the world while appendix B discuss Cairo metro history

1-2 Problem definition

Cairo, the premiere city of Egypt and one of the historical beacons of the Arab World, has reached a cross-road; its population has swelled to more than 14 million persons, thus placing growing stress on a variety of infrastructure systems. The increasingly difficult urban transport situation, characterized by a high degree of traffic congestion, constrained resources for public transport services and deteriorating air quality, lies in the forefront of such concerns, concurrently, the political, spatial and economic rules of Greater Cairo are changing; the ongoing implementation of the new communities program.

It's clear that new additional infrastructure construction cannot in isolation provide a comprehensive solution without being attached with an optimal operation.

There is a Continuous increase in passenger's demand relative to trips without a corresponding increase in the ordinary means of transportation which makes UM represents the ideal way to achieve the balance between supply & the demand.

So we must search for UM optimal utilization where it can achieve this balance with the lowest costs and safely operation.

An unorganized operation represented in the existence of two operating systems which don't achieve the optimal utilization and they are as follows:-

- Scheduled by the Authority

- The actual schedule

This mismatch between the previous systems tends two the following:

1- Wasting money during the unoccupied trips
2- This unorganized operation assure the possibility of accidents during the terrific jam at rush hours Which sequentially lead to that the rest of passengers stay waiting for the next train and thus wasting time

1-3Thesis Hypotheses

- Time taken for alighting or boarding divided by the number of passengers is assumed to be 0.5, 1.5, & 4.5 second/passenger for optimistic, normal & pessimistic operation respectively

- Each of Opening & Closing door time will be taken 1.5 second

- Maximum speed (Su) = 80 km/hr for line 1 & line 2

- Brake acceleration (b) & the brake jerk (J) are 1.1 m/s^2 & 0.5 m/s^3 respectively for Both lines
- Reaction time (Tr) is 3 seconds

- Maximum & minimum passenger's density inside coaches are 7& 3 pass/m^2 Respectively
- Maximum passengers density on the platform is 2 pass/m^2

1-4Thesis Scope

This thesis will introduce the optimal operation for GCURN lines (Helwan – Al Marg Al Gdida) & (Shobra Al Khima – Al Munib) safely and economically

1-5Thesis Objectives

This thesis aims to:
- Introduce suitable solutions for high workability efficiency using different technologies which lead to high quality of operating Systems for both lines and its effect on increasing the performance status.

- Design platform dimesions to satisfy passenger's services.

- Verify that the traffic demands have compliance with the official train schedule.

- Design a timetable which taking all the parameters dealing with passengers, Trains and station inter actions.

- Provide guidelines and recommendations aiming to support decision makers to improve the efficiency of metro's operating systems.

1-6 Thesis Methodology

In order to achieve the main objectives, this thesis followed the following methodologies:

1- Study of CRURN. (Chapter three)

2- Data collection of Rolling stock & platform specifications. (Chapter four)

3- Study of the passengers Traffic fluctuations annually and monthly. (Chapter five)

4- Field survey at peak and off peak hours for normal days and vacation days (Chapter six)

5- Proposing a mathematical model to analyze the collected data (Chapter six)

6- Derivation the suitable solutions and recommendations (Chapter seven)

1-7 Thesis contents

To realize this goal, the thesis is divided into seven chapters, which can be summarized as follows:

Chapter (1): Introduction

It consists of the problem definition, thesis hypotheses, thesis scope, thesis objectives and Thesis Methodology

Chapter (2): literature review

It is considered as a literature review for national and international studies, researches and projects

Chapter (3): Cairo Regional Underground Railway Network

It is Specified in studying and analyzing the construction and operation criterias for the first three lines (El Marg – Helwan), (Shobra el khima – AL Mounib) and (Al attaba – al abbasia) historically and geographically.

Chapter (4): Rolling stock & platform specifications

This chapter Discusses the engineering properties of the rolling stock represented in dimensions, , internal areas and number of seats also the mechanical properties represented in feeding and operation.

