amination of the underlying basic principles of the process indicates that they remain basically valid and require only some expansion to provide a technically sound and sensible basis for extending the evolutionary process of transportation system planning into the 1980s and beyond.

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Parametric Analysis: A Sketch-Planning Tool

Walter Cherwony, Simpson and Curtin, Philadelphia
Lewis Polin, Orange County Transit District, Santa Ana, California

An analytical procedure to conduct sketch-planning analysis for exclusive transit facilities and its application in the Jacksonville, Florida, metropolitan area are described. Unlike detailed testing, in which the objective is to select a single recommended transportation scheme, the sketch-planning technique only screens alternatives to identify candidate transportation systems for more detailed testing. The method suggested for assessing the feasibility of rapid transit is termed parametric analysis and generally conforms to the transportation planning process currently used throughout the nation. Two major differences are that the parametric analysis is usually conducted at a larger-than-zonal scale and, instead of computing a single modal split, assumes various transit capture rates. In addition, each transit technology is specified in terms of performance parameters such as minimum headways, speeds, and unit costs. The consequences for patronage, revenue, and cost can be determined for each capture rate and test situation, and thus the feasibility of exclusive transit facilities can be assessed. Parametric analysis provides a useful, cost-effective procedure for conducting rapid transit sketch planning.

During the past two decades, the focus of most long-range transportation research and analysis has been on the detailed study of transportation alternatives. Because of the effort and cost involved in detailed testing of transportation networks, planners have been limited in the number of alternatives that could be considered. In response to this constraint, analytical techniques are needed that can inexpensively examine a large number of alternatives at a less detailed level. The intent of these procedures, which are termed sketch planning, is not to select a recommended plan but rather to identify promising alternatives that should be subjected to more detailed planning and to eliminate from further analysis those schemes that do not prove workable. The use of a two-tiered testing process (sketch planning and detailed) provides a cost-effective method for examining a wide range of alternatives and ultimately selecting a recommended transportation plan.

One such sketch-planning tool is the community aggregate planning model (CAPM), which has been successfully used in conducting analysis of highway alternatives. Unfortunately, transit analysis lacks a comparable, widely accepted planning tool.

This paper describes one such approach—a sketch-planning tool called parametric analysis—and its application to the testing of the feasibility of exclusive transit facilities and the desirability of various regional land-use schemes in the Jacksonville, Florida, metropolitan area.

OUTLINE OF METHODOLOGY

In detailed evaluation, a transit system is specified and ridership estimates are determined from sophisticated travel simulation models. The resulting patronage permits the calculation of revenue and the computation of both system operating and capital costs to satisfy the forecast demand. In parametric analysis, various levels of modal split are assumed for alternative test systems.

The resulting revenue and cost for each hypothetical estimate of patronage can be calculated, and an order-of-magnitude assessment can be made of the feasibility of long-range transit plans.

The methodology used in parametric analysis generally conforms to the transportation planning process used throughout the nation. Because of the complex array of variables that influence travel and the extensive data required to describe an urban area, the process relies substantially on the program battery of the Urban Mass Transportation Administration. In essence, land-use and socioeconomic data are converted to total person travel desires by using trip generation and distribution models. As noted previously, modal split is determined by assuming several capture rates that are also applied to the results of the transit network assignment. Plan evaluation for sketch-planning purposes is performed by assessing system results in terms of patronage, revenue, and costs. Unlike the conventional detailed testing conducted at the zonal level the sketch planning was performed at a larger areal scale—the census tract. The portion of the sketch-planning process that interfaces with traditional planning steps and is unique to parametric analysis consists of the following three steps:

1. Network development—Network development involves two sequential tasks. The first is the delineation of the guideway alignment and station locations. The parametric analysis is partially network dependent in that routes and stations for the guideway system must be specified. The system of surface (local and feeder) bus routes is not identified by alignment. Instead this "background" transit component is described by levels of service necessary to support the exclusive transit facilities at various capture rates. The second task is to define the range of transit technologies to be considered in the analysis.
2. Identification of parameters—The second step in the analysis is to specify the several factors or parameters that influence transit performance. These parameters include both supply and demand characteristics of the guideway system. Demand parameters would include hourly distribution of riders and capture rates. Supply parameters would describe operating speeds, seating capacity, and dwell time as well as operating and capital unit costs.
3. Network evaluation—The final step in the parametric analysis is to determine the patronage, revenue, and cost associated with each test condition. In this way, the supply characteristics of each test situation and their accompanying costs can be contrasted with patronage and revenue results to assess their financial workability. Alternatives that require subsidy beyond anticipated funding levels can be eliminated from further detailed testing.

