line triples, it will have an economic impact greater than the behavioral changes discussed in this paper. Therefore, the results presented here only help to explain the mechanisms of personal long-distance travel and make it possible to forecast the individual behavioral changes that would result under certain conditions.

However, the findings of this paper clearly show that the existence and actualization of personal long-distance travel are the result of highly complex decisionmaking processes within private households. Although travel time and travel costs involved in using different modes are important, it is the subjective perception of these factors that influences decisionmaking. In concrete decisionmaking situations, other factors besides travel time and travel costs are important determinants of behavior. Changes in travel time and travel costs have only a limited effect on modal choice. Thus, the problem of trip generation plays a much larger role than modal choice. When it becomes more difficult to make personal long-distance trips, a change of mode is not the most likely response; it is more frequent for persons taking vacation trips to travel to a nearer destination and for persons making other personal long-distance trips to reduce the frequency with which they make these trips.

Because there is a great need for data (a problem discussed at the beginning of this paper), the main goals of this study were to make explanatory data for the analysis of long-distance travel available and to develop a model that can more realistically depict behavioral changes. The quality of further forecasts dealing with personal long-distance travel in Germany will depend, to a large degree, on the extent to which these new data can be included in the synthetic models that are already operating.

REFERENCES

1. Socialdata. Marktanalyse des Verhaltens im Personenfernverkehr. German Ministry of Transport, Munich, 1981.
2. Socialdata. Marktanalyse des Verhaltens im Personenfernverkehr: Tabellenband. German Ministry of Transport, Munich, 1981.
3. M. Wermut. Verhaltensorientierte Verkehrsnachfragemodelle: Entwicklung und Stand der Kunst. WIST-Information, No. 45, June 1979.
4. Socialdata. Marktanalyse des Verhaltens im Personenfernverkehr: Expert Volume. German Ministry of Transport, 1981.
5. W. Brög. Behavior as a Result of Individual Decision in Social Situations. Presented at Conference on Mobility in Urban Life, Arc-et-Senance, France, Sept. 1978.
6. W. Brög. Latest Empirical Findings of Individual Travel Behaviour as a Tool for Establishing Better Policy-Sensitive Planning Models. Presented at World Conference on Transport Research, London, England, April 1980.
7. W. Brög and E. Erl. Interactive Measurement Methods: Theoretical Bases and Practical Applications. TRB, Transportation Research Record 765, 1980, pp. 1-6.
8. W. Brög. Cooperation Between Empirical Social Research on Transport Behaviour and Transport Policy Making. Presented at Conference on Social Aspects of Transport: How to Use Social Research in Transport Policy Making, Chichester, England, Sept. 1980.
9. W. Brög. Transport and the Challenge of Structural Change, Passenger Transport: Mobility and Lifestyle--Sociological Aspects. Presented at 8th International Symposium on Theory and Practice in Transport Economics, Istanbul, Sept. 1979.

Publication of this paper sponsored by Committee on Traveler Behavior and Values.

