Code	Major activity	Minor activity	TV	Prerequisit	R1/R2
H6		Installing securing, monitoring and	60	H1, H2,	2 6
I1	Hardware and software configuration	Configuring apps and server database	65	H5, H6	2 5
I2		Configuring wireless network	50	H5, H6	1 7
J1	Field testing	Testing apps	50	I1,I2	2 4
J2		Testing feeder bus and station matching	50	I1,I2	1 6
J3		Testing controlling and managing system	50	I1,I2	3 5
K1	Training and finalizing	Training dispatchers	40	J1,J2,J3	2 5
K2		Training repairers	40	J1,J2,J4	1 7
L	Subsystem integration and verification	Integration of system with train stations	65	K1,K2	1 6
M	Initial system deployment and system validation	Final preparing and integrating actions	75	M	1 4
N	System validation		85	N	2 4

$$Min\ Z = \sum_{EST_i}^{LST_i} t \times x_{n+1,1,t} + \sum_{i=1}^{n} \sum_{m=1}^{Mi} \sum_{EST_i}^{LST_i} C_{im} \times x_{imt} \tag{1}$$

Subject to,

$$\sum_{m=1}^{M_i} \sum_{EST_i}^{LST_i} x_{imt} = 1 \tag{2}$$

$$\sum_{m=1}^{M_i} \sum_{EST_{n+1}}^{LST_{n+1}} (t + d_i) \times x_{n+1,i,t} \leq DD - 1 \tag{3}$$

$$\sum_{m=1}^{M_i} \sum_{EST_i}^{LST_i} (t + d_i) \times x_{imt} \leq \sum_{m=1}^{M_j} \sum_{EST_j}^{LST_j} t \times x_{jmt} \tag{4}$$

$$\sum_{i=1}^{n} \sum_{m=1}^{M_i} r_{iml} \sum_{t=1}^{DD} x_{imt} \leq R_l \tag{5}$$

$$\sum_{i=1}^{n} \sum_{m=1}^{M_i} r_{imk} \sum_{\max(t-d_{im},EST_i)}^{\min(t,LST_i)} \leq \gamma_k \tag{6}$$

$$x_{imt} \in \{1,0\}$$
$$i = \{0, \ldots, n+1\}, M = \{0, \ldots, M_i\}$$
$$l = \{0, \ldots, L\}, k = \{0, \ldots, K\}$$
$$t = \{EST_i, \ldots, LST_i\}$$

Indexes and indicators:

i: the index of non-dummy activities

$t_{i:}$ indictor for the time duration between the earliest and latest times of starting activity i

m_i: indictor of approach of conducting activity i

k: indicator of renewable resource

l: indicator of non-renewable resource

EST_i: earliest start time for starting activity i

LST_i: latest start time for starting activity i

Parameters:

C_{im}: cost of activity i with approach m

x_{imt}: the binary decision variable $\{\begin{matrix} 1, if\ activity\ i\ with\ approach\ of\ m\ starts\ at\ t \\ 0, otherwise \end{matrix}$

d_i: required time duration for activity i

DD: deadline of completing the project

R_l: accessibility level to non-renewable resource l

γ_k: accessibility level to renewable resource k

r_{imk}: consumption amount of activity i with approach m from renewable resource k

r_{iml}: consumption amount of activity i with approach m from non-renewable resource l

The Eq. 1 is the objective function of the model that includes two parts. The first part minimizes the starting time of the last activity and the second part minimizes the total cost of completing the project. Eq. 2 ensures each activity must be completed. Eq. 3 ensures that all activities of the project must be completed before the deadline. Eq. 4 is related to the precedence of activities when the start time of an activity considering its required duration of time must be less than start time of the next activity in sequence. Eq. 5 is related to non-renewable resources. The value and amount of these resources must be defined before the start of the project and these resources should be consumed during the project. Materials and budget are examples of these resources. Eq. 6 is related to renewable resources. These resources can be used in the project several times. Infrastructures and manpower can be examples of these resources.

ANALYSIS AND RESULTS

The SA approach has been used widely for solving RCPSP in past studies (Kolisch 1996, Bouleimen and Lecocq 2003). The SA algorithm has a permutative structure that seeks to find the optimal solution through an iterative neighbor generation procedure. This iterative process would be continued until the best value for the objective function of the problem was found. One of the main advantages of the SA algorithm is the ability of escaping from local traps by having a mechanism of accepting worse neighbor solutions in a controlled manner (Bouleimen and Lecocq 2003). Table 2 shows the proposed SA algorithm for solving RCPSP in this study. As discussed, due to the binary variable in the constraints, the problem turns to a NP-Hard problem which makes the proposed model different from the standard project scheduling problem. The proposed SA algorithm has been coded in MATLAB 2019. The best solution of the algorithm is 975 unit time (see Figure 2). Also, Figure 3 shows the activity precedence diagram and critical route of the project.