To facilitate the parametric analysis, a computer program called sketch planning of rapid transit (SPORT) was used. SPORT performs the calculations necessary for sketch-planning testing. The data input includes the information from the traditional planning process (e.g., ULOAD line volumes) and the parameters specified for each test condition. The output of the program is various operating statistics, such as miles of service and vehicle requirements, as well as the financial results of the analysis—revenue, cost, and margin.

NETWORK DEVELOPMENT

To provide the proper framework for conducting the analysis, two steps were undertaken: (a) specification of test systems including route alignments and station locations and (b) identification of alternative vehicle technologies. The first step in network development was a review of population, employment, and travel forecasts for the horizon year 2000. These data provided information on the location and intensity of activity in the urban area that was used to specify major travel corridors to be served by the guideway system. Two test systems were developed for testing purposes. One concept consisted of 63 km (39 miles) of line and 38 stations; a more ambitious scheme called for 93.5 km (58 miles) of line and 50 stations. For purposes of simplification, only the results for the smaller system are reported in this paper. In addition, each of the transit test systems was analyzed for four different technologies: high-capacity rapid transit (HCRT), intermediate-capacity rapid transit (ICRT), low-capacity rapid transit (LCRT), and busway. These four generic systems were selected because they have inherently different operating parameters that can be used in a comparative analysis for sketch-planning purposes.

IDENTIFICATION OF PARAMETERS

The next step in the analysis was to specify the several factors or parameters that influence transit performance. Only a single set of parameters was identified for each guideway mode, but it should be recognized that each parameter could be varied to test the sensitivity and consequences of different values. Since the intent of the sketch-planning analysis is to screen alternatives for subsequent detailed testing, only a single set of parameter values was used. The key parameters and values used in the analysis are given in Tables 1 and 2. Other parameters include capture rate, hourly distribution of riders, policy headways, load factor, economic life, interest rate, and surface bus parameters.

NETWORK EVALUATION

Since the principal purpose of this analysis was to assess the feasibility of instituting an exclusive-guideway system in Jacksonville by the year 2000, the evaluation considered three fundamental measures: patronage, revenue, and cost. The value of each of these performance indicators was deemed sufficient to provide the information necessary to determine the feasibility of such a system for metropolitan Jacksonville.

The parametric analysis was performed for three land-use concepts, two transit plans, and four transit technologies. This resulted in 24 test situations. Since each test situation was performed at 11 capture rates, the results of 264 alternatives were tested. For simplicity, the detailed results of the parametric analysis are presented here for only a single land-use plan and transit alternative. All revenues and costs have been projected in 1976 dollars under the assumption of economic equilibrium (i.e., any escalation attributed to inflation would affect revenues and costs to the same extent). For this reason, the analysis does not accurately reflect program cash flows, but it is adequate to render a preliminary decision on the financial feasibility and potential patronage of fixed-guideway mass transit in the study area.

Patronage

Under parametric analysis, estimates of ridership were developed through the application of various capture rates to the total trip market. Since nearly 2.7 million daily person trips are expected to make up the total travel market in 2000, transit patronage may range

Table 1. Input values to parametric analysis: capital cost and service life of guideway system.

Technology	Unit Cost ($000s)			Life (years)		
	Guideway[a]	Station	Vehicle	Guideway	Station	Vehicle
HCRT	13 440	4000	650	40	40	20
ICRT	7 769	3000	500	40	40	20
LCRT	4 475	2000	100	40	40	20
Busway	6 774	1500	70	40	40	12

Note: 1 km = 0.62 mile.
[a]Cost per kilometer.

Table 2. Input values to parametric analysis: guideway operating characteristics.

Characteristic	HCRT	ICRT	LCRT	Busway
Speed (km/h)	97	80	40	72
Acceleration (m/s^2)	0.45	0.45	0.45	0.45
Deceleration (m/s^2)	0.45	0.45	0.45	0.45
Dwell time (s)	25	20	15	30
Seating capacity	80	40	15	45
Train consist (cars)	8	4	2	
Minimum headway (s)	90	45	15	25
Layover	6 min/ round trip	4 min/ round trip	2 min/ round trip	10 percent of running time
Cost per kilometer ($)	1.03	0.44	0.22	0.72

Note: 1 km = 0.62 mile; 1 m/s^2 = 3.28 ft/s^2.

quite significantly from 26 900 daily trips under an assumed capture rate of 1 percent to 2 690 000 daily journeys under an assumed capture rate of 100 percent. Nonetheless, experience in other communities with comparable exclusive-guideway-bus systems suggests that capture rates may reasonably be expected to vary from about 5 to 25 percent.