Traveler Responses to Reconstruction of Parkway East (I-376) in Pittsburgh

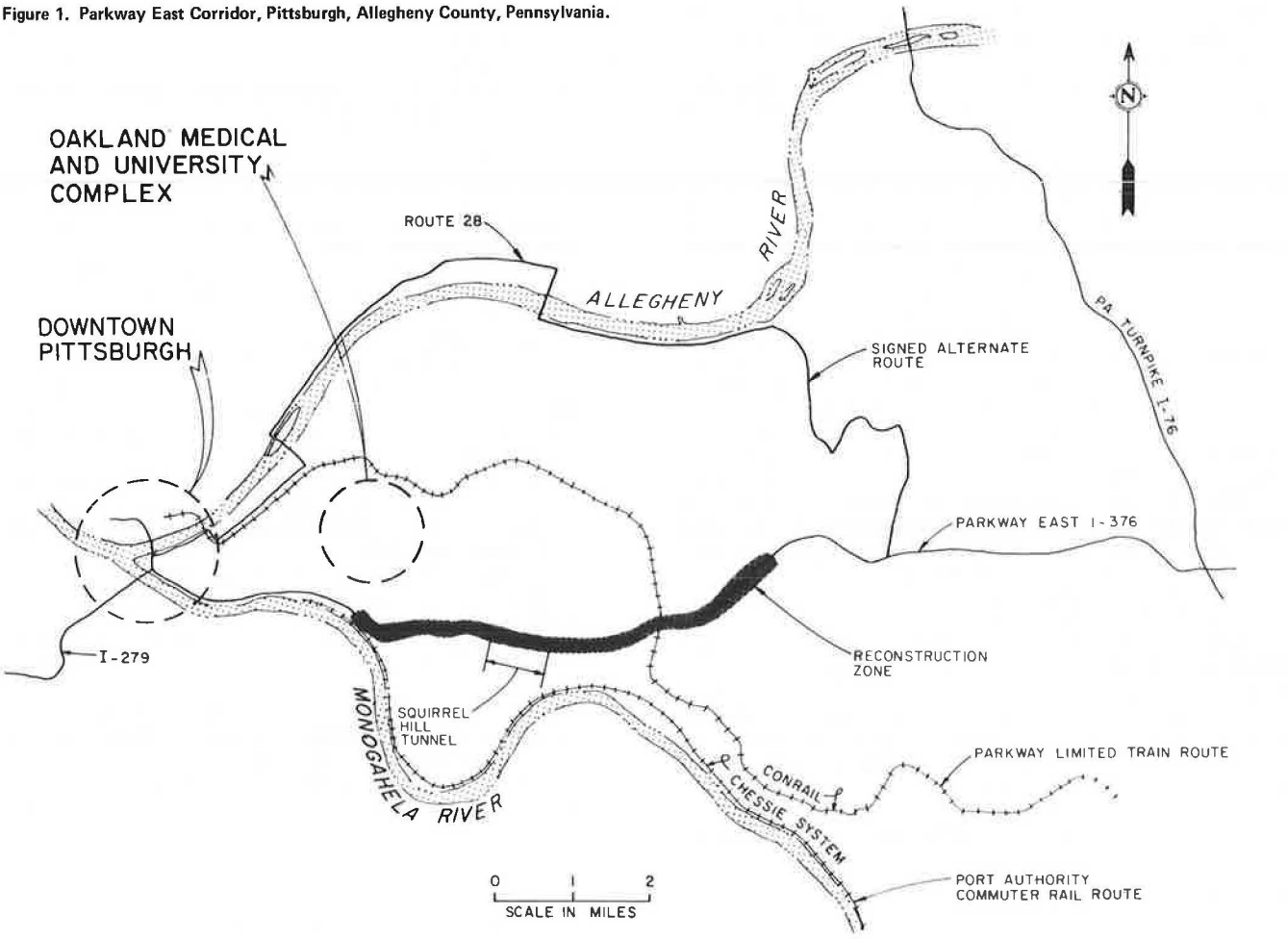
CHRIS T. HENDRICKSON, ROGER E. CARRIER, THOMAS J. DUBYAK, AND ROBERT B. ANDERSON

Reconstruction of urban expressways will be required in many metropolitan areas in the next few decades. A summary is presented of traveler responses to a reconstruction project on the Parkway East (I-376) in Pittsburgh, Pennsylvania, which normally serves more than 100 000 daily vehicle trips. Volume counts, vehicle occupancy counts, travel time measurements, and traveler surveys were made before and during the reconstruction. The major responses observed were in route choice and departure times. Large modal diversion did not occur despite ridesharing promotions and train, bus, and park-and-ride lot service improvements. However, a slight measured shift to shared-ride modes may have resulted in significant local benefits for Parkway East travelers during peak periods. Generally, the roadway system in the parkway corridor accommodated a major change in traffic patterns without substantially increased levels of congestion.

Maintaining traffic and minimizing adverse traffic impacts during reconstruction on roadways have long been a concern to highway departments. This concern is especially critical during the reconstruction of urban freeways that serve large volumes of traffic and may require several construction seasons. Major reconstruction projects of this type will become increasingly frequent in the next decade due to the deterioration of many urban roadways. Planning traffic control measures for these projects requires an understanding of traveler responses to major reconstructions.

This paper reviews the type and range of traveler responses that have occurred during reconstruction of a 10.5-km (6.5-mile) section of the Parkway East (I-376) in Pittsburgh, Pennsylvania. This highway connects the Pennsylvania Turnpike (I-76) to I-279 via downtown Pittsburgh. It is the most heavily traveled highway in the region (see Figure 1): Approximately 84 000 vehicles pass through its Squir-

Figure 1. Parkway East Corridor, Pittsburgh, Allegheny County, Pennsylvania.



rel Hill Tunnel each weekday. During the two-year reconstruction project, parkway traffic was limited to one lane in each direction and on-ramps at four interchanges were closed. The $58 million reconstruction included a 20-cm (8-in) concrete pavement overlay, rehabilitation of 21 bridges, new lighting and ventilation in the Squirrel Hill Tunnel, new signing and high-mast lighting, and a concrete median barrier.

