year forecast period on Plaistow's streets and highways vary from less than 50 percent on roadways that serve primarily local traffic to more than 150 percent on highways that carry traffic to and from more rapidly growing neighboring towns. The major through highway in Plaistow, NH-125, is the exception since it has a projected growth of 40 percent. Since these forecasts are based on certain anticipated growth trends, substantial changes in patterns of development will affect the projected traffic volumes.

Obviously, the anticipated traffic volumes on many of the links of the Plaistow network will result in congestion and less than ideal travel conditions. The next phase of the Plaistow Highway Transportation Study will compute the hourly capacity of the streets and highways in Plaistow and compare these with the forecast volumes. In this way, deficiencies in the existing network may be identified so that remedial measures can be planned.

REFERENCE

1. Urban Trip Distribution Friction Factors. Federal Highway Administration, U.S. Department of Transportation, 1974.

Publication of this paper sponsored by Committee on Transportation Planning Needs and Requirements of Small and Medium-Sized Communities.

Evaluation of the Impact of Restricted Interchanges on Travel Demand

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A study was conducted to develop and apply a low-cost process for assessing the effect on travel demand of a less-than-optimal design for proposed freeway interchanges on I-476 in Delaware County, Pennsylvania. The principal strength of the procedure developed lies in its computational simplicity. It is primarily manual and, although it does not require the excessive computer costs associated with the usual set of transportation planning models, it produces the detailed information required for such an analysis. The process relies on travel demand, trip length, and service provided for each trip movement to isolate possible impacts. The diversions expected to result from the constrained interchange designs are then determined based on the conditions of the surrounding network. For the two interchanges considered in the study, the process provided detailed information not usually associated with typical planning models. Although little effect on demand was anticipated at either interchange, the information generated was used for incorporating design revisions at one of the locations analyzed to eliminate deficiencies in capacity.

Provisions contained in the National Environmental Policy Act of 1969 allow for the transportation-related use of parkland or historical sites if and only if no feasible and prudent alternative can be found. In response to testimony delivered at public hearings on the draft environmental impact statement (EIS) for I-476, the Pennsylvania Department of Transportation (PennDOT) modified two interchange designs to avoid the taking of such lands. Inherent in these modifications was a lessening in the quality of service provided at each interchange, where traffic signals replaced previously free-flow ramp movements at specified locations.

Concerned over the possible diversion of travel from these locations and its effect on the surrounding communities, PennDOT requested the Delaware Valley Regional Planning Commission (DVRPC) to evaluate the impacts of the design changes on future travel. In reviewing the request, it was deemed impractical to perform the analysis by using conventional simulation techniques because of both scope and cost. Such an approach would likely conceal the interaction between the system and the users and consequently hinder proper evaluation. To avoid these shortcomings, it was decided to accomplish the analysis by relying on a primarily manual process and using accepted techniques wherever possible.

The procedure developed is divided into two principal phases. Phase 1 focuses on traffic demand and operating characteristics for the original design of the freeway and each interchange. Phase 2 assesses the constraints created by the redesigned interchange and determines the movements affected.

This report details the procedure developed by DVRPC and presents an evaluation of the modifications proposed for the Mid-County Expressway. Figure 1 shows an outline of the process developed for this analysis and a description of each of the phases discussed.

PHASE 1—ORIGINAL DESIGN

Define Immediate Area of Impact

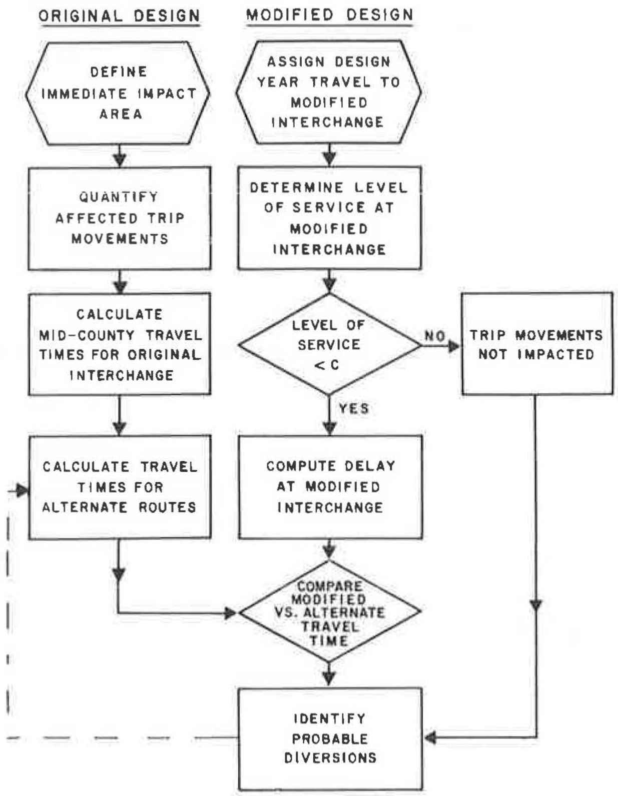
Trips that use the subject interchange will not be equally affected by the proposed modifications. Long-distance travel by the freeway will likely not divert to an alternative path regardless of the localized conditions at the interchange. The premise is that the time these trips save once they are on the freeway outweighs the time lost at the interchange.

