Three-Step Operations Planning Procedure for Transit Corridor Alternatives Analyses

GREGORY P. BENZ

This paper briefly describes the UMTA transit project planning process and outlines the role that operations planning plays in alternatives analyses (AAs) conducted under the Urban Mass Transportation Administration's (UMTA's) Urban Mass Transportation Major Capital Investment Policy. Operations planning provides input essential for defining alternatives, patronage forecasting, operations and maintenance cost estimating, capital-cost estimating, and environmental impact assessments. Despite its critical role, operations planning is given little attention in UMTA's latest guidance of alternatives analyses—*Procedures and Technical Methods for Transit Project Planning*. A discussion of operations planning issues often encountered during the AA is provided, and a three-step operations planning process for transit corridor alternatives analyses is described. A discussion on the role that computer models can play in operations planning concludes the paper.

Over the past decade, requests for federal support for new fixed-guideway transit projects in urban areas throughout the country have far outstripped the funds available. Not only has the number of projects increased, but the size and cost of the projects have grown as well. Unable to meet all demands for funds, the Urban Mass Transportation Administration (UMTA) has established a framework of policies and procedures to evaluate competing projects. The process, most recently spelled out in UMTA's May 1984 Urban Mass Transportation Major Capital Investment Policy, outlines the five steps for project development, as shown in Figure 1 (*1*).

The systems planning step leads to identification of the existing and future transportation problems to be addressed, the transportation corridor that has the most serious problems to be solved, and a set of potentially cost-effective, fixed-guideway alternatives to address the problems. The second step involves detailed planning evaluation of a set of transit alternatives, called the alternatives analysis/draft environmental impact statement (AA/DEIS) step. Following this step, an alternative is chosen, followed by the design and construction stages. UMTA concurrence and approval are required to advance to each stage after systems planning, presuming after each stage, that the locality wishes to remain eligible for federal funds.

To evaluate each candidate project using comparably developed data, UMTA has developed documentation providing technical guidance on the procedures used during the alternatives analysis and evaluation. The latest edition (review draft) of these guidelines, entitled *Procedures and Technical Methods for Transit Project Planning* was issued in September 1986 (*2*). This document builds on previous editions and provides a set of well-established procedures which focus on areas generally considered to have greatest influence on the outcome of the alternatives analysis—alternatives definition, demand forecasting, operations and maintenance (O&M), capital-cost estimating, and alternatives evaluation. Operations planning, however, is given very little attention in the UMTA guidelines while O&M cost-estimating procedures, which depend entirely on input derived from the operations planning steps, are specified in great detail; the document devotes 23 pages (an entire chapter) to O&M cost estimating.

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OPERATIONS PLANNING FOR AAs

Operations planning involves identification and analysis of the movement of passengers and vehicles along routes, frequency and coverage of service, station/stop locations, travel speeds and running times, and the estimation of various operational data. Operations planning analysis provides important input to several key areas:

- Alternatives definition—identification of routes, service types (express, local), types of vehicles, transfers and fare policies, feeder/distribution systems, and other policies and characteristics that make up the various alternatives;
- Demand forecasting—estimation of travel times, service frequency, average waiting times, and other inputs to the demand forecasting process and the balancing of travel demand and service capacity (equilibration);
- Operations and maintenance cost estimation—determination of various operating statistics, such as vehicle miles or platform hours, for example, as inputs to the cost modeling.
- Capital cost estimation—determination of vehicle fleet size and the needed maintenance facilities as well as any special physical facilities required to allow the vehicles and passengers to move in the manner desired.
- Environmental impact assessment—the identification of factors such as frequency and speed of vehicles which may affect noise levels, air quality, and energy consumption, and consequently require mitigating measures that add to the capital costs (such as noise barriers) or impose operating restrictions (speed reductions) on the various alternatives.

