II. AN EVALUATION OF TEMS METHODOLOGIES

A. Large Scale/Statistical Models

Before discussing the details of the ridership and financial ratio estimates regarding the Ohio Hub passenger rail system in specifics, this section describes some generic issues pertaining to large scale statistical models.

Planners regularly use large-scale mathematical/statistical models to simulate operations of complex social and economic systems. Such models are characterized by multiple parts or subsystems; applying statistical techniques to estimate relationships between variables; and recycling estimates from one part of the model into other parts. Careful use of large-scale models such as COMPASS to estimate travel patterns is customary and appropriate. However, all large-scale mathematical/statistical models have inherent strengths and weaknesses. Important strengths include:

1. They provide a replicable framework for estimating impacts. This allows their methods and forecasts to be tested over time.

2. They provide estimates of variables for regions having large numbers of distinct places at reasonable costs.

3. Because of the low cost of models, they can be used in early stages of project development to examine the feasibility of alternative configurations.

4. They are grounded in established theories and methods that have been accepted by academics and other “disinterested” observers.

5. Models provide a relatively low-cost method of estimating the average impact of a transportation investment in a region. It is usually not feasible to examine the details of each community or station, but a large-scale model can use the benefits of aggregation to develop a reasonably reliable estimate of impacts (or, in this case, ridership).

However, these advantages come at a cost. As complex as many models are, they still greatly oversimplify reality. Several sources of error can develop even in theoretically well-grounded and statistically correct models.

1. Most large scale/statistical models are structured so that several events must take place before an outcome or impact is forecast. Thus, because variables in a model are linked, an inaccuracy in one part of the model can render the entire projection inaccurate. For instance, suppose that variables, A B, C, and D are can be estimated accurately 90% of the time. Suppose also that accuracy of all four variables is needed to reach a valid conclusion. The likelihood that the entire chain of events will result in an accurate conclusion is only 0.65 (0.9x0.9x0.9x0.9) or about six or seven times out of ten. The more critical the assumptions to the accuracy of the projection, the larger the extent of the problem will be.

   In the COMPASS model, the number of trips was estimated as a function of travel utility. Travel utility is in turn based on an estimate of generalized cost. Generalized cost is based on a variety of estimates regarding various aspects of travel time including estimates of the value of travel time. Because of the interrelationship of the various parts of the model, the overall error in the estimate may be greater than an error estimate in any one component.

2. Many statistical models are based on equations that use the exponential form a number (a number raised to an exponent, such as X^2). A problem with the exponential form is that errors can be magnified if the exponent is not measured with precision. For example, consider the relationship between A, B and C. Suppose the "true" value of A is 6, the value of B is 2 and the true value of C is 4. Suppose also that B is known with certainty but C is in error. It is actually 4 but estimated as 5.

   Assume the relationship between the variables is $A = B + C$ and that the true value of B is estimated accurately, $B=2$. However, assume C is mismeasured or misestimated as equal to 5 instead of 4. Consequently, the model will predict the value of A to be 7 (2+5), instead of the true value of 8 (2+4). The 25% error in the estimated of C (¼) resulted in only a 12.5% (1/8) error in the model's estimate of A. C was being added to an accurate variable, so the size of the error was dampened.

   In contrast, consider the exponential form, $A = B^C$. If this were the correct relationship, and assuming the true values of C and B are still 4 and 2, A would equal 16 (2^4). Again, suppose that C is misestimated as 5 instead of 4. Now the model will predict $A = 2^5 = 32$. In this case, the 12.5% error in the initial measurement or estimate of C resulted in a (16/16) 100% misestimate of the true value of A. Thus, models that depend upon estimates of the exponential form are likely to generate larger magnitudes of errors. The likelihood that C is misstated is usually more likely if it is the output of another part of a statistical model than if it is measured directly.

   Large-scale transportation models, including the COMPASS model, often are dependent upon power terms in the estimating equations. Consider the trip model in equation 1 (discussed in detail in the next section). Because of the strength of exponent terms, models are susceptible to large errors if the relevant parameters are incorrect. Of course, the potential for error is not a valid reason for rejecting a methodology.

Rather, it highlights the importance of an independent check of "reasonableness" to ensure the potential for error is minimized. Further, policymakers and other users of these studies should be aware of the potential error because of the possible impacts on policy and investment decisions.

3. The ability of models to describe consequences of major changes is often problematic because **large** scale changes affect so many things they may alter the relationships between variables that the model is based. The coefficients estimated in most models show how a change in one variable (the independent variable) will cause a change in another variable (the dependent variable), assuming all other things remain equal. The greatest confidence can be placed in statistically determined relationships when they are interpreted showing how one variable will change when there is a **small** change in another variable and when the rest of the environment is similar to the environment that existed when the relationship was measured. When changes in the variables are outside the range of previous observations, less confidence can be placed in the conclusions because the relationships between the variables no longer hold. When there are large changes in a system, the entire environment may change. With regard to the ridership estimates, a successful high speed passenger rail system is likely to alter the basic relationships between socio-economic variables, generalized costs and ridership undermining the relationships upon which the original forecasts are based. For example, the number of housing units near key model exchange points may increase changing the population distribution that was the basis for the original forecasts.

4. When models are calibrated, it is necessary to assume that the system is in equilibrium--relationships are "at rest." Otherwise, the relation between, say, travel cost and number of trips will be changing and valid only for one point in time. Given the dynamic changes that occur in the transportation system nearly every day and the long time it may take for other key variables such as population and construction to catch-up, it is unlikely that the system will ever be measured in equilibrium.

5. Another important source of error involves misspecification. Often a variable is left out or not included in regression equations because the value of that variable cannot be obtained. Some misspecification is embedded in all models because even the most complex models oversimplify reality. When the misspecification occurs in an unimportant variable, the problem is not great. However, when a misspecified variable is critical, the statistical model may fail. Different communities may have unique factors that will affect the impact of an improved transportation system. Industry structure, community cohesion, specific locations of the rail station and other businesses, the nature of competitive industries and so forth will be important determinants of how communities respond to the proposed rail system. COMPASS is designed to show how a community that is "average" in every respect but for the explicitly considered variables will be affected. Large-scale statistical models are essential to providing an overall picture of impacts, but detailed analysis of particularly communities will help round out the picture and providing a check on the large-scale models.