This reasoning does not prevail for short-distance travel. Time saved on the freeway can readily be offset by time lost at the restricted movements and by the more circuitous routing caused by the freeway.

Trips that use the redesigned interchange and a short segment of the freeway should therefore be most severely affected, and the overall impact should be inversely related to distance traveled by way of the freeway. In conjunction with this hypothesis, trip movements by the modified interchange and a single segment of the freeway were first isolated for analysis as the most critical movements.

Since the facility under study is proposed, a "select link analysis" was performed to define trip movements that used the modified and adjacent interchanges. Ser-

Figure 1. Study methodology.



vice areas that surround each of these interchanges were then devised based on the select link trip matrixes and the logical trip patterns via the available highway network.

Quantify Affected Trip Movements

Next, the demand between the defined areas via the freeway is quantified by relying on select link data from an available traffic assignment. From this assignment, the number of trips that use I-476 was extracted for traffic analysis zones in each service area and aggregated to establish area-to-area traffic movements.

The selected link process used design-year (1996) traffic estimates forecast for the freeway. Design-year forecasts were used because they represent the adopted criterion for assessing proper design and denote the maximum impact caused by the revision.

Calculate Travel Times for Original Design

Travel times between service areas via the expressway are then calculated by using the original design scheme and accompanying travel forecasts. This calculation is performed by using peak-hour demand to reflect the critical period of maximum impact. The amount of travel is best defined during this period, and travel speeds can be estimated with reasonable accuracy.

For the I-476 analysis, evening peak-hour travel times between service areas were tabulated by using a relation for speed based on the volume, capacity, speed limit, and signal density of each link (1). Speeds were computed directionally because the proposed modifications will not provide balanced service. In addition, several modifications will create directional constraints.

Peak flow by direction was derived from the daily assignment by using adjustment factors created for the original design of the expressway and data provided by PennDOT on the proposed modifications (2).

Calculate Travel Times by Alternate Route

Peak-hour speeds are then similarly computed for competing alternative arterial paths between each service area. The predicted speeds that resulted were validated by using existing speed and delay data (3). To ensure compatibility, travel times for arterial and freeway paths are calculated from common points of divergence located at the approximate center of each service area.

PHASE 2—MODIFIED DESIGN

Assign Design-Year Travel to Modified Interchange

Concurrent with phase 1, design-year travel forecasts are also assigned to the appropriate movements at the redesigned interchanges. Again, evening peak-hour travel is allotted by direction.

Determine Level of Service at Modified Interchange

By using procedures described in the Highway Capacity Manual (4), a capacity analysis is conducted for all movements at each interchange, and the level of service is determined. For I-476, the analysis focused on the service provided at the signalized ramp termini introduced at each interchange. A signal phasing plan was developed to provide balanced operation wherever possible under geometric constraints imposed by the design. It was assumed in the analysis that the ramp designs were adequate to accommodate expected queues.

Level of service C, the accepted urban design standard, is the decision variable adopted in the process. At service levels A through C, drivers are not objectionably restricted and no more than a third of the cycles are fully loaded (4). Below level of service C (D through F), delays to approaching vehicles become substantial, queues develop, and vehicles are often detained for more than a single cycle.

Since drivers are not objectionably restricted until service falls below level C, it is reasonable that delays created by the modified designs will not be perceived by the public. If the capacity analysis then indicates future peak-hour service of C or better, the modified design is assumed to have no impact. If, conversely, level of service C is not achieved, the analysis must be continued to quantify the effect on travel.

Compute Delay at Modified Interchange

Where level of service C is not reached, the additional delay imposed by the modified design is needed to determine the new travel time between service areas via the freeway. For the analysis of I-476, this additional segment of travel time was estimated based on level of service and implied load factor. A relation developed by May and Pratt (5) that assumes that the surrounding signals will not be interconnected was applied. This relation is shown graphically in Figure 2.

Note that no estimate of delay exists for movements at level of service F at which demand exceeds capacity. The actual determination of delay in this instance is more complex and depends on (a) the period in which demand exceeds capacity, (b) the degree to which this occurs, and (c) the queue length that results from these

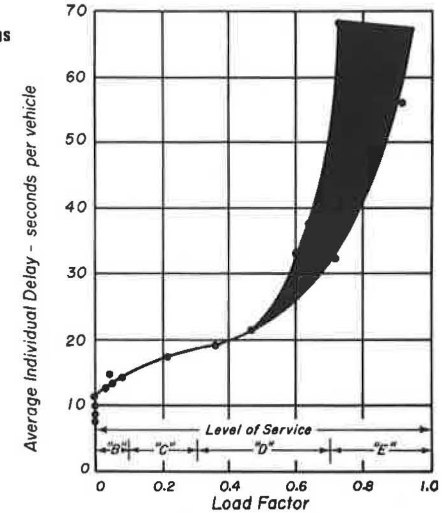


Figure 2. Average intersection delay versus load factor.

