SKETCH PLANNING OF MULTIMODAL RAPID TRANSIT

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ABSTRACT

This paper presents an interactive computer system called SPORT developed for the sketch planning of multimodal rapid transit corridors, together with the fundamental procedures that underlie SPORT. These procedures are proposed for (a) broad-brush design of alternative plans, (b) analysis of their impacts (at less level of detail), and (c) identification of the trade-offs among them. SPORT enables the planner to focus the best feasible alternative plans that should be subjected to a more detailed investigation within the framework of a multidimensional evaluation process. SPORT has been tested by being applied for the planning of a rapid transit system in Alexandria. Some results of this application are interpreted and discussed.

INTRODUCTION

Regionalwide rapid transit plan should be conceived as an integrated multimodal strategy that involves elements tailored to the service requirements and the travel volumes on the particular corridors of a public transport network [6]. As an example, a plan may involve the construction of a high-capacity rapid transit line on a corridor with heavy demand, supplemented by intermediate- and low-capacity transit lines on the lower density portions of a multimodal network.

One of the more frequently expressed concerns in the planning of a multimodal transit system involves the need for a wider range of alternative plans. More plans are needed, for example, to explore greater variation in transit technology or to investigate additional right-of-way locations [8].

When the number of plans to be analysed in the planning process is significantly increased, it is unlikely that all alternatives can be examined at once. A way to deal with this problem is to stage the planning process into two or more successive phases. A preliminary phase defines possible alternatives and identifies only candidate solutions for more detailed investigations in further planning phases.

In this paper a new process, which is termed here sketch planning, is proposed to test at less detailed level the feasibility of possible multimodal rapid transit systems with varying assumptions as to alternative future.

Thus, the intent of this process is not to select a recommended plan, but rather to screen alternatives that should be subjected to the more detailed testing and to eliminate from further analysis the alternatives that do not prove workable, i.e. saving the expense of a detailed examination of unfeasible alternatives.

To facilitate the planning process, a man-computer interactive system called SPORT (Sketch Planning Of Rapid Transit) is developed by the author. It takes the planner step-by-step through the planning process and performs the calculations necessary for sketch planning.

This paper is organized as follows: Section 2 gives a brief description of the conceptual elements of the proposed planning process. Section 3 demonstrates the SPORT interactive system. In section 4 a case study is presented, where SPORT was applied for the planning of a rapid transit system in Alexandria. Finally, the conclusions are stated in section 5 regarding the usage of SPORT as a planning instrument.

THE PLANNING PROCESS

The sketch planning of a multimodal rapid transit system is a three- step iterative process: design, analysis and evaluation of alternatives Figure (1).

At less detailed level, the planner generates first a great number of alternative plans in terms of primary service characteristics, and forecasts their impacts using simplified modelling analysis. These impacts are then tested to identify significant differences and trade-offs among alternatives according to certain evaluation criteria. Finally, the best convenient alternatives are chosen for a more detailed examination, and if it is necessary, original alternative plans are revised, additional alternative plans are devised and the process is repeated.