B. Demand and Ridership Estimation

Ridership is a critical factor and is at the foundation of a successful passenger rail system. An evaluation of the financial feasibility and social benefits of the Ohio Hub will depend critically on the ability to attract riders. This section reviews the TEMS ridership analysis. In addition to the study of published documents, especially The Ohio and Lake Erie Regional Rail HUB Study, several conversations, and a “workshop” held at the Ohio Rail Development Commission contributed to our understanding of the travel demand estimation techniques. [1].In this review priority was given to examining reasonableness and “economic sense” of the overall approach and techniques used to estimate ridership.

The TEMS team used the COMPASS model to estimate ridership and revenue forecasts. COMPASS uses information about the rail network, transportation alternatives such as bus, car or rail, and demographic information to determine likely trips between specific destinations. Trips are further divided by purpose, business or other. The model is based on the widely accepted and verified assumption that the number of trips between places is related to social/economic variables and travel costs. The COMPASS model focuses on the transportation costs associated with travel time, frequency, and the quality of service to determine the level of use and market share for rail (and other modes). Using reasonable theoretical assumptions, the cost of travel is expected to reflect the utility generated by the transportation system. The lower the cost of travel, the greater benefit the transportation system provides. This assumption is “common sense” and consistent with transportation economics practices.

1. Trip Distribution

The model is built in several parts. The foundation is an estimate of total travel demand in the current year and in future years. The model is expressed as:

$$1)T_{ijp}=e^{B0p}{}_{*}(SEijp)^{B1p}e^{B2pUijp}$$

Where Tijp is the annual number of trips between places i and j for purpose p (business or other). SE represents a set of socioeconomic variables, and U represents travel utility.Bs represents parameters estimated in the calibration process. See the appendix to this report for an identification of important variables. TEMS used a modified gravity model to estimate expected ridership. In general, gravity models assume that travel between places increase with size and decrease with distance. In the particular case of the TEMS projections of ridership (which in turn drives revenues) increase directly with population and regional per capita income and decrease with travel cost (utility, $U_{ijp,}$ increases as travel costs decrease) .

In order to estimate the model empirically and calibrate it, the general equation was expressed in a different form:

$$2)\ \mathrm{Log}\ (T_{ijp}) = B_{0p} + B_{1p}\log(SE_{ijp}) + B_{2p}(U_{ijp})$$

The transformation of equation 1 into a log form is a common economic practice and allows for empirically evaluating relationships among variables using a standard linear regression framework.

The actual number of trips between places for business and other purposes, T_{ijp}, was collected based primarily on existing data from appropriate state and federal agencies. Counties were the principal geographic areas of origin and destination. The center point of the county was normally used for calculating distance and estimating travel costs between the county and other places. In some instances, adjustments were made to ensure accuracy and avoid errors that could occur due to an overly mechanical approach. For instance, the center of county approach would not work well if most of the population lived in one corner of a county. Airports have their own travel/ridership models and these were used for estimating travel to and from airports. In some instances, such as when other data were not available, data were simulated based upon observed travel patterns between similar pairs of communities. The development of the Tij's was not a mechanical process. Our conversations with TEMS suggested that they were careful in developing the data used to estimate the points of origin and destinations.

Data on income, population and employment constitute the social/economic data (SE) in equation 2. The data are available by county and are used in the trip generation model. The use of SE's as a measure of attraction is an accepted practice in gravity models used in transportation studies and in other areas of economic analysis such a market research. Gravity models estimate human behavior and choices based on factors representing attraction and repulsion. Distance, travel time, or costs are repulsive factors and measures of size such as population are attraction factors. For example, in determining human migration, areas with low unemployment rates would be an attraction feature but the high cost of living would be a discouraging factor. Gravity models combine these factors with distance and/or time traveled to estimate travel demand for particular modes and trips.

Throughout the study, business trips are distinguished from other trips. Commuter trips are included in the other or non business category. This distinction is important because business travel usually has a higher opportunity cost than commuter travel during work hours. In the business trip models, employment and income are the key variables determining trip frequency. Population and income are the variables used in estimating non-business trips. The model is designed to indicate that the number of trips starting at i and ending at j will equal the number of trips starting at j and ending at i. This symmetry is reasonable in light of the fact that most passenger trips are two way, except for residential moves.

The estimation of the U term in equations 1 and 2 for the base period was more complicated. U stands for "utility" but does not measure satisfaction directly. Utility is considered too difficult, or impossible, to measure precisely.

Utility is approximated as a function of generalized travel cost and derived from the “Split Mode” technique discussed near the end of this section where the mode of travel is estimated based upon relative travel costs. The split mode models are common in transportation modeling to differentiate trips between auto, air, rail, and bus.

2. Calibration of Trip Distributions

After the values of SE and U are estimated, the model can be calibrated to determine the value of the parameters in equation 2—the B terms. Trip distribution patterns, are based upon observed travel patterns between similar pairs of communities. Once the model is calibrated for existing travel patterns, it can also be used to estimate future trips. Using the model in equation 2, an estimated equation to show trips between places by purpose was generated for the base year. Standard regression techniques are used to “fit” the model for the base year.

Econometric models are usually considered successful when they explain variations in the key variables and the statistical relationships are consistent with theoretical expectations. Based on generally accepted econometric standards, the TEMS travel demand model can be described as “successful”. The set of independent variables, SEs and Us were related to the Tij’s with a statistically significant degree of confidence as indicated by the high “T” statistics. The R^2’s indicated that the independent variables explained about 70% of the variation in trip distribution. While no formal tests for spatial autocorrelation were undertaken, the TEMS team examined the correlation matrix to ensure that the independent variables were not significantly correlated with each other. The signs on the coefficients are consistent with expectations and the magnitudes seem reasonable, giving added confidence in the underlying model.

The model was calibrated for both short and long distance trips and for business and other travel modes. The segmentation of various types of trips is a methodological plus because each category responds differently to changes in generalized cost. Commuters were not a separate category but potential commuter ridership will be considered in the community studies. The fact that the model was disaggregated by trip and mode and the results of each model are very acceptable provides additional confidence in the approach.