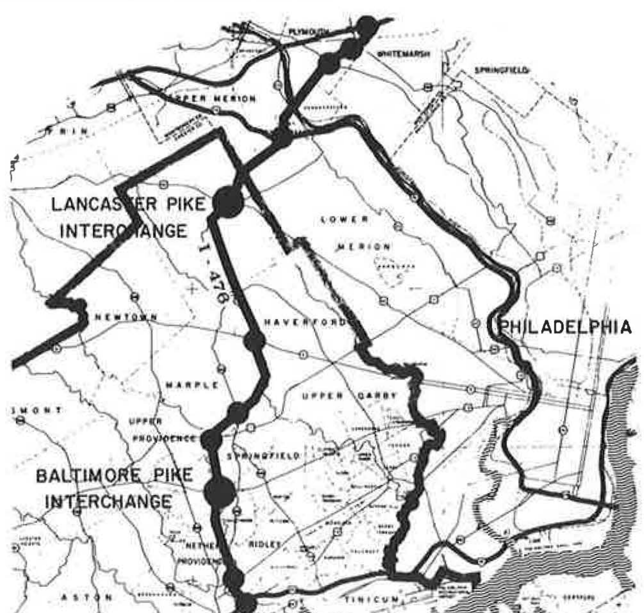


Figure 3. Map of I-476 area studied.

conditions. For the evaluation of I-476, a minimum value of 90 s was assumed in this instance by means of extrapolation of the graph shown in Figure 2. This simplified reapproximation rather than a more rigorous determination was applied because detailed flow data for the periods surrounding the peak hour were not available and subsequent design modifications were expected to correct these conditions.

Compare Modified and Alternate Travel Times

The appropriate signal delays calculated in the preceding step are then added to the travel times determined for each movement via the freeway for the original design. The estimated travel time for each trip when the interchanges are modified is then compared with the travel times previously determined for the alternative arterial paths between each service area.

Identify Probable Diversions

If travel times for the modified freeway designs exceed that for the alternative path, peak-hour trips for the identified movements are expected to divert from the freeway. Movements that provide faster service via the freeway are concluded to be unaffected by the modifications. As indicated, the alternative assignment assumes an all-or-nothing relation. Although a more complicated phenomenon assuredly exists, the small magnitude of diversions from I-476 renders a more sophisticated approach inappropriate.

Although peak-hour data are principally used in the analysis, the trends cited can be considered indicative of daily conditions and similar impacts can be expected throughout the day.

Depending on the results of this analysis, service areas may be extended to include the next adjacent interchanges along the freeway if the arterial paths indicate a marked improvement in travel time in comparison with the modified freeway. This extension would conceivably continue until an equilibrium point is reached where the freeway is obviously the faster alternative. Additionally, if a sizable magnitude of travel is diverted to the arterials, speeds should be recomputed to determine the impact and the process should be reiterated until a balance is achieved. For the I-476 analysis, neither of these feedback options was necessary.

MID-COUNTY EXPRESSWAY

I-476, the Mid-County Expressway, is a proposed six-lane facility extending 32.6 km (20.2 miles) through suburban Delaware and Montgomery counties in Pennsylvania. The expressway connects I-95 (the Delaware Expressway) with I-276 (the Pennsylvania Turnpike) and is designed to create a beltway facility around the city of Philadelphia. Along its route, 11 interchanges are proposed, including a third Interstate connection via I-76 (the Schuylkill Expressway).

The two interchanges for which modifications have been proposed are (a) US-30, Lancaster Pike; and (b) Baltimore Pike. The locations of I-476 and these interchanges are indicated on the map shown in Figure 3.

Both of these four-lane arterials that radiate from central Philadelphia currently accommodate approximately 25 000 vehicles/d with peak-hour flow near capacity. If the freeway is constructed as originally proposed, daily travel on these facilities is expected to climb in the design year to 40 000 vehicles/d at Lancaster Pike and 35 000 vehicles/d at Baltimore Pike.

Figures 4 and 5 show the original and modified design schemes and the location of the environmentally sensitive tracts that surround each interchange. As indicated, the directional interchange at Lancaster Pike has been revised so that all movements are accommodated in the southwest quadrant and these tracts are thus avoided. This design uses less right-of-way but requires signal control for all movements between Lancaster Pike and the Mid-County Expressway. Access to the freeway from the east is accomplished by way of dual left-turn lanes (movement B-D in Figure 4). Double left-turn lanes are also provided for traffic exiting the Mid-County Expressway from the north and destined west on Lancaster Pike (D-A).

At the Baltimore Pike interchange, the proposed modifications to the original cloverleaf scheme are less

Figure 4. Original and modified schemes for Lancaster Pike interchange.

