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Mahmoud El-Shourbagy

*Assistant Professor of Civil Engineering Department, Faculty of Engineering, Mansoura University, Mansoura, Egypt.*

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## Timetable Optimization in Urban Areas

جدول نموذجي للمسير بالمناطق الحضرية

By

Dr. Mahmoud E. El-Shourbagy,  
Assistant professor, civil Engineering Dept.,  
Faculty of. Eng. El-Mansoura University,  
El-Mansoura - Egypt

الخلاصة : الهدف من اعداد هذا البحث هو تشكيل جدول زمني لمسير وحدات النقل العام داخل المناطق الحضرية الواقعه في الدول الناميه وكمثال لذلك مدينة المنصورة بجمهورية مصر العربية بحيث يناسب الظروف الاقتصادية لهذه المناطق فقد تم تشكيله على أنه يستخدم أقل عدد ممكن من الوحدات المتحركة . وفي هذا البحث تم اعداد برنامج على الكمبيوتر لاجاد الأزمنه المطلوبه لتشكيل هذا الجدول على جزء من شبكه الاتوبيسات داخل مدينة المنصورة كمثال لاحدى المناطق الحضرية الصغيرة (في حاله الشبكات الكبيرة يستحسن استخدام لغه Turbo - Pascal نظرا لصغر وقت تشغيله) . كما يمكن تطبيق هذا البرنامج أيضا على شبكات وسائل النقل العام الأخرى بالمناطق الحضرية .

### ABSTRACT:

The aim of the paper is to prepare time - tables for the bus networks under the special conditions of urban areas (El-Mansoura city as example). The time-table optimization presented herein is based on the minimization of bus units. The paper describes a computer program (in case of great bus networks, computer program using Turbo - Pascal can be used for saving time). The practical applications of this program leads to good results. This program can also be applied for other public transport networks in urban areas.

### 1. INTRODUCTION

The increasing difficulties involved in handling today's urban public transport explain the recently numerous efforts under the special economic conditions to develop new transportation systems.

For economic considerations, the bus system can be used in most transportation planning.

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For preparing optimal time-tables

- Data should be available to optimize the planning of public transport services.
- Time-tables should be feasible to be executed. The scheduled route times should provide the drivers the possibility of arriving in due time at the terminal.
- Deviation in trip times on one route should not influence the execution of the service at the next route.
- The actual number of passengers must be considered.

References of this subject are almost few. Most of them are not explicitly demand - oriented, referring to complete public transport network planning. Thus Holroyd [3] calculates the optimum size of a square grid side to minimize total travel time, while Kreko [4] gives a solution for the axes network case. Byrne and El-Shourbagy [1,2] present a method for deriving the bus route positions which minimizes the bus units and user costs.

Rüger [6] gives an interactive graphic method for the connection between bus routes as first stage for time-tables optimization.

In this research computer program has been developed for planning and optimization of public transport time-tables control.

This research has been based upon the applications of Rüger [5] and Voigt [7] dealing with such subject.

## 2. PROBLEM POSITION

The preparation of public transport time-tables is one of the most essential steps within the process of transportation planning. The select of public transport mode leads to the applicable time-tables. The advantages of bus transport include the flexibility of lines that enables management to adjust the time-table alignment.

The general trade-off in this time-tables optimization is between the minimum direct travel time to the user and the cost of travel to the user. Theoretically, quickest direct travel to each passenger would minimize user cost, but also maximize operating cost and therefore is impossible.

Thus this paper describes computer program planning by using of turbo-pascal language under 2-special conditions:

1. minimum travel time,
2. minimizes of bus units.

### 3. MODEL INPUTS

The proposed computer programs presented herein on the transportation demand with transportation supply.

Model input on the side of transportation demand is the trip demand matrix  $(T_{ij})$ , with its field  $(i,j)$  denoting the number of bus passenger trips for each route from zone  $i$  to zone  $j$ . Matrix  $(T_{ij})$  might be obtained from a passenger survey in El-Mansoura city [2].

Model input on the side of transportation supply is the network of potential bus lines, that is normally the urban main street network. It consists of nodes  $\{p\} = p_1, p_2 \dots$  etc. and of links  $\{L\} = L_1, L_2 \dots$  etc. . Each link is defined by travel time  $\{t_r\}$ , sequence time between any 2- vehicles  $\{tz\}$ , sequence time between 2- vehicles at the same line  $\{t_s\}$  and change time for the each new trip  $\{tw\}$ . The travel time  $\{t_r\}$  implying the time to travel from node  $p_1$  to node  $p_2$ .

