TRAVEL DEMAND MODEL ANALYSIS - FUTURE TRAFFIC*

The BHJ Travel Demand Model is a series of mathematical programs designed to predict travel behavior across specific transportation alternatives. This particular type of model is required of all MPOs in Ohio. Besides determining effects of transportation alternatives in corridor or regional studies, the model is also instrumental in determining air quality and environmental conformity for the region. The model measures regional travel *demand* for a specific alternative. The travel demand model is an extremely useful tool in corridor and regional studies because it presents a consistent, objective summary of different transportation alternatives.

The focus of the BHJ Travel Demand Model in this Study is to determine if a transportation need exists for a new Ohio River crossing in the region. The consultant team in coordination with BHJ staff focused their attention to finding if total river crossings (i.e., vehicles that use one of the three bridges) exceed the supply (capacity) of those bridges. The first part of the analysis concentrated on river-crossing demand under current conditions and in the horizon year. The second part of the analysis examined river-crossing demand if one or two bridges become inoperable by 2020. Both parts of the analysis use daily river crossings for comparison because it is the most commonly used level of analysis.

Figure 7 shows the daily river crossings for 1999 and 2020 analysis years. Overall, total Ohio River crossings in the region increase 10% over the 21-year period, from 43,700 to 48,100. Veterans Memorial Bridge has the highest daily volume of the three bridges. Its use increases 9.6%, from 29,100 vehicles/day in 1999 to 31,900 vehicles/day in 2020. Use of the Market Street Bridge increases 16%, from 10,000 to 11,600 vehicles/day respectively. Volumes on the Fort Steuben Bridge remain constant for both years (4,600 vehicles/ day). While there is growth in demand to cross the Ohio River, it does not appear to overwhelm any of the three facilities.

It is important to note that these results are directly attributable to the population, employment, and highway project forecasts in the model. The population and employment forecasts were developed by BHJ using standard planning techniques. To ensure a fair and consistent analysis, only existing streets and committed highway projects were included in the highway networks. Committed projects are defined as those being in the local Transportation Improvement Program.

* Prepared by team member Burgess & Niple.

The growth in total regional river crossings does not provide evidence of need for a new river crossing. Consequently, the consultant team studied the travel demand for crossing the river if one or two bridges were inoperable in 2020. Four alternatives were specified:

- **2020 Base Alternative**. This alternative assumes that all three Ohio River bridges remain open and fully operational in 2020.
- **2020 Fort Steuben Bridge Removed (FSBR)**. This alternative assumes that the Veterans Memorial and Market Street Bridges are open and fully operational in 2020. The Fort Steuben Bridge is closed to traffic.
- **2020 Market Street Bridge Removed (MSBR).** This alternative assumes that the Fort Steuben and Veterans Memorial Bridges are open and fully operational in 2020. The Market Street Bridge is closed to traffic.
- **2020 Fort Steuben and Market Street Bridges Removed (FS&MSBR)**. This alternative assumes that only the Veterans Memorial Bridge is open and fully operational in 2020. The Fort Steuben and Market Street bridges are closed to traffic.

The Veterans Memorial Bridge is the region's youngest bridge and, therefore, is always assumed to be fully operable in 2020.

Figure 8 shows the daily volumes on the bridges under each alternative. The results of the base alternative correspond exactly to the 2020 results shown earlier. The base alternative is estimated to draw 48,100 vehicles/day across the Ohio River. This is the highest regional river crossings of all the alternatives. One peculiar trip movement was found. If all three bridges are open, the model shows a double-crossing movement. A "double-crosser" is a vehicle that crosses the river twice; that is, the origin and destination of the trip are on the same side of the river. This type of movement is common in cities with multiple bridges that are close to each other. The double-crossing movement in this region occurs on the Market Street and Fort Steuben bridges in a northbound direction and on the Fort Steuben and Veterans Memorial Bridges in the southbound direction. The total amount of double crossing accounts for 6% of total regional river crossings. This movement will have an impact on reporting results for the other alternatives since the opportunities to double cross will be reduced.