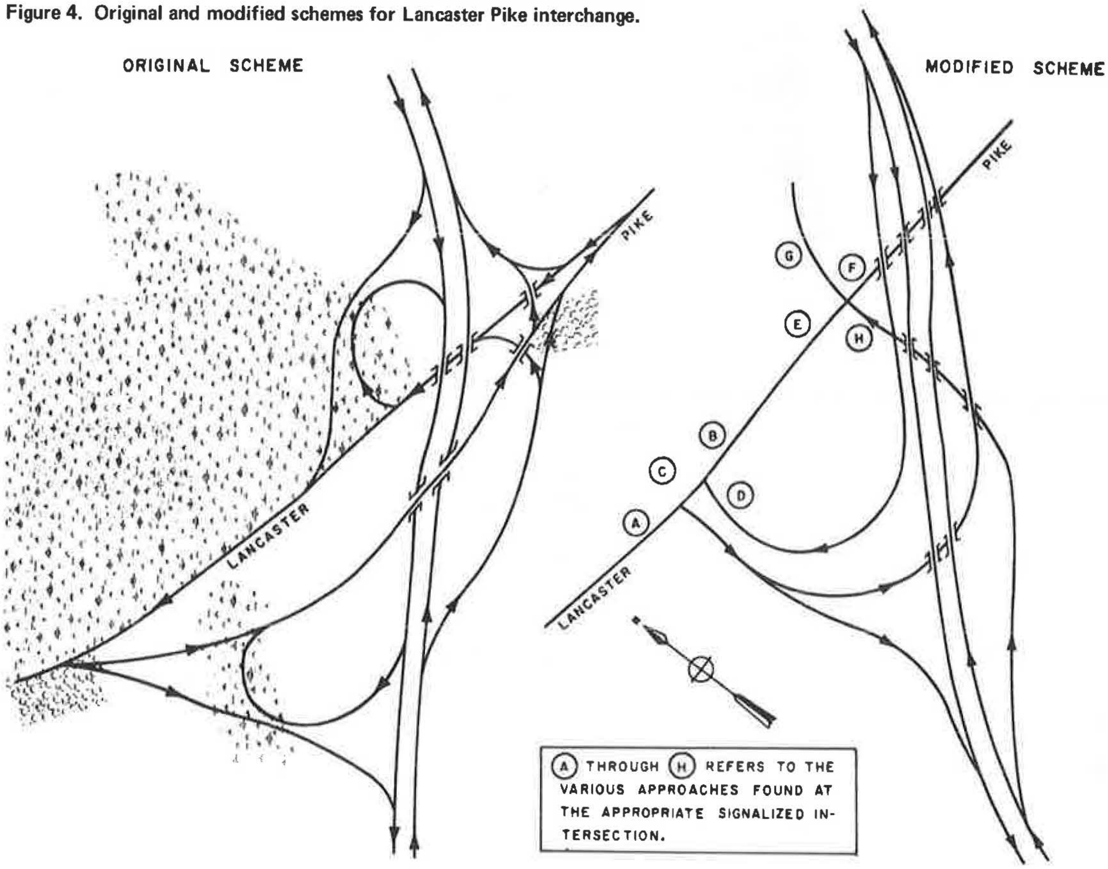
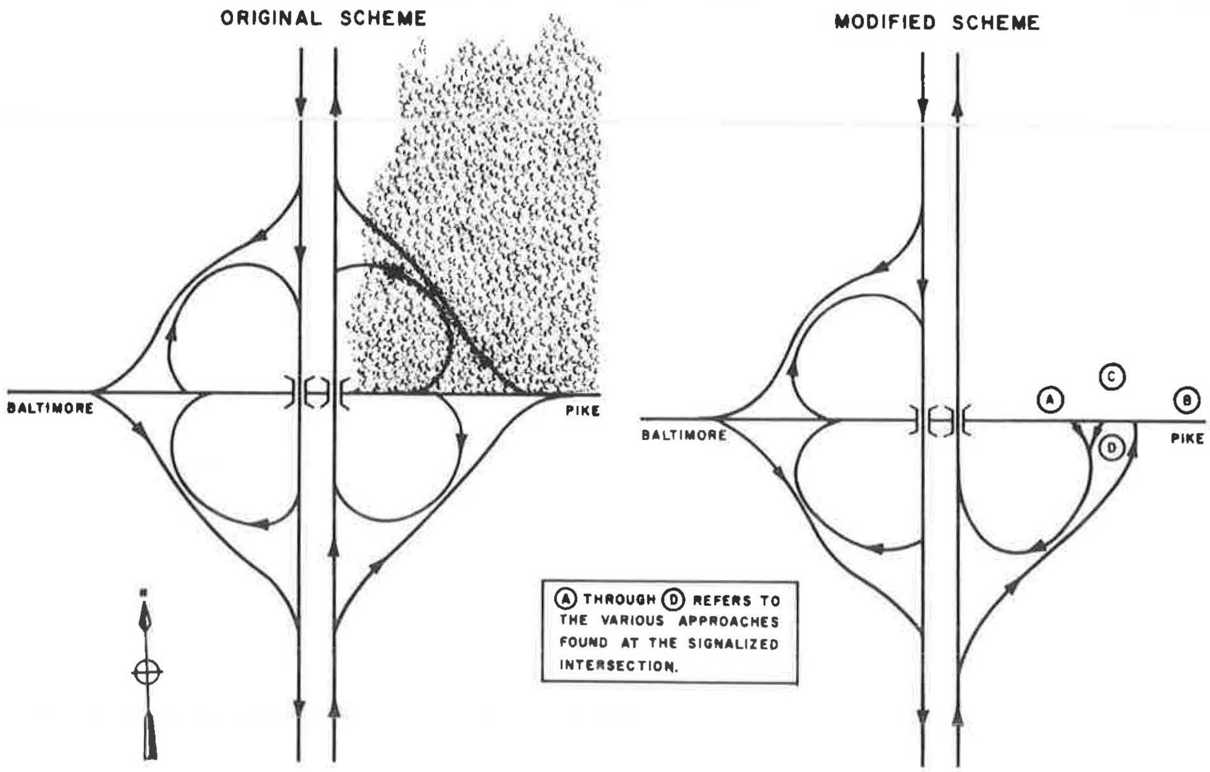