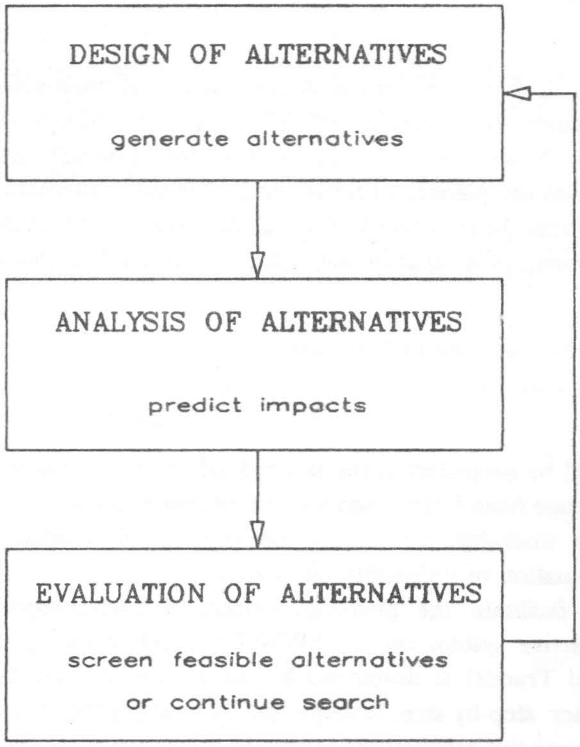

Figure 1. The Sketch planning process

Design of Alternatives

The first step of the planning process is the design of packages of alternative plans at a sketch planning level. An alternative rapid transit plan is defined in terms of route alignments and transit modes. The primary operating characteristics such as transit speeds and capacities must also be established.

Search strategies which might be used for the design of alternatives should be developed. These strategies do not lead to the automatic design of specific alternatives, but can serve as stimuli to such design. Any one, or some combination, of the following three search strategies may be used:

- *Land use options*

The basic objective of this search strategy is to encourage different land use scenarios.

- *Shifting modal split*

One measure of the effectiveness of a rapid transit system is its ability to attract automobile users. The generation of different levels for the share of rapid transit leads to the development of a wide range of alternatives. This could be done in varying modal split values within the framework of a comprehensive traffic and transportation study.

- *Level of service*

Alternatives should be developed to meet different specified level of service; such as transit frequency, maximum door-to-door travel time, and walking distance from and to a transit stop.

It should also be stressed that the planners are free to develop their own approaches, not limiting themselves to the strategies described above.

Analysis of Alternatives

An alternative is one of several candidate solutions for providing a multimodal rapid transit system. Each alternative has supply characteristics and offers transport services. Therefore, the second step in the planning process (analysis of alternatives) should be carried out in order to:

- predict the amount and geographic distribution of trips on the different corridors, using simplified modeling analysis (all-or-nothing assignment) at less (large-zone) level of detail,
- calculate the operating statistics necessary to analyse the efficiency of each alternative; e.g., number of required vehicles, and
- refine the operating characteristics on the various transit corridors to more carefully match supply with forecast demand.

Evaluation of Alternatives

A multidimensional evaluation should be conducted at a number of different levels. The initial evaluation would be undertaken with a set of alternative plans that define a broad spectrum of options. The alternatives should be tested in the face of a wide set of planning objectives and evaluation criteria. The evaluation process should involve the careful analysis of the impacts of the alternatives through a series of steps aimed at identifying significant differences and trade-offs among alternatives [2]. At this point, it may be possible to eliminate a number of alternatives because of obvious shortcomings or inferiority. This would narrow the choice to a limited number of alternatives that can be examined in greater detail at subsequent phases of the evaluation process.

In this study an overall structure for testing the alternative plans at sketch planning level is suggested. The purpose is to shape the sequence of steps that can be applied for a goal-oriented evaluation. The following steps may be used for such an evaluation process:

1. Examine the ability of each alternative plan to meet the overall planning objectives.
2. If all plans are equally or almost equally successful at meeting certain criteria, those criteria will not affect the decision and can be eliminated.
3. If any plan falls bellow any other plan in all criteria, it is dominated by the superior plan and can be eliminated.
4. If a set of criteria are similar in what they are measuring, they can be combined into a single criterion.
5. Repeat steps 2, 3 and 4 as often as necessary until no more changes occur. At that point, a reduced evaluation matrix in which no one plan dominates and all criteria measure significant differences in the remaining alternatives will remain.
6. Study the marginal costs and gains. Arrange the remaining plans in order of increasing costs and examine the gains as the costs increase in a manner similar to cost-benefit analysis. Some plans will have a lower gain per unit cost than others and can be be dropped from further consideration.
7. The trade-offs can be defined by comparing the alternatives in pairs in a sequence of increasing costs and should indicate the gains that should occur if the more expensive plan were chosen over the less expensive one and the costs necessary to obtain these gains.
8. At this point, new alternatives that combine some of the best features of the earlier alternatives may be developed. These alternatives would then be analysed in a manner consistent with the original alternatives.
9. Select alternative plans for more detailed evaluation.