Connection between transportation demand and transportation supply must be taken for preparing time-tables for the public transport networks. Connecting transportation demand and transportation supply means here: to supply as many passengers as possible with direct travel on routes with restrained travel time, whereas the number of bus lines, busses etc. may not exceed the available means of the operator. The travel time restraint works as a function of the actual shortest travel time.

Thus, the time-table optimization presented herein is based on the minimization of bus units and direct travel time. The calculations for preparing time-tables has been programmed in turbo-pascal language.

The particular calculation steps of the turbo-pascal programs are depicted in item (5).

#### 4. MODEL OUTPUTS

Of course model outputs depend tightly on model inputs. In this case, if we consider the bus lines networks (travel time and the sequence time between vehicles), we can get the following results:

1. Start time for each line in case of peak-hours, day and evening traffic.
2. Change time for each new trip between the arriving to the destination and starting from it.

These results are presented the main base for preparing time tables.

#### 5. ILLUSTRATIVE EXAMPLE

The example of application will be a part of the bus network in El-Mansoura city as shown in Fig. (1)

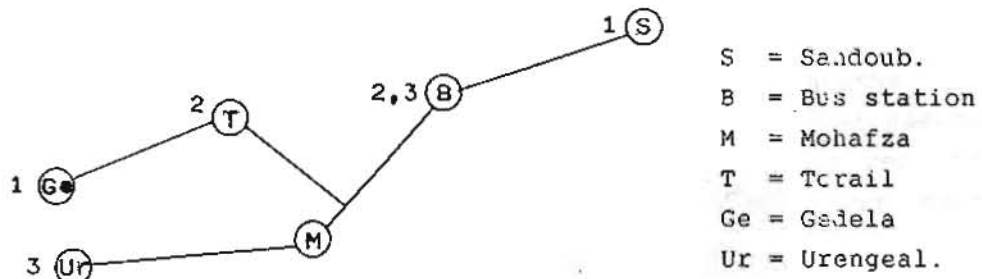


Fig. 1. Part of bus network in El-Mansoura City.

The corresponding travel time for each link in above network shown in table (1).

Table (1) Travel time for each link in El-Mansoura bus network

Link	S-B	B-M	M-Ur	M-T	T-Ge
Travel time (min.)	9	8	6	5	3

The data tabulated in table (1) and traffic time in table (3) were given through interview by one of the responsible managers in East - Delta - Bus - company.

The above bus network might be obtained as a result of axes network solution by using of "Ungarische mathematical method" [1,4]. This solution gives a minimum number of bus lines and bus units as shown in the following table (2).

Table (2) No of lines and bus units in El-Mansoura city

Line	Route (O/D)	No of vehicles
1	S/Ge	7
2	B/T	
3	B/Ur	
Total	Network	10

For the above bus network, we can obtain the graph of the time-tables connection for the lines 1,2 and 3 as a shown in figure (2).

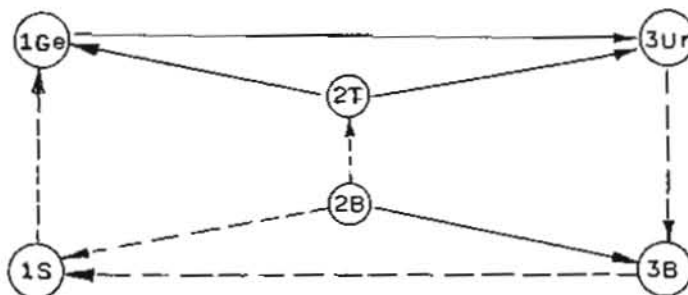


Fig. (2) The probable time-table connections for lines 1,2 and 3.

In this paper a computer program using turbo-pascal language has been written and used to prepare time-tables for the above bus network in El-Mansoura city. The cases taken into account are peak-hours, day and evening traffic. This program is based on the solution of the following equations according to the shape of the time-tables connection (see fig. 2).