Table 2. proposed SA algorithm for solving RCPSP

Step 1: Problem definition
Create model of the problem
Define cost function
Step 2: Setting SA parameters
Set maximum iteration to 200, set minimum iteration to 20
Set initial temperature =10, set temperature dumping rate to 0.97
Step 3: Initialization
Create initial solution (random solution)
Update best solution ever found
Array to hold best cost values
Array to hold NFEs
Set initial temperature
Step 4: Set main loop
For it=1:MaxIt
For it2=1:MaxIt2
create neighbor
IF x_{new} is better, so it is accepted
Else x_{new} is not better, so it is accepted conditionally
IF if $x=x_{new}$
End
End
Update best solution
IF x=BestSol
End
End
Reduce temperature, T=alpha*T
End

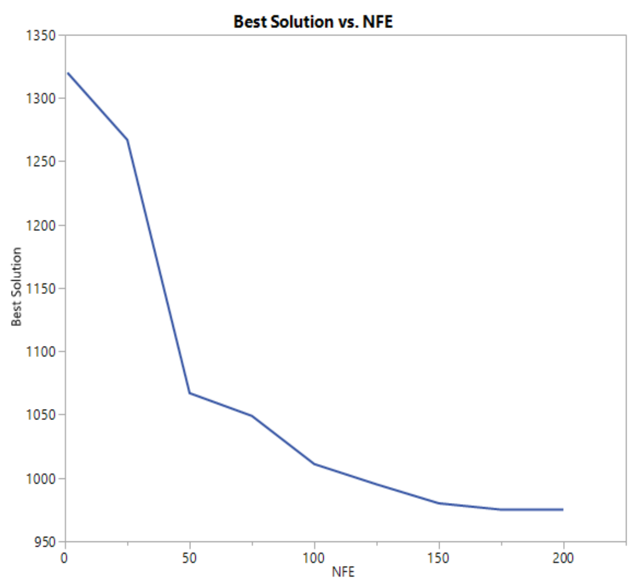

Figure 2. The result of SA algorithm

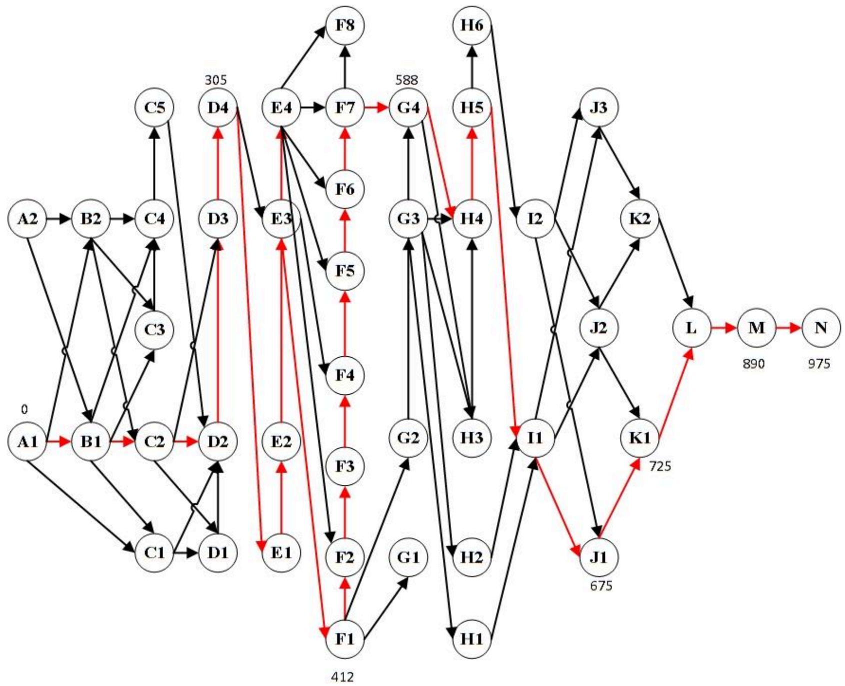

Figure 3. Activity precedence (AON) diagram and critical route of activities

Based on the precedence of activities in the ATRF project, a network can be formed to represent the relationship between activities. The critical path is the longest path from start activity to end activity of the project, and it determines the total time required to accomplish the project. All the activities on the critical path must be started and finished exactly according to the schedule; otherwise, the finish time for the entire project will be affected (Ma 2012). As it shown in Figure 3, the red arrows represent the critical route of the activities and optimal values of critical tasks are shown for the critical activates.