In response to the parkway restrictions, travelers could change mode of travel, switch to off-peak hours, use alternative routes, change destinations for nonwork trips, or even reduce the number of trips made. The extent to which each of these responses occurred is considered here. In addition, changes in travel times and volumes on the Parkway East and on alternative routes are discussed.

Observations of traveler responses were made from surveys completed by travelers in the parkway corridor, traffic counts, vehicle occupancy and classification counts, and transit patronage records. Changes in travel times were determined from both survey responses and floating car travel time measurements.

This information was gathered in order to evaluate the effectiveness of a series of innovative strategies to reduce the adverse impacts of the parkway reconstruction. These strategies included a new commuter rail line (that would use existing tracks), a special vanpool promotion program, new park-and-ride lots, several new bus routes, restriction of two on-ramps to high-occupancy vehicles, and various traffic system improvements such as parking restrictions and signal synchronization. These strategies were developed by District 11 of the Pennsylvania Department of Transportation (PennDOT) as an experimental portion of the general plan for maintenance and protection of traffic associated with the Parkway East project. Although evaluation of these strategies is beyond the scope of this paper, the use of various strategies is considered in relation to overall traveler responses. Evaluation of these strategies is the objective of an ongoing joint research project conducted by GAI Consultants, Inc., and Carnegie-Mellon University and sponsored by PennDOT and the Federal Highway Administration.

POTENTIAL EFFECTS OF RECONSTRUCTION PROJECT

The potential for severe traffic disruption due to the reconstruction of the Parkway East certainly existed. During the early stages of planning for the project, the decision was made to ensure that one lane of traffic in each direction was available throughout the reconstruction period. With two lanes open for traffic, the project required two full construction seasons and traffic restrictions were scheduled from March to November in both 1981 and 1982. During these periods, on-ramps throughout the length of the affected roadway would be closed.

The most prominent bottleneck along the length of the Parkway East is the Squirrel Hill Tunnel, which includes two 1.3-km (0.8-mile) long tunnel bores with two lanes each. There were lengthy queues during peak periods at these tunnels even prior to re-

construction. During reconstruction, all traffic was routed through one tunnel bore without lane separation. Thus, the number of lanes was cut in half, and the lack of tunnel traffic separation meant that the effective capacity was reduced by more than 50 percent.

Traffic on the Parkway East dropped dramatically after the traffic restrictions were introduced (see Table 1). At the Squirrel Hill Tunnel, average daily volume dropped more than 50 percent, from an average of 84 000 vehicles to 37 000. There was a drop in traffic volumes even before 24-h traffic restrictions were imposed in March 1981 as the public was alerted to the impending restriction and the availability of alternatives. The late February volume counts already represented a decline of 9000 vehicles/day at the tunnel (Table 1).

Alternative routes in the Parkway East corridor are limited. The parkway serves as the major route to and through the central business district (CBD) from the eastern portion of the Pittsburgh metropolitan region; it is the only access-controlled, multilane expressway from this direction (Figure 1). The designated alternative to the parkway during the reconstruction involved travel via arterial streets to PA-28, located roughly 4 miles north of the Parkway East. PA-28 is a high-speed, access-controlled expressway outside of Pittsburgh but becomes an arterial street within 2 miles of the CBD. Thus, only arterial streets were generally available as alternative routes to the parkway. Many of these roads were congested even before traffic restrictions were imposed on the parkway.

This lack of alternative roadways was a motivation for introducing strategies that would concentrate on movement of people rather than just vehicles through the parkway corridor. Diverting trips to transit, carpools, or vanpools would permit equal numbers of person trips while reducing the number of vehicle trips in the corridor.

In this regard, the regional transit agency (the Port Authority of Allegheny County) operates about 80 bus routes and a commuter rail line in the corridor. During the reconstruction project, another commuter rail line, six new bus routes, and a number of park-and-ride lots were introduced by PennDOT. With traffic restrictions on the parkway and newly available capacity in the transit system, a significant diversion of trips to transit was expected.

EVIDENCE OF MODAL DIVERSION

Although attention to transit and other people-moving strategies is understandable in the parkway corridor, the response of travelers indicates that very little modal diversion occurred. Relatively few travelers switched to carpools, vanpools, or transit.

One direct indication of the lack of modal change is vehicle counts across screenlines in the parkway corridor. Observations of vehicle volumes crossing two screenlines are summarized in Table 1. Screenline 3 passes roughly through the center of the reconstruction project and includes the Squirrel Hill Tunnel (see Figure 2). Total traffic volume past screenline 3 was within 1 percent of that measured in 1978 even after traffic restrictions were imposed. For screenline 2, which was 2 miles closer to the CBD than screenline 3, a 5 percent decrease in traffic was observed. Given the amount of measurement error in the volume counts, it would be difficult to conclude that volumes either increased or decreased in the corridor, but it is certain that little overall change in volumes occurred.