Among the alternative plans to be considered, an alternative which does not involve the construction of new facilities should also be included in the evaluation process. This alternative can be defined as a do-nothing solution; i.e. the existing systems modified perhaps with low-cost policy measures. The purpose of comparing the proposed alternative plans with this solution is to guarantee that the consequences of the alternatives are preferable to the consequences of the do-nothing solution. If the effects of the alternatives are worse than the do-nothing, then, these alternatives should not be taken [5].

THE "SPORT" PLANNING SYSTEM

Figure 2 gives a schematic representation of the overall structure of the SPORT planning system. It is a man-computer modelling system designed for interactive use, and accommodates a maximum of 300 nodes. SPORT includes four routines: GENALTER, IMPACTS, VIEW, and EVAL. All programmes are written in TURBO-C and primarily for the use on Personal-computers (IBM and compatible).

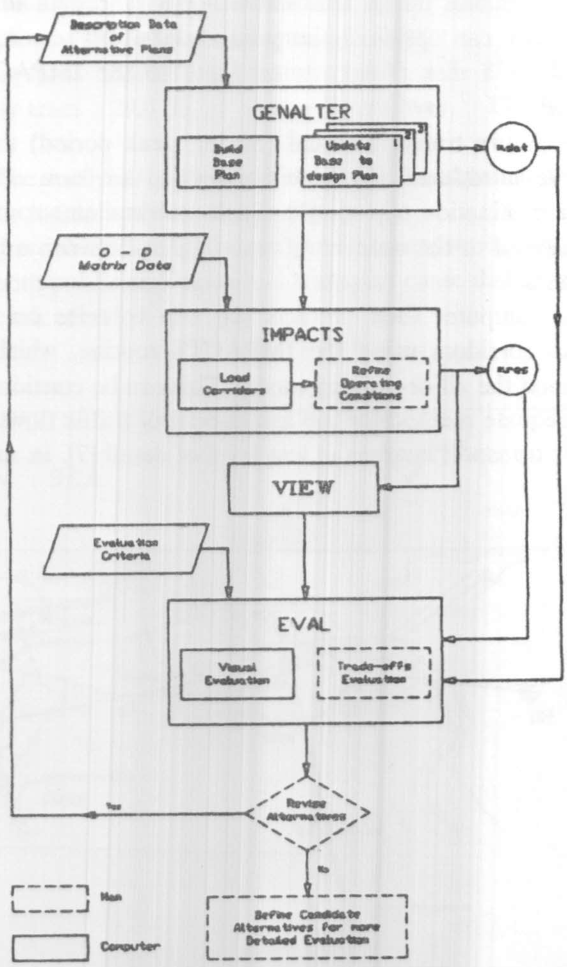

Figure 2. Developmental framework of SPORT

At first, a basic alternative plan (any possible alternative) should be introduced to the system using the input data editor GENALTER (Generate Alternatives). The basic alternative is the set of all nodes and links that potentially can be used to specify the routing of the individual transit corridors. Coordinates must also be assigned to all nodes. In addition, the primary operating characteristics (i.e., vehicle types, transit speeds and the waiting time at terminals) should be determined and entered into the system.

The planner should then develop a lot of alternatives by modifying the basic alternative. A new alternative plan can be defined by making the appropriate changes in the components of the data set of the basic alternative. These changes can easily be carried out through the ability of the input data editor for direct interaction between the planner and the computer. Each complete data set makes up an alternative plan. The data of an alternative can optionally be printed, listed on screen, or stored on a disk (*.dat) as an input to the IMPACTS routine.

The future transit demand (during peak period) must also be introduced to the computer in the form of an origin-destination trip matrix. Each matrix element must correspond to the number of transit trips between a pair of zones.