One of the major assumptions in travel demand forecasting is that people will typically behave in the future as they currently do. For example, assume a person travels 25 minutes from home to work each morning. His or her daily journey requires crossing the Ohio River using one of the three available bridges. If that bridge becomes permanently inoperable, that person's daily work trip length increases to 45 minutes. Since the person travels 25 minutes to work under current conditions, the model assumes that that person would either move or change jobs by 2020 so that their work trip would again be 25 minutes. In most cases, this would result in the person's home and job being on the same side of the river. The net result of this assumption is that total regional river crossings will decline because everyday trips will be considered to be too far and take too long. This is an

Figure 7

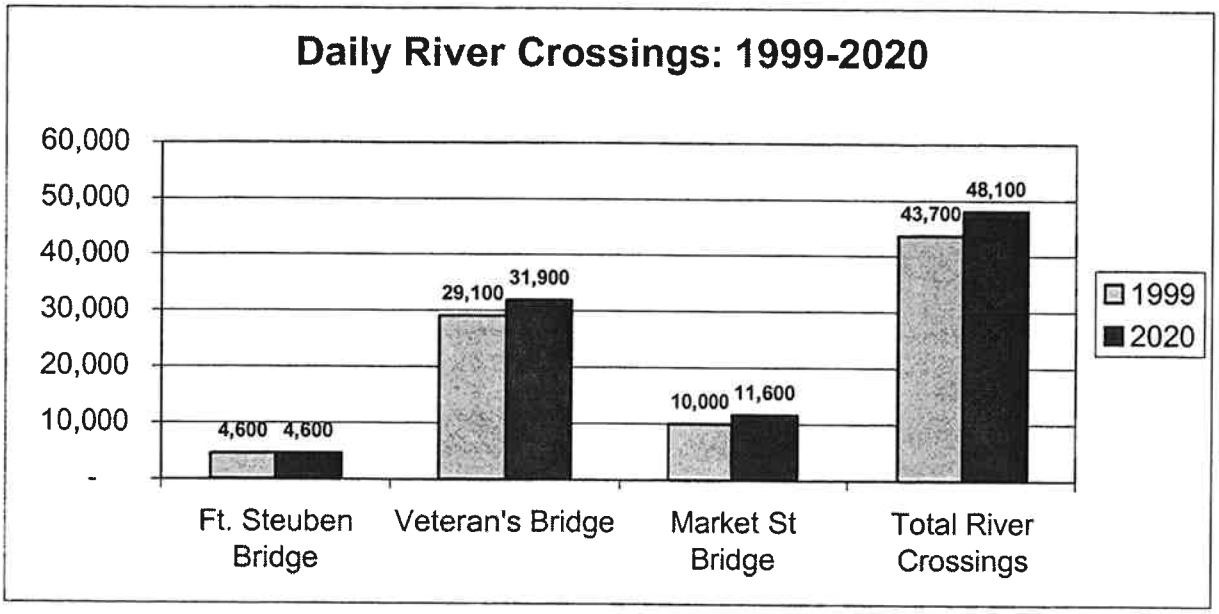

Figure 8
Projected Traffic Volumes

Volumes	Alternatives			
	All bridges remain	Fort Steuben removed	Market Street removed	Fort Steuben & Market Street removed
Fort Steuben Bridge	4,600	---	4,600	---
Veterans Memorial Bridge	31,900	32,300	43,100	42,700
Market Street Bridge	11,600	10,900	---	---
Total River Crossings	48,100	43,200	47,700	42,700

important point to consider before reporting the results of the following three alternatives.

If the Fort Steuben Bridge is inoperable in 2020, total river-crossing demand in the region falls to 43,200 vehicles/day. The reduction occurs for several reasons. The model shows that the double-crossing movement in the Base Alternative is no longer a viable option. The total river crossings are reduced by 6%. Although some trips using the Fort Steuben Bridge in the Base Alternative transferred to the Veterans Memorial Bridge, only one-fourth of the trips transfer (about 1,000). The remaining trips using the Fort Steuben Bridge in the Base Alternative simply choose not to cross the Ohio River. The remaining options (i.e., Veterans Memorial or Market Street) are not viable alternatives because people perceive a greatly increased distance and hassle to cross the river. The model estimates that most of the trips using the Fort Steuben Bridge in the Base Alternative do not use any bridge if the Fort Steuben Bridge is inoperable.

Total regional river crossing demand decreases slightly to 47,700 vehicles/day if the Market Street Bridge is inoperable in 2020. The model shows that the trips using the Market Street Bridge in the Base Alternative are much more *inelastic* than are those using the Fort Steuben Bridge in the Base Alternative. Almost all of these trips transferred to the Veterans Memorial Bridge, causing the Veterans Memorial Bridge traffic to rise over 11,000 vehicles/day compared to the Base Alternative. The remaining trips using the Market Street Bridge in the Base Alternative choose to stay of the same side of the river because of the corresponding increase in time and distance.