Figure 5. Original and modified schemes for Baltimore Pike interchange.



severe. Only those ramps in the northeast quadrant of the interchange have been relocated. This causes northbound travel both entering and exiting the freeway to proceed through a signalized intersection. Again, double left-turn lanes will be provided on (a) westbound Baltimore Pike for travel destined north on the Mid-County Expressway (B-D in Figure 5) and (b) the northbound exit ramp from the Mid-County Expressway for travel destined west on Baltimore Pike (D-A).

Lancaster Pike

The study areas that surround the modified interchange at Lancaster Pike, including the adjoining interchanges at the Schuylkill Expressway and West Chester Pike, are shown in Figure 6. The east-west boundaries for the areas of analysis were delineated from the origins and destinations assigned to the expressway.

The major road network that services the delineated areas is composed primarily of two-lane undivided facilities and is also shown in Figure 6. Table 1 gives the calculated travel times for the original design between Lancaster Pike and the adjoining interchanges by way of the Mid-County Expressway and the surrounding parallel arterials. Note that the travel time between areas 2 and 6 is less via Matson Ford Road and Montgomery Avenue even under the original design plan for this interchange. Appropriately, no trips were assigned to the Mid-County Expressway between these areas.

A capacity analysis conducted for the southbound entrance and exit of the freeway showed that the signalized intersection would operate at capacity in the peak hour

Figure 6. Lancaster Pike interchange study area.

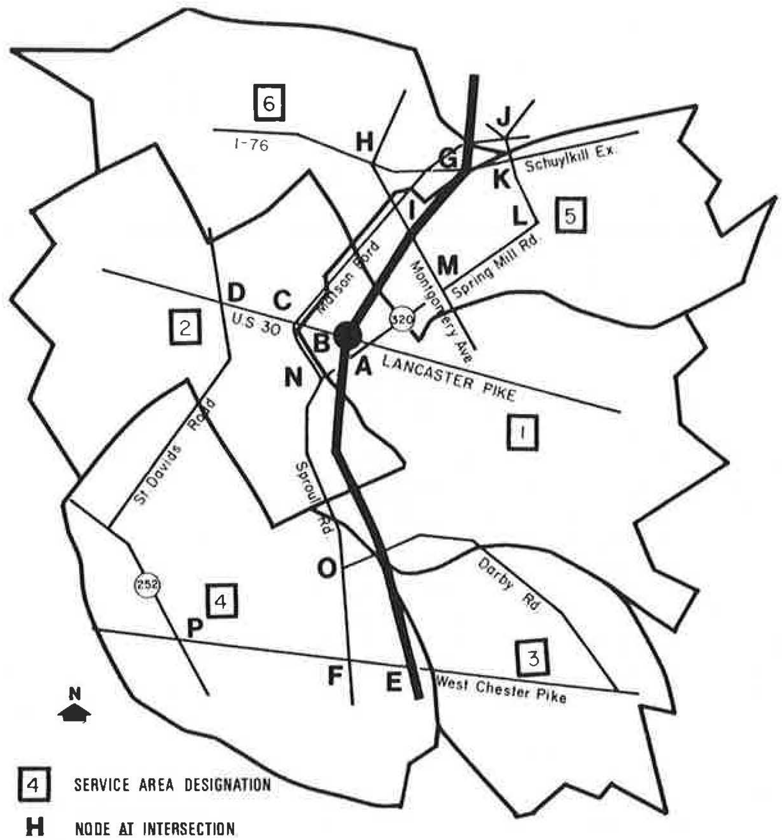


Table 1. Peak travel times between service areas for Lancaster Pike interchange (original design).