The computer then predicts the trip volumes on the transit corridors using the IMPACTS routine, which is based on the all-or-nothing model. This can be considered an adequate method for the assignment of traffic flows on public transport systems at less level of detail [7]. In such manner all trips are assigned to the minimum resistance route; i.e., minimum travel time taking into consideration transfer and waiting time.

The most critical subroutine used by IMPACTS is the short path which uses Dehnert's algorithm [3]. It provides a memory-intensive solution but a fast one. This subroutine separates a multimodal network into transit networks (each represents a network of one transit submode) and transfer networks (imaginary networks). A transfer network exists at each point where transfers between the transit corridors are possible (Figure (3)). The travel time between a pair of nodes of the transfer networks depicts either stopping time or both transfer and waiting time.

In addition, IMPACTS calculates and prints automatically the following operating statistics of each corridor: transit frequency, travel time, route length, and the number of required vehicles. By reviewing these statistics the planner may interactively revise the operating characteristics to converge on an improved transit plan.

To identify the overloaded links, SPORT is provided with the graphic facility VIEW, which allows the planner to display the loaded (as well as unloaded) transit corridors as a graph on the screen. In such wise, the planner can observe the number of trips to be expected on each link, particularly the critical links that determine the service required. Any graph produced on the screen can be run out as a hard copy.

In addition to the visual evaluation, the planner may apply the nine steps of the evaluation process described above (evaluation of alternatives) to enhance the

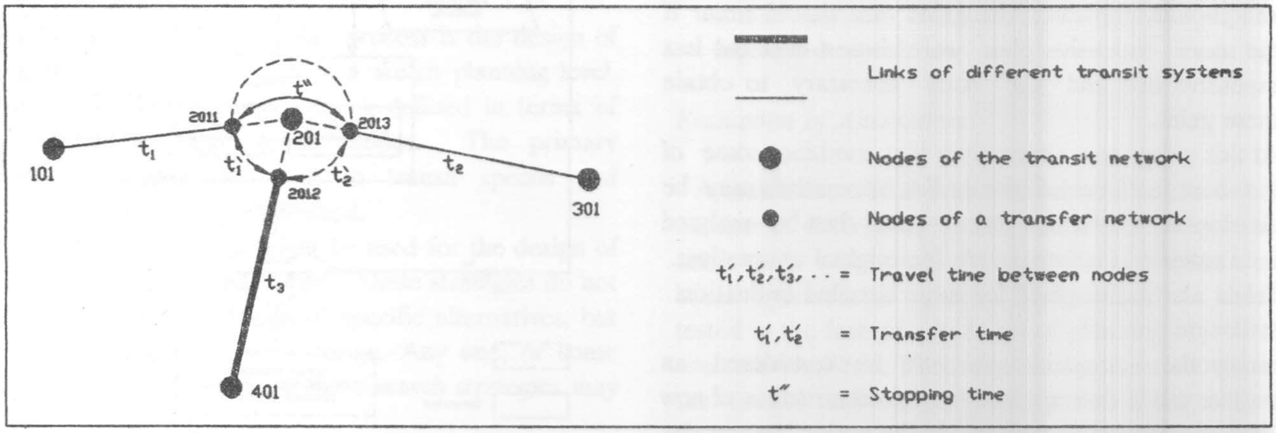

Figure 3. Transit network

considerable differences and the trade- offs among the various alternative plans. Based on the experience performed during the evaluation process, new alternatives that come closed to planning objectives may be proposed, introduced to the system, analysed and evaluated analogous the original alternatives.

SYSTEM APPLICATION

General

The sketch planning of a multimodal rapid transit system for Alexandria will be an exercise to apply the SPORT planning system. It should be emphasized that the purpose of the application here is not to present the most feasible plans, but rather to demonstrate the capability, usefulness and practicality of SPORT.

Alexandria, with about 3 million inhabitants, is the second largest metropolis in Egypt. Due to the low figure of car-ownership (50 car/1000 inh.), the modest share of the motorized trips is done by public transport (about 70 % of the whole trips) [9].