CONSIDERATIONS IN AA OPERATIONS PLANNING

The operations planning process must address numerous issues, such as demonstrating the operational feasibility of the bus

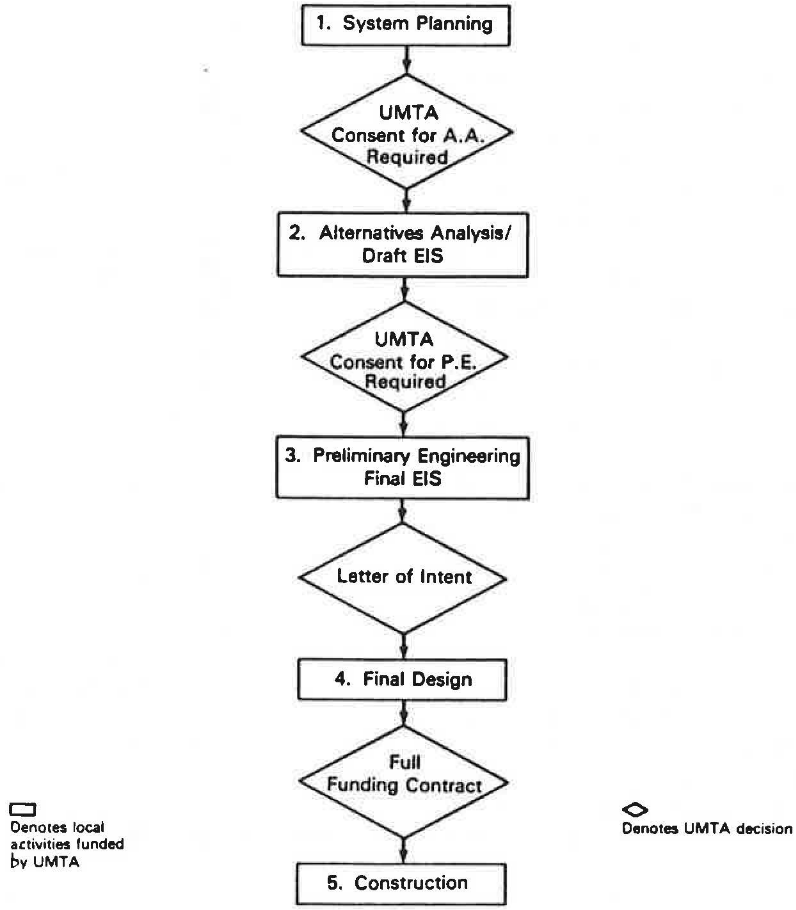

FIGURE 1 UMTA project development process (*1*).

and rail alternatives; other issues involve features peculiar to the bus and rail modes under consideration. Still others involve the need to provide comparable data for evaluating alternatives under the UMTA guidelines. The following discussion is not exhaustive, but illustrates some of the more important issues.

Transit supply (frequency of service, capacity) should match passenger demand. Initial service levels assumed for each alternative or subalternative will attract a certain passenger demand, which must then be compared to the available capacity of the alternative at the initial service level assumed. Frequency of service is adjusted to provide the proper service level, although the range of headways is bounded by safe operating practices for particular modes at one end, and policies on minimum levels of service at the other end, and must take into account current and future bus and rail operations. Changes in initial headway assumptions used in the patronage projections will result in shifting demand; a change in demand, in turn, causes a change in headways. This balancing, or equilibration, of supply and demand is essential in refining the definition of the alternatives.

The operations plan, particularly for the bus alternatives, should consider service subalternatives such as routing variations (skip-stop, branching, express services) or policy/operational variations (on-board fare collection, self-service fare collection, policies regarding elderly and handicapped passengers). Compatibility with current operating practices elsewhere in the corridor, however, is important, and the extent to which current and future services are integrated must be determined at policy and operational levels.

Estimates of travel times and headways should be realistic, recognizing the physical and operational constraints of the alternatives and their alignments. Headways should be achievable and maintainable, taking into account traffic patterns and congestion, transit travel speeds based on traffic/parking regulation enforcement, safe operating standards, vehicle availability, turnaround time at the terminals, and signal system capacity.

