

# Designing Fast Transportation Network in Damascus: An Approach Using Flow Capturing Location Allocation Model

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**Abstract.** The increasing population in large cities, such as Damascus, leads imperatively to upgrade the transport system to fulfill new requirements in terms of modern, effective, secure, operational and fast transport network services. Damascus future Metro network is probably one of the solutions to realize the social, economic and technological development. This paper applies Flow Capturing Location Allocation Model (FCLM) to trace the optimal lines, localize the appropriate stations, and estimate the approximate cost. It suggests changes to Damascus directorate Initial line plans based on optimal stations localization criteria..

**Keywords:** Transportation Management, Damascus Metro Network, Flow Capturing Location Allocation Model, Station Localization.

## 1. Introduction

Damascus city population amounts to 7 million with around 200000 registered vehicles in 2016. According to General Company of Technical Studies and Consulting, nearly 84 million passengers are circulating in Damascus per year. National Statistics estimate that Damascus city population will reach 2020 approximately 8 million and approximately 16 million in 2040. The Syrian capital is a focal point because of its commercial and industrial importance and it is located in the highway between Jordan and Turkey.

Similar to many old cities, Damascus has certain specific features affecting its transport circulation system (Hall, 2012):

-Narrow streets and one-line crossings.

-Many housing quarters in non-authorized zones. Therefore, it is too difficult to provide modern and comfortable transport services.

-Accelerated increasing number of vehicles that outnumbered the rhythm of establishing and enlarging streets and squares.

-The lack of parking stations with many vehicles barking in the pavements, particularly in the central zone, occupying 25 – 30% of its surface, disturbing and causing danger to walkers.

The empirical contribution of this research is threefold. First, it suggests a modification of stations localization (The Green Line) already determined by Damascus Directorate. Second, it locates stations in an already traced line without determined stations (The Red Line). Third, it suggests an entirely new line (proposing the path and the stations) (The Blue Line).

## **2. Modern Transport Systems**

Tramway old systems have been utilized in the past in Damascus and some other Syrian cities. New Tramway systems are now common in western cities to insure collective and comfortable transport. The modern tramway trains are nearly 30 meters' length and 2.5 meters' width, with a capacity of almost 300 passengers per train (6 passengers per square meter) (Schöbel, 2012).

This system is flexible in terms of integration with other transport systems particularly in crossroads. On the other hand, it is easily (with reduced cost) adaptable to add new trains in case of increased demand without disturbing walkers (De Dios Ortuzar and Willumsen, 2011) The main disadvantage is its limited ability to be developed or redirected.

Scientists and engineers around the world have focused on inventing and developing Metros as new railing transport system (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2011). The Metro is well known for its advantages (compared to tramway) in terms of speed, security, return on investment and environment protection. The Metro system is a collective fast transport system with a high transportation capacity, appropriate to satisfy the demand in big cities and to reduce the circulation bottlenecks in more than million citizens' cities. Moreover, Metro lines could be under the ground at several levels (deep, medium, flat) or on ground separately in specific paths or based on columns.

Cruz-Zambrano et al. (2013) argue that there are 360 urban railway transport networks around the world with 155 ongoing networks including the cities that gave up their tramway lines in the fifties then renewed them (Schöbel, 2012). Metro systems are proved to be the optimal collective transport in the world due to the following advantages:

1. High transportation capacity reaching 50 thousand passengers per hour in one direction. Tramway capacity is only 23 thousand passengers per hour.

2. Economic consuming of energy.
3. Environment protection against oil flaming pollution.
4. Timetable punctuality and high transport speed.
5. More safe than other transports means.
6. Distances between stations vary from 1000 to 1200 meters while tramway distances between stations vary from 500 to 700 meters.

### **3. Optimal Stations Localization Criteria**

Walker (2011) suggests the following elements to be considered in setting up the station localization: train speed, service rate, population density, minimal distance between two stations, maximal distance between two stations, streets slopes, infrastructure expansion, network robustness.

Train speed: speed should be between 25 and 30 km/hour, according to distance between stations. As stations are close to each other, speed should not be too high.