3. Generalized Costs and Utility

In addition to the socio-economic variables, utility of the transportation system, U, is also used to estimate future trips. The utility term is a function of travel costs. The generalized travel costs are calculated as:

$$3)\ GC_{ijmp} = TT_{ijm} + TC_{ijmp} / VOT_{mp} + (VOF_{mp} * OH) / (VOT_{mp} * F_{ijm} * C_{ijm}) + (VOR_{mp} * \exp(-otp_{ijm}) / VOT_{mp})$$

The meaning of the symbols are identified in the appendix to this report.

Generalized costs are time costs attributable to travel between zones (zones i and j) for trip purpose p (business or non-business) using mode m (air, auto, bus, or train). The costs are expressed in travel time rather than money, a common practice because time is often the most direct measure of costs. Time is also widely recognized as a primary driver of travel behavior; commuters and travelers, for example, attempt to minimize travel time (or travel costs) rather than maximize income or wages. Travel time includes moving or in-mode time, station wait time, connection wait time, access/egress time and an interchange penalty. Each element is multiplied by a factor designed to reflect the fact that some types of delays are more onerous than others. For instance unexpected delays or "stop and go" traffic may have higher psychological costs than an anticipated detour. Value of frequency, reliability and other factors are converted to time costs based on the value of time as indicated by a survey administered by TEMS. The forecasts assume that wait values do not change during the forecast period.

C. Survey Techniques and the Value of Travel Time

People are among the most expensive things to transport, in part because of the high value that people place on their time or the time of their employees. The value of time and variations of the value of time in different travel situations is an important driver of the COMPUSS model.

TEMS used a quota sampling technique in conducting the survey. The quota samples are selected in a way that important demographic characteristics are represented in the sample in proportion to their presence in reality. However this technique is not like stratified random sample in two regards. First, respondents are not selected from a random list of names. For instance, they might be selected as they passed an interviewer on the street. Second, classification factors used for a stratified sample are selected based on the existence of a correlation between the factor and the behavior of interest. In the case of a quota sample classification factors may be selected on the basis of research judgment [2]. While the use of quota sampling is less formal than the stratified sample, it is an appropriate technique for the travel analysis because the results are very similar to more cumbersome and time consuming techniques.

The 2002 questionnaire used by TEMS to estimate travel costs by mode and purpose was two pages and reasonably easy to read and understand. Accordingly, errors due to lack of understanding or impatience on the part of respondents are likely to be less than with a more complex or longer questionnaire.

No breakdown or unreliability costs are attributed to auto travel. In reality, there is a degree of unreliability to auto travel as well as other modes. Congestion costs on Ohio's roadways may exceed $1.1 billion according to the Texas Transportation Institute[3] Indeed, a significant cost associated with highway congestion is generated by "incident-related" congestion—accidents, breakdowns, debris, weather, unanticipated construction zones, etc. In smaller metropolitan areas, nearly all measured congestion is incident related.

The Ohio Department of Transportation estimates that 45 percent of the delays motorists experience on the states highways may be attributed to these kinds of unpredictable events [4].

The variability associated with these types of incidents is an important factor in estimating the total personal and economic costs of congestion. Similarly, over the next decade, it can be reasonably anticipated that Ohio highway congestion will increase, lengthening travel times and contribution to additional unanticipated delays.

However, the bias introduced by virtue of the failure to account for auto related breakdowns or delays, is likely to decrease the estimate of utility from auto travel and increase the utility from passenger rail. Accordingly, the exclusion of auto delays is a conservative assumption and will not bias upward the estimate of rail travel demand.
Because reducing the subjective time costs of travel may be an important factor in rail success, several findings from previous studies may have relevance for scheduling, station location, and operations of rail.

- Personal travel time is usually estimated at one-quarter of the prevailing wage, but varies depending on traveler comfort, income and type of trip. Per-minute time costs tend to increase for longer commutes (more than about 20 minutes).[5]
- Travel time costs tend to increase with income and be lower for children and retired people. This finding is consistent with traditional theory and common sense because a lower value is placed on the time of low-income people, children and retired people. Thus the benefits of ridership are likely to vary depending on the demographics of the passenger.
- Travel time costs tend to be higher for driving when traffic is congested. This finding leads us to conclude that if the rail system reduces congestion (from what it might otherwise be in the future) auto travel will increase in utility.
- Travel time costs are particularly high for unexpected delays. This finding can be explained because when someone is expected to arrive at a particular time, not only is that person’s time wasted by an unexpected delay, but also the time of persons who expected the arrival. Delays beget other delays, as schedules require rearrangement. Important events may have to be postponed or canceled [6]. The high cost of unexpected delays reinforces the importance developing a highly reliable performance standard for the proposed passenger train system.
- Under pleasant conditions, walking cycling and waiting can have low or positive value. Under unpleasant conditions, costs of walking and cycling can be two or three times higher than in-vehicle time. Further, travel time costs tend to be lower for some trips such as recreational train trips. [7] This finding suggests the importance of a potential tourist/recreational passenger market.
- Preferences vary regarding cost of driving compared to time spent as a passenger in a public transportation system. [8]

An important implication of travel cost surveys is that subjective valuations of wait time are very important determinants of travel costs. Subjective valuations are likely to be influenced by image and advertising, which are variables that may affect the reliability of the ridership estimates.

For instance, effective promotional advertising may soften attitudes toward wait times. The subjective valuation may be influenced by the publicity involved in the rail system development. The valuation may be somewhat controllable by transportation officials during the construction and operation phase of the rail system.

The results of the TEMS estimates of the value of travel seem to be consistent with the other studies of travel time. However, no information was provided regarding the validity or reliability of the travel survey. Validity concerns whether the survey measures what is intended and whether the results can be generalized. Reliability considers whether the procedure or questionnaire yields similar outcomes in repeated tests. Since feelings about time value are difficult for the respondent to calculate “in the imagination” , validity is a more likely source of error than reliability.

1. Future Socio-Economic Patterns

The rail project was evaluated for a period extending to 2042, assuming a 30-year economic life. Forecasts of the socio-economic variables were based on estimates by the well-known forecasting firm of Woods and Poole and projected through 2025. Projections beyond that point are based on extrapolation of current trends. Projections this far into the future are problematic under the best of circumstances because over such a long time horizon, many events can occur that will alter the forecast. However, socio-economic data are easier to estimate than many types of data because they are more stable over time compared to other data such as employment and job growth. However, any forecast 30 years out will be subject to substantial error because so many other relevant relationships will change.