Chapter (5): Passengers Traffic Fluctuation

This chapter analyzes statistical data of both lines for annual passenger's traffic since metro start in 1987 till now, as well as a monthly survey for (2008, 2009 & 2010).

Chapter (6): Field survey & applications

Chapter six deals with a field survey which was carried out inside the train at peak and off peak hours, hence the passenger's density on the platform has been estimated.

A suggested mathematical model is proposed for analyzing the field survey data and concluding the conflict points inside the train and on the platform as well as determining the timing and stations where passenger's occupancy go less than the international standards.

Chapter (7): Conclusions & Recommendations

Chapter seven deals with Introducing suitable solutions and recommendations for acquiring high workability efficiency and improving service level, to achieve the highest economical, environmental and social profit

Chapter (2)
Literature Review

2-1 introduction

There are many researches that deal with underground metros; two research projects had been prepared, the first by Greater Cairo Transportation Planning with Japan International Cooperation Agency (JICA) while the second by the national authority of the underground metro.

Two research papers are presented as a sample; the first deals with evaluation of the first stage of Cairo regional underground railway line and had been published in Journal of the Egyptian Society of Engineering, while the second deals with the formulization of the proposed traffic evaluation function.

Two research studies are presented as a sample; the first deals with Railway Stations Planning, Design and Management, while the second dicusses the methodology for low cost improvment of the rural railway line capacity.

2-2 Research projects

The following two research projects deals with studying greater Cairo underground metro's planning and safety

2-2-1 a challenge for innovative Cairo transport (CREATS, September, 2002)

2-2-1-1 Project Objective

CREATS is comprehensive in nature that is adopting approaches designed to mitigate urban transport problems and contribute to sustainable development of the Greater Cairo Region. Three key objective form the foundation of planning effort:

- To formulate a master plan for the urban transport network in the study area to the year 2022.
- To conduct a feasibility study for the priority project(s) identified under the master plan.
- To carry out technology transfer to the Egyptian counter personnel in the course of the study.

2-2-1-2 Project Methodology

- Overall issues
- Goals and visions
- Missions of transport
- Propose five key strategies
    a- Improvement of people's mobility
    b- Optimal infrastructure development
    c- Safe and comfortable transport
    d- Accessible Transport for all
    e- Establishment of a sustainable institutional and financial mechanism

2-2-1-3 Project Conclusion

CREATS proposes a phasing concept that shows what activities, grouped into three dimensions, namely hardware (infrastructure); software (institutional arrangement); and humanware (education and training), should be carried out in the three phases over the next two decades, with both sectoral project linkages and inter-sectoral linkages.

CREATS proposes also a number of projects and programs to realize the five key strategies embedded in the master plan for achieving an integrated transport system.

2-2-2 Safety systems in Greater Cairo Underground Metro (Eng/ Sameh A. Refaat, May, 2004**)**

2-2-2-1 Project Objective

As a result of the modern technology & scientific theories which cause a gigantic revolution in the means of transportation including UM, so underground metro national authority focused on safety systems in all it's great projects carefully represented in:-

1- The 1st line of UM (Helwan – Al Marg Al Gdida.

2- the 2nd line of UM (Shobra el Khima – El Giza Supurb) & it's final extension (under construction (Saqiet Mekky- El Munib)).

3- UM lines which is in the present study

- The 3rd line of UM.

4- Ramses Complex mother building which consists of the central control building for both lines the 1st and the 2nd – high voltage plant 220 k.v

This is due to providing security to UM, its users, all electromechanical equipments & metro coaches through developing safety systems to fit the continuous increase in UM projects field in order to match the recent dangerous sources in this field & the threats facing UM & it's users so as to keep project continuity and public service providing.

2-2-2-2 Project Methodology

The following elements have been discussed for the 1st line as a safety system:

- Warning system in the 1st line.
- Air conditioning and ventilation equipment and the expulsion of smoke.
- Communication systems (PA system, Clocks system, Recording system).
- Securing the power supply.