CONCLUSION

This study aimed to solve a RCPSP for optimizing the construction phases for automated demand responsive feeder transit system projects in suburban and rural areas with the objective of minimizing implementation makespan costs. The authors reviewed related literature and consulted with experts in automated and emerging transportation systems to understand the details of all required activities considering their required time durations and precedence constraints for implementing an automated demand responsive feeder transit system in a suburban and rural area. The proposed RCPSP of this study was highly constrained and was categorized as a NP-hard problem; therefore, a metaheuristic SA algorithm has been implemented to solve the problem. The proposed algorithm successfully handled solving the problem.

One important point in this study is that since the shared automated feeder transit services are not currently available, the proposed activities and their required time durations and precedence constraints are based on estimations from the literature reviews and experts in the related fields.

Therefore, by considering the rapid improvement of related technologies, obtained results of this study would be uncertain and open to change. Despite this fact, this study attempted to cover that gap by designing a realistic automated feeder transit service, and the authors believe that the presented results illustrate a big picture of future related projects and activity priorities regarding these emerging transit services. Future studies are recommended to use more detailed activities with updated technologies and also implement other metaheuristics.

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Demand Characteristics of the Newly Proposed Kuwait Metro

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ABSTRACT

Traffic models are of foremost importance in the planning of any transportation infrastructure. This importance lies on the ability to predict future behaviour of users. In order to properly study the demand patterns and characteristics of the city of Kuwait, a detailed modelling of these phenomena is required. The purpose of this modelling is to create a useful tool with which to objectively evaluate the alternatives proposed in this paper research. Future demand on the proposed public transport network had been forecasted based on the transportation model developed by Atkins for Colin Buchanan & Partners in the framework of the 3rd Kuwait Masterplan Review. This model, built on a SATURN platform, was translated to a CUBE environment. That initial model, built for a 2003 base year, was then updated to the current situation. The current road network was checked, and amended or completed when necessary, as well as the public transport services.

Keywords: Demand; Kuwait; Metro; Railways; Transportation; Networks.

INTRODUCTION

Population in general has seen a very enormous growth in the twentieth century. As a result, urban population had moved for areas that are away from cities. Because of the massive urban development, many challenges showed up such as high density over limited space and the outsized increase in number of vehicles (Aljoufie 2014; Global Mass Transit 2015; Pojani and Stead 2015). Population is considered an indicator of travel demand (Javid et al, 2013). Sperling and Gordon (2009) stated that number of vehicles is expected to reach two billion globally in the coming two decades. This increase had caused several problems such as traffic jams, air pollution and highway accidents (WHO 2004; Santos et al, 2010a). Using cars by riders for road trips is harmful to rural areas. The infrastructure design is usually not able to cope up with the huge numbers of cars (Jaarsma et al., 2009). Meanwhile, the growing numbers of vehicles cause noise pollution (Gray et al., 2001). Also, parked vehicles are a kind of visual pollution (Tolley, 1996). The overall amount of automobile kilometres travelled had increased from 48 billion in 1980 to 84 billion in 2011 (FOD Mobiliteit en Vervoer, 2013). The huge increase in traffic associated with more peak periods had caused a heavy congestion and extensive time losses (Redmond and Mokhtarian, 2001; Sultana, 2002). Encouraging people to use the public transport is very important (Benenson et al, 2010; Boon, 2003; Mavoa et al, 2012). Moreover, public transport is good for health in some ways like walking to the stations or cycling (Rojas-Rueda et al, 2012). So as to convince people to utilize public transport, travel time is a vital unequivocal factor (Beirão and Sarsfield Cabral, 2007; Kwok and Yeh, 2004; Redman et al, 2013). Public transportation networks are dependent of their uses. For example, the distance of the trip and time required are less than other automobiles. Also, the tracks used for public transport are less congested as compared to cars using normal roads (Owen and Levinson, 2015). Likewise, these public networks like buses and railways had been assembled and enhanced in numerous urban communities to augment access and support travel ridership (Cervero, 2004). In general, the greater part of the transportation problems rises when vehicle don't fulfill the request of urban mobility (Global Mass Transit, 2015). Many researches had been done to determine certain transport related issues in urban regions (Rodrigue et al, 2013; Doi and Kii, 2012; Pan, 2012). The process of re-arranging streets, transport frameworks and railways can help in controlling the use of land to accomplish more reasonable mobility (Rodrigue et al, 2013; Pojani and Stead, 2015; Litman, 2017). Finally, cities would incredibly benefit from reducing the problems related to transportation. This can be achieved through executing techniques and strategies adopted worldwide that match city-particular needs (Zavitsas et al, 2010).