2. The Pivot Point Forecast

The pivot point forecast is a technique for phasing in changes that will occur due to an improvement to the transportation system. Once the base year for the model is calibrated and the future socio-economic variables are projected, an analyst could conceivably estimate future trips between two places by “plugging in” estimated future values of SE and U into the base model to determine $Tijp^{f}$, where f represents a future year. However, people are creatures of habit, so travel patterns may continue due to inertia or factors unique to the area even after important factors that determine transportation behavior change. Accordingly, a “pivot point” model was employed to calculate changes from the base year thus allowing for a gradual change. The form of the pivot point transformation is:

$$4)T_{ijp}^{f}/T_{ijp}^{B}=(SE_{ijp}^{f}/SE_{ijp}^{b})^{b1p}{}_{*}exp^{(B2p(UijpF-UijpB))} \qquad .$$

The pivot point model expresses the change in travel patterns in future years. The changes are used to adjust the base forecast. The advantage of a pivot point approach is that if a region has a travel pattern that differs from the "average" then the gap between the subject region and the average is closed more slowly than would be the case using a simpler approach. Pivot point models are widely used in travel demand estimations.

3. Utility and the Split Mode Model

Once generalized costs are estimated, utilities for each mode and the transportation system as a whole are derived by TEMS using a "hierarchical modal split model". The split mode approach allocates travel to various transportation modes—auto, plane, rail and bus. The model essentially measures the utility of each travel mode as the increase in utility that travelers receive when new travel modes-such as the high speed rail system are added to the network. The split mode approach is also useful in splitting the travel among modes based upon relative costs.

The model builds utility of the transportation system incrementally by starting with the "surface modes" which are bus and rail. The utility attributable to the air mode is determined as the increase in total utility when air is added to the available modes and so forth with automobile transportation. Theoretically, it is necessary to group modes according to common characteristics. The modal split model assumes air, bus and rail have more commonalities than auto since they tend to transport large numbers of people at one time along scheduled and usually fixed routes. Accordingly, they are considered public modes. Automobile travel is considered a private mode. While this division seems reasonable, the results would differ if auto, bus and rail were grouped together and air was considered the "least alike" mode due to its higher costs.

The estimation of the regression equations for each of the modal split models indicates good statistical fits based on the relationship between the variables and the R^2s The coefficients are statistically significant and the biases indicated by the constant term are reasonable. The signs are all consistent with what one would expect. For instance as generalized cost of travel by particular modes increases, the likely hood of using that mode decreases. The R^2s indicate that between 44 and 70 percent of the variation in the dependent variable (the log ratio of trips by mode) is explained by the model.

After calibration of the modal split model, a pivot point approach was again used to estimate the year to year changes from the base.

4. Induced Travel Demand and Transportation Oriented Development

Induced travel demand refers to the increases in travel that will occur because of improvements in the transportation system. Within COMPASS, the improved rail system was assumed to lower the generalized costs of travel.
The consequences were determined by "feeding" the lower generalized travel costs of passenger rail into the modal split model.

This technique is an appropriate way to estimate induced ridership, however, it may not capture the full extent of induced ridership because a new transportation system will influence land uses in the long run. Where we build our homes and business will be altered.

In some perspectives, induced travel demand refers to the extra ridership that may occur due to changes in residential patterns. For instance, new housing developments near transportation centers will increase the transportation market areas. In the TEMS model changes in residential patterns due to the rail system are not built into the forecasts. However, they may be important and constitute another source of ridership support as well as economic development. Allowing for transportation oriented development will likely increase ridership as housing with access to transportation is developed.

Because COMPASS does not fully account for the long run induced demand due to residential relocation, the model is likely to be more accurate in the short or intermediate term. In the long run the model may underestimate ridership, thus the TEMS ridership estimates are likely to be conservative.

The location of the station stops will be major determinants of transportation related development. Robert Cervero and his associates [9] found strong evidence that new development, particularly housing development, near station stops was a source of additional ridership and other transit benefits. “A considerable body of research shows that under the right conditions, TOD (transportation oriented development) can increase transit ridership and its associated environmental benefits (p. 157)

Transit oriented development is likely strengthened by ridership in the long run rather than in the short run because property improvements will lag transportation access. In assessing possible sites for station stops and the potential for TOD, the willingness of communities to accommodate the needs of such development, including flexibility in land use planning, should be considered.

5. Key Assumptions and Implications

There are several important assumptions and implications regarding ridership generated that should be made explicit. Consideration of these factors will help determine the accuracy of the ridership forecasts. In many cases they may be factors that policy makers can influence during the construction and operation of the Ohio Hub system. Several of these assumptions and implications can be further examined at the community phase of the GEM study.

1. The most favorable ridership estimates in the TEMS forecasts assumed significant rail linkages with other Midwestern states. Connectivity with rail systems throughout the Midwest is critical to the success of the Ohio HUB. Connectivity will add about 600,000 (20% of system ridership) passengers annually. Thus in the implementation stage, the success of the Ohio system will depend upon what is done in other states. At the present time, other states are planning for high speed passenger rail, but whether the plans will materialize is speculative. Accuracy of the TEMS estimates depend upon the development of the entire Midwest Regional Rail System. Connectivity will not be explored in the community studies, but will be examined in benchmark studies.

2. The feeder bus service is also a key to boosting ridership. The TEMS model calls for distances of between 60-90 miles in length and “each route should run at least 1 bus per day”. (p. 1-15). Further, the rail ridership estimate will be impacted by timing, convenience, and predictability of bus routes.. Bus connectivity also can be important in attracting pre-construction support from communities that are not directly served by the improved rail system. The effectiveness in attracting rail ridership based on bus feeder services will require excellent coordination because modal transfers constitute one of the most important sources of transit travel time. The more transfers, the longer the commute and the less demand for rail service.

3. Station locations will have a tremendous effect on ridership. The location of a station will affect the overall, door-to-door, time of a trip. Trip time will also be influenced by accessibility, including the ability to park and exit. Thus the traffic conditions around the station will be important consideration. Congestion around the train station will decrease ridership. The availability of amenities and a sense of safety, on the other hand, will increase ridership. The TEMS survey found that people assign different values to time spent in travel depending on how enjoyable or onerous the trip. Several academic studies have similar findings. Wait time has a high disutility and thus increase travel costs significantly. Hence, a pleasant station with comfortable chairs, provisions for snacks, and a clean, safe environment will significantly increase ridership. Since location and design of stations are very uncertain at this time, the ridership estimates are problematic. The nature of stations will be an important factor in the community studies. Station location requirements should be developed early in the planning process.