The following equations are valid for the cases under consideration with changing the constant F:

$$t_{22B3B} = t_{22B1S} - t_{23B1S}$$

$$t_{22T1Ge} = F_1 + t_{W1Ge} + t_{22B1S} - t_{W2T}$$

$$t_{22T3Ur} = F_2 - t_{W3B} - t_{23B1S} + t_{22B1S} - t_{W2T}$$

$$t_{21Ge3Ur} = F_3 - t_{W3B} - t_{23B1S} - t_{W1Ge}$$

WHERE,

$t_{22B3B}$  = Sequence vehicle time for line 2 from B before line 3 from B.

$t_{W3B}$  = Change time for line 3 at B.

$F_1, F_2, F_3$  = Constants depend on type of trips according to conditions of traffic along the routes through the day (Refer to Appendix A)

The solution of the above mentioned equations in case of peak-hours, day and evening traffic can be obtained by the program listed in the appendix A.

#### 6. RESULTS AND CONCLUSIONS:

The obtained results using the written program have been listed in table (3) considering the above mentioned different cases.

Two special conditions must be taken for preparing time tables: - minimum travel time with  
- minimum bus-units.

For realizing the result of this research in the field, two conditions must be examined for that. First, the sidewalk should be wide enough to accommodate waiting passengers and allow easy passage for other pedestrians. Second, bus-stop bays should be designed. Bus-stop bays are particularly useful on streets with one lane per direction where stopping in a driving lane causes major delays and disruption of traffic flow.

Under the above conditions, the practical applications of this research program leads to good results. The research program can also be applied in other public transport networks in urban areas.

Table (3) : Bus time - table for lines 1,2 and 3 in El-Mansoura City

Type of traffic	Line	Route O/D	Start Travel time	Change time for a new trip
Peak - hours traffic ( $t_T = 15$ min)	1	S	01 16 31 46	6
		Ge	00 15 30 45	4
	2	B	04 19 34 49	10
		T	11 26 41 56	9
	3	B	00 15 30 45	10
		Ur	06 21 36 51	7
Day traffic ( $t_T = 20$ min)	1	S	05 25 45	7
		Ge	13 33 53	3
	2	B	06 26 46	5
		T	08 28 48	9
	3	B	00 20 40	5
		Ur	01 21 41	7
Evening traffic ( $t_T = 30$ min)	1	S	01 31	6
		Ge	00 30	4
	2	B	22 52	24
		T	15 45	10
	3	B	00 30	24
		Ur	22 52	8



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*APPENDIX (A)*

The list of the "time tab" program using Turbo-Pascal-language during the peak-hours traffic headway ( $t_r=15\text{min}$ ), day traffic headway ( $t_r= 20 \text{ min}$ ) and evening traffic headway ( $t_r= 30 \text{ min}$ ) respectively is given below.

```

PROGRAM Time tab for  $t\tau = 15 \text{ min}$  ;
VAR a,b,c,G,G1,G2,G3,G4,i,k,s,x,y,z : INTEGER;
    H : REAL;
PROCEDURE UMRECHNUNG ;
BEGIN
IF G > 15 THEN
BEGIN
H := G/15
G := G - (15 * TRUNC(H) );
END ;
IF G < 0 THEN
BEGIN
H := -G /15 ;
G := 15 + (G - 15 * TRUNC (H) ) ;
END ;
END ;
BEGIN
FOR a = 5 TO 6 DO
BEGIN
WRITE ( 'A - SCHLEIFE, a = ', a, ' ;' ) ;
FOR b := 5 to 13 DO
BEGIN
WRITE ( 'B - SCHLEIFE, b = ', b, ' ;' ) ;
FOR C := 6 TO 13 DO
BEGIN
WRITE ( 'C - SCHLEIFE, C = ', C, ' ;' ) ;
FOR i := 4 TO 11 DO
FOR K := 6 TO 9 DO
FOR S := 4 TO 11 DO
FOR X := 6 TO 9 DO
FOR Y := 4 TO 11 DO
FOR Z := 4 TO 11 DO
BEGIN
G := X - Y ;
UMRECHNUNG ;
G1 := G ;
G := 6 + a + x - b ;
UMRECHNUNG ;
G2 := G ;
G := 4 - C - Y + X - b ;
UMRECHNUNG ;
G3 := G ;
G := 13 - C - Y - a ;
UMRECHNUNG ;
G4 := G ;
IF ( (G1 = i) AND (G2 = K) AND (G3 = s) and (G4 = Z) ) THEN
BEGIN
WRITELN ;
WRITE ( 'a = ', a, ' , 'b = ', b, ' , 'c = ', c ) ;
WRITE ( 'i = ', i, ' , 'k = ', k, ' , 's = ', s ) ;
WRITE ( 'x = ', x, ' , 'y = ', y, ' , 'z = ', z ) ;
READLN ;
END ;
END ;
END ;
END ;
END ;
END.