The following elements have been discussed for the 2nd line as a safety system:

- Safe ride of metro trains
- Fire alarm systems

- Air conditioning and ventilation equipment and the expulsion of smoke (Smoke suction experiments)

- Water supplies

- Surveillance & control system in warden's room

- Central control position (CCP) in Ramses Complex

- Communication systems (intercom system, PA system, Clocks system, (CCTV))

- Securing the power supply for the metro

- Signage

The following elements have been discussed for Ramses complex building as a safety system:

all the necessary precautions have been taken into consideration for providing safety , prevention and Means of early warning against fire, mentioned as follows:-

- General Planning of the Site.
- The building is provided with emergency stairs for Rapid evacuation.
- The building is provided with Means of early warning against fire through Alarm buttons which is scattered in the vital areas.
- The building is provided with Means of direct contact with the management of Civil Defense of the relevant region In addition to means of wireless communication.
- Fire extinguishers of (5kg) for fires type (A, B, C) are distributed to each floor in the building with suitable number.
- The building is designed to resist collapse in case of explosion in one of the transformers.
- A special system is designed in direct auto extinguishing in case of burning one of the four transformers or in the oil tanks of cables and this through water reservoirs in the bedroom (5 reservoirs each of 10000liters).
- Each floor of the building is provided with two hose fire of 1" diameter & 20 meters long on a roller inside a fire wheel in two different directions as it can be used by individuals.

these fire hoses is feed by water elevated tanks through a free pipe of 2" which is connected to the bottom of these elevated tanks by 2 water pumps beside the tanks To achieve the required pressure where 30 cubic meter of water is saved Permanently to be used in extinguishing purposes till the arrival of fire trucks.

- each floor of the building is provided with two fire taps of 2" & a hose of 30 meters long, these taps are feed from the dry supply of 4" which is connected to a rapid rakour outside the building (beside the main entrance of the operation agency) on the rod – to be used by firemen When necessary.

- Fire extinguishers of (6kg) for fires type (A, B, C) are distributed to each floor in the building with suitable number.

- It is taken into consideration during the design of the electrical cables not to permit the proliferation of smoke and fire in case of any fire in the cables.

- Fire valves closes air ducts once sensing the high temperature by special sensors.

2-2-2-3 Project Conclusion

The research has concluded the following

- The modern international standard specifications concerning security & safety must be followed during the design of several equipments.
- Risks probabilities analyzing study must be implemented which have the way about how to deal with every attitude and its effect on passengers & line security.
- The used material must be selected from the non- flammable, fire resistant materials and the one which produce non-toxic gases on burning.
- Alternative systems methods must be used for sensitive systems in trains , also secure suspension systems for equipments which is harmful to passengers & line security in case of falling down.
- Following the procedures and means of strict security in every site during construction and Selecting competent persons for Following-up to comply with the rules of safety and health Indo.
- Using of high safety factors in calculating stresses and loads.
- Studying collision probabilities of trains and improving trains with safety systems which reduce collision effect on both passengers & trains.
- A dynamic load tests must be carried out to one of the coaches and some sensitive components to ensure its tolerance to the operating conditions throughout its life time.
-

2-3 Research Paper

2-3-1 Evaluation of the first stage of Cairo regional underground railway line (Hany Sobhy Riad, 1989)

2-3-1-1 Thesis Objective

- It is necessary to analyze the traffic fluctuations of passengers used the Metro of the Cairo Regional Underground Rail Line (CRURL)- first stage during its operation time (27 September 1987 - 12 April 1989) to evaluate its performance, level of service, impacts, and costs.
- The results of these studies are, normally, interesting and useful to be applied on the second stage of the CRURL which extends from El Shohdaa station to EL Marg station.

2-3-1-2 Thesis Methodology

The present research paper is dealt with the following main topics:

1- Description of Helwan - El Shohdaa line.
2- Rolling Stock Performances and Characteristics.
3- Travel Fare.
4- Carrying Capacity Fluctuations.
5- Derivation of Results, Applications and Recommendations.