4. Commuters will be an important source of ridership. The COMPASS model estimates that 20-30 % of the passenger rail riders will be commuters. Accordingly, the appeal of the train system to commuters will be critical to the ridership forecast. However, in the state of Ohio, where long train commutes are not a part of the culture, the commuters may not materialize. Also, the number of commuters will obviously depend on the location of the community in relationship to job growth areas. The success of the rail system in appealing to commuters will depend heavily on the management and marketing of the system and the station sites on both ends of the trip. The appeal and market potential of the rail system for commuting is an aspect of rider ship that should be explored at the community level.

5. Times of arrivals and departures were not an explicit input into the ridership model, although it clearly factors into traffic volume. Because of the importance of commuters, times should be adjusted to accommodate job hours. Thus, the ridership forecast could be diminished by weak time schedules. The best times for passenger service should be refined ahead of negotiations with freight carriers regarding track usage.

6. The ticket prices represent only a part of the overall cost of travel. In fact, time and other costs are often larger than ticket prices. However, the ticket prices is usually the most visible cost to consumers and hence, may be more important in the decision making process than time costs, especially in the short run during the start-up phase.

Table II.1 provides a brief cost comparison of travel under the assumptions set forth in the COMPASS model.

Table II.1 Round Trip Cost by Mode in Dollars---High Speed Scenario

Mode	Cleveland/Columbus	Cleveland/Cincinnati
Rail	$100	$190
Auto/business	$88	$168
Auto/other	$28	$52
Air/3 week advance	$163	$186
Air/business	$706	$755

Source TEMS, p. 5-15.

The acceptability of the fare differentials, particularly the gap between auto/other and the rail service is significant and poses a potential impediment to the success of the high speed rail system. Most of the rail traffic will be diverted from automobiles, the lowest cost form of travel next to walking. The cost to commuters may be a particularly significant hurdle since the round trip difference will be multiplied by the number of work days. In the future, further consideration to fare structure should considered the possibility of “commuter fares”. Accordingly a more precise picture of likely ridership will be gained by addressing the cost issues at the community level.

The Ohio Hub study stated that fares were determined by the following process:

“Using Amtrak’s year 2000 city–pair fares, employment, socioeconomic and income data and the results of the stated preference survey, base year fares were determined on a per mile basis. City-pair fares were divided by the distances between two cities (or station stops) to derive a fare-per-mile, which in turn was used to estimate fares for city-pairs that did not have Amtrak service in the base year”. P. 5-15.

The use of Amtrak information was a starting point for price determination. The fares were refined later in the study using an approach internal to the TEMS model:

“The passenger rail fares used in this analysis are the average optimal fares derived from the Revenue-maximization Analysis that was performed for each Ohio Hub corridor.” P.9-3.

The phrase “revenue maximization analysis” does not adequately describe the outcome of the analysis. The price generated in the model is not intended to maximize revenue. It is designed to maximize the sum of revenues plus consumer surplus. Dollar revenues will not be maximized. The use of a revenue target below the revenue maximum fare has two advantages. First, it is conservative and provides some room for error. Second, there will be some marginal costs of travel and a price that maximized revenues would imply (incorrectly) that marginal costs were zero if profits were maximized.

6. Ridership Conclusions

The ridership models examined by TEMS concluded that the high speed rail scenario with connectivity with the Midwest Regional Rail System will generate approximately 3.2 million riders annually by 2025. The estimates of travel generated by the COMPASS model provide feasible ridership estimates using appropriate economic forecasting techniques.

The ridership estimates from the COMPASS model can serve as points of departure for the GEM local studies. The development of additional information at the community level and analysis of benchmark communities will provide additional data points and serve as accuracy checks. Future community analysis should explore fare structure, commuter usage, transportation oriented development and station locations at the community level. Nevertheless, the COMPASS approach is based on legitimate theoretical assumptions and employed careful empirical research. However, it is limited by weaknesses inherent in almost all large-scale models in a world with imperfect information. These limitations are discussed in the next section.

D. Financial Ratios and Benefit /Cost Analysis

Two ratios were employed to determine the financial feasibility of the Ohio passenger rail system:

1) the ratio of operating revenues to costs and

2) the ratio of the discounted monetary value of benefits to discounted monetary value of costs.

1. Operating Ratio

The ratio of operating revenues to costs is intended to ensure that the rail system will not become an ongoing public expense. With regard to the operating cost ratio, the TEMS model considered both the high-speed speed scenarios with and without MWRRS connectivity. The most favorable ratio was option 1, high-speed scenario for the Cleveland-Columbus-Cincinnati route. The 1.84 operating ratio for 2025 for this segment shows that it is the strongest corridor in the Ohio Hub system. For the entire system, option 1, high-speed passenger scenario with MWRRS connectivity, generated ratios of 1.23 and 1.39 for 2015 and 2025, respectively. This finding means that the system will eventually generate $1.39 for every operating dollar spent. The ratio does not mean the system will be profitable in the traditional sense because the capital costs are not accounted for in the operating ratio. However, given the anticipated federal contribution to the capital costs, the passenger rail system should be capable of operating without a periodic state contribution from tax revenues.

The 1.39 operating ratio meets minimum requirements for federal funding which requires a ratio of 1. However the figure is very low compared to private sector, capital intensive projects such as real estate. Whether this ratio provides a satisfactory measure of safety will become clearer as the confidence in the estimates increase. The feasibility study level of confidence on the cost side of the ratio is +/- 30% which could drop the ratio below 1 if the costs are underestimated by the full amount.

2. Benefit/Cost Analysis

The TEMS team also generated a benefit cost analysis for the high speed MWRRS connectivity model 1. Benefit-cost analysis answers a different question from traditional profit/feasibility analysis. Benefit-cost studies consider all of the benefits and costs that can be quantified. They are more comprehensive than profit feasibility studies because benefit cost studies are concerned not only with costs and benefits that accrue to an individual or organization but with all social cost and benefits. Because benefit cost studies attempt to be comprehensive, many of the benefits are difficult to quantify and are not directly measurable.