If both Fort Steuben and Market Street Bridges are inoperable, total regional river crossing demand is reduced to 42,700 vehicles/day. This represents the lowest total regional river crossings of all four alternatives. The closing of the Fort Steuben and Market Street Bridges has a combined overall effect in this alternative. Trips using the Fort Steuben Bridge in the Base Alternative transfer to the Veterans Memorial Bridge or choose not to cross the river, just as in the second alternative (FSBR). Trips using the Market Street Bridge in the Base Alternative transfer to the Veterans Memorial Bridge (just as they did in the third alternative (MSBR). The double-crossing movement in the Base Alternative is completely eliminated, again reducing the number of river crossings.

The results of this analysis show that the projected growth in river-crossing demand is not expected to increase dramatically if all three bridges remain open. If the Fort Steuben Bridge, Market Street Bridge, or both bridges are inoperable in the future, the increased demand on the Veterans Memorial Bridge does not appear to be excessive.

TRAFFIC OPERATIONS ANALYSIS*

The purpose of the traffic operations analysis is to define, analyze, and make recommendations regarding the traffic operations of the existing bridges and adjacent roadways in the Steubenville, Ohio/Weirton, West Virginia area. It is also intended as a point of reference with respect to larger questions regarding the overall bridge system within the project study area.

After reviewing data provided by various agencies as well as information obtained during site visits, we have identified areas with high accident rates, deficient geometrics, and inadequate signal operations. We have also performed accident analyses to determine types of accidents, probable causes, and possible countermeasures. In addition, the capacity of the three existing bridges was also analyzed, particularly with regard to how traffic would operate if one or more of the bridges were closed. All analyses were performed using both existing traffic and 20-year projected traffic volumes.

All traffic counts, capacity analyses, and accident data used for this report are included in the Appendix. Reproductions of photographs taken at key locations have also been included. In some cases assumptions as to probable traffic distribution were made in order to analyze the impact of bridge closures on roadways and intersections. All these assumptions were made based on knowledge of the study area, field observations, and common traffic engineering practices.

* Prepared by team member Pflum, Klausmeier and Gehrum Consultants

Bridge System Description

The project area spans the Ohio River and includes the eastern portion of Steubenville, Ohio and the western reaches of the Weirton, West Virginia area. The primary roadways involved are Ohio Rt. 7, US 22 and WV 2. Other streets included in the study area are University Boulevard in Steubenville and Freedom Way in Weirton. Ohio Rt. 7 and WV 2 are north-south routes, and US 22 is an east-west route, which crosses the Ohio River via the Veterans Memorial Bridge. This Bridge as well as the Fort Steuben and Market Street Bridges are also included in the study area, and are the primary focus of the study.

The Market Street Bridge, constructed in 1904, has a vehicular weight limit of 5 tons and is located south of the Veterans Memorial Bridge near downtown Steubenville. The Fort Steuben Bridge, dating from 1928, does not have a weight limit, but is very narrow so that large trucks cannot pass each other on the Bridge. It is located immediately north of the Veterans Memorial Bridge. Currently the Market Street Bridge has an Average Daily Traffic volume (ADT) of 9,200 vehicles, and the Fort Steuben Bridge has an ADT of 5,910 vehicles. Several key intersections in the immediate vicinity of the Bridges have also been considered as part of this Study. The following signalized intersections were examined: University Boulevard/ Ohio Rt. 7 and University Boulevard/7th Street/US 22 ramps in Steubenville; WV 2/Market Street Bridge and US 22/WV 2/Main Street/Freedom Way in Weirton.

The traffic volumes used for this portion of the Study were obtained from several sources. Data was provided by both ODOT and WVDOT; in addition, spot traffic counts were performed at several locations within the project area to ascertain turning movement and directional volumes at key intersections and locations.

Existing Conditions Analysis

Accident Analysis

Accident data was provided by the Ohio Department of Public Safety (ODPS), the West Virginia Department of Transportation (WVDOT), Division of Highways, and BHJ. The records from all sources were for the three-year period from 1996 through 1998. The ODPS data provided information on accidents, which occurred on Ohio Rt. 7 (Dean Martin Boulevard within the Steubenville city limits), US 22, University Boulevard, and the associated ramps and intersections. The WVDOT data listed accidents on the Fort Steuben Bridge, Veterans Memorial Bridge and the Market Street Bridge. No crashes involving animals were considered in this Study. On the Ohio side 100 accidents were recorded during the three-year period within the limits of the project; the location of sixteen of these accidents could not be determined accurately from the data provided and were not used in the analysis. The accidents analyzed occurred in the area between the Ohio Rt. 7/US 22 split to the north and University Boulevard to the south, including ramps to and from the Fort Steuben and Veterans Memorial Bridges. The total length of roadways involved in this area is less than 2 miles, which indicates a very high accident rate for the area. Accident rates for straight-through sections of roadway and for intersections or other spot locations are calculated in different ways. For this Study accident rates were calculated at specific locations using the following formula,

$$R_e = (A \times 1{,}000{,}000)/(3 \times 365 \times v_e)$$

where R_e is the calculated accident rate, A is the number of accidents occurring in a three-year period and v_e is the total volume of vehicles passing through an intersection or location in a 24-hour period. The rate is expressed in number of accidents per million vehicles entering the intersection.