Transportation system management (TSM) actions can result in changed operations for current or future transit lines that can influence travel times, operating speeds, vehicle miles, vehicle hours, and other measures. Operations planning must estimate the level of improvement that will result from implementing TSM actions for the bus alternatives and the feeder bus component of the rail transit alternatives.

Assumed operating practices and standards, particularly standee comfort levels on vehicles, must enable bus and rail alternatives to be compared. However, these standards and practices must recognize the particular features of each modal alternative and allow them to be emphasized where possible.

A critical consideration for rail transit alternatives is the relationship between operations planning and the engineering/capital-cost-estimating at the terminal stations. Operationally, a terminal must be able to accommodate the reversal of train directions, and possible crew shifts, train layovers, and storage of bad-order trains and maintenance vehicles. The signal and control system and the location of crossovers or tail tracks will influence the turnaround time at the end of the line, which in turn may affect desired peak-period headways or increase vehicle and crew requirements. Because of the cost of underground construction and potential constraints, the operations at subsurface terminal stations must be carefully analyzed to avoid unnecessary expense. At the same time, however, capital expenditures must be balanced with long-range operating costs, as well as the goal of efficient and flexible operations. In addition, it is possible that the station may be an interim terminal, if a line is built incrementally. Constructing crossovers and other elements at the interim terminal, which may not be needed once the line is extended, may sink resources into features which would have relatively short useful lives. Thus, the terminal operations, especially at interim locations, must be carefully integrated with both operating policies and plans for the rail system and the engineering and capital-cost analysis. The potential for interface problems at terminals with feeder bus routes, park-and-ride lots, pedestrian circulation, and spillover parking into residential areas also needs careful consideration.

Current transit service in the study corridor will be altered with the introduction of one of the "build" alternatives. Feeder services to a new line-haul system will be created by rerouting existing services or instituting new routes. Much of the line-haul service patronage usually comes from bus services on or near the new alignment. Thus, some of the present bus service can be reduced because of the shift of passengers, although trips not accommodated by the new services may continue to be provided. The potential reduction in background bus service needs means that resources (vehicles, personnel, etc.) can be applied to new feeder services or converted into operating cost savings.

THREE-STEP OPERATIONS PLANNING PROCESS

A three-step operations planning process—applicable to most transit corridor studies—has been developed and refined in several UMTA-sponsored projects: originally in the Baltimore North Corridor and recently in the Milwaukee Northwest Corridor and Baltimore Northeast Corridor. The process presented here does not depart dramatically from current practice but formally presents ideas and procedures which have evolved from previous technical guidance (*3*) and discussions among the participants in these studies—transit and planning agencies, consultants, and UMTA. Briefly, the three steps are as follows (Figure 2):

Step One: Develop operating and service policies and standards, including characteristics of the vehicles to be used for operations planning purposes.

Step Two: Prepare initial operations plans to supply input to demand forecasting: network data, station-to-station travel times, access linkages, headways, and transfers. These should reflect operating characteristics of the modes and the alignment/right-of-way.

Step Three: Develop detailed operating plans. Following initial patronage results, an "equilibration" process is conducted in which transit demand (peak-load points) and supply

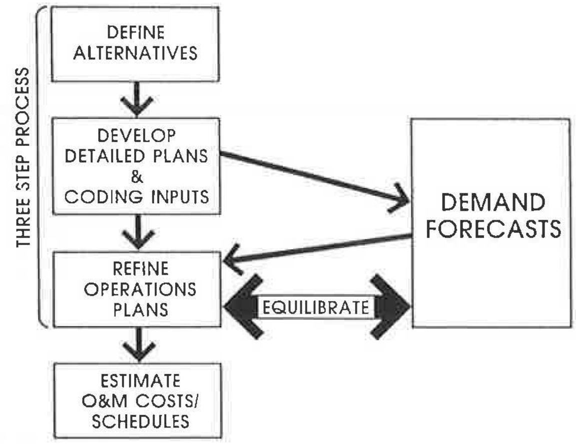

FIGURE 2 Three-step operations planning process.