Consider the four principal benefits described in the TEMS study:

Table II. 2 Benefits/Option 1 with / MWRRS Conductivity, High Speed Scenario (2002 dollars in millions)

Revenue	Value (millions)
Revenue	$1,949
Consumer Surplus	$1,992
Other Modes	$1,134
Resource Benefits	$233
Total Benefits	$5,308

Source: TEMS, p, 9-7.

The only benefit directly measurable (and then only after the system is operational, of course) is revenue. “Consumer surplus” is an additional benefit consumers receive above what passengers pay to use the rail system. “Other Modes” account for benefits received by air and automobile travelers principally due to reduced congestion.

Resource benefits represent reduced pollution due to rail travel. Each type of benefit is important and should be included in a benefit cost analysis. However, as the outcomes become more difficult to measure and check, the ability to estimate the benefits accurately diminishes.

The interest rate used to discount future benefits was 3.9%. This represents a real rate of interest (the inflation premium removed), which is appropriate since neither revenues nor costs have been adjusted for inflation. Theoretically, the real rate of interest is the actual rate minus the inflation premium. In the long run, the real interest rate is likely to fluctuate less than the actual rate because anticipated increases cause nominal interest rates to rise. Therefore, the use of the real interest rate allows forecasters to avoid making independent estimates of the effects of inflation on costs, revenues, and interest rates. If, during the 30-year life of the project, costs increase faster than inflation, or if the value of any benefits increase slower than the rate of inflation, the benefit cost ratio will decline.

One of the most controversial factors is price of oil, which will affect the benefits of rail travel. If gasoline prices continue to climb, it is reasonable to assume that the benefit cost ratio will become more positive for the high-speed rail alternative. Benefits of passenger rail will increase as the cost of automobile travel increases. The rail options will become more valuable and more frequently used to avoid the higher costs of driving. However, cost of automobile travel will not necessarily increase in the future. New technologies on the horizon promise to reduce the cost of driving per mile.

Possible innovations include hybrid cars, ethanol, ceramic engines and so forth. In light of the potential for new technologies, we believe the relative costs differences between automobiles and trains used in the TEMS study is appropriate.

Cost overruns sometimes characterized large public projects. Flyvbjerg and his associates examined cost overruns in 258 transportation projects. [7]. They found that costs were underestimated in 90% of the cases they studied and actual costs were on average 28% higher than estimated. Furthermore, the problem of cost underestimation was greater for rail projects than other transportation projects with an average cost escalation of 45%. The authors concluded that the reason for the underestimation problem was not technical errors. If the errors had been technical, the mistakes would tend to average to zero because honest mistakes are as likely to overestimate as underestimate costs. Instead, there appeared to be a systematic bias to keep costs estimates too low. What's more, they found that there was no significant improvement in the tendency to underestimate costs over time. If cost estimators were correcting for technical mistakes, they would diminish with learning and improved techniques.

The Flyyberg group's result indicates that the possibility of systematic bias on the cost side needs to be considered when evaluating cost benefit ratios. However, there are reasons to believe that the cost estimates for the Ohio Hub will be more accurate than would be indicated by the Flyvberg study. Unlike many of the projects evaluated by Flyvberg's group, The Ohio Hub has a predetermined route along an already known rail system.

Consequently, there will be fewer "surprises" involving legal issues of ownership, engineering problems associated with terrain, and so forth. Consequently, the risk of cost over runs will be lower than otherwise.

The benefit/cost ratio for the Ohio HUB was 1.24. Theoretically any ratio greater than 1 would be acceptable because the present value of the benefits would be greater than the present value of the costs. In practice, "when a benefit/cost ratio is above 1.2, the ratio validates the proposed system's economic feasibility" (TEMS p. 9-6). As a point of comparison, in a benefit cost analysis of a proposed California passenger rail system, a benefit cost ratio of 2.06 was reported [8]. Furthermore, a cost underestimation equal to the average cost error in the Flyvberg and his associates would result in an unacceptable benefit cost ratio for the Ohio Hub. While Ohio Hub benefit cost ratio of 1.24 is acceptable, it leaves little room for error.

The benefit cost analysis was conducted from the perspective of the nation as a whole. From the perspective of Ohio citizens, the benefit to cost ratio will be much higher because it is anticipated that 80% of the capital costs will be provided by the federal government and not directly from Ohio citizens. However, many of the benefits from rail ridership will also accrue to non-Ohio citizens.

The benchmark studies and community evaluations will provide essential information for evaluating the validity of the potential benefits from a high speed rail project in Ohio.

The benchmark case studies, in particular, should reveal the nature and magnitude of potential benefits for stations in different locations along the proposed system.

E. Rents and Economic Impacts

Economic impact studies consider important factors that are not always appropriate to include in a benefit-cost study. One set of factors excluded from benefit cost studies are dynamic economic changes. Dynamic effects refer to new economic activity and opportunities that may be sparked by major improvements to the transportation system. By lowering the travel costs associated with movement between major cities in Ohio, the Midwest, and the world, the Ohio Hub can be expected to improve the location advantages of Ohio cities. Impacts of construction and operations are another important type of economic impact. Both dynamic and construction-operation impacts are estimate indirectly in the RENTS model. A more complete understanding may be achieved by a perspective that looks specifically at construction impacts and the details of station locations in specific areas.

1. Rents

The RENTS model has been used to estimate the dynamic impacts of changes in the rail system. This review of the RENTS model is based primarily on four studies;

1) “Economic Rent: A New Dimension in the Economic Evaluation Process”,

2) The Great American Station Foundation Economic Impact of Station Revitalization,

3) Ohio Hub Regional Rail System Economic Impact Study Proposal

4) the Ohio Hub Economic Impact Methodology Report. [10]

The RENTS model is grounded on the theoretical assumption that by improving access the value of resources near the improved access point will be increased. Consequently, the incomes, population, employment, and property values will increase.

Previous applications of the RENTS model resulted in calibration for counties in Illinois and for places in the Midwest in the Great American Station study. The heart of the theoretical model is summarized in the equation 5 where SE represents measures of impact such as property value, income, employment, or population:

$$5)\ SE = f(GC).$$

The generalized cost of travel represents a comprehensive set of factors including actual cost, time costs and costs of delays. The formula for generalized costs in the previous rents model differs in small ways from the same method used in the Ohio Hub study. While the differences are not likely to be critical, the approaches should be consistent in future work.