Ohio Rt. 7/University Boulevard

The intersection of Ohio Rt. 7 and University Boulevard had the highest number of accidents at a single location, with 24 crashes in the three-year period. This translates to an accident rate of 1.6 accidents per million entering vehicles. Of these crashes, ten were angle-type accidents, mostly involving northbound left-turning vehicles and southbound through vehicles. There were also seven rear-end type accidents at this location. Bad weather or slippery pavement was not a factor in 58% of the crashes. There were a total of six injuries from two of these crashes. No fatalities occurred from accidents at this location.

University Boulevard/7th Street/US 22 Ramps

The intersection of University Boulevard and 7th Street/US 22 ramps was the site of thirteen accidents during the analysis period. The accident rate at this intersection is 0.8 accidents per million entering vehicles, with 85% of them occurring on dry pavement during clear weather. Nine (69%) of these accidents were angle type, seven of which were caused by eastbound vehicles turning left into the path of westbound traffic. There were no fatalities resulting from accidents at this intersection, but there were nine injuries from five of the crashes.

Westbound US 22 Ramps

On the ramp from westbound Veterans Memorial Bridge to Ohio Rt. 7, there were three overturned semi-trailers in the three-year period. While this is a small percentage of the total accidents, due to the location and nature of the accidents, there is the possibility of a great impact on the surrounding area. According to a conversation with Dave Snelting (City of Steubenville Engineer), these accidents generally cause the Veterans Memorial Bridge to close, forcing all traffic to use either the Fort Steuben Bridge or the Market Street Bridge. Other accidents on this ramp include five one-vehicle accidents involving crashing into the concrete barrier and five rear-end type accidents near the merge with Ohio Rt. 7. For purposes of this Study, the ramps were treated as a spot location rather than a through section because of the minimal length of roadway involved. Accident rate calculations for through roadways take into consideration the length of the section in miles. A total of 23 accidents occurred during a three-year period along the entire ramp sections, for a rate of 0.77 accidents per million vehicles using the ramps. One of these accidents produced two injuries and no fatalities.

Veterans Memorial Bridge

The accident data provided by the WVDOT indicates 23 identifiable accidents occurred on the Veterans Memorial Bridge between 1996 through 1998. In addition there were eleven accidents that were not analyzed because the location or other factors could not be determined from the data. More than fifty percent of the analyzed accidents (12/23) were fixed object-type crashes, with motorists striking fences, concrete median barrier, etc. Half of this type accident occurred during wet or slippery conditions. Of the total accidents, 35% occurred on wet or snowy pavement. There were a total of 12 injuries resulting from nine of the accidents; there were no fatalities.

Capacity Analysis

According to the Highway Capacity Manual (HCM), the capacity of a roadway indicates its ability to accommodate a moving stream of vehicles. Capacity refers to the maximum hourly rate of vehicles to proceed through a certain point or section of roadway under specific conditions. The rates indicated in this report assume ideal conditions, which include good weather, good pavement conditions, users familiar with the roadway, and no incidents to impede

traffic flow. Specific factors such as lane width, shoulder width, design speed, terrain, horizontal alignment of the roadway, and volume of trucks can also affect capacity. Level of Service (LOS), as defined by the HCM, is a function of average delay encountered by the motorist. Delay, of course, is a measure of driver discomfort, frustration, fuel consumption and the cost of lost travel time. Levels of service are given in terms of average delay per vehicle for signalized and unsignalized intersections. The criteria that is used by the American Association of State Highway and Transportation Officials (AASHTO), and the Ohio Department of Transportation (ODOT) and Municipal Engineering Departments for signalized intersections is as follows:

LEVEL OF SERVICE CRITERIA FOR SIGNALIZED INTERSECTIONS

Level Of Service*	Delay/Vehicle (Second)	Description
A	< 5.0	Most vehicles do not stop at all.
B	5.1 to 15.0	More vehicles stop than for LOS A.
C	15.1 to 25.0	The number of vehicles stopping is significant, although many pass through without stopping.
D	25.1 to 40.0	Many vehicles stop. Individual cycle failures are noticeable.
E	40.1 to 60.0	Considered to be the limit of Acceptable delay. Individual cycle failures are frequent.
F	> 60.0	Unacceptable delay.