The public transport in Alexandria is operated by two organizations. The "Public Authority for Passenger Transport" which as municipal local transport organization operates buses and trams (City tram and Raml tram), and the state railway organization "Egyptian Railway Authority", which operates regional train service (Abou Kir railway). Figure (4) shows the public transport network of Alexandria.

The bus is the most significant transportation mode in Alexandria. It runs approximately on all main roads.

The City tram runs on its network in the middle of the narrow roads of the old city. It has no own separated track.

The Raml tram has its own track, and joins the eastern part of the city with the city centre. The track is interrupted by several road junctions, which lead to a reduction of the traveling speed.

The Abou Kir railway is the fastest mean of the public transport in Alexandria; average speed is about 25 km/h. It is a two-track system, serves the connection of the city centre with Abou Kir suburb as well as the various low-income areas along the southern edge of the urban area.

The average daily number of trips carried out by the public transport in Alexandria in 1989 was some 1.25 million. The modal split was as follows :

Bus	35.0 %	Raml tram	22.5 %
City tram	29.0 %	Abou Kir railway	13.5 %

The analysis of the existing public transport system of Alexandria has shown that [4]:

- there is a shortage in the public transport capacity;
- both public and individual transport cause disruption to each other;

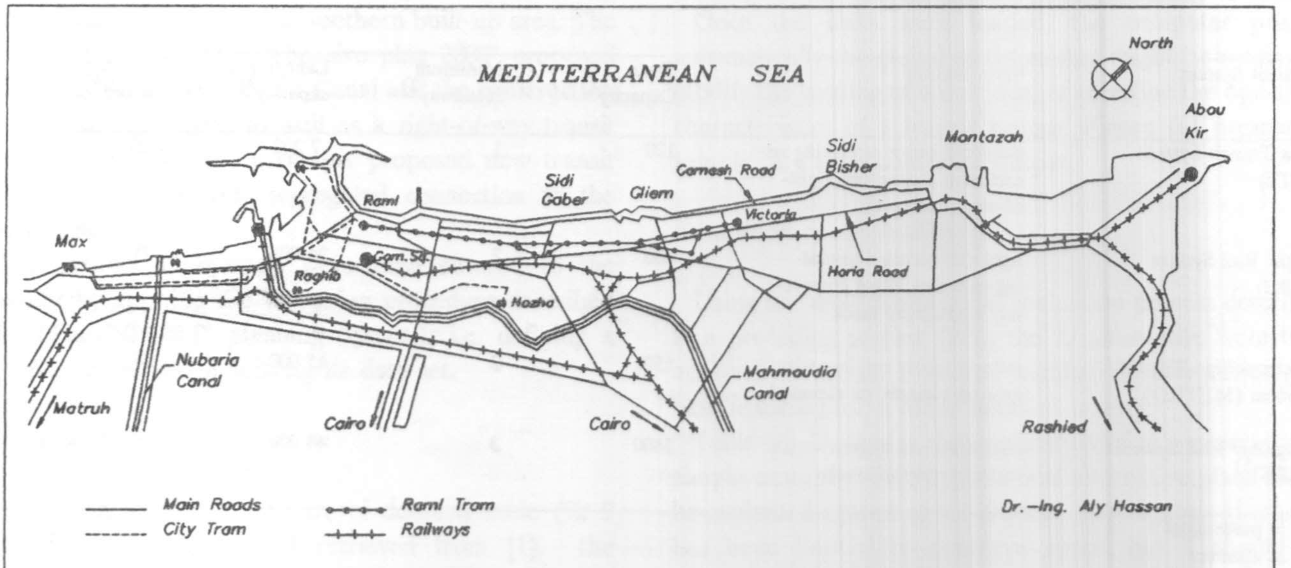

Figure 4. Existing public transport system in Alexandria

- priorities to public transport over individual transport are inadequate, and thus the efficiency of the public transport is passively affected; and
- there is no integration between the various components of the public transport system (Bus, Raml tram, City tram and Abou Kir railway).