Service Areas	Mid-County Expressway Path[a]	Minutes Between Areas Peak	Minutes Between Areas Nonpeak	Arterial Path[a]	Minutes Between Areas Peak	Minutes Between Areas Nonpeak
1-3	1-A-B-E-3	23.5	16.3	1-A-N-O-3	31.9	28.0
				1-A-N-O-F-E-3	37.7	31.8
1-4	1-A-B-E-F-4	21.1	19.3	1-A-N-O-F-4	22.3	21.5
				1-A-B-C-D-P-4	28.5	21.5
1-5	1-A-B-G-K-5	7.7	6.3	1-A-M-L-K-5	9.8	9.0
1-6	1-A-B-G-H-6	7.1	10.1	1-A-M-I-H-6	13.6	11.5
2-3	2-D-C-B-E-3	32.9	25.2	2-D-C-N-O-3	38.3	32.7
				2-D-P-F-E-3	42.3	37.9
				2-D-C-N-O-F-E-3	44.2	38.5
2-4	2-D-C-B-E-F-4	29.0	26.0	2-D-P-4	32.3	25.1
				2-D-C-N-O-F-4	32.6	31.1
2-5	2-D-C-B-G-K-5	16.8	15.7	2-D-C-I-J-K-5	21.6	19.4
				2-D-C-I-H-G-K-5	25.0	18.8
2-6	2-D-C-B-G-H-6	19.1	17.5	2-D-C-I-H-6	18.1	15.3

[a]See Figure 6.

(level of service E). A similar analysis performed at the northbound off-ramp connection with Lancaster Pike indicated this to be the more critical juncture. Peak-hour volumes are expected to exceed capacity at this location and produce significant delays and intersection failure (level of service F). The table below gives the results of these analyses for specific movements at the interchange and also the delay incurred at the intersection because of the signalized control (no delay is added for movement E-F since the signal is currently in operation and level of service is not affected):

Entrance or Exit Point for Mid-County Expressway	Movement	Level of Service	Additional Delay (min)
North Exit	F-E	F	1.5
North Exit	H-F	F	1.5
North Exit	E-F	A	None
North Exit	H-E	F	1.5
South Exit	D-B	B	0.3
South Exit	D-A	D	0.7
Entrance	A-D	E	1.2
Entrance	B-D	E	0.7

The additional delays encountered for each movement produce the expected travel times when the modified interchange is in operation. For the Mid-County Expressway paths, Table 2 gives the travel times for each movement with the original and modified interchange, the number of peak-hour and daily trips between the respective service areas, and movements for which a faster alternative path exists.

In Table 2 the modified design will increase travel time through the interchange from 0.3 to 2.2 min depending on the specific movement. This range is applicable for all travel that passes through the interchange including the long-distance trips not directly analyzed.

For short-distance trips, the average increase is 1.4 min/vehicle. With this change, two-way trips between the Villanova and Marple Township areas (1 to 4) and directional trips from the Villanova to Conshohocken areas (1 to 5) are provided a slightly faster routing by way of PA-320. Although the maximum time savings is limited to approximately 20 s, it is reasonable to expect these trips to divert when one considers the expected congestion near the interchange and its psychological impact on driver behavior.

The impact on the remaining trips that approach the interchange from the south and those that originate in the Villanova area (area 1) is less clear. The estimated travel times on the Mid-County Expressway are faster than on the alternative arterial paths available. However, all of these movements will encounter the level of service F conditions cited. Depending on the degree of congestion reached at this location, some of this traffic may choose to avoid the location.

Assuming that this condition is tolerable, the analysis indicates that approximately 600 trips will divert from the Mid-County Expressway to the parallel section of Sproul Road (PA-320) and an additional 100 trips will divert to the parallel section of PA-320 and Spring Mill Road if the modified interchange is constructed.

Baltimore Pike

The service areas and major road network that surround Baltimore Pike are shown in Figure 7; Sproul Road (PA-320), Providence Road (PA-252), and Woodland Avenue (PA-420) are the principal alternative arterial facilities to the Mid-County Expressway. The alternative paths considered and their respective travel times are given in Table 3. Again, the area-to-area movements that have no trips are afforded faster travel by way of the arterials even with the original design plan for the Baltimore Pike interchange.

The capacity analysis conducted at the approaches is summarized below (see Figure 5 for movements):

Entrance or Exit Point for Mid-County Expressway	Movement	Level of Service	Additional Delay (min)
North Entrance	B-D	D	0.7
North Entrance	A-D	Nonsignalized free-flow movement	—
North Exit	D-B	B	0.3
North Exit	D-A	D	0.7
Intersection	B-A	A	0.1

Overall service at the signalized ramps is favorable: Level of service ranges between A and D for specific movements. The D conditions are recorded at the double left-turning movements both on and off the northbound section of the Mid-County Expressway.