2-3-1-3 Thesis Conclusion

1- Train frequency: must be changeable in harmony with the fluctuation of passenger's volume in Summer-Vacation, On Friday, and daily peak hours Train formations and trip length can be also varied to be harmonized with the fluctuation .
2- Travel fare: must be reduced for both one tripped tickets passengers and 3 monthed tickets passengers - (in particularly private sectors ones) to attract more passengers.
3- Severe punishment and regular inspections to penal the illegal passengers, the penalty of illegal passengers=225 P.T, only 0.04% of the total 10 % who had paid, and the penalty of cleanliness=1010 P.T 0.0035 %)
4- Coordination between Cairo Transit Authority (Buses), Heliopolis Metro Company, and Egypt National Railway would be achieved to realize the Rerouted transit lines suggested by Cairo Metro Interchange Coordination study.

2-3-2 a Passenger-Oriented Traffic Regulation Method for Metro-Type Railways (Murata, S. and Goodman, C J, 1997)

2-3-2-1 Thesis Objective

This paper deals with formulization of the proposed traffic evaluation function and the proposed traffic regulation method is shown. And techniques used in the proposed traffic regulation method are described in detail.

2-3-2-2 Thesis Methodology

The proposed traffic evaluation function has three passenger oriented terms, namely, waiting time inconvenience, travelling time inconvenience and congestion inconvenience, and an energy consumption term.
The traffic regulation problem to be solved is to find an optimum set of departure times and arrival times of trains that give the minimum passenger inconvenience, considering the following three constraints;
- The minimum running time constraint,
- The minimum departure-arrival interval constraint
- The passenger exchange constraint.

This problem is a large scale, constrained optimization problem. To cope with constraints, an idea of gradient projection is used.

To reduce computing time, three ideas,
- Decomposition of partial derivatives
- Fixed length receding horizon
- Recursive optimization are used

2-3-2-3 Thesis Conclusion

The proposed traffic regulation method is a kind of predictive controller, which periodically checks status of traffic and generates an optimal schedule.
Simulation results show that the proposed method can reduce passenger inconvenience up to 57% compared with two previously proposed methods within acceptable computation time, around 10 seconds for each cycle using 120 MHz PC.

2-4 Research studies

2-4-1 Railway Stations Planning, Design and Management (Julian Ross, 2006)

2-4-1-1 Study Objectives

The study examines a whole range of stations, from city stations handling tens of millions passengers annually, through smaller urban and suburban stations, to rural halts.
As important aspects of the rail renaissance that the world is now enjoying, metro and light rail stations are not neglected. Neither are specialist stations such as parkways, rail-sea terminals and airports terminals.

2-4-1-2 Study Methodology

The study is dividing metro station building into six layers as following:

1- Site

This is the plot of land on which the building stands, its geographical location, which is 'eternal'.

2- Structure

The foundations and load-bearing elements define a building. They are difficult and costly to change. A structure of steel, concrete, brick or occasionally timber or stone might last 30-300 years.

3- Skin

This is the outer covering, intended to repel the elements, absorb wear-and-tear, and give the building an attractive appearance. The skin may last up to 20 years. Roofing materials, wall cladding, windows and floor tiles all fall into the category of 'skin'. Deterioration, technical obsolescence and changing fashions are all reasons for renewing the skin of a building.

4-Services

These are cables, ducts and pipes containing the materials and data to allow the building to function, in the commercial world lasting 7-15 years.

5- Space plan

The interior layout, comprising non-structural walls, floors and ceilings, might only last three years in an office building but could remain longer elsewhere. Station space plans may change from time to time as ticket offices are enlarged (or reduced or even abolished), as new retail units are added, as buildings are extended to provide additional accommodation, and so on.

6- Stuff

Includes furniture, vending machines, public telephones, and signage and so on, They may appear, be moved around and then depart on timescales of weeks, months or even a few years. Deeply embedded systems are more expensive to renew.

2-4-1-3 Study Conclusion

Metro stations must be pleasant and simple to use, providing facilities that passengers need. They must function as ' managed spaces', maintained in good condition, with the owner in control, so that passengers feel safe and secure.

2-4-2 Methodology for low cost improvment of the rural railway line capacity (Wael Mohamed Ibrahim, 2007)

2-4-2-1 Study Objectives

Suggest different scenarios to calculate and improve the railwa line capacity with low cost.