Observations of average vehicle occupancy in the corridor during the morning peak period also suggest that little modal diversion to high-occupancy vehicles occurred. On screenline 2 and on the parkway near downtown, no significant change in vehicle occupancy was observed. Farther from the CBD, screenline 3 had a slight increase in average vehicle occupancy. As with vehicle volumes, however, it is unclear whether average vehicle occupancy increased or decreased on balance, but it is apparent that little overall change took place.

Surveys of travelers in the corridor also suggest that little modal change occurred. These survey respondents were identified by mail-back cards handed to travelers on transit services, alternative routes, and the Parkway East. A panel was formed from the respondents that was representative of travelers affected by the Parkway East travel restrictions (1). This panel was contacted periodically during the course of the project. The following data are taken from the July 1981 traveler panel surveys. The responses are weighted to reflect vehicle occupancies and the differential sampling rate for transit users:

Mode	Before Reconstruction (%)	During Reconstruction (%)
Drive alone	37	34
Shared ride		
Carpool with family	9	9
Carpool with others	19	20
Vanpool	3	5
Total	31	34
Transit	31	31
Other	1	1

As the table indicates, shared rides increased slightly, primarily due to an increase in vanpooling. Transit modal share remained approximately constant.

A special survey asked for the former mode of travel of new members of vanpools. Interestingly, the results suggest that new vanpool members were largely attracted from carpools and transit services (data from a survey of 249 new vanpool riders with a 72 percent response rate):

Mode	Percentage
Drive alone	21.7
Carpool	26.7
Port Authority Transit	43.3
Commuter train	2.8
Other vanpool	5.5

Thus, vanpools do not seem to have directly resulted in an appreciable reduction in the amount of vehicle travel despite increases in ridership.

Whereas increases in shared-ride modes did not represent a significant shift of overall travel in the corridor, promotion of shared rides, particularly vanpools, was relatively inexpensive and may have resulted in significant benefits during peak hours of travel on the Parkway East. The effectiveness of ridesharing and other strategies in reducing peak-period congestion is being studied and will be reported on later.

ROUTE CHANGES

With little change in the average weekday volumes observed past screenlines and substantial decreases in volumes on the parkway, it is no surprise that a substantial diversion in routes occurred in the corridor. For occupants of the 37 000 vehicles that formerly used the on-ramps in the construction section on the Parkway East, there was little choice:

New routes had to be adopted if the trips were to be made at all. Other travelers changed routes to avoid the congestion on the parkway.

Although substantial route diversion did occur, it was concentrated on the arterial streets close to the parkway. Figure 3 summarizes the changes in average daily volumes measured on screenline 3 between 1978 and April 1981. Whereas the parkway had a decrease of 47 000 vehicles/day, the six counting stations within 2 miles of the parkway showed an in-

Table 1. Changes in roadway volumes and vehicle occupancies during reconstruction of Parkway East.

Item	Measurement Data			Change (%)	
	1978	February 1981	April 1981	1978-April 1981	February-April 1981
Avg daily vehicle volume (000s)					
Screenline 2[a]					
Parkway	68	NA	51	-25	
Twelve locations including parkway	268	NA	255	-5	
Screenline 3[b]					
Parkway	84	75	37	-56	-51
Seventeen locations including parkway	285	NA	281	-1	
Avg morning peak vehicle occupancy (persons/vehicle)[c]					
Screenline 2[a]					
Parkway	NA	1.43	1.39		-3
Twelve locations including parkway	NA	1.42	1.40		-1
Screenline 3[b]					
Parkway	NA	1.40	1.49		+6
Seventeen locations including parkway	NA	1.40	1.43		+2

Note: Measurements made by GAI Consultants, Inc., for 1981 and Southwestern Pennsylvania Regional Planning Commission for 1978. Occupancy counts are an average for all inbound vehicles during a 15-min interval of the morning peak period.

[a] Screenline 2 is located 3 miles east of the CBD.
[b] Screenline 3 is located 5 miles east of the CBD.
[c] Average screenline occupancies are calculated as total persons crossing the screenline divided by total vehicles crossing the screenline, excluding transit vehicles.

Figure 2. Pittsburgh experiment: alternative routes and modes.