A comparison of peak-hour travel times with the original and modified interchange design plan and the number of local trips affected are given in Table 4. Only 10 of the possible 16 movements are affected by the modified design, and the average additional delay is calculated at 0.4 min or 25 s/vehicle. Individual delays range from 0.0 to 0.7 min/vehicle movement.

This table, used in conjunction with the alternative route travel times given in Table 3, indicates that movements assigned to the Mid-County Expressway are still served better via the freeway. As a result, no diversion is expected with the modified design plan proposed at the Baltimore Pike interchange.

Table 2. Travel times between service areas via Mid-County Expressway for 1996 Lancaster Pike interchange.

	Peak Direction					Nonpeak Direction				
	Travel Time (min)		Number of Trips[a]			Travel Time (min)		Number of Trips		
Service Areas	Original	Modified	Peak	Daily	Condition of Movements	Original	Modified	Peak	Daily	Condition of Movements
1-3	23.5	25.0	80	600	1[b]	16.3	18.5	60	600	1[b]
1-4	21.1	22.6	40	300	2[c]	19.3	21.5	30	300	2[c]
1-5	7.7	9.9	10	100	2[c]	6.3	6.6	10	100	
1-6	7.1	9.3	10	100	1[b]	10.1	10.4	10	100	
2-3	32.9	34.4	380	2900		25.2	26.4	250	2900	1[b]
2-4	29.0	30.5	80	600		26.0	27.2	50	600	1[b]
2-5	16.8	18.0	70	500		15.7	16.0	50	500	
2-6	19.1	20.3	0	0	2[c]	16.5	16.8	0	0	2[c]

[a]Data summarized from selected link.
[b]Movements that must use approach operating at level of service F.
[c]Movements with faster arterial path when Lancaster Pike interchange is modified.

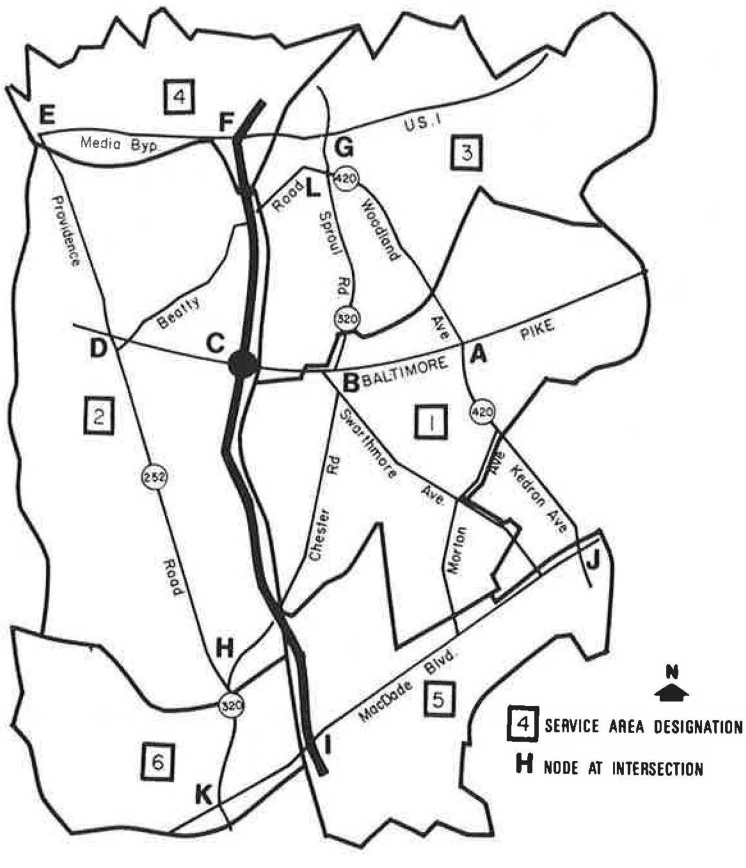


Figure 7. Baltimore Pike interchange study area.

Table 3. Peak travel times between service areas for Baltimore Pike interchange (original design).

	Mid-County Expressway			Arterial		
		Minutes Between Areas			Minutes Between Areas	
Service Areas	Path[a]	Peak Direction	Nonpeak Direction	Path	Peak Direction	Nonpeak Direction
1-3	1-B-C-F-G-3	5.3	4.7	1-B-L-G-3	6.2	5.1
				1-A-L-G-3	6.2	6.2
1-4	1-B-C-F-4	5.3	4.7	1-B-L-G-F-4	7.5	6.3
				1-B-C-D-E-4	14.2	10.9
1-5	1-B-C-I-5	15.7	13.4	1-A-J-5	11.9	11.4
1-6	1-B-C-I-K-6	10.5	9.1	1-B-H-K-6	20.0	18.0
2-3	2-C-F-G-3	7.9	6.4	2-C-B-L-G-3	12.9	10.4
2-4	2-C-F-4	5.4	4.9	2-D-E-4	5.8	5.8
2-5	2-C-I-5	17.4	13.8	2-C-B-A-J-5	20.9	17.8
2-6	2-C-I-K-6	10.8	9.5	2-D-H-K-6	9.2	8.4

[a]See Figure 7.