*LOS "C" and "D" are generally accepted as a reasonable design criteria. LOS "E" and "F" are generally unacceptable.

Both capacity and LOS calculations have been used to analyze the traffic operations in the study area. The bridges were analyzed using capacity, while signalized intersections were analyzed using Highway Capacity Software (HCS) to determine the LOS. Analysis was made for various scenarios involving the closure of one or more of the bridges in the study area.

Bridge Analysis

In addition to closures due to traffic accidents, the Veterans Memorial Bridge closes each year during annual inspections. At these times there is advance notification and detour signage to guide motorists to the Fort Steuben and Market Street Bridges. During closures of the Veterans Memorial Bridge, these two bridges must carry an additional volume of 26,500 vehicles per day.

Assuming two-thirds of the Veterans Memorial Bridge traffic would use the Fort Steuben Bridge, the daily traffic volume would be increased to 23,577 vehicles. Based on 1997 traffic counts provided by ODOT for the Fort Steuben Bridge, approximately 20% of the daily traffic occurs during the peak hour of 7:00-8:00 a.m. Hourly traffic volume breakdowns are not available for the Veterans Memorial Bridge, therefore, it cannot be determined when the peak hour occurs. For the increased daily traffic volume, we have assumed that the peak hour volume would be 12% of the ADT, or 2,829 vehicles in the peak hour on the Fort Steuben Bridge.

Under ideal conditions the maximum capacity for a two-lane facility is 2,800 passenger cars per hour. Note that this figure does not account for truck traffic; the traffic on the Fort Steuben Bridge is composed of 20% trucks, which lowers the capacity of the bridge to 2,268 vehicles per hour. Due to the narrow lanes and the "no passing" regulation, the actual capacity of the bridge would be even lower. Since the resultant peak hour volume already exceeds capacity, these additional factors have been ignored.

With one-third of the Veterans Memorial Bridge traffic using the Market Street Bridge, the daily traffic volume increases to 18,033 vehicles. From a peak hour traffic count performed in January 2000, it was determined that the peak hour volume on the Market Street Bridge is approximately 7% of the ADT. This is lower than normal, possibly due to traffic conditions on the day the counts were performed. Assuming a peak hour volume of 10% of ADT, the resultant volume on the Market Street Bridge would be 1,803 vehicles during the peak hour. This is lower than the 2,800 maximum. However, since there is a traffic signal at the eastern end of the Bridge, the capacity at the intersection of WV 2 and the Bridge is controlled by the signal operation.

Lane capacity at a signalized intersection is based on the ratio between the green time for the relevant lane and the total cycle length of the signal. Using signal timing values obtained in the field, the capacity for the eastbound lane of the Market Street Bridge is calculated to be 665 vehicles per hour. According to the January counts, 59% of the traffic on the Bridge is eastbound during the afternoon peak hour. After adding the Veterans Memorial Bridge traffic, the eastbound peak hour volume on the Market Street Bridge would be 1,064 vehicles. HCS analysis shows that the intersection fails under this volume of traffic.

If the Fort Steuben Bridge is closed during closures due to accidents or inspections, all traffic from both that bridge and the Veterans Memorial Bridge would be rerouted to the Market Street Bridge. The resultant peak hour volume would be 3,893 vehicles. This would cause a

breakdown of traffic operations on the Bridge itself as well as on the streets of Steubenville. The roadways and intersections through downtown Steubenville are not at full capacity now, but nearly quadrupling the traffic would have a significantly negative impact on the local street system. No heavy vehicles can use the Market Street Bridge, so all truck traffic would be forced north to East Liverpool or south to Martins Ferry, a distance of 20-25 miles in either direction.

Looking at the reverse situation, if either the Market Street or Fort Steuben Bridge or both were to be closed, all traffic from those bridges would be rerouted to the Veterans Memorial Bridge. Using the ideal conditions capacity of 2,300 passenger cars per hour per lane for basic freeway sections, the maximum capacity on the Veterans Memorial Bridge is 13,800 passenger cars per hour. According to the traffic model prepared by Burgess & Niple, if both the Fort Steuben and Market Street Bridges are eliminated, river-crossing traffic is reduced by 10% due to a decrease in vehicles "double-crossing" the river. Therefore, with an adjusted ADT of 37,449 vehicles and assuming a peak hour volume of 10% of ADT, the through section of the Bridge can accommodate a peak hour volume of 3,745 vehicles from the additional traffic of both the Fort Steuben and Market Street bridges.