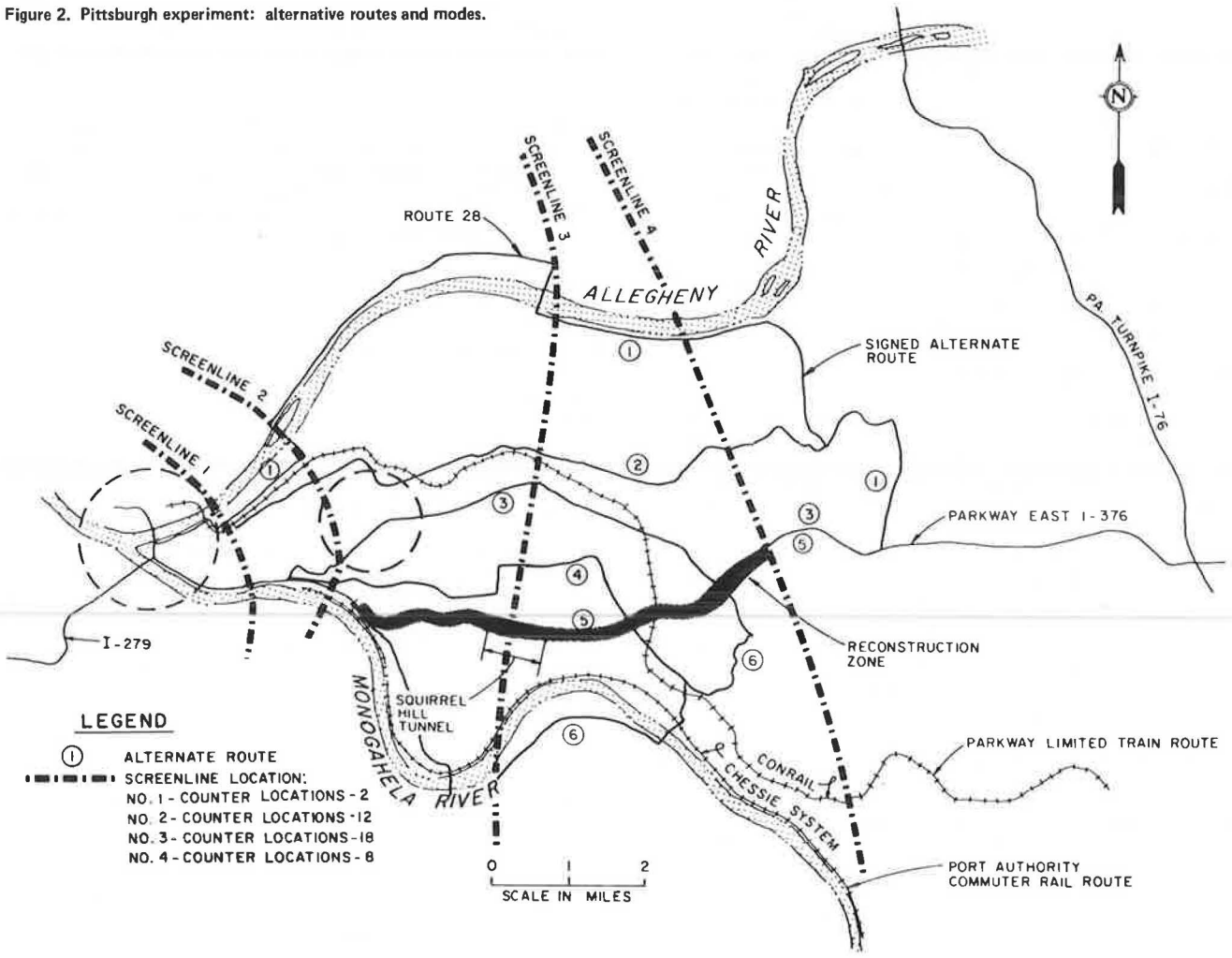


Figure 3. Changes in average daily traffic volumes between 1978 and April 1981 on screenline 3.