Although aggregate transit demand is a useful guideline, of equal importance is the assignment of patronage to the test network to determine ridership on each of the constituent route segments. These more detailed estimates of patronage (maximum load volumes) function as inputs to the computations of the headways and vehicle requirements necessary to satisfy demand. In addition, the transit assignment indicates the number of trips that are not conveniently served by the guideway system and would rely on local bus service. Only about a third of the 269 200 daily trips assigned to the transit network would use the exclusive transit facility system at an assumed 10 percent capture rate.

Revenue

Since revenue is a function of ridership, revenue forecasts were developed by considering both modal-split percentages and rate of fare. Revenue projections for the parametric analysis were prepared for 11 capture rates at an average fare of 30 cents. Annual revenue in 2000 would range from $2.34 million under an assumed capture rate of 1 percent to $234.05 million if all trips in the region employed either test system. More likely, however, annual revenue would probably vary from $11.70 million to $58.51 million, which is representative of current experience and corresponds to modal-split percentages of 5 and 25 percent, respectively.

Costs

To provide an accurate assessment of total system costs, it is necessary to describe the operating and capital expenditures associated with the guideway transit concept and for each of the four technology options under consideration.

Capital Expenditures

Capital expenditures represent the essential long-term assets of the system, including the acquisition of vehicles and the construction of guideway and stations. As Table 3 indicates, the cost of constructing the transit concept would be substantial regardless of the generic transit mode selected for implementation. Institution of the small-vehicle system (LCRT) would require the least capital outlay. At the other end of the spectrum, inauguration of an HCRT system would require the greatest capital expenditure and would be about three times as costly as the small-vehicle option. Both ICRT and busway occupy intermediate cost positions, but the bus system is the less expensive to construct.

In addition to expenditures for guideway and stations, fleet size and costs must be determined for the assumed complementary bus system as well as for the exclusive transit facility plan. Peak vehicle needs are related to several factors, including maximum load values, vehicle capacity, headway policies, operating speed, and recovery time. The interrelationship among all of these factors accounts for the significant disparity in peak vehicle requirements (see Table 4). At all capture rates, the HCRT system would require the fewest vehicles principally because of its superior operating speed and higher seating capacities (Table 4). In contrast, the LCRT system, which has the lowest seating capacity and operating speed of the four modes, would require by far the largest number of peak vehicles. At lower capture rates, the number of vehicles required does not change because headway rather than demand governs the frequency of service.

Interestingly, the number of buses allocated to surface transit functions, particularly local services, would decline at increasing capture rates. This phenomenon is a result of two related assumptions: (a) The effectiveness of local service, or the number of passengers carried per vehicle kilometer operated, is directly proportional to the capture rate and (b) as the relative number of mass transit users increases, the accentuation in demand, or peaking, diminishes. Thus, as more riders are transported at higher levels of effectiveness, the number of buses required for peak service is presumed to decrease.

Because the busway alternative offers the lowest cost per seat ($1555) of the four technologies, it would necessitate the least initial capital expenditure for vehicles. The ICRT system, which exhibits the most expensive capital cost per seat ($12 500), would result in the highest overall vehicle cost at all capture rates under both network alternatives.

The relative differences in total vehicle cost among modes are somewhat mitigated when vehicle expenditures

Table 3. Construction costs for guideway system.

	Cost ($000 000s)					
	Unit		Construction			
Technology	Guideway*	Stations	Guideway	Stations	Total	Amortized
HCRT	13.40	4.00	844.67	152.00	996.67	83.58
ICRT	7.75	3.00	488.25	114.00	602.25	50.50
LCRT	4.46	2.00	281.23	76.00	357.23	29.95
Busway	6.76	1.50	425.75	57.00	482.75	40.48

Note: 1 km = 0.62 mile.
*Cost per kilometer.

Table 4. Peak vehicle requirements for bus and guideway systems.