However, due to geometry and number of lanes, the ramp sections cannot support the same volume of traffic as the Bridge itself. Under ideal conditions a one-lane ramp section can accommodate 1,700 passenger cars per hour. The curvature and reduced speed of the exit ramps on the Ohio side of the Bridge greatly reduce the capacity. With a peak hour volume of 3,745 vehicles and assuming a 50/50 directional split, there would be 1,873 vehicles exiting at the west end of the Bridge. According to recent afternoon peak hour traffic counts, 45% of westbound vehicles exit to southbound Ohio Rt. 7. A projected total volume of 843 vehicles would use this ramp during the afternoon peak.

The ramp to southbound Ohio Rt. 7 is a single lane with a high degree of curvature. Due to prevailing conditions, the capacity of the ramp from westbound US 22 to southbound Ohio Rt. 7 would be much less than the ideal capacity. For purposes of this Study, the capacity has been estimated as 1,000 vehicles per hour, based on horizontal and vertical alignment, truck volume, and merging at the ramp terminus.

At the east end of the Veterans Memorial Bridge, the ramps have better geometrics, but at the intersection of the US 22 ramp with northbound WV 2 (Main Street) and Freedom Way, the angle of the intersection makes the left-turn movement difficult for large trucks. Closure of the Fort Steuben Bridge would force a significant amount of truck traffic through this intersection. Since the majority of the trucks currently using the Fort Steuben Bridge use it to access the Half Moon Industrial Park, a left turn onto Freedom Way from the US 22 ramp would be required.

PKG was provided with conceptual drawings for a new interchange between US 22, southbound WV 2 and Freedom

Way, that might provide an alternative should the Fort Steuben Bridge be closed.

Field observation indicates that the concept as provided fails to account for adequate vertical clearances between ramps. While such an interchange may be possible, a detailed feasibility analysis would be required. Certainly, the physical geometry of the location provides significant challenges that would need to be overcome for such an interchange to be workable.

Intersection Analysis

In addition to affecting the Bridge and ramps, any bridge closures will also have an effect on the traffic at intersections adjacent the bridges. The intersections of University Boulevard with Ohio Rt. 7 and 7th Street/US 22 ramps will be impacted. Currently the signalized intersection of University Boulevard and Ohio Rt. 7 operates at a Level of Service (LOS) "B" with an average delay of 9.5 seconds per vehicle. If the Fort Steuben Bridge is closed, therefore, altering traffic patterns and volumes through this intersection so that motorists can access the Veterans Memorial Bridge, the LOS remains "B" with a delay of 11.4 seconds per vehicle. The northbound left-turn movement is impacted the most, dropping from LOS "C" to LOS "D". If traffic from the Market Street Bridge is also considered at this intersection, there is a minimal increase in the delay, to 11.6 seconds per vehicle.

The intersection of University Boulevard and 7th Street/US 22 ramps currently operates at LOS "B" with a delay of 12.5 seconds per vehicle. Southbound traffic is currently at LOS "D" based on signal timings obtained in the field.

Observations at this intersection do not indicate that the operation is deficient, however. This is probably due to vehicles turning right during the red phase when there are sufficient gaps in westbound traffic. This incidence is not accounted for in the capacity analysis. When the traffic which now uses the Fort Steuben Bridge is added, the delay increases to 12.8 seconds per vehicle, for a LOS "B". Due to increased westbound traffic, the eastbound left-turn movement sustains the greatest impact but remains at LOS "B". If the Market Street Bridge is also closed and the resultant traffic is considered in the capacity analysis of the University Boulevard/7th Street/US 22 ramps intersection, the overall LOS remains at "B" with a delay of 13.0 seconds per vehicle. There are no additional significant changes to any individual movements.

According to field observations and a capacity analysis based on peak hour traffic counts, the signal at WV 2 and the Market Street Bridge currently operates at LOS "B" with a delay of 13.4 seconds per vehicle. This analysis is based on timing obtained in the field. There are plans to widen WV 2 in this area, including lengthening the turn lanes for the Market Street Bridge. However, if the Bridge is closed, the turn lanes would be unnecessary as would the signal.