Design of Alternatives

The forecast of the future travel demand in Alexandria has been carried out in the framework of the project "Alexandria Comprehensive Plan 2005" [1]. The main features of this travel demand can be summed up as follows:

- The structure of the future travel demand basically emphasizes the longitudinal configuration of the trips on the East-West direction.
- The city centre will not any longer be the only destination point.
- The main demand axis will still be in those areas with high population densities between the Abou Kir railway and the coast.
- In the eastern part, another longitudinal demand axis will appear due to the traffic that will be generated from the newly built-up areas south of the Abou Kir railway.
- Additional travel demand will also be created in consequence of the new industrial activities and development settlements projected in the western part of Alexandria.

On the basis of the future travel demand, several alternatives were generated and defined in sufficient detail to permit initial screening. Each alternative include the configuration of a multimodal network (route location), and a variety of transit systems with different capacities (high-, intermediate-, and low-capacity). The main characteristics of the transit systems which were used in this exercise are set out in Table (1).

Table (2) illustrates and summarizes the different rapid transit options which were developed for Alexandria in the framework of this exercise, and presents the number of test situations.

Alexandria has two railway systems, one in the eastern part (Abou Kir railway) and the other in the West (Matruh line). The first line is operated for regional service and the second is used for long distance transport. All alternatives presented in Table (2) include the upgrading of both systems to create a RRS. Upgrading involves electrification, new rolling stock, improved platforms, new track and control system, as well as grade-separation or given priority signalling at intersections.

Table 1. Transit System Characteristics

Transit System	Main feature	Train Capacity 1)	Minimum Headway 2)	Lane/track capacity 3)	Journey speed 4)
Bus Transit System (BTS)	standard buses operating on exclusive segregated right-of-way (busways)	120	1	7 200	20
Light Rail System (LRS)	light rail vehicles operating in trains along completely segregated track	800	2	24 000	25
Metropolitan Transit System (METRO)	railway trains run in under ground tunnels, or elevated	1500	2	45 000	35
Regional Rail System (RRS) 5)	suburban rail system with exclusive use of tracks	2400	3	48 000	45

1) in passengers
2) in minutes
3) in passengers/hour in one direction
4) in km/h
5) when a RRS is a part of a multipurpose rail system, its performance depends on the amount and the type of track sharing.

Table 2. Summary of the different rapid transit options planned for Alexandria

Network configuration	Transit capacity	Route location	Transit options	options of new sections	No.of cases	No. of options
A	High-capacity	Connecting both Abou Kir and Matruh railways together through the city centre.	RRS	04 km; elevated or underground	2	32
	Intermediate-capacity	Upgrading the Raml tram and its extension westwards to El Max.	LRS or METRO	10 km; elevated or underground	4	
	Low-capacity	Creation of a new system south of the Abou Kir rail.	BTS or LRS	10 km; elevated or underground	4	
B	High-capacity	Upgrading Abou Kir rail, and Matruh rail (until Amria).	RRS	No new sections	1	16
	Intermediate-capacity	As network configuration A	LRS or METRO	As in A	4	
	Low-capacity	As network configuration A	BTS or LRS	As in A	4	
C	High-capacity	Upgrading Abou Kir railway on existing track.	RRS	No new sections	1	24
	Intermediate-capacity	Creation of a new system, starting from Victoria along Horia Road to Amria	BTS, LRS, or METRO	20 km; elevated or underground	6	
	Low-capacity	As network configuration A	BTS or LRS	10 km; elevated or underground	4	
					Total	72

All the transit alternatives in Table (2) contain also the creation of a new low-capacity transit system to cover the travel demand expected in the southern built-up area. The project "Alexandria Comprehensive plan 2000" proposed the infilling of the Mahmoudia Canal and the construction of an urban expressway as well as a right-of-way transit system over it. The route of this proposed new transit system has a completely segregated connection to the central area.