2-4-2-2 Study Methodology

a- Study the affecting factors on the line capacity.
b- Study of untraditional methods.
c- Prepare some different scenarios.
d- An economic comparison between those methods and that of providing electric signal system.

2-4-2-3 Study Conclusion

The proposed method gives safety & rapid use to study easily the rural railway line capacity corresponding to other scenarios.

Chapter (3)
Cairo Regional Underground Railway Network

3-1 introduction

This chapter dicusses the historical and technical development for both lines (Al Marg Al Gdida – Helwan), (Shobra Al Khima – Al Munib) under the supervision of the Egyptian company for Metro and talking about the running project of the third line as illustrated in Figure 3-1

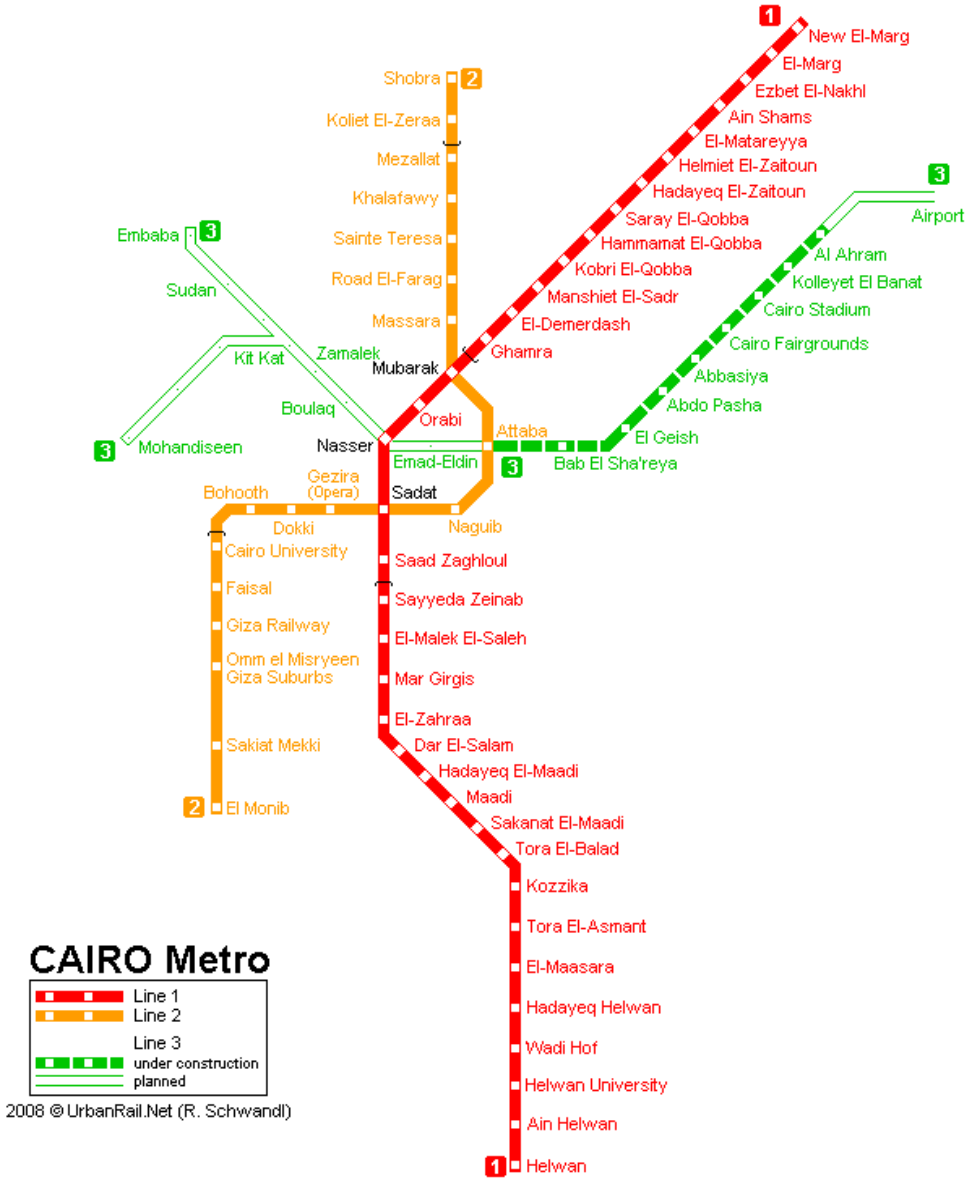

Figure 3-1 Greater Cairo Underground railway network

3-2 First line

The implementation of the first line started in 1982 to connect the industrial area and Helwan University with the Commercial zone in downtown and North-east of Cairo, where it reaches to Al Marg Al Gdida with length 43.7 km, mutually linked to:-

- The main railway lines Of Upper and Lower Egypt at Al Shohdaa station.
- (Suez – Ismailia) line at Ain Shams station.
- (Al Marg - Shebein El Kanater – Qalyoub) line at Al Marg station.

This line consists of 35 stations (5of them is underground).

Underground stations and the tunnel had been established by short excavation manner through constructing sheet walls for supporting excavation sides to become a part of the origin with the upper slab and foundation, The soil had been injected below these sheet walls to reduce permeability and to avoid affecting water level outside them to protect the adjacent buildings.