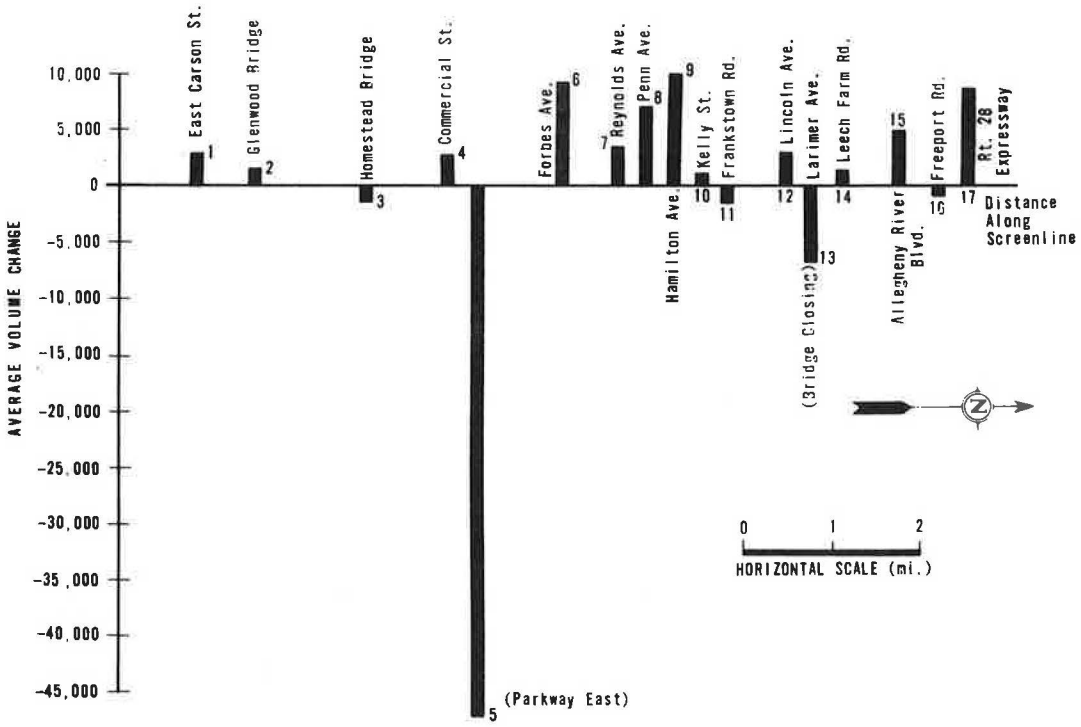
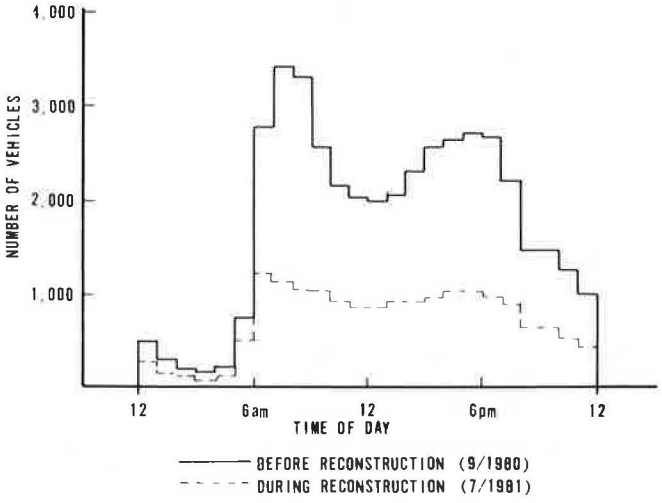


Figure 4. Average weekday traffic volume westbound at Squirrel Hill Tunnel on Parkway East.



crease of 29 000 vehicles. In comparison, traffic on the PA-28 section of the designated parkway alternative increased by only 7000 vehicles/day.

DEPARTURE TIME AND TRAVEL PEAKING CHANGES

In addition to route changes, travelers also reported earlier departure times for work. The data given in the following table are from July 1981 and February 1982 surveys of Parkway East travelers. The responses are weighted to reflect vehicle occupancy:

Departure Time from Home	Before Reconstruction (%)	During Reconstruction (%)
Before 6:00 a.m.	5	10
6:00-6:30 a.m.	8	9
6:30-7:00 a.m.	41	41
7:00-7:30 a.m.	41	35
7:30-8:00 a.m.	2	2
After 8:00 a.m.	2	3

Average departure time was earlier by 20 min during the reconstruction. Although some of this shift is attributable to seasonal effects, travelers also shifted departure times to ensure arrival on time or to avoid congestion.

On the parkway itself, the effect of the traffic restrictions was to nearly eliminate peak traffic periods altogether. Figure 4 summarizes hourly traffic counts in the westbound direction (toward the CBD) on the Parkway East for average weekdays before and during the reconstruction. The traffic volumes shown in Figure 4 occurred at the Squirrel Hill Tunnel. As can be seen in Figure 4, the pattern of traffic before reconstruction has an early morning peak for travel toward the CBD. During the reconstruction, traffic volumes are nearly constant on the Parkway East throughout the day. What little peaking exists during reconstruction begins earlier than the peak before the reconstruction. Volumes in the eastbound direction had a similar shift from the peak evening commuting hours.