DESCRIPTION OF THE INITIAL SATURN MODEL. TRANSLATION TO CUBE

Networks

The model developed in the frame of the 3rd Kuwait Master Plan Review included an extremely detailed road network, as well as highly comprehensive Public Transport network. Both networks included all necessary data for a correct demand modelling. Where the road network is concerned, link lengths, number of lanes, free-flow speed, hourly capacity and delay-flow functions, are also included as shown in Table 1. The public transport service attributes included routes, stops and headways and fares. Additional data were also taken in account such as parking fares at selected facilities. Both of these networks where successfully translated to CUBE, with some minor adjustments due to software requirements, such as zoning system, among others. Figure 1 shows the base year road network in CUBE.

Zoning System

The zoning system includes 495 zones (Sectors 1, 2, 3 and part of sector 4). This system was kept in CUBE, though centroids where renumbered to comply with CUBE requirements (correlative zone numbers). This zoning system covers both existing urban areas and future/ongoing urban developments (New Towns). Figure 2 shows the zoning areas.

Demand Data

The base year 2003 demand data, that is matrices for both private vehicle and bus trips, used in the 3rd KMPR model, were derived form 1995 matrices, updated with 2003 count data.
The data used in building the model included the following:

- Surveying of over than 50000 residents of 6334 households throughout the Metropolitan Area of Kuwait.
- Surveying of almost 3000 employees and their employers at establishments close to the alignment of the proposed transit system.
- Manual and automatic traffic counts at almost 500 locations throughout the Metropolitan area

Table 1: Flow Delay Functions

Road Type					Junction	F.F. Speed	Speed @ Capacity	Capacity/Lane	Power
Index	Type	Speed	Lanes	Frontage					
1	Dual	120				96	70	2000	4.64
2	Dual	100				95	70	2000	3.04
3	Dual	80	3+			76	55	1850	4.34
4	Dual	80	2			68	50	1650	3.33
5	Dual	45		Primary		62	30	1450	2.89
6	Dual	45		Secondary		47	30	850	2.68
7	Dual	45	2	Shopping		49	30	1000	3.84
8	Single	45				42	25	1000	1
9	Dual	80			Rbt	63	52	1150	5.83
10	Dual	45			Rbt	56	41	1150	2.68
11	Dual	45			Rbt	45	25	8550	3.59
12	Dual	45			Rbt	46	30	1000	2.53
13	Dual	120			Signals	96(+27s)	70(+57s)	2000*	4.64
14	Dual	100			Signals	95(+27s)	70(+57s)	2000*	3.04
15	Dual	80	3+		Signals	76(+27s)	55(+57s)	1850*	4.34
16	Dual	80	2		Signals	68(+27s)	50(+57s)	1650*	3.33
17	Dual	45		Primary	Signals	62(+27s)	30(+57s)	1450*	2.89
18	Dual	45		Secondary	Signals	47(+27s)	30(+57s)	850*	2.68
19	Dual	45	2	Shopping	Signals	49(+27s)	30(+57s)	1000*	3.84
20	Single	45			Signals	42(+27s)	25(+57s)	1000*	1
21	Short Traffic Signal Approach				Signals	30(+27s)	30(+57s)	*	1
22	Traffic Signal Exit Link					30	0	0	0
23	On-/Off-Ramps					68	50	1650	3.33
24	Filter Lane		1			50	50	1000	0
25	Filter Lane		2			55	55	1000	0
26	U-turn					33	30	850	1
27	Roundabout Circulating Link					22	0	0	0
99	Bus/Zone					30	0	0	0

*Signals are given the smaller value of the link capacity or (850 x the number of entry lanes)

- Measurements of travel time and traffic speed on over than 300 km of roads of different types on 9 routes in the Metropolitan Area.
- Observations of junction operation, capacity, delays and queuing behaviour at 27 separate locations.
- Measurements of traffic signal timings and phasing at 62 junctions.
- Bus passenger counts at every major stop on every route operated by KPTC scheduled services.

These data were validated and analysed using different software's such as SPSS: household and establishment interview data analysis; trip end modelling, RIAS and ROADWAY (trip matrix Building and Validation): roadside interview data analysis; trip matrix building, SATURN: private vehicle network building; matrix building and assignment, MOTORS: public