In detail, the first line had been opened after finishing the linkage between an existing railway line which is already extends from Bab El Louk Square (Abdeen) to Helwan (south suburb in Cairo) and another railway line extending from Ramses Square to El Marg (north suburb in Cairo), this is through a tunnel excavation to connect between them so as To avoid the general layout of the streets in downtown.

The tunnel includes 5 stations (with length 4.8 km):-

- Al shohdaa (Ramses Square)
- Ahmed Orabi
- Gamal Abdel Nasser (Ambulance Station)
- Anwar El Sadat (El Tahrir)
- Saad Zaghloul

Respectively from north to south, with the knowledge that there are between these stations two main stations (El Shohdaa) & (Anwar El Sadat), where it represents the linkage point between the first and the second line which was subsequently implemented.

This project is designed for headway of 2.5 minutes and a capacity of 60000 passengers per hour/direction, with maximum speed 100 km/hr and a travel time within 65 minutes from Helwan to Al Marg Al Gdida.

So, this project achieved a great success in social, economical and environmental fields after its operation also getting rid of the traffic jam was one of the most remarkable points, as well as reducing environmental pollution in the greater capital because of reducing surface means of transportation percentage.

The first line of underground metro represents the backbone of metro lines network in greater Cairo, where it passes through the most populated areas.

<u>This line was established in three phases:-</u>

- Phase :1 Ramses – Helwan (opened in 01/10/1987)-(with length 29 km).
- Phase: 2 Ramses – El Marg (opened in 12/04/1989)-(with length 14 km).
- Phase: 3 El Marg – El Marg Al Gdida Completion of the north part of the line (Opened in 05/1999) - (with length 1.3 km)