OTHER TRAVEL RESPONSES

The preceding sections described changes in mode, route, and time of travel. The travelers in the parkway corridor might also have responded by changing the destination of trips and by traveling less frequently. Observations of the travel volumes past screenlines in the corridor (as summarized in Table 1) indicate that little net change in the overall

Table 2. Inbound (westbound) travel times in Parkway East corridor.

Period	Travel Time (min) PA-28	PA-380	Penn Avenue	Allies Boulevard	Parkway	PA-837	Weighted Avg[a]	Weighted Change (%)
Morning peak								
After[b]	38	36	42	30	37	35	36	
Before[c]	43	36	30	28	28	40	31	
Change	−5	0	+12	+2	+9	−5	+5	16
Off-peak								
After[b]	36	33	32	24	16	32	27	
Before[c]	37	32	36	25	20	35	26	
Change	−1	+1	−4	−1	−4	−3	+1	4
Evening peak								
After[b]	28	29	44	25	21	29	28	
Before[c]	38	35	34	28	17	32	25	
Change	−10	−6	+10	−3	+4	−3	+3	12

Note: Each travel time represents the average of five separate vehicle runs.
[a]Calculated as the travel time on each route weighted by the February or April 1981 volume counts at the intersection of screenline 3 and each route.
[b]Measurements taken in April 1981.
[c]Measurements taken in February 1981.

Table 3. Outbound (eastbound) travel times in Parkway East corridor.

Period	Travel Time (min) PA-28	PA-380	Penn Avenue	Allies Boulevard	Parkway	PA-837	Weighted Avg[a]	Weighted Change (%)
Morning peak								
After[b]	31	25	28	23	21	29	26	
Before[c]	34	27	30	19	13	21	19	
Change	−3	−2	−2	+4	+8	+8	+6	37
Off-peak								
After[b]	39	33	39	17	33	33	32	
Before[c]	34	30	34	22	12	31	21	
Change	+5	+3	+5	−5	+21	+2	+11	52
Evening peak								
After[b]	45	34	36	33	33	32	36	
Before[c]	39	31	37	26	13	38	23	
Change	+6	+3	−1	+7	+20	−6	+13	57

Note: Each travel time represents the average of five separate vehicle runs.
[a]Calculated as the travel time on each route weighted by the February or April 1981 volume counts at the intersection of screenline 3 and each route.
[b]Measurements taken in April 1981.
[c]Measurements taken in February 1981.

number of trips occurred in the corridor, although these observations might be the combination of decreased tripmaking for one purpose and increased tripmaking for other purposes.

Survey responses provide another indication of the extent of traveler responses along these two dimensions. In July 1981, travelers were surveyed who were identified as making nonwork trips in the corridor prior to the traffic restrictions. Of these 700 travelers, 83 percent reported the use of new routes and 69 percent indicated that they often avoided travel on the Parkway East during the construction project. In addition, approximately one-third of the travelers reported that they occasionally shopped in different places and made fewer trips than they normally did as a response to the parkway reconstruction and associated traffic restrictions. Since only one-third of these travelers indicated that they made fewer trips, and since only nonwork trips may have changed, the net effect of such changes was likely to be relatively small.

Downtown merchants corroborated this conclusion with respect to downtown shopping. According to an article in the Pittsburgh Post Gazette on April 1, 1981, merchants could not identify any reduction in sales after imposition of traffic restrictions.

TRAVEL TIME AND DISTANCE CHANGES IN PARKWAY EAST CORRIDOR

Floating-car travel time measurements were made immediately before and then two months after the imposition of 24-h traffic restrictions on the parkway. These travel time measurements were made between points at the eastern end of the Parkway East and in the Pittsburgh CBD for both directions during three time periods and on the six separate routes illustrated in Figure 2. Before reconstruction, in all but one case the travel time on the Parkway East was somewhat less than the travel time on alternative routes. After traffic restrictions were imposed, times for other routes were within a few minutes of the travel time on the Parkway East.

Table 2 summarizes the average travel times for westbound travel (toward the CBD) on the six routes. As noted above, the parkway provides the fastest travel times for the trips taken, even after the imposition of traffic restrictions. Surprisingly, some routes showed a decrease in travel time between February and April 1981. Because there was diversion of traffic from the parkway to other routes, travel times on these other routes would normally be expected to increase. With the traffic restrictions, inbound travel times on the parkway during peak periods showed significant increases of 9 min in the morning peak and 4 min in the evening peak. However, a decrease in the average travel time during off-peak periods was observed even on the parkway.

