International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Passenger Capacity of Underground Metro by the Use of Neural Network Program (NNP)

Mai M Eldeeb, Akram S kotb, Hany S Riad, Ayman A. Ashour

Abstract: The present paper deals with studying on (GCUM) by the use of (NNP), consequently, the future passenger fluctuations can be well predicted and it will be helpful to make wise decisions for realizing the most safety and economic future operation.To attain this goal, a methodology was proposed to collect the necessary data and analyze them. These data were applied as the inputs into the Neural Network Program (NNP) for the two (GCUM) lines '1' & '2' to have two models as inputs and outputs, one for the 1st line and the other for the 2nd one, taking only into consideration, the input, and output variables which gave tolerances less 19% than that were obtained by applying excel program. Thus, it is easily to predict the future capacity for any predicted year, and the corresponding headway as well as to prepare an estimated schedule complies with the required future Rolling Stock (RS).

Keywords: Greater Cairo Underground Metro (GCUM), metro schedule; annual fluctuations of metro passengers, Neural Network Program (NNP), Rolling Stock (RS)

I. INTRODUCTION

An Artificial Neural Network (ANN) can be defined as a system composed of units distributed parallel processing that calculates certain simple mathematical functions (usually nonlinear) [1]. The key element in the structure of ANN is the neuron. This structure is inspired by the format of the human brain, which consists of a vast network of cells called neurons [2]. Wei and Yiting [3] verified the control of the volatile neural network (NN) by learning impedance for a restricted robot, subject to the dynamics of the unknown system, the effect of state restrictions, and the uncertain compatibility environment that the robot deals with. A mysterious NN learning algorithm was developed to determine the uncertain plant model. The salient feature of the mysterious NN is that there is no need to obtain prior knowledge about the uncertainty and sufficient amount of observed data. Also, impedance learning is introduced to deal with the interaction between robot and its environment, so that the robot follows the desired destination resulting from learning impedance. Lyapunov barrier function is used to address the impact of State restrictions. With the proposed control, closed loop system is stabilized by Lyapunov stability theory and trace performance is guaranteed under conditions of State restrictions and uncertainty. Simulation studies are performed to illustrate the effectiveness. [3]. Barbara [4] has made use of the Hopfield-type neural network for construction problems schedule. This general scouting method has provided good results in the school schedule. The main purpose of the paper is to describe the way we applied the neural network to produce feasible school timetables, which are polynomial time in the length of the input. When mapping a school timetabling problem onto a Hopfield-type neural network, the complexity of the network can become quite large. The incorporation of a genetic algorithm allows more complex scheduling problems to be solved more efficiently. Two examples, first on a simple and second on a `real' data set, are used to demonstrate the potential on neural networks and genetic algorithms that seem to outperform traditional Operational Research methods in solving some NP-complete problems. Masoud Yaghini et al. [5] display a high-resolution artificial neural network model to predict the delay of passenger trains in Iranian railways. In their model, three different methods were used to determine inputs including normal real number, binary encoding, binary array input and encoding. One of the major challenges of using a neural network is how to design a superior network for a specific task. To find an appropriate structure, three different strategies are called the Quick Method, the Dynamic Method, and the Multiple Method. Masoud Yaghini et al. [6] also, prevented the proposed model from overfitting in modeling, according to cross validation, we divide existing passenger train delays data set into three subsets called training set, validation set, and testing set. To evaluate the proposed model, we compare the results of three different data input methods and three different architectures with each other and with some common prediction methods such as decision tree and multinomial logistic regression. To compare different neural networks, we consider training time and accuracy of neural networks on the test data set and network size. In addition, to compare neural networks with other known prediction methods, training time and neural network accuracy were taken on the test data sets. To make a fair comparison among all models, we sketch a time-accuracy graph. The results revealed that the proposed model has higher accuracy. [6]. Carey and Kwiecinski [7] developed a simple stochastic method to knock-on train delays. Knock-on delay refers to that part of a train's delay, which is caused by other trains in front of it.