A standard assumption in economics is that property values are a function of access (and protection from environmental bads). Travel costs are a reasonable indicator of access. Since improved access increases demand for land, the value of land at points of improved access will increase. Accordingly, the land will be used more intensively—more square feet of developed property and workers per acre. Households will also want improved access to shopping, jobs and so forth. Hence, population will increase near points of improved transportation. The higher property values, increase employment, and increased population will also contribute to an increase in per household incomes as workers require compensation for higher land and congestion costs. At the same time, a new transportation system will weaken the location advantages of other places causing some property values to decrease and some places to lose employment and population. The impact of the improved transportation system can be expected to be a net positive but an accounting of the adverse consequences for some places will be needed to provide a comprehensive picture.

The model assumes that changes in employment, income, and property values are a good proxy for the welfare benefits of improves transportation efficiency. However, there may not be a direct method of translating changes in the socio-economic variables (employment, population and property values) into consumer or producer surpluses.

In Metcalf (1992) the RENTS model was calibrated for 102 counties in Illinois, for a variety of measures including employment, income and property values. The overall model showed reasonable predictive power. Economic rents coefficients were also estimated for The Tri-State High Speed Rail project. The Tri-State High Speed Rail study appeared to generate higher R^2's than the Illinois Study. However, the calibration was not statistically significant for some smaller places.

The RENTS model was also employed in the Great American Station report. In this case, the rent coefficients differed significantly from those previously cited. The difference in the coefficients suggests that other factors such as local conditions may mediate the impact of improved access. For instance, Metcalf recognized the importance of Chicago and the presences of other large cities. There may be other factors that could be incorporated in the RENTS model. However, the calibration of the model for both studies was very good as indicated by generally good R^2s and statistically significant coefficients. Thus, the generalized cost of travel appears to an important determinant of key socio-economic variables.

The TEMS model correctly anticipates that the principal impact of improved transportation systems is likely to be more pronounced in areas where transportation costs are reduced the most, such as locations along the improved transit system. The TEMS approach also has the advantage of showing long-term impacts that are likely to develop after the community fully adjusts to the new transportation system. The ability to estimate long run impacts is a strength. However, in the case of improvements to the transportation system, it may take a generation to fully realized the benefits. Furthermore, positive impacts are likely to occur within the immediate vicinity of the station rather than be spread through-out the county.

Additional thought should be given to how to account for negative effects—places that may be disadvantaged. Also, it should be recognized that city size and household income are not independent.

Likewise, size and cost of living co-vary so changes in nominal household income may differ from changes in real household income as city size increases.

2. Dynamics Effects

Dynamic effects that reflect job creation and economic development consequences are among the most important benefits that a high speed rail system can potentially provide. Yet, ironically, they are the most speculative and therefore the difficult to measure. Most major investments in transportation capacity have generated significant economic opportunities for existing businesses and for businesses that have yet to be envisioned. They are sometimes not included in benefit-cost analyses.

The Interstate Highway System, for example, was originally conceived as a transportation network that would link major regions of the U.S. One of its large if unintended benefits was to increase mobility between and within metropolitan areas and regions. This allowed manufacturers and distribution companies to improve efficiency and tap into labor pools that would not have been available without the system. The consequences for the tourism and hospitality industry were largely unanticipated. Accordingly, to ignore the possibility of dynamic impacts would greatly understate the consequences of improvements to the transportation system.

Some of the possibilities can be shown by comparing what is planned in the Ohio Hub system with similar rail improvements in other places throughout the United States. Discussions with knowledgeable officials in selected communities will also add to our understanding of dynamic effects.

Dynamic impacts also reflect changes that could alter relationships among producers, suppliers, markets, information flows, and labor pools. They will create new cluster economies likely spanning greater distances. Regions that were separated by transportation costs may be able to share economic strengths. For instance, medical knowledge that may require face-to-face communications may be disseminated more quickly, bolstering the medical sectors in both Columbus and Cleveland. In-order to estimate the dynamic impacts of transportation system changes the GEM team will examine the industry structure in selected cities. Community interviews with individuals knowledgeable about the specific local economies will also be conducted to help determine how specific areas and industries are likely to respond to improved transportation systems. GEM will use TEMS estimates of ridership and schedules to inform local respondents regarding the likely magnitudes of changes in order to give them a basis for discussing the dynamic consequences of potential changes.

Another anticipated dynamic impact will be the stabilizing effect rail stations may have on downtown areas. One of the most widely discussed problems among urban planners is the problem of sprawl combined with weaknesses in central cities.

Improved transportation systems could alter the pattern of residential development. Central cities face congestion that has reduced access to individuals living at longer distances from the central business district. Some of the congestion is due to the central city's positioning as a cross-road for the metropolitan area.

While the congestion may or may not be the result of increased economic activity, it generally serves as an impediment to further development. An intercity rail system could reduce unproductive congestion and provide a base of new urban investment.

GEM will also conduct several bench-mark studies to determine how improved transportation systems have influenced other communities throughout the United States. While recognizing that the impacts of passenger rail will not be the same in any two places, the bench-mark studies will provide an independent methodology for determining dynamic impacts as well as providing a check on other methods.

3. Construction and Operations Impacts

The important short run economic impacts of high speed rail will be the income, jobs, output, and fiscal consequences generated by the construction and operation of the system. Construction impacts include:

1. Direct Economic Impacts—economic activity associated with the organizations that construct and operate the rail system.

2. Indirect Economic Impacts— companies building the rail system purchase inputs from other firms setting off successive rounds of off-site purchases from one firm to another.

3. Induced (spending) Impacts—workers receive income from the first two factors and make additional consumption purchases generating even more income and re-spending.

The direct, indirect, and induced effects of the initial spending are not counted in cost-benefit analysis because the benefits from additional jobs, and output change depend on the state of the economy. For instance, according to strict economic theory and assuming full employment, there is no net benefit from the creation of a job or additional production because the workers or resources are assumed to be taken from alternative uses that have equal value to what is being produced. In other words, the opportunity cost of additional construction and employment equal the benefits. In reality, communities value job creation, in part because of the belief that the resources (such as otherwise unemployed workers) used in construction have low or zero opportunity costs. In fact, in communities and regions with above average unemployment rates, the new construction and operating expenditures can lead to higher levels of real output, employment, and household income.