	Surface Bus			Guideway			
Capture Rate (%)	Local	Feeder	Total	HCRT	ICRT	LCRT	Busway
1	103	6	109	45	50	63	53
3	256	14	270	45	50	126	53
5	362	20	382	45	64	205	60
10	513	27	540	57	120	407	113
15	581	32	613	82	178	609	165
20	609	45	654	107	235	811	219
25	618	56	674	132	293	1015	273
30	615	67	682	157	353	1216	329
50	564	103	667	260	584	2027	544
75	489	133	622	390	876	3039	816
100	427	155	582	520	1168	4052	1087

are amortized and translated into annual costs:

	Annual Vehicle Cost ($000 000s)				
		Guideway			
Capture Rate (%)	Surface Bus	HCRT	ICRT	LCRT	Busway
1	1.01	2.74	2.55	0.64	0.49
3	2.51	2.74	2.55	1.28	0.49
5	3.55	2.74	3.26	2.09	0.56
10	5.02	3.47	6.11	4.15	1.05
15	5.69	4.99	9.06	6.20	1.53
20	6.07	6.52	11.97	8.26	2.03
25	6.26	8.04	14.92	10.34	2.54
30	6.33	9.56	17.98	12.39	3.06
50	6.20	15.83	29.74	20.65	5.05
75	5.78	23.75	44.61	30.95	7.58
100	5.41	31.66	59.48	41.27	10.10

For example, at the 10 percent capture rate, ICRT vehicle costs (the most expensive) are about seven to eight times greater than the corresponding busway vehicle costs (the least expensive). However, on an annual basis, ICRT is only about five times as costly as the busway option because of the different economic life assumed for each technology option. Similarly, at the 10 percent capture rate, the total vehicle costs of LCRT are roughly 20 percent higher than those of HCRT. On an annual basis, the relative difference between rapid transit and the small-vehicle system is reduced even further and the absolute monetary difference is less pronounced.

As given in the table below, summation of all capital costs on an amortized basis reveals that HCRT would be the most expensive alternative at all modal splits although its relative disadvantage diminishes at increasing capture rates. On the other hand, LCRT would be least costly at capture rates of approximately 30 percent or less whereas at higher capture rates the busway system would consume the lowest level of capital resources:

	Annual Guideway System Cost ($000 000s)			
Capture Rate (%)	HCRT	ICRT	LCRT	Busway
1	87.33	54.06	31.61	41.99
3	88.82	55.56	33.75	43.48
5	89.87	57.31	35.59	44.59
10	92.07	61.63	39.12	46.55
15	94.24	65.26	41.85	47.71
20	96.17	68.55	44.29	48.59
25	97.88	71.69	46.56	49.28
30	99.48	74.82	46.68	49.87
50	105.61	86.44	56.80	51.73
75	113.11	100.89	66.69	53.84
100	120.65	115.39	76.63	55.99

Operating Expenditures

Operating expenditures include costs for items such as wages and salaries, maintenance of equipment and ways, and energy consumption. As indicated in the table below, more capital-intensive HCRT and ICRT systems would generally be less costly to operate than the LCRT and busway alternatives at capture rates of 15 percent or more:

	Annual Operating Cost ($000 000s)				
		Guideway			
Capture Rate (%)	Surface Bus	HCRT	ICRT	LCRT	Busway
1	3.82	7.64	3.24	1.62	5.37
3	9.83	7.64	3.24	2.49	5.37
5	14.35	7.64	3.67	3.95	5.70
10	21.91	8.65	6.01	7.81	8.91
15	26.61	11.25	8.86	11.67	13.10
20	30.29	14.18	11.76	15.57	17.34
25	33.18	17.52	14.64	19.44	21.56
30	35.55	20.89	17.55	23.32	25.88
50	42.47	34.52	29.18	38.85	42.97
75	48.68	51.60	43.74	58.27	64.44
100	53.89	68.79	58.30	77.68	85.85

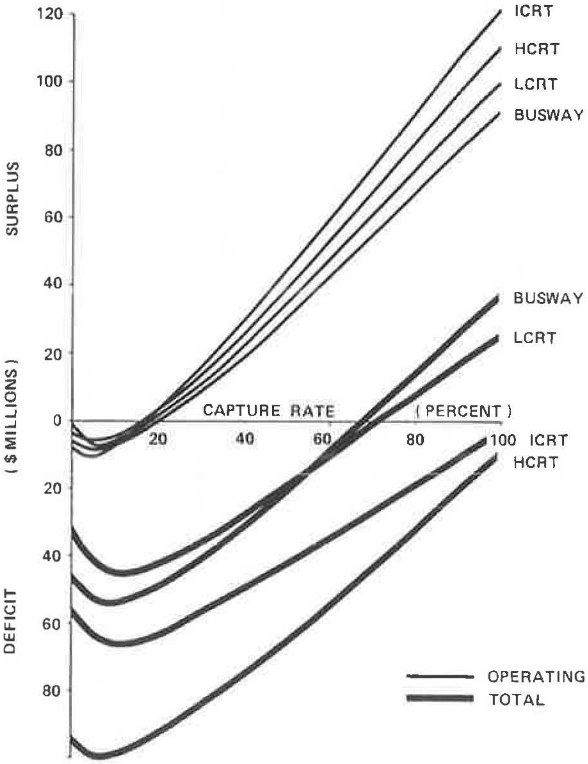
At lower modal-split values, the performance of HCRT and ICRT is detrimentally affected by the requirement to provide schedules that would be governed by policy rather than demand. For this reason, the LCRT and busway options would provide some cost saving at the more realistic capture rates—less than 15 percent.