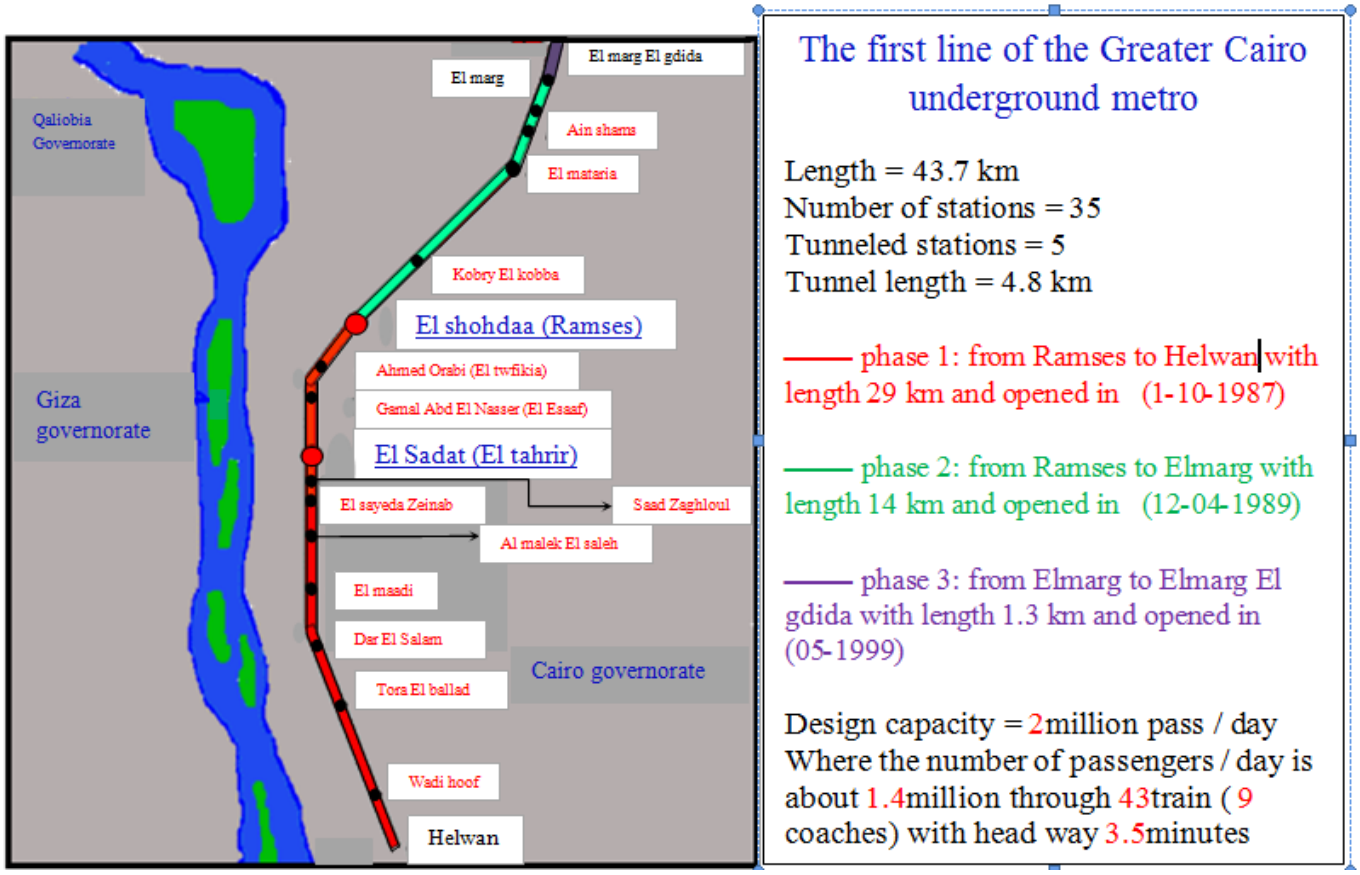

Figure 3-2 underground metro of the first line

The first line stations are designed to be easily maintained, as well as designers used metro logo in many designs. Through these 3 phases the abilities of the line developed to rise from 500 thousands passengers /day before the operation of the third phase until it reaches to 850 thousands passengers /day in 1993continuing rising till 1million passengers in Al-Fitr feast in the same year (1.056 million passengers / day), in 2010 it reaches (1.430 million passengers / day) through 43train.

There is no doubt that UM is a civilized step for solving the problem of traffic and transportation in Cairo, but there is a huge potential for this line which can add a lot if it were considered and utilized.

Despite the steady increase in traffic volume (6.3% annually for passenger /km, 4.8% per day for the passengers and 3.8% for the seat /km), the percentage of coaches occupation (Occupancy of seats and places) did not exceed 45% in spite of the slight increase year after year.

Despite the movement regularity by 97% of the schedule time, 94% of the headway, it is remarkable that the delays caused by the breakdowns of the rolling stock increases where as the delays caused by operation decreased.

But as a result of the continuous increase in population and public transportation problems it was necessary to think about establishment of metro second line.