The various alternatives were then entered to the computer by applying the foregoing procedure described above (The "SPORT" planning System); i.e. defining a basic alternative and modifying its data set.

Analysis of Alternatives

According to the future travel demand table (9x 9 zones) for the peak period retrieved from [1], the computer predicted the trip volumes on the different transit corridors of each alternative.

Figure (5) shows the display of the structure of a multimodal network of an alternative and the corresponding loading, as an example.

Once the links were loaded, the computer printed automatically the global statistics that might be needed to modify the routing of a corridor, or to refine the operating characteristics of a transit system. Figure (6) presents a sample of a such computer output.

Evaluation of Alternatives

Using the multidimensional evaluation process described in a preceding section (2.3), the 72 alternative were then analysed to screen a limited number of alternatives (the best feasible) for a more detailed testing.

Table (3) illustrates the application of this process by a simple example. Five hypothetical alternative plans are to be evaluated against seven criteria. The number of criteria has been limited to conserve space, but it should be recognized that additional criteria beyond those shown transit should be used in an actual evaluation.

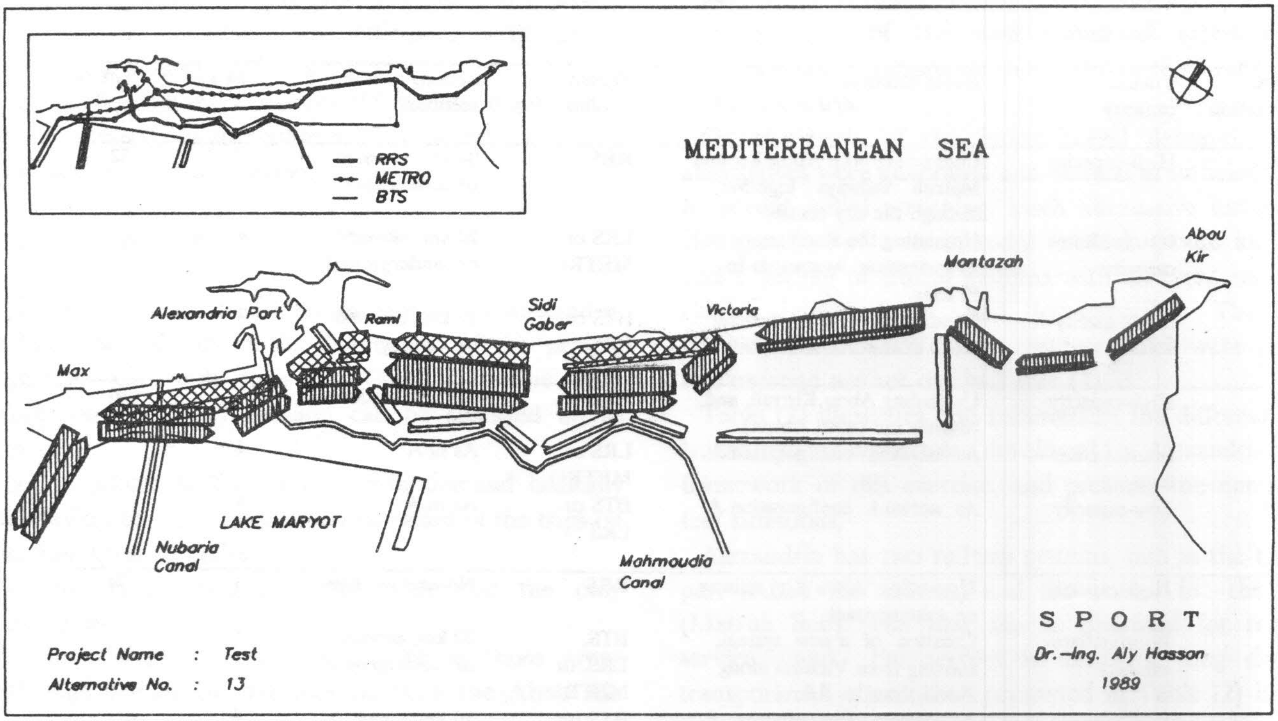

Figure 5. Display of a loaded multimodal transit network

S P O R T

Project Name : Test

Alternative No. : 13

Transit type	RRS	Transit type	METRO	Transit type	BTS
Route length, km.	52.5	Route length	21.8	Route length	15.8
Journey speed, km/h.	45.0	Journey speed, km/h.	35.0	Journey speed, km/h.	20.0
Passengers per hour	41782	Passengers per hour	27745	Passengers per hour	9453
Train capacity	2100	Train capacity	1200	Train capacity	120
Headway, sec.	180.0	Headway, sec.	150.0	Headway, sec.	45.0
Round trip, min.	160.0	Round trip, min.	94.0	Round trip, min.	105.0
Fleet size	54	Fleet size	38	Fleet size	45

Figure 6. Computer output presenting the operating characteristics of a rapid transit system

Table 3. Hypothetical evaluation matrix

Criterion	Plan A	Plan B	Plan C	Plan D	Plan E
1. Investment costs, Millions L.E.	1023	1023	1063	1479	1939
2. First year benefit, % 1)	11.3	11.3	10.9	10.6	10.0
3. Operating costs saving, Millions L.E. 2)	71	66	64	71	71
4. Time value Saving, Millions L.E. 2)	73	78	78	74	74
5. Average trip time, minutes	42.0	41.7	39.9	37.2	38.5
6. Transit use to major trip generators, %	41.9	42.6	42.8	44.4	43.9

1) Benefits/Costs
2) difference between the costs of the various alternatives and the do-nothing solution