Future Traffic

In addition to analyzing operating conditions under existing traffic, we have also looked at future conditions. Projected bridge traffic volumes for the year 2020 were used to determine the impact of increased traffic on the project area. The projected ADT volumes for each bridge are as follows:

Fort Steuben Bridge	4,631 vehicles
Veterans Memorial Bridge	31,907 vehicles
Market Street Bridge	11,630 vehicles

Accident Analysis

It is a foregone conclusion that as traffic increases, the number of traffic accidents also increases. What is difficult to determine is whether the accidents increase at the same rate as the volume of traffic. For instance, an increase in traffic volumes of 30% could result in an increase in accidents of 35% due to reduced level of service, increased congestion, driver frustration, etc. The relationship between increased traffic and the resulting increase in accidents is impossible to quantify, therefore, a straight 1:1 ratio has been used for purposes of this Study. Using this assumption, while the actual number of accidents at each analyzed location would increase, the calculated accident rate per million entering vehicles would not change. Again, this may not be a true scenario but is impossible to predict at any given location.

Capacity Analysis

Using the projected traffic volumes listed above, a capacity analysis using HCS was performed for the University Boulevard/ Ohio Rt. 7 and University Boulevard/7th Street/US 22 ramps intersections. Traffic was distributed in the same manner and proportions as is indicated by existing conditions. Capacity on the bridge sections was also examined with the future volumes.

Bridge Analysis

When compared to the existing volume, the traffic on the Fort Steuben Bridge is expected to reduce by nearly 1,300 vehicles per day, or approximately 22%. Therefore, if all three bridges remain open, there will not be a capacity problem on this Bridge. Adding in two-thirds of the increased traffic from the Veterans Memorial Bridge during closures results in an ADT of 25,902 vehicles. Using the same factors as before, namely that 12% of this traffic would occur during the peak hour, the volume on the Fort Steuben Bridge would rise to 3,108 vehicles during the peak hour.

The Market Street Bridge traffic is expected to rise from 9,200 vehicles per day currently to 11,630 vehicles per day in the year 2020. This is an increase of approximately 26%. When one-third of the Veterans Memorial Bridge traffic is added to this the resultant ADT becomes 22,266 vehicles per day. Assuming a peak hour volume of 10% of ADT indicates a volume of 2,227 vehicles in the peak hour, with 1,314 of that traffic eastbound. With the signal at the eastern end of the Bridge controlling lane capacity, the projected traffic is well above the capacity of the Market Street Bridge.

Total future traffic on the three bridges is 48,168 vehicles per day. As stated previously, if the Market Street and Fort

Steuben Bridges close the amount of river-crossing traffic decreases by approximately 10%. The projected volume on the Veterans Memorial Bridge for the year 2020 if both bridges close is 42,721 vehicles per day. This leads to a peak hour volume of 4,272 vehicles, and westbound traffic of 2,136 vehicles. Maintaining the earlier directional distribution, the projected number of vehicles exiting from westbound Veterans Memorial Bridge to southbound Ohio Rt. 7 during the peak hour is 961. This rapidly approaches the estimated capacity for the westbound-southbound ramp of 1,000 vehicles per hour.

Intersection Analysis

By comparing the projected bridge volumes to the existing volumes, an annual growth rate was calculated and then applied to the existing peak hour volumes at the two intersections on University Boulevard. The growth rate on both the Veterans Memorial Bridge and the Market Street Bridge is approximately 1% per year. The Fort Steuben Bridge was not used for this purpose since a decline is projected rather than an increase.

When the growth factor was applied to the traffic at the Ohio Rt. 7/University Boulevard intersection, the results of the HCS analysis show an overall intersection LOS of "C" with an average delay of 16.8 seconds per vehicle. This was performed maintaining existing timing. The delay for northbound left turns was 60.7 seconds per vehicle, indicating LOS "F". Eastbound left-turning traffic dropped to LOS "D" with a delay of 34.4 seconds per vehicle.

At the University Boulevard/7th Street/US 22 ramps intersection using the projected traffic volumes yielded an overall LOS of "C" with a delay of 21.0 seconds per vehicle. However, the northbound traffic is at LOS "F" and the southbound at LOS "E".

Summary & Recommendations

Based on the data and analyses outlined above, certain conclusions can be reached regarding the current operating conditions of the bridges and adjacent roadways. The bridges themselves do not appear to be over capacity at this time. Neither does there appear to be any significant capacity problems at the nearby intersections. However, there are a high number of accidents at both the University Boulevard/ Ohio Rt. 7 and University Boulevard/7th Street/US 22 ramps intersections. Without additional data for similar intersections (volumes, geometric configuration, etc.), it is impossible to state whether the actual accident rate is low, high or moderate. Based strictly on the average number of crashes per year, it appears that this is a high accident area.