The same three effects, direct, indirect, and induced will occur during the operating phase of the project.

4. Fiscal Impacts

Fiscal effects are also critical. Fiscal impacts are not normally part of benefit-cost studies because taxes represent a transfer of benefits rather than value creation. Nevertheless, most communities consider potential fiscal impacts critical to providing support for projects. The GEM research team will consider the revenue impacts based upon ratios of tax revenues to economic activity.

F. Conclusion

In concluding a review of travel demand methodologies, noted economist Kenneth Small wrote:

> "Travel-demand analysis seems to produce strong opinions concerning the validity of various approaches. A careful review of the theory and empirical evidence, however, makes clear that all quantitative approaches are based upon greatly simplified portrayals of travel behavior. This is necessary because the purposes of travel and the variety of choices available make travel choices so complex. As a result, each provide useful information for particular circumstances, and the sophisticated planner will want to understand a wide variety of approaches."[11]

Similarly this review of the events that are likely to flow from the development of high-speed passenger rail in Ohio suggests that multiple approaches and methodologies will provide a more accurate and robust picture of likely consequences than reliance on any single technique.

Further analysis will focus on the immediate economic impact of construction of the rail project on Ohio and on specific areas. Additionally, discussions with community officials will shed additional light on issues of ridership, station location (including the potential for transportation oriented development), and economic development consequences of improved rail service. A review of the experience of regions that have already developed passenger rail systems will also refine likely impacts of the rail system.

The findings of our evaluation of the TEMS methodologies are summarized as follows:

> In our opinion, TEMS employed a reasonable, appropriate and professionally acceptable discount rate for evaluating long-term benefits and costs of the Ohio HUB project.
>
> The TEMS ridership projections are reasonable and based upon generally acceptable forecasting methods and principles.
>
> The positive operating ratio suggests that, once built and fully operational, the Ohio HUB will generate revenue in excess of operating costs.
>
> The TEMS calculations suggest that a capital subsidy will be necessary to construct the Ohio HUB but, as discussed, once it is operational the Ohio HUB will be self-financing.
>
> Our analysis agrees with TEMS that Federal and state subsidies of capital construction costs are justified based on the benefit cost analysis and necessary to stimulate the development of high-speed rail services in Ohio as well as in other states.
>
> With Federal sharing of capital construction costs, the Ohio HUB is an economically feasible project for Ohio.
>
> The TEMS economic rent model, RENTS, provides a reasonable and professionally sound method for estimating the localized aggregate economic impacts along the corridors and at the stations; however, the methodology is not sufficient to estimate the full induced investment and economic development effects that could occur.

G. Terms used in key equations

Tijp = Number of trips between zones I and j for trip purpose p

i,j = names of zones

p = trip purpose—business or other

m= mode of travel, air, auto, bus or train

SE$_{ijp}$ = total utility of the transportation system for trips between zones i and j for purpose p

B = coefficients used in model calibration

TT= travel time between zones. In-mode time + station wait time + connection wait time + access/egress time multiplied by a factor to account for the additional disutility felt by travelers for these activities.

TC = Travel costs between zones –out of pocket costs.

VOT = Value of time for mode m and trip purpose p

VOF = Value of frequency

VOR = Value of reliability

F = Frequency of departures per week

C = Convenience factor of schedule times

OTP = On-time performance

OH = Operating hours per week

Source: TEMS

H. References

[1] Transportation Economics and Management Systems, The Ohio and Lake Erie Regional Rail Ohio Hub Study. Prepared for the Ohio Rail Development Commission, Oct. 2004.

[2] Carl McDaniel and Robert Gates, Marketing Research Essentials, John Wiley and sons, New York, 2006.

[3] Michael and Welch and Huw Williams, “Sensitivity of Transport Investment Benefits to the Evaluation of Small Travel-Time Savings” Journal of Transportation Economics and Policy, vol 31, no. 3, Sept. 1997.

[4] Kenneth Small and et al. Valuation of Travel-time Savings and Predictability in Congested Conditions for Highway User-Cost Estimation, NCHRP 431, Transportation Research Board,1999 (www.trb.org). <http://www.trb.org%29./>and Lisa Schweitzer et. al. Highway Performance and Time-Sensitive Industries, Public Policy Center, University of Iowa, 1998 , (www.uiowa.edu <http://www.uiowa.edu/>).

[5] Rachel Goodman, “A Traveler in Time: Understand Deterrents to Walking to Work”, World Transport Policy and Practice, vol. 7, No. 4, 2001. (www.ecoplan.org.wtpp) <http://www.ecoplan.org.wtpp/>).

R. Crum, Hoghway Performance and Time-Sensitive Industries, Public Policy Center, University of Iowa, 1998. (www.uiowa.edu/~ppc <http://www.uiowa.edu/%7Eppc>)

[6] Raymond Novaco and Cheryl Collier, Commuting Stress, Ridesharing, and Gender: Analysis form the 1993 State of the Commute Study in Southern California, UCTC #206 1994. (www.its.berkeley.edu <http://www.its.berkeley.edu/>)

[7] Bent Flyvbjerg, Mette Skamris Holm, and Soren Buhl, "Underestimating Costs in Public Works Projects" American Planning Association Journal, summer 2002, vol. 68, no 3, pp 279-295.

[8] Benefits of High Speed Trains at http://www.cahighspeedrail.ca.gov/plan/

[9] Robert Cervero et. Al. Transit-Oriented Development in the Unites States. Transportation Research Board, Washington, D. C 2004.

[10] 1. A.E. Metcalf, "Economic Rent: A New Dimensions in the Economic Evaluation Process, Transportation Research Board, 71^st Annual Meeting, Washington, D.C. January1992. 2. Economic Impact of Station Revitalization, Great American Station Foundation, Economic Impact of Station Revitalization, 2001.3. Transportation Economics and Management Systems, Ohio Hub Regional Rail System Economic Impact Study Proposal, submitted to the Ohio Rail Development Commission, August 12^th , 2005. TEMS, Ohio Hub Economic Impact Methodology Report, April, 2006.

[11] Small, Kenneth A, Urban Transportation Economics, Harwood Academic Publishers, Philadelphia, 1992, P. 45.