(headways, capacities) are balanced. Then, detailed operating characteristics and statistics are prepared for input to the operating and maintenance cost estimates, capital-cost estimates (vehicle fleet size and storage/maintenance facilities), and environmental impacts/mitigation measures.

The three steps in the process are described in more detail in the following paragraphs.

Step One Operating Plan

This step develops the initial assumptions and major operating philosophies and concepts for modal alternatives proposed for the transit corridor. They are arrived at through examination of travel patterns in the corridor, passenger demand levels estimated in earlier studies of the corridor (if any), results of previous transit improvements in other parts of the region, and the experiences of similar corridors in other cities. In addition, the policies and constraints of present transit operations in the corridor are major factors in developing the Step One Plan. Typically, this effort involves extensive interaction among the planning and operating staffs of the transit properties operating or planning to operate in the corridor, and the study planners.

The Step One Plan should reflect relevant results of the AA/DEIS Scoping Process and begin concurrently with alternatives definition. The plan also serves as the starting point for the patronage forecast and engineering efforts. For each modal alternative, operating assumptions, philosophy, and concepts are established to include the following items:

- nature of line-haul service
- collection/distribution service (feeder bus, park-and-ride lots)
- fare collection method/policy
- initial headway assumptions by time of day
- operating environment
- equipment type
- integration with existing transit operations
- labor policies
- station policies
- elderly and handicapped accessibility (Section 504) policies

For many alternatives much of this information will be similar, although some items such as access mode concepts may differ because of site constraints and potential impacts. Some policies could be assumed to be constant for all alternatives. For example, it could be assumed that the desired size of area per standee, and associated comfort level, may be relatively consistent across all modes, but may vary with trip distance and duration, and the operating environment.

As a rule, many of these policies have already been established by the operating authorities/properties serving the corridor or region.

In addition to the items just discussed, it is useful to document the characteristics of the vehicles which would likely be used, or at least used for purposes of the study. Generally, bus and rail transit vehicles which are already (or soon to be) part of the transit system are used. Vehicle characteristics should be based on recent or future procurements, as well as on information from vehicle manufacturers. The characteristics of various bus types, such as articulated buses, might also be included if they are not already in the fleet, since they may offer operating and capital-cost savings on high-volume routes.

The following types of information should be included in the list of the vehicle characteristics: vehicle dimensions and capacities (seated and standing), performance and operating characteristics (energy consumption, maximum speeds, acceleration/deceleration rates), operating and maintenance costs, market conditions such as availability and delivery times, purchase price, usable life expectancy (replacement cycle), spare ratios, environmental specifications (noise and emissions levels), and elderly and handicapped accessibility features. Table 1 shows an example of typical bus characteristics.

Where a vehicle type or mode not currently used in the region is considered, or where there is a range of vehicle

TABLE 1 EXAMPLE OF TYPICAL BUS CHARACTERISTICS (*4*)

	Articulated	Conventional
Dimensions		
Length	60'	40'
Width	102"	102"
Height	129"	120"
Overhang		
- Front	108"	91"
- Rear	106"	90"
Turning Radius:		
- Outside	40'	44'
- Inside	20'	37'
Entrance Steps		
- From Ground	15"	13"
Exit Steps		
- From Ground	15"	16"
Door Clear Opening		
- Front	48"	30"
- Rear	48"	44"
Aisle Width	17"	16"
Curb Weight	37,500 lbs.	26,000 lbs.
Approach Angle	8°	10°
Breakover Angle	7.5°	10°
Departure Angle	8°	9.5°
Passenger Accommodation		
Capacity		
- Seated	64	40
- Standing	32	20
Total	96	60
Performance		
Acceleration (mph/sec.)		
0-10 mph	3.1	3.33
10-30 mph	1.5	2.22
30-50 mph	0.75	0.95
Top Speed (mph)	65	65
Normal Deceleration (mph/sec.)	2-3	2-3 average
Fuel Consumption (miles/gallon)	2.5	4 Average