This mixture of travel time changes can be ascribed to a number of factors. Most prominent are

the traffic system improvements installed by PennDOT, a process of searching by travelers immediately prior to the imposition of traffic restrictions, and the effects of measurement variation. PennDOT system improvements, such as parking restrictions, signalization, pavement patching, and traffic policemen, undoubtedly contributed to a reduction in travel times on alternative routes.

The impact of traveler searches is more ambiguous, but they may well have influenced the travel time measurements. The travel time measurements for the before case in Table 2 were taken in February 1981. During this month, the traffic volume on the parkway had already dropped (Table 1). Travelers diverted from the parkway may already have been searching for new routes, and their unfamiliarity with the alternative routes may have caused a temporary increase in travel times during February. Measurements taken after traffic restrictions were removed may give some indication of the magnitude of this effect. Such measurements will be presented in future reports.

Changes in the weighted average of travel times give an indication of the overall effect on travel times in the Parkway East corridor. As Table 2 indicates, the average inbound morning peak travel times increased by 5 min, off-peak travel times by 1 min, and evening peak travel times by 3 min. Thus, although travel time was reduced on individual routes, the overall effect was that of increased travel times in each period. In comparison with the overall travel times before the traffic restrictions, the weighted average travel times increased from 4 to 16 percent; the largest increase was for inbound travelers in the morning peak and the smallest was for off-peak travelers.

Changes in travel times outbound were similar to those inbound, although the magnitudes of the changes were somewhat larger (see Table 3). Again, some routes showed a decrease in the measured travel times. The weighted average travel times showed increases of 7 min in the morning peak, 11 min in the off-peak, and 13 min in the evening peak. The magnitude of these changes may be somewhat overestimated because of the abnormally low traffic volumes on the parkway in the week prior to traffic restrictions, when these measurements were taken. As noted earlier, a process of searching among alternative routes began even before the traffic restrictions were imposed.

Surveys of commuters in the corridor also suggest that the changes in travel times and trip distances are relatively small. In a mail-back survey of 1350 commuters, approximately two-thirds of the respondents reported increased travel times with an average change of slightly less than 7 min. In the same survey, one-third of the respondents reported increased travel distance to work with an average increase of 1.3 km (0.8 mile).

CONCLUSIONS AND IMPLICATIONS

Despite a large reduction in the effective capacity of the Parkway East and a large diversion of traffic in the corridor, the overall traveler impacts and responses to the reconstruction were small. Changes in route choice and somewhat earlier departure times for work were the primary responses.

The changes in trip characteristics were also relatively small, with a reported increase of roughly 7 min in travel time and 1.3 km (0.8 mile) in travel distance for work trips. These travel time increases were not significant enough to induce more extensive changes in route, departure time, or modal choice. As with the recent Eden Expressway reconstruction in Chicago, predictions of chaos resulting from the traffic restrictions on the Parkway East were quite exaggerated (2).

Of course, the lack of serious impact may be due to some special characteristics of the Parkway East corridor, to effective preconstruction traffic planning, and to the local benefits of ridesharing promotions, including transit and vanpooling. There was a measurable increase in vanpooling in the corridor. PennDOT made special efforts to increase the capacity of streets that were alternative routes. It may also be the case that an unusually large amount of excess capacity existed in the corridor's arterial streets, although this was not evident prior to the project. Further research will attempt to isolate the effects of these considerations.

The major conclusions of this study are twofold:

1. Large modal diversions did not result from temporary traffic restrictions. Decisions on route choice and departure time appear to be more flexible and were the primary mechanisms of traveler response.
2. The roadway system accommodated a major change in traffic patterns without substantially increased levels of congestion.

Several interesting questions remain for research:

1. To what extent are traffic systems improvements on alternative routes and ridesharing promotions warranted in order to reduce traffic congestion? More broadly, what is the cost-effectiveness of alternative, congestion-reducing strategies? If particular strategies are inexpensive, they may be cost effective even if they have small overall impact.
2. Could greater traffic restrictions on an expressway be accommodated without unacceptable congestion elsewhere? This issue is particularly important since maintenance of traffic on the Parkway East (I-376) involved considerable expense, including a longer construction period.

REFERENCES

1. C. Hendrickson and T. Dubyak. Corridor Traveler Surveys for the Evaluation of Alternative Transportation Strategies During the Parkway East (I-376) Reconstruction. Department of Civil Engineering, Carnegie-Mellon Univ., Pittsburgh, PA, Tech. Rept., 1982.
2. C.B. McLean. The Edens Expressway Project. TRB, Transportation Research News, No. 94, May-June 1981, pp. 9-13.

Publication of this paper sponsored by Committee on Passenger Travel Demand Forecasting.