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DIVERSION MODEL FOR ESTIMATING HIGH-SPEED RAIL USE

John F. DiRenzo and Louis P. Rossi,
New York State Department of Transportation

One proposed solution for many intercity transportation problems affecting densely populated travel corridors in the nation is the provision of high-speed rail service. An important parameter that must be estimated to determine the feasibility of this proposed service is anticipated use. This paper presents a diversion model that estimates high-speed rail passenger use and is applicable to studies attempting to identify corridors that would likely support such service and to determine whether previously proposed high-speed rail service offers sufficient potential to justify conducting detailed feasibility studies. The potential market for high-speed rail service is estimated first by stratifying intercity trips on each nonrail mode by termination point (CBD or non-CBD), by trip purpose (business or non-business), and by group size for automobile trips. The characteristics of the resulting market segments are then analyzed by using travel time and cost data for high-speed rail and each competing mode to determine whether each market segment is completely divertible, possibly divertible, or nondivertible to high-speed rail service. The diversion model provided satisfactory results in a concept study of high-speed rail service in 3 travel corridors within New York State. Certain benefits of this technique are that it is simple to understand and apply, it does not have to be calibrated in the traditional manner, and it can be applied by using available travel data.

•THE PROVISION of high-speed rail passenger service has been suggested as a possible solution for many intercity transportation problems in certain densely populated corridors in the nation. Widespread consideration is being given to this transportation concept. The U.S. Department of Transportation and the Penn-Central Railroad, cooperating in the Northeast Corridor Transportation Project, are attempting to evaluate the feasibility and impacts of providing high-speed rail service between New York City and Boston, and between New York City and Washington. Currently, New York State is also conducting a study of the feasibility of high-speed rail service between New York City and Buffalo (via Albany). Similar studies are being sponsored by the Commonwealth of Pennsylvania and the Southeastern Pennsylvania Transportation Authority for proposed service between Philadelphia and Harrisburg, and by the New England