characteristics from "off-the-shelf" vehicles, such as light rail vehicles, it is useful to develop a "composite" vehicle. For some characteristics, such as physical dimensions, the most limiting or largest factors, such as lateral and horizontal clearances and turning radii, should be used for physical design tasks. In this way, the widest range of vehicle types can be accommodated and no particular vehicle model or manufacturer is precluded at this early planning phase. For other characteristics, such as acceleration and deceleration rates, maximum speeds, and passenger capacities, it is appropriate to use average or most likely values.

The vehicle characteristics data are used in the three-step operations planning process as well as in the engineering, capital, and operations and maintenance cost estimating, and environmental analysis tasks.

Step Two Operating Plan

This step results in detailed operating characteristics for each alternative. Besides elaborating on the operating assumptions and concepts presented in the Step One Plan, it develops network coding input to the patronage forecasting task.

The initial alternative concepts are translated into specific configurations of line-haul, feeder, and distribution services in the corridor and the central business district (if the corridor is oriented toward one), with corresponding descriptive data. Descriptions will include relevant physical characteristics from the alternatives definition and engineering tasks—alignment (horizontal and vertical), routing, vehicles, and operational features, as well as descriptions of service function, coverage, accessibility, connectivity (or transferability to current services), and service performance. Specific detailed characteristics for patronage analysis include initial headways for peak and nonpeak periods, travel times (from link speeds, dwell times, access times, etc.), and network configurations. Travel-time data for routes can be developed using established schedules, field speed runs (actual time and speed measurements), operator's data, and calculations using standard speed/distance formulas.

Microcomputers can store the data using an electronic spreadsheet program such as Lotus 1-2-3. Besides enabling systematic storage and retrieval, the microcomputer makes it easy to revise, modify, and conduct sensitivity testing.

The travel time for alternatives introducing new modes or routes is developed in similar fashion. If the alternative extends current systems, this information can be developed in close coordination with the systems' operating staffs, especially at the terminal stations.

Step Three Operating Plan

This step follows the development of initial patronage projections for each alternative. It consists of three elements: equilibration of transit supply and demand; development of detailed operations plans, characteristics, and statistics; and preparation of annual operating statistics, personnel requirements, and energy consumption.

Equilibration of Supply and Demand and Refinement of Alternatives

The first effort in Step Three is refining the alternatives by balancing the transit supply (frequency of service, vehicle capacity) and passenger demand. Patronage projections, which are based on information in the Step Two Operating Plan, include such factors as assumed headways for initial service planning. Once the initial patronage projections are available, the alternatives are refined, if appropriate, to adjust capacity, service, and facility elements.

The number of peak-period transit-vehicle departures on the line-haul service required by the forecasted demand is compared with the original assumption on departures and frequency of service. If the revised frequency varies significantly from the original assumption, then the patronage estimates are adjusted by rerunning the demand forecast model iteratively until the supply and demand are balanced. Another less costly approach is to use an elasticity-based procedure where the change in frequency of service causes a change in ridership based on the specific elasticity factor used. If the capacity is too much or too little after the first try, the process will be repeated until a balance is achieved. Experience has shown that the balancing generally occurs within two iterations of this process. The final headway must fall within the limits of safe operating practices, the property's operating plans and policies, and minimum levels of service (maximum headway). The equilibration is performed for the peak (high-demand) periods only; nonpeak-period headways generally are based on policy decisions. Table 2 shows the results of an equilibration step. Other refinements may include adjustments to dwell times due to station/stop loadings, and elimination or adjustment of certain components of the alternatives (such as parking facilities) for cost, use, or environmental reasons.