Table 4. Travel times between service areas via Mid-County Expressway for 1996 Baltimore Pike interchange.

	Peak Direction				Nonpeak Direction			
	Travel Time (min)		Number of Trips[a]		Travel Time (min)		Number of Trips	
Service Areas	Original	Modified	Peak	Daily	Original	Modified	Peak	Daily
1-3	5.3	6.0	30	300	4.7	5.0	30	300
1-4	5.3	6.0	90	900	4.7	5.0	90	900
1-5[b]	15.7	16.0	0	0	13.4	13.5	0	0
1-6	10.5	10.8	10	100	9.1	9.2	10	100
2-3	7.9	7.9	70	700	6.4	6.4	70	700
2-4	5.4	5.4	140	1300	4.9	4.9	140	1300
2-5	17.4	18.1	30	300	13.8	13.8	30	330
2-6[b]	10.8	11.5	0	0	9.5	9.5	0	0

[a] Data summarized from selected link.
[b] Movements with faster arterial path when Baltimore Pike interchange is modified.

CONCLUSIONS

The process developed achieved the objective of the analysis. By using negligible computer modeling and relying on accepted relations, specific information was produced that detailed the probable effects of each modification on travel movements.

The process appears most appropriate for analyzing the many alternatives that often result from the EIS process, as in the case of I-476. Its rational as well as computational simplicity allows for a clear presentation of impacts to the public, which facilitates development of an alternative that will achieve the desires of the community and its decision makers.

For I-476, the effect of the modified design plans at both interchanges will be predominately restricted to the localized area around each interchange. At Lancaster Pike, the probable diversion of 600 vehicles is relatively minute and should be considered negligible. The prime concern at this interchange should focus on alleviating the intersection problem expected at the terminus of the northbound off-ramp from the Mid-County Expressway. It is the magnitude of the associated congestion that will dictate the acceptability of the design and determine the extent to which travel through the interchange is altered.

For the Baltimore Pike, less severe modifications combined with smaller daily demand result in no travel diversion from the Mid-County Expressway. Here, capacity can adequately accommodate anticipated demand with only two movements below normal design standards.

In essence, the modifications do not measurably divert traffic, but a lower quality of service is provided to the users.

After the completion of the study, improvements were introduced by PennDOT at the Lancaster Pike interchange to eliminate the level F service cited in the analysis. Additional left-turning lanes have been introduced for movements G-F and H-E (Figure 4). In addition, widening of Lancaster Avenue to accommodate an additional lane of through travel from the east is assumed (6). These modifications improve the level of service to D in all cases.

ACKNOWLEDGMENTS

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REFERENCES

1. Freeway-Surface Arterial VMT Splitter. Creighton, Hamburg and Federal Highway Administration, 1971, pp. 22-24.
2. Draft Environmental Impact Statement and Section 4(F) Statement. McCormick, Taylor and Associates, Philadelphia, 1976, plate IV-16.
3. Travel Time Survey. Delaware Valley Regional Planning Commission, Philadelphia, Stages 1, 2, and 3, 1972, 1973, 1974.
4. Highway Capacity Manual. HRB, Special Rept. 87, 1965, p. 130.
5. A. D. May and D. Pratt. A Simulation Study of Load Factor at Signalized Intersections. Traffic Engineering, Vol. 38, Feb. 1968, pp. 44-49.
6. Traffic and Transportation Basis Report. McCormick, Taylor and Associates, Philadelphia, Final Environmental Impact/Section 4(F) Statement, 1976, p. IV-88.

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Interactive Computer Graphics for Station Simulation Models

Gregory P. Benz and Jerome M. Lutin, Princeton University

A model developed for the Urban Mass Transportation Administration (UMTA) as an aid to the designers of transit stations—the UMTA Station Simulation (USS) model—was originally designed to give tabular output of numeric data on a batch-process computer. The potential for interactive running of the program with graphic as well as tabular output is studied. The 22 output reports of USS are examined for their ability to answer basic design questions. The following four types of computer graphics presentations are discussed as means of improving the ability of USS to answer such design questions: station animation and three types of static displays—histograms, station diagrams, and performance charts. Prototype graphic displays have been developed for each of the three static presentations and matched to present USS output.

A computer program developed for the Urban Mass Transportation Administration (UMTA) as an aid to designers of transit stations—the UMTA Station Simulation (USS) model—is a discrete-event, Monte Carlo type of simulation model programmed in FORTRAN for use on IBM 360/370 computers. A semi-interactive version of USS was developed at Princeton University by using the IBM virtual machine (VM) operating system on an IBM 370/158 computer. A conversational monitoring system (CMS) EXEC program was written to create a user-oriented dialogue to handle language for file manipulation and job control. The semi-interactive version of USS reduced the cost of running the program by 95 percent in comparison with the conventional version (5).

The semi-interactive version of USS has made the program a more responsive part of the designer's creative process. Current research at Princeton and Avia-