Service rate: it is the number of trains serving the concerned line. According to the population density in the area, in case of high population density such as "Souk Al-Hamidieh", "Midhat Pacha", "Al-Hijaz" Station, increasing the trains' number is a necessity to serve more passengers.

Population density: it is primordial to determine the path of any line and its stations localization. When the population density augments, the stations number and the wagons number should be increased (WTPI, 2012).

Minimal distance between two stations: Minimal distance between two stations should be at least 400 meters, going up to 1000 meters (Zhao and Siu, 2015). A walker can usually walk this distance.

Maximal distance between two stations: when distances between stations are long, it is easier to enlarge the network coverage of streets, serving more zones without duplicating services.

Streets slopes: when streets are not horizontal, passengers cannot walk in ascending or descending streets for 400 meters. In this case, distances between stations should be less than 400 meters.

Infrastructure expansion: reducing the number of stations on a line allows for a better exploitation of the city infrastructure and an extension of development/investment projects (Matsubara, 2013).

Network robustness: The Metro network must be able to react effectively and efficiently to accidents caused by external elements (fire, explosion). In addition to the network capacity to add, transfer and remove quickly and safely some links or some stations without work stoppage.

## 4. Research Methodology and Results

This research uses Flow Capturing Location Allocation Model (FCLM) based on “minimal time between two specific points” to trace the optimal lines, localize the appropriate stations, and estimate the approximate cost.

The Green Line (Damascus Directorate, 2007): it is the first element of the global network permitting Damascus to continue its economic and demographic growth. This Line links northern Damascus (Qaboun) to its South-West (Moadamiyeh) with a length of 16.5 km.

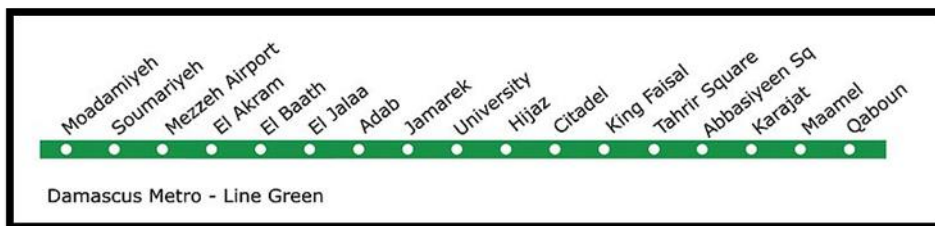


Fig. 1: Damascus Metro as suggested by Damascus Directorate (2007)

This 17 stations line can serve the habitation and commercial areas. The line will be on a bridge between (Moadamiyeh) and (Mezza Airport), but becomes under the ground between (Mezza Airport) and (Qaboun). The line can transport 840,000 passengers per day (25000 passengers per hour in one direction) during the rush hour with 29 trains to 40 trains in 2030.

Trains are scheduled nearly automatically with a speed of 30 km/hour spending half an hour to arrive to Qaboun coming from Moadamiyeh. The distance between stations is 1 km, with a stopping time of 25 seconds.

Working hours are divided in three periods (rush hour, day out rush hour, night) starting at 5 o'clock a.m. until midnight. Trains width is 3 to 3.2 meters, with a maximal length of 104 to 107 meters assuring a capacity of 1100 to 1200 passengers per train, with a density of 5 standing passengers per meter. The Electricity network needed to provide trains with energy is composed of 10 generators transforming electricity from alternative current 20 KV (treated in two high voltage 230kv stations) to a continual current of 750 volts.

Maintenance and parking locations are of 950 meters' length and 150 meters' width between Moadamiyeh and Soumariyeh.

We suggest the following Modifications of stations' localization following the above criteria:

- Due to the current Syrian crisis and for more security, Moadamiyeh station will not be linked to the line, keeping it open to be re-linked in the future.

- (Mezza) highway's length is nearly 4 km with a high population and circulation densities. The adopted criteria concerning distances between stations and service

rate lead to increase the number of stations on the (Mezza) highway to 7 stations with 400 meters' distance between: El-Akram, El-Baath, AL-Jalaa, Al-Iskan, Al-Razi, University Residence, and Literature faculties.

-Damascus university station should be located among 5 faculties, because of the very intensive circulation.

-A new station located at Souk Al-Hamidieh should be established instead of Citadel station to accommodate the high population density at the Souk entrance.

-King-Faisal station should be replaced by a station located under Al-Thawra Bridge, because of the high population density (Hamidiyeh, Bzouriyeh and Manakhliyeh souks).

-A new station should be added after Al-Dahdah Cemetery, because of the high population density in Baghdad Street.

-Kaboun station should be temporary cancelled due to security reasons.

-Cars parks should be established in Soumariyeh, Hijaz, Karajat stations, in order to encourage people to use the Metro.

-Rush hours are between 7 hours a.m. and 16 hours p.m.

When it comes to cost-profit analysis, the cost of this line is estimated to be 1200 million Euros (inflation rate is excluded). Economic Internal Rate of Return (EIRR) for 30 years is 11% which is higher than 10% the break-even rate of return which indicates that the project is feasible. The green line Cost is composed of digging cost, stations cost, trains cost, garage and maintenance costs, passengers' cars parking cost, Electricity and technical costs.

According to the European Central Bank, the inflation rate on the Euro during the last 5 years is 0.7 %. Hence, the project cost is expected to be 1,208 million euros (1200 million Euros \* 0.7 % = 1,208). Distributing the total cost on different types of costs (fixed such as stations and trains costs, variables such as labor and maintenance costs) the approximate cost of each station is equal to (1,208 million / 17 = 71.08 million Euros).

The Red Line: Although this line route that links Barzeh to Mukhayyam AL-Yarmouk has been examined in previous studies (Damascus Directorate, 2007), station distributions on this line has not been localized.

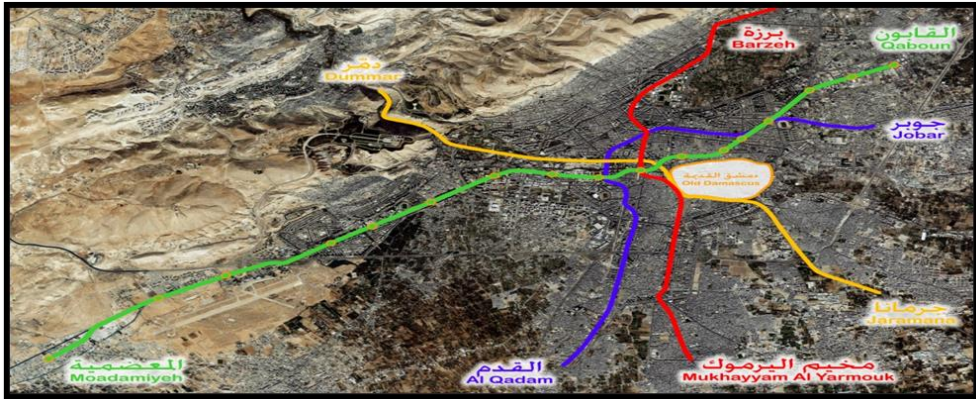


Fig. 2: Three Lines (Green, Red and Blue) routes as suggested by Damascus Directorate

After applying the above-mentioned criteria of localization, and considering the zones' infrastructure, 17 stations have been determined to be efficient and effective: Barzeh (at Hamish Hospital to serve Barzeh zone, HIBA and HIAST students), Kasioun malls (shopping activities), Ibn Al-Nafis Hospital (to serve the patients and their visitors), Ibn Al-Amid (ascending street toward, Ibn Al Nafis Hospital with 400 meters length), Salah-Eddin Mosque (to serve the East of Rokn-Eddin and Salah Eddin avenues), Shamdin Square (to serve Shamdin, Abonnour Mosque and Sheikh-Mheddin zones), Maysat Square (to serve the street going to Jessre El-Abiad, Jobbeh and Bernieh), Shahbandar Square (to serve the street going to Arnous Square, AL-Hamra, Education Ministry and Mazraa Street till Iman Mosque), Sabeh-Bahrat (Seven Lakes – to serve Al Abed, Pakistan, 29 MAI and Baghdad streets), Mohafaza (to serve AL sahm hotel, Victoria bridge, Al Bahsa, 29 MAI streets), Al-Hijaz railway (it's a main station in the Metro Network), Bab-Sreejeh (to serve Bab-Sreejeh souk), Al-Moujtahed Hospital (to serve the hospital and the zone of Al-Moujtahed), The Southern zone Entrance (An important station to be linked with Bab Mousalla to serve passengers travelling to the south), Cross Al-Zahera with the Southern Surround (to reduce the traffic density in that zone).

AL-Hakleh (to serve AL-Zahera zone), and Mukayyam AL-Yarmouk (at AL Batikha square to serve this high population density zone with it will more secure and to be linked to Al Qadam railway).

The Blue Line: this is a new proposed line that links south Damascus to its north. We apply the same method in order to determine the path of this Metro line and to localize its stations according to the adopted criteria.

First, it's necessary to consider areas that have not been served by the others two lines. Then, the same criteria will be applied to localize the stations according to the infrastructure and the ability of establishing a station in the selected area.

The main areas that have not been served by others lines are: Kafar Souseh residence area (sham city center and Damscino malls), Kafar Souseh Square, Jisre

Al Rais (already served but it's a corresponding station to be linked to other lines. The Green zone covering Al-Malki, Abou-Rommaneh, Rawda, Al-Mouhajerin).

According to the criteria, Kafar Souseh residence area is a high-density populated area even at night because of the commercial centers. Hence, it needs to be served. Kafar Souseh Square is a very high traffic circulation zone. It needs to be served to reduce the traffic bottle neck.

Busses assembly under the bridge Jisre Al Rais is a main place in Damascus-city daily transport. This place should be linked to several stations in all lines. Green line zone needs to be served because of its importance in the modern part of Damascus-city (banks, hospitals, shops, and so on).



Fig. 3: Three Lines (Green, Red and Blue) routes as suggested by FCLM

The localization of stations for the new Blue Line could be as follows; Al-Akram Mosque, Al-Razi farms (a governmental decision has been taken to upgrade Kafar Souseh and Mezzeh zones in order to become an integral residential city). Two stations on this line are necessary to serve this wide modern area. Abdullah-ben-Rouaha Square (important stations because it is close to sham city center and Damscino malls). Al-Andalus Hospital (it is a new urban zone, so it needs to be served by a low rate service station). Kafar Souseh Square (is the most important station due to its high population density). SANA Agency (it is close to the future Syria towers project). Jisre Al Rais (it is a link between the Line Bleu and the suburbs buses). Al-Madfah Park Cross (the first station in the Green zone). Al-Rawda Square. Shora Stop (the first important station for Al-Mohajerin habitants). Adel-Beyham School (a station close to the school and to Al-Morabit Mosque). Finally, Al-Neiraben Park (the last station with a train maintenance location).

Cross stations in the Metro Network consists from Al-Akram Mosque station, Al-Hijaz station and Bab-Mosallah station.

Al-Akram Mosque station is a cross (commutation) station between the Green Line and the Blue Line in addition to the south entrance of Damascus. Therefore, this station should be a big one with wide stairs to ensure more security.

Al-Hijaz station is a commutation station between the Green Line and the Red Line. Therefore, this station should be a big one with wide stairs to ensure more security.

Bab-Mosallah station could be a commutation station if there is a link between Bab-Mosallah and the south zone buses.

## **5. Conclusion**

Transportation Demand growth rate in Damascus is nearly 6.57 %, which makes it primordial to adopt a new modern transportation system. Tramway trains can be used instead of Metro trains in the Blue Line, because of the line shortness and the medium population density along its stations. The Metro lines and particularly the Green Line will generate large economic and social advantages. The Green Line covers the critical traffic zones such as Al-Somarieh, Al-Baramkeh, Jesr-ALrais, Al-Thawra Street, where transport buses are assembled. Robustness procedures could be first applied only on the large and commutation stations, because of its high traffic density. Underground garages should be established to reduce the number of cars parking in the streets, to facilitate the traffic movements.

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