Detailed Operations Plans Characteristics and Statistics

The detailed operating characteristics and statistics of each alternative and subalternative are developed for each service or route in the alternative. Trip times and distances are available from the Step Two plan. Recovery and layover or turnaround times are added. Headways are taken from the equilibration and refinement results. Using trip times and headways throughout the day for the various services and trip distances, vehicle requirements (by time of day), vehicle miles, vehicle hours, vehicle trips, and related statistics are developed for a typical weekday. Related statistics include car miles and hours, and train consists (where relevant) as well as place miles and hours. These statistics must recognize two-way trips, one-way trips, deadheading, and other operating features. Access modes are treated in similar, although possibly more aggregate, manner. Reductions in background bus services can be estimated based on the number of bus riders who would shift to the alternative and the current bus service levels. The resulting operations plans are compared with similar transit operations for validity, including checks such as average speed, load factors, and revenue miles to total miles.

For rail transit alternatives, the configuration of the terminal is often a key factor in determining the capacity of the proposed line. If the proposed line is an extension of a current

TABLE 2 EXAMPLE OF EQUILIBRATION OF SUMMARY SHEET (*4*): BUSWAY ALTERNATIVE—AM PEAK

Service	Inbound/ Outbound	Original Headway (Minutes)	Original Demand (Pass.)	Revised Headway (Minutes)	Revised Demand (Pass.)	%*
Hunt Valley Express	I	15	321	15	321	0
Hunt Valley Express	O	15	147	15	147	--
Warren Road	I	15	329	15	329	0
Warren Road	O	15	24	30	23	-4.2
Padonia	I	30	156	30	156	0
Padonia	O	30	19	No Service		--
Spring Lake	I	10	444	12	425	-4.3
Spring Lake	O	10	47	30	46	-2.2
Providence Road	I	20	125	30	114	-4.3
Providence Road	O	20	10	No Service		--
Dulaney Valley	I	15	444	10	499	+12.4
Dulaney Valley	O	15	204	20	201	-1.3
GBMC/Towson State/ Towsontowne	I	20	240	20	240	0
GBMC/Towson State/ Towsontowne	O	20	176	20	176	0
York Road	I	10	625	8	654	+4.7
York Road	O	--	0	No Service		--
Hunt Valley Local	I	2	2875**	2	2875**	0
Hunt Valley Local	O	2	481**	2	481**	0

*Percent change of revised demand from original forecast.
**Peak Line Volume north of MetroCenter.

line, capacity of that line will be affected as well. Signal timings, speed restrictions for curves, crossovers, and turnouts, dwell times, and vehicle acceleration and deceleration rates for the current line are used to calculate the time required to turn trains. Also, possible requirements for laying up trains and providing trackage for turnback service, emergency use, and maintenance-of-way equipment are examined. Operational requirements for track work and signals are determined and used as input to the engineering task.

In addition, the relationship between line-haul and feeder service operations at the terminals should be examined in light of peak-period travel demand. This information is used to provide pedestrian flow data for use in station design and feeder bus, park-and-ride, and kiss-and-ride facilities.

Preparation of Annual Operating Statistics

The statistics and characteristics of each alternative, including access modes must be summarized and documented. Daily statistics for each alternative are converted into annual statistics, energy consumption is estimated, personnel needs are projected, and total vehicle requirements (including spares) derived. Annualization factors are based on data obtained from services or derived from number of holidays, weekends, and full work days. Generally, the annualization factor for service operations should be slightly higher than the annualization factor for ridership. Energy consumption is based on the vehicle type, average speed, vehicle miles, and operating experience in the study area as well as areas with similar

TABLE 3 EXAMPLE OF STEP THREE SUMMARY SHEET (*4*): 1995 NORTH CORRIDOR ANNUAL TRANSIT STATISTICS AND VEHICLE REQUIREMENTS