In summary, if both the Fort Steuben and Market Street Bridges were to be closed, there would be nearly double the amount of traffic on the Veterans Memorial Bridge. At this time it appears that the adjacent roadways and intersections may be seriously affected by the increased traffic but alterations to signal timing could alleviate some of the effects.

- While the bridge can accommodate the increased volume, the ramp systems cannot.

- If the Veterans Memorial Bridge is closed due to traffic accidents or inspections, the traffic on the other two bridges will exceed capacity.
- If only one of these bridges remains open to traffic, the impact of closures of Veterans Memorial Bridge will be even more severe.
- Also, at times when the Bridge is closed due to accidents or inspection, the nearest existing Ohio River crossing is at such a distance from the Weirton/Steubenville area that the impact on local traffic would be seriously impacted, essentially cutting the two cities off from one another.

After analyzing the data and reviewing the results, some recommendations can be made as to improving the existing conditions and planning for future traffic increases. Recommendations for how to improve both accident occurrences and capacity are presented below.

Accident Analysis

There are standard accepted countermeasures for decreasing accidents based on the type of crashes experienced. For example, angle type accidents involving left-turning vehicles are often caused by driver frustration from lengthy delays. Rather than wait for an adequate gap, the driver attempts to turn in front of oncoming traffic, thus causing an accident. In the case of the intersection of Ohio Rt. 7/University Boulevard, there is a delay of 20.6 seconds per vehicle for northbound left turns. The most effective countermeasure for angle-type accidents would be to permit left turns only during the protected (green arrow) phase. However, this reduces the overall efficiency of the intersection. Another possibility is to adjust the timing of the signals to allow more green time for the problematic left-turn movement.

Preliminary HCS analysis with existing traffic volumes indicates that the timing can be adjusted to provide a longer permitted phase for northbound left turns without adversely affecting the other movements. In fact, the overall delay is reduced to 9.1 seconds per vehicle from 9.5 seconds.

At the University Boulevard/7th Street/US 22 ramps intersection, the current delay for eastbound left turns is less than six seconds per vehicle, indicating that driver frustration is not the reason behind the high number of angle accidents. There is also not a sight distance problem at this intersection, so the only effective countermeasure would be to restrict left turns to the protected phase, thereby eliminating the conflict with opposing traffic. Although there would be an increase in delay, the reduction of accidents should take precedence.

On the ramps from westbound US 22 to Ohio Rt. 7, there is no easy solution to reduce accidents. There is existing signage on the Veterans Memorial Bridge indicating a sharp curve with reduced speeds ahead. Other countermeasures to reduce accidents would involve redesign of the ramps to lessen the degree of curvature or altering the merge area at southbound Ohio Rt. 7. Neither of these appears feasible due to space constraints and the high cost of rebuilding freeway ramps.

On the Veterans Memorial Bridge, many of the accidents appear to occur during wet or slippery conditions. New signage indicating "Slippery When Wet" or "Bridge Freezes Before Roadway" may help to alleviate this problem.

Capacity Analysis

With regard to the capacity of the nearby intersections, currently there are no significant problems with overall LOS at any of the intersections. However, as indicated above at the Ohio Rt. 7/ University Boulevard intersection, the same timing changes that would reduce accidents would also improve the LOS of the northbound left-turn movement. This holds true both for existing traffic and with volumes from the Fort Steuben and Market Street bridges included.

When future traffic volumes are considered, much can be done to improve LOS through simple timing changes. At the Ohio Rt. 7/University Boulevard intersection, the overall LOS can be increased to "B" with an average delay of 13.1 seconds per vehicle. No individual movement would have a LOS lower than "C".

At the University Boulevard/7th Street/US 22 ramps intersection, an overall LOS "B" with a delay of 13.5 seconds per vehicle can be achieved through timing adjustments. Again, individual movements are at a LOS "C" or better.

If it is determined that either the Fort Steuben or Market Street Bridge or both must be closed due to structural deficiencies or other reasons, another bridge will be needed to accommodate traffic demands.

Since there is a high volume of truck traffic on the Fort Steuben Bridge that would be rerouted to the Veterans Memorial Bridge, an interchange to Freedom Way would prevent possible delays and accidents at the intersection of WV 2/Main Street and Freedom Way. As stated this idea will require further study. If such an interchange project is not feasible, the intersection at the end of the existing ramps to northbound WV 2 and Freedom Way will require widening or realignment to accommodate the increase in truck traffic.

APPENDIX