Criterion 2 can be eliminated since it shows few significant differences among the alternatives. Criteria 3 and 4 can be combined since they both are the efficiency measures of the various alternatives against the do-nothing solution, and are roughly proportional to each other. Plan A can be eliminated, as it is dominated by plan B. Plan E can also be eliminated since it is dominated by plan D, and once plan E is eliminated, criteria 3 and 4 can be eliminated. The resulting evaluation matrix, shown in Table (4), has three alternative and three criteria.

The evaluation of the alternatives then reduces to an examination of the trade-offs between the alternatives as follows :

- Plan C versus plan B

Plan C provides a reduction of the average trip time and an increase of the use of transit systems at the cost the investments

- Plan D versus Plan C

Plan C reduces further the average trip time and increases the use of the transit systems at the cost of further investments

This information should be given to the relevant decision makers for their consideration. The choice of the best feasible plans then becomes a question of the relative degrees of the importance placed on each of the associated gains and costs.

Table 4. Reduced evaluation matrix

Criterion	Plan B	Plan C	Plan D
1	1023	1063	1479
5	41.7	39.9	37.2
6	42.6	42.8	44.4

An important question is, are the differences between the selected and the remaining alternatives significantly large enough that they are not within the range of differences that might be expected from the data and procedures used ? If these differences are beyond the range of variance of the forecasting techniques, there should be a great degree of confidence in the best alternatives.

CONCLUSIONS

The development of the SPORT interactive system was an attempt to accommodate a large number of alternatives in the planning process of multimodal rapid transit corridors. A large number of alternatives is needed to investigate more right-of-way locations, transit systems, and level of services.

SPORT can be used by the planner to define and to modify alternative plans in a rational systematic easy way. The computer then immediately predicts, lists, and graphically displays the consequences of these plans by assigning potential transit trips to the alternative networks. It assists the planner in the search for the the best plans by automatically generating the objective-oriented evaluation criteria required to identify the significant trade-offs among the alternatives.

The application of SPORT to the transit planning in Alexandria illustrates that the issues involved in a complex decision can be favorably described through a process of the careful analysis of the information contained in an evaluation matrix. Such a process can be used as an effective aid to decision making and to overcome some of the shortcomings inherent in overly mechanical techniques of evaluation.

The application also indicated that SPORT is a valuable planning tool. It can be successfully applied to large transit networks, and the results are quite encouraging.

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