```

```

PROGRAM Time tab for  $t_1 = 20 \text{ min}$  ;
VAR a,b,c,G,G1,G2,G3,G4,i,k,s,x,y,z : INTEGER;
    H : REAL;
PROCEDURE UMRECHNUNG ;
BEGIN
IF G > 20 THEN
BEGIN
H := G/20
G := G - (20 * TRUNC(H)) ;
END ;
IF G < 0 THEN
BEGIN
H := -G /20 ;
G := 20 + (G + 20 * TRUNC (H)) ;
END ;
END ;
BEGIN
FOR a = 3 TO 6 DO
BEGIN
WRITE ( 'A - SCHLEIFE, a = ', a, ' ;' ) ;
FOR b := 5 TO 9 DO
BEGIN
WRITE ( 'B - SCHLEIFE, b = ', b, ' ;' ) ;
FOR c := 5 TO 8 DO
BEGIN
WRITE ( 'C - SCHLEIFE, c = ', c, ' ;' ) ;
FOR i := 6 TO 14 DO
FOR k := 8 TO 12 DO
FOR s := 6 TO 14 DO
FOR x := 8 TO 12 DO
FOR y := 6 TO 14 DO
FOR z := 6 TO 14 DO
BEGIN
G := X - Y ;
UMRECHNUNG ;
G1 := G ;
G := 6 + a + x - b ;
UMRECHNUNG ;
G2 := G ;
G := 14 - C - Y + X - b ;
UMRECHNUNG ;
G3 := G ;
G := 8 - C - Y - a ;
UMRECHNUNG ;
G4 := G ;
IF ( (G1 = i) AND (G2 = k) AND (G3 = s) AND (G4 = z) ) THEN
BEGIN
WRITELN ;
WRITE ( 'a = ', a, ' , 'b = ', b, ' , 'c = ', c ) ;
WRITE ( 'i = ', i, ' , 'k = ', k, ' , 's = ', s ) ;
WRITE ( 'x = ', x, ' , 'y = ', y, ' , 'z = ', z ) ;
READLN ;
END ;
END ;
END ;
END ;
END ;
END .

```

```

PROGRAM Time tab for tr = 30 min ;
VAR a,b,c,G,G1,G2,G3,G4,i,k,s,x,y,z : INTEGER;
    H : REAL;
PROCEDURE UMRECHNUNG ;
BEGIN
IF G > 30 THEN
BEGIN
H := G/30
G := G - (30 * TRUNC(H)) ;
END ;
IF G < 0 THEN
BEGIN
H := - G /30 ;
G := 30 + (G + 30 * TRUNC (H)) ;
END ;
END ;
FOR a = 4 TO 6 DO
BEGIN
WRITE ( 'A - SCHLEIFE, a = ', a, ' ;' ) ;
FOR b := 5 to 28 DO
BEGIN
WRITE ( 'B - SCHLEIFE, b = ', b, ' ;' ) ;
FOR C := 6 TO 28 DO
BEGIN
WRITE ( 'C - SCHLEIFE, C = ', C, ' ;' ) ;
FOR i := 8 TO 22 DO
FOR K := 12 TO 18 DO
FOR S := 8 TO 22 DO
FOR X := 12 TO 18 DO
FOR Y := 10 TO 20 DO
FOR Z := 10 TO 20 DO
BEGIN
G := X - Y ;
UMRECHNUNG ;
G1 := G ;
G := 6 + a + x - b ;
UMRECHNUNG ;
G2 := G ;
G := 4 - C - Y + X - b ;
UMRECHNUNG ;
G3 := G ;
G := 28 - C - Y - a ;
UMRECHNUNG ;
G4 := G ;
IF ( (G1 = 1) AND (G2 = K) AND (G3 = S) AND (G4 = Z) ) THEN
BEGIN
WRITELN ;
WRITE ('a = ', a, ' ', 'b = ', b, ' ', 'c = ', c) ;
WRITE ('i = ', i, ' ', 'k = ', k, ' ', 's = ', s) ;
WRITE ('x = ', x, ' ', 'y = ', y, ' ', 'z = ', z) ;
READLN ;
END ;
END ;
END ;
END ;
END ;
END .

```