A compilation of both annual operating and capital cost indicates that LCRT attains the lowest overall cost of the four options under consideration for capture rates of 30 percent or less:

	Total Annual Cost ($000 000s)			
Capture Rate (%)	HCRT	ICRT	LCRT	Busway
1	98.79	61.12	37.05	51.18
3	106.30	68.63	46.07	58.69
5	111.86	75.33	53.90	64.64
10	122.62	89.55	68.83	77.37
15	132.13	100.74	80.14	87.42
20	140.64	110.60	90.15	96.23
25	148.57	119.51	99.18	104.02
30	155.92	127.92	107.55	111.30
50	182.60	158.09	138.12	137.17
75	213.38	193.31	173.63	166.96
100	243.33	227.59	208.20	195.73

When the modal-split ratio surpasses 30 percent, the busway alternative would appear to be most satisfactory. Nevertheless, the relative disadvantage of the more capital-intensive systems (HCRT and ICRT) diminishes at increasing market shares.

Figure 1. Operating and total annual cost margin for four transit technologies.



Evaluation of Costs and Revenues

Comparison of system revenues and costs demonstrates that all four transit modes would require considerable subsidy at most capture rates. If only operating costs are considered, ICRT would appear to be the most acceptable mode since it would provide "break-even" operation at about the 15 percent capture rate (see Figure 1). Even under a more realistic modal-split ratio of 10 percent, the operating deficit associated with the ICRT option is estimated to be a comparatively low $4.52 million.

When total costs are taken into account, however, the less capital-intensive LCRT system would require the lowest level of public assistance for capture rates up to 30 percent whereas the busway option would result in the lowest deficit for modal-split ratios greater than 30 percent.

RESULTS

The results of the parametric analysis would suggest that a guideway system for the Jacksonville urban area is financially feasible at reasonable capture rates. This is especially true since the plan would be eligible for 80 percent capital assistance and as much as 50 percent of the operating deficit. More detailed testing of a guideway system would thus appear to be warranted. The results also suggest that a technology that includes the elements of ICRT and LCRT is the preferred mode. Had the financial results of the sketch-planning analysis demonstrated that the cost of exclusive transit facilities was prohibitive at reasonable market shares, then capital-intensive options would be eliminated from costly detailed testing.

CONCLUSIONS

Although the analysis performed in Jacksonville represents only a single case, certain conclusions can be drawn about parametric analysis:

1. In view of the increasing concern for testing a broad range of land-use and transit options, there is a need for sketch-planning tools to supplement the accepted testing procedure.
2. Parametric analysis represents a simple and inexpensive technique for assessing the feasibility of exclusive transit facilities and candidate modal technologies in a metropolitan area.
3. An initial screening of transit alternatives can save the expense of a more detailed examination of a transit system or land use that will ultimately prove infeasible. Furthermore, alternatives that successfully emerge from the parametric analysis can be subjected to more rigorous scrutiny than if only detailed testing procedures were utilized.
4. Because parametric analysis does not rely on a modal-split model but assumes various capture rates, it permits alternative evaluation to proceed concurrently with model calibration.
5. Although only a single set of values for each mode was defined for each parameter, the values could be varied to permit sensitivity analysis as well as assess the consequences of different values.
6. The fact that parametric analysis is readily adaptable to computer processing means that many alternatives and parametric values could be tested quickly and inexpensively.

Preliminary Screening of Transit Corridor Alternatives

Ronald W. Eash and Arnold H. Rosenbluh, Chicago Area Transportation Study

Part of a major analysis of transit corridor alternatives done by the Chicago Area Transportation Study is presented. A method was developed to screen out, for further study, a limited number of proposed transit improvements from a large number of suggested alternatives for a corridor. The principles of this screening are (a) that some alternatives are not consistent with patronage in the corridor and (b) that some alternatives are dominated by others. The screening methodology is discussed, and the use of corridor supply and demand functions for evaluation and the estimation of these functions are presented. Demand and supply estimates prepared for several light-