	Vehicle Miles		Vehicle Hours		Peak Vehicle Requirements		Vehicle Fleet Requirements	
	Bus	Rail	Bus	Rail	Bus	Rail	Bus	Rail
1995 North Corridor Base	11,908,252	-	893,601	-	319	-	407	-
Baseline	12,449,903	-	911,416	-	334	-	426	-
Express Bus Park'n'Ride/TSM	13,361,242	-	949,951	-	363	-	460	-
Busway	16,288,242	-	1,066,172	-	453	-	570	-
Commuter Rail	12,237,806	546,000	942,247	21,600	351	12	426	14
Rail Transit								
- Towson Mainline	11,838,568	1,366,200	841,730	45,900	308	27	392	32
- Ruxton Mainline	11,846,256	1,209,300	846,325	41,400	309	24	393	29
- Baltimore St. At-Grade	11,319,559	1,338,000	802,783	50,400	294	30	375	36
- Redwood St. At-Grade	11,847,714	1,273,000	842,416	42,000	314	27	399	32

operating environments. Personnel needs are estimated using a labor buildup approach, considering local experience and practices as well as those of other areas, recognizing that the many proposed alternatives are generally expansions of present systems.

The information developed in this step for each of the alternatives, subalternatives, and variations is assembled for presentation in summary form—an example of which is shown in Table 3. This information supplies input to alternatives refinement, engineering, environmental analysis, and capital and operations and maintenance cost estimating. Generally, a Step Three Operating Plan technical memorandum forms the basis of a Final Operations Plan Report, which will include relevant portions of Step One and Step Two Technical Memoranda and a Vehicle Characteristics Report. Appendices provide backup data. The report is prepared so that key portions can be readily inserted into the AA/DEIS document with minimal reformatting and rewriting.

USE OF COMPUTER OPERATIONS PLANNING MODELS

Keeping track of changes to a large number of transit routes and services—changes in headways, vehicle hours, platform hours—can be quite complex, especially when several alternatives are being considered. Various computer-based tools are available to help with this task.

Some regional transportation planning models used for travel demand analyses, such as UMTA/FHWA's Urban Transportation Planning System (UTPS), include components that deal with transit operations. UTPS's Integrated Transit Network program (INET) (*4*) can be used to compute the operating statistics for the entire transit system, including keeping track of statistics by various modes, lines, operating divisions, or companies. There are now PC-based programs available with similar capabilities.

Operations simulation models can also be used; however, these models are geared to single-mode systems, such as a rail line or people mover system, and often focus on propulsion power requirements. Modeling the entire transit system, including feeder and background bus network, is either not possible or cumbersome at best.

These types of models are often expensive to use—both in terms of labor to prepare input data and computer time. Often, PC-based spreadsheet programs can be effective tools for operation analysis. One attribute of PC-based programs is that the consequences of changes to individual routes and services are very visible to the analyst. Sensitivity testing is relatively easy, quick, and inexpensive.

SUMMARY

Operations planning is an important part of transit corridor alternatives analysis which is not adequately addressed in current UMTA technical guidelines. The three-step operations planning process described provides a structure that is integrated into the recommended overall analytical work flow.

The three-step planning process as applied in the Baltimore North Corridor alternatives analysis (*5*) was described in a state-of-the-art review on operations planning as follows (*6*):

> Recent transit guideway planning has also included significantly greater effort for the development of operating plans. One study (Baltimore North Corridor AA/DEIS) structured a three-stage process for plan development that proceeded from a conceptual definition through an initial detailed specification to a final plan that was revised and refined to match the patronage levels and travel patterns in the corridor. The final operating plan for the busway included a mix of express services focused on the center city and local busway services stopping at busway stations served by feeder buses. The process significantly increased the reliability of the service, patronage, and cost estimates in that it ensured that these estimates reflect an appropriate, efficient operating scheme for the facility.

The three-step process has since been applied to numerous AAs with comparable success. Where it has been included in the work scope for AA/DEISs, operations planning has been properly incorporated into the study process. In studies where operations planning has not been explicitly treated, operational issues and factors have been given insufficient attention, especially in defining and refining the TSM and bus alternatives. The three-step process provides a structure to address operating policies and issues early in the study, which is vital to developing alternatives that address the problems to be solved in the corridor.

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