Manuscript published on 30 August 2019.
*Correspondence Author(s)
Mai Moaz Eldeeb, civil department, higher technological institute 10th of Ramadan city,
Akram soltan kotb, construction building, faculty of engineering and technology Arab academy for science, technology and maritime transport, Cairo
Hany Sobhy Riad, Civil Eng. Dept. Ain Shams University Cairo,
Mohamed Ayman Ashour, architecture Eng. Dept. Ain Shams University Cairo

Yuan [8] developed a randomly modified model to delay trains and delay deployment at stations. The most important scientific contribution of this research is an innovative analytical probabilistic model that accurately predicts the impact on train delays, including the impact on the accuracy of trains' dates in the stations on the basis of an extension of the theory of time hindering railway operations to random phenomena. Zonglei et al. [9] developed a new method based on machine learning to predict large scale of flight delays. This new method first does k-means on the data of the flight delays, which is an unsupervised learning to get the standard of each class of delay. With these classes of delay, a supervised learning method can be used to build an alarm model. For the supervised learning, they use decision tree, back propagation (BP) neural network, and Naive Bayes. Dragana et al. [10] developed decision support system developed on the basis of artificial neural network to predict the number of sleeping cars in rail transport. VCD input system of train track, month and sleeping car type and number of wharves (supply) and the number of departures and ticket price and GDP, while the output of the neural network is the number of tickets sold (demand). By comparing the results obtained through the form with the results derived from historical data, it was found that the developed model is largely compatible with reality. You can use the decision support system developer for capacity planning, because it is important for the rail operator that already knows the number of sleeper cars that must be met. All data is obtained from the Serbian railways.

II. PROBLEM DEFINITION

As the growing number of citizens in large metropolises, public traffic jam has become a big problem. Due to the large transport capacity, metro, or subway, was a critical cure to the over population in big cities. However, the routes of metro were set in advance and the rail was exclusive. The ceiling of metro was surpassed easily with the development of the cities. GCUM has now introduced the tide strategy to relief the burden of traffic, which is to increase the number of metro in rush hours. Yet, the number of passengers varies widely between different days, and traffic jams are heavily time to time. It will be helpful if the governors know the amount of passengers in future to make wise decisions. The number of metro passengers was determined not only by the passenger flow at previous moment but also the passenger flow at the same time in the days before. It is required to propose a methodology based on field data to easily predict the future capacity for any predicted year, and the corresponding headway as well as prepare an estimated schedule complies with the required future Rolling Stock (RS).

III. RESEARCH METHODOLOGY

It is practically useful to predict the future operation metro demands and supplies taking into consideration the past and present operation metro demands and supplies.

The present methodology proposes the steps to collect the necessary data and analyze them to have the most safety and economic future operation applying The Neural Network Program (NNP).

The Neural Network has been a rapidly growing field of computer science that has direct applications in the construction industry. Neural Networks are among the Current Artificial Intelligent research areas.

Neural Network Program (NNP) differs from Excel Program (EP) that it can deal with non-numerical variables such as peak, off peak hours, and different circumstances and consequently it can analysis them while (EP) can't deal with non-numerical variables. It combines them in some way, performs a generally nonlinear operation on the result, and then outputs the final result relative to the base year (2017).

i. INPUT DATA

Eight factors were proposed as the factors affecting passenger capacity as given data (Inputs), while only one output (which is the average capacity (Y)) had been obtained by applying the Neural Network Program (NNP).

The program determined five affecting factors which are the following:

Travel time between two successive stations. (x1)

Waiting passenger on waiting zone (x2)

Alighting and boarding passenger (passenger exchange). (x3)

Different conditions (education, vacations, Fridays and Eid). (x4)

Operating hours (peak and off-peak) (x5)

While there are three infecting factors which will be cancelled as they gave illogical outputs for the following three reasons:

Social level of passengers in each station (x6): as the operating conditions depending upon the driver and the passengers at operating time.

Passenger density at waiting zone (x7): as it is similar to standing passengers onto metro.

Factor of safety (x8): as it depends on the driver behavior.

1- Obtaining the official data for the Annual fluctuations of metro capacity for line 1 and line 2 during 2008 till 2017

Table (1) summarizes the annual fluctuations of metro capacity (passenger /hour / directions) within the period 2007/08 and 2016/17 and the corresponding best fitted capacity

Table (1) the annual fluctuations of metro capacity (passenger /hour / directions) for the sum of the passengers for both line '1' and line '2'

X	1	2	3	4	5	6	7	8	9	10
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017*
Official data	746	791	813	859	926	1039	1201	1406	1680	1829
Best fitted	769	766	793	853	943	1065	1218	1402	1617	1864

Retrieval Number: J95380881019/19©BEIESP
DOI: 10.35940/ijitee.J9538.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
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* Notes:
1) Source: Greater Cairo Underground Metro
2) Year 2017 is considered as the base year.
3) Year 2017 represents also the actual field data collected by the authors.
2- Questioner
The following table gives an example of the answers of some metro passengers during the personal meetings for the 1st and 2nd lines passengers
Table (2) an example of the personal meetings results for the 1st and 2nd lines passengers.

Gender : male □ female □	**Age:**	**time: peak □ off □ peak / off □**
exchange between lines: yes □ no □ maybe □	purpose: work □ study □ visit □ other □	increase ticket price effect: yes □ no □ may be □
line: 1st □ 2nd □3rd □	ticket waiting time:	platform waiting time:
exchange station	origin station:	destination station
trips/day:	trips / week □	advantages:
disadvantages	recommendations:	

Source: authors.
2- Field survey
Field survey were collected for the peak and off peak of both passenger traffics and metro trips at different operation conditions for both 1st and 2nd line.

ii. DATA ANALYSIS (OUTPUTS)

There is only one output which is the average capacity (Y) representing the number of passenger per hour per direction (either up or down).
1- Analyzing the annual fluctuations of metro capacity (passenger/hour/directions) within the period 2007/08 and 2016/17 and the corresponding best fitted capacity
Figure (1) illustrates the growth Metro passenger within 2008-2017 for the sum of 1st and 2nd lines

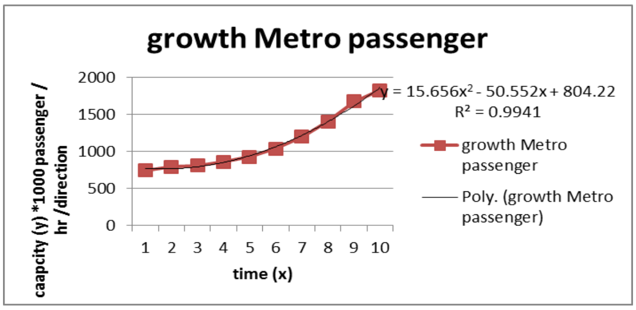

Figure (1) growth Metro passenger within 2008-2017 for the sum of 1st and 2nd lines

2- table (3) gives an example of field survey were collected for the peak and off peak of both passenger traffics and metro trips at different operation conditions for both 1st and 2nd lines.
Table (3) example of field survey for the off peak passenger traffics at Friday for 1st line (up direction)

station	kilometer	interval distance (D)	interval times between two succsesive station (measured) (T)	speed (S)	Act. headway (H)	capacity (Y)
	Km	Km	Hr.	Km/hr	min	
New EL-Marg	42.448	1.18	0.0528	22.28	3.50	11245.71
EL-Marg	41.271	1.80	0.0337	53.35	3.40	16217.65
Ezbet EL-Nakhl	39.475	1.19	0.0217	55.06	4.50	12866.67
Ain shams	38.282	1.12	0.0212	52.96	5.10	14482.35
El-Matarya	37.161	0.78	0.0178	43.79	5.00	14016.00
Helmiyet El-zeitoun	36.380	1.06	0.0200	52.95	4.80	14350.00
hadayek El-zeitoun	35.321	1.00	0.0215	46.47	4.80	12425.00
saray El-Kobba	34.322	0.90	0.0207	43.50	4.00	14460.00
Hammamat El-Kobba	33.423	0.65	0.0182	35.50	3.60	16800.00
kobri El-Kobba	32.778	0.99	0.0188	52.41	3.90	14153.85

3 Neural networks
Preparing a neural network two models for both 1st, 2nd lines ,considering that (X) and (Y) are the input and output variables respectively which gave tolerances less than 19% than that were obtained by applying excel program.
This difference is due to either uncontrolled human behavior or the neural network model itself ability.
Figure (2a and 2b) show two examples for the inputs /outputs data: (X) and (Y) at feast and main holiday

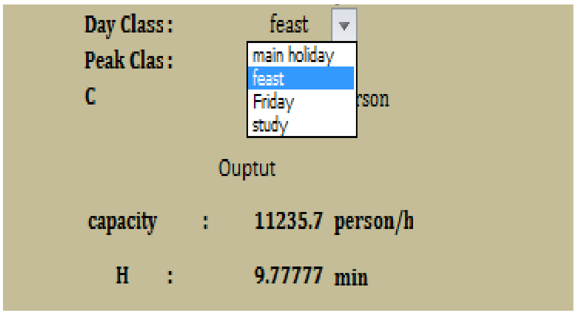

Fig (2a) an examples for inputs (X) /outputs(Y) data at feast

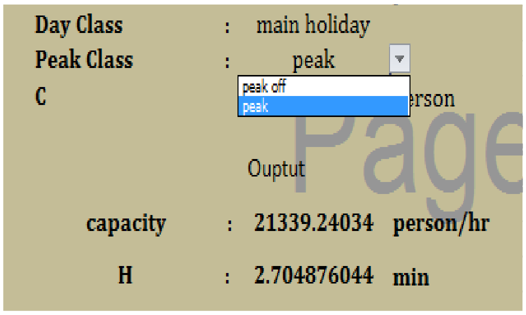

Fig (2b) an examples for inputs (X) /outputs(Y) data at main holiday

4- Prediction of the future capacity for the period 2018 till any predicted year
4.1 Estimate the capacity (Y) before year 2017
To estimate the capacity at any past year, the following equation was obtained as the best fitting of the previous official records.

$Y = 15.656\ X2 - 50.552\ X + 804.22$……………………………………...….(1)

(As shown in figure (1))
Where,
Y represents the capacity in 1000 passengers / hour /direction
X gives the difference between the current year and 2007

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DOI: 10.35940/ijitee.J9538.0881019
Journal Website: www.ijitee.org

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4.2 Prediction of passenger capacity (Yt) and the corresponding minimum headway (Hmin) at any predicted year after 2007

Yt = Y* growth rate

Which: Yt passenger capacity at the predicted year

Y passenger capacity at the base year 2017

Growth rate Y= 15.656*(t^2)-(t*50.552) +804.22 (1')

x = predicted year – 2007 (2)

Consequently, the minimum headway (Hmin) can be calculated from the following equation

$$Hmin = \frac{C}{Y} \quad (3)$$

Where C is the maximum allowable passengers per train which was taken 7 standing passengers per meter square at peak hours, and 3 standing passengers per meter square at off-peak hours taking into consideration the growth ratio of the metro passengers relative to the base year 2017.

4.2 estimate the required Rolling Stock (RS) in future;

Knowing the minimum headway (H), one can conclude the minimum required (RS) at peak and off peak hours using the following formulae:

Trip / direction at peak hours $= \left(\frac{\text{Peak hours duration (min)}}{H\left(\frac{min}{train}\right)}\right)$ (4) (To be approximated to the just smaller figure)

Shift / train at peak hours = $\left(\frac{\text{Peak hours duration (min.)}}{\text{turnaround time (T)}\left(\frac{min.}{train}\right)}\right)$ ……… (5)

(To be approximated to the just bigger figure)

(T) = (T duration up + T duration down + T Stop destination+ Tstop origin) ....…….. (6)

Where:

(T): Turnaround time (min. /train)

T duration up and T duration down : trip duration within both the up and the down directions

T Stop destination and Tstop origin: stop time at both destination station and origin station

$$\text{Required (RS) for peak} = \frac{(\text{Trip/direction}) * 2}{\text{Shift / train}} * 1.15 \quad (7)$$

Assuming that:

15% of (RS) are under maintenance.

The train capacity is nearly equal for both up and down direction

Similarly, the required (RS) for off peak can be estimated.

I. CONCLUSION

This paper deals with the study (GCUM) using (NNP), therefore, could predict future passenger swings well and it would be useful to make wise decisions to achieve more practical future economic security.

To achieve the objective, a methodology was proposed to collect and analyze the necessary data using Neural Network Program NNP for two (GCUM) lines '1' & '2'. All conclusion and recommendation are summarized by:

1- Estimation of passenger capacity for 1st line by (ANN)

- Comparing the ratio between study and main holiday circumstance on peak hours was 1.507, while the ratio on offpeak was 0.96. To explain these figures, the passenger traffic purpose during study was for school and university as well as works, while in main holiday the traffic purpose was only for works.
- Comparing the ratio between Friday and feast circumstance on offpeak hours was 1.63. To explain these figures, the passenger traffic purpose during Friday was mainly for shopping and visits, while in feasts, most of passengers travel outside Cairo.

Table (4) passenger capacity for 1st line on different circumstance

Circumstance	main holiday		study		feast	Friday
peak/ off	peak	off	peak	off	offpeak	offpeak
Capacity (pass/hr.)	32567	15110	49086	14539	11236	18361

2- Estimation of passenger capacity for 2nd line by (ANN)

- Comparing the ratio between study and main holiday circumstance on peak hours was 1.48, while the ratio on offpeak was 1.33. To explain these figures, the passenger traffic purpose during study was for school and university as well as works, while in main holiday the traffic purpose was only for works.
- Comparing the ratio between Friday and feast circumstance on offpeak hours was 1.24. To explain these figures, the most of passengers travel outside Cairo.

Table () passenger capacity for 1st line on different circumstance

Circumstance	main holiday		study		feast	Friday
peak/ off	peak	off	peak	off	off	off
Capacity (pass/hr.)	21339	18301	31570	24289	10373	12903

3- According to future capacity on can predict the required RS to achieve maximum GCUM's ability

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AUTHORS PROFILE

Mai Moaz Eldeeb
Civil engineering, Msc, teching assistatnt higher technological institute, Asharqya, Egypt, Address: Address: 93 Hafez Ramadan St. from Ahmed Fakhry st., Nasr City, Cairo, Egypt.
E-Mail: mai.moaz@hti.edu.eg, eng_maimoaz@hotmail.com
Place of birth: Cairo-Egypt Date of birth: November 21, 1984 Languages: Arabic and English Educational Qualifications: PhD Candidate in Railway Engineering, Dept. of Public Works, Ain Shams University. Thesis title "Maximizing Passenger Capacity and Socio- Economic Impact of Greater Cairo Underground Metro (GCUM)", Aug. 2015.
M.Sc. in Civil Engineering, Department of Civil Engineering, Faculty of Engineering, AlAzhar University, Egypt, March 2015.
Thesis Title: "Strengthening of reinforced concrete elements using carbon fibers reinforces polymers fabric".
B.Sc. in Civil Engineering, Department of Civil Engineering, Faculty of Engineering, Higher Technological Institute (Excellent with honor, 90.4%), Egypt, August 2006.
Project Management Professional PMP, preparation course

Akram Soltan kotb, construction and building engineering department, associate professor, Arab academy for science technology and maritime transport, Sheraton, Egypt, aksoltan@aast.edu
Associate Professor of Transportation & Railway Engineering, Arab Academy for Science & Technology & Maritime Transport, College of Engineering & Technology, Construction & Building Engineering Dept., Cairo, Egypt.
Member of the JOINT RAILWAY EXPERTS TEAM between AFRICAN UNION and PEOPLE'S REPUBLIC OF CHINA for AFRICA INTEGRATED HIGH SPEED TRAIN INITIATIVE
Executive Director of the Center of Engineering Consultant at the College of Engineering and Technology (Cairo Branch), Arab Academy for Science & Technology & Maritime Transport
Research areas: Transportation and Traffic Engineering, Railway Engineering, Railway Noise and Vibration, Traffic Noise, and Highway engineering

HANY SOBHY RIAD, Nationality : Egyptian, Specialization : Railway and Transportation Planning, Position : railway expert, Actual Profession: Professor of Railway Engineering at Faculty of Engineering – Ain Shams University – Cairo – Egypt, Year of birth : 4 March 1948 , Address: 5 Staff members of Ain Shams University Apartments – Demerdash – Abbasia – Cairo – Egypt E-mail Address: hanysobhyr@yahoo.com
Mobile Phone: +2 01117557275
Telephone : +2 26823976
KEY QUALIFICATION

- Experience of railway track design and maintenance for lines , station signals and turnouts.
- Experience of rail way economy and management
- Experience of traffic data collection and analysis of transport system.

Prof. Mohamed Ayman Ashour , Prof. of Architecture & Urban Planning Dean of Faculty of Engineering – Ain Shams University.
ayman.ashour@eng.asu.edu.eg
The experience of Prof. Ayman Ashour includes several axes, some of which are related to the academic and educational aspects, where he has been assigned to the academic posts starting from 1982 as a demonstrator to the post of professor of architecture and urban planning since 2005. As for the administrative and leadership aspects, he has been assigned as Vice Dean of the faculty for the post graduate and research and Dean of the Faculty of Engineering, Ain Shams University since October 2014 to date. Regarding his professional and consultancy expertise, he established his consultancy office (ArchPlan International) since 1985 to date. The academic and administrative experience includes the development of engineering and architectural programs to keep up with international systems through international partnerships with the best universities to award double degrees, as well as linking scientific research and student projects and innovations to the needs of the country's development plans and contributing through applied research in the development of the industrial sector and thus economic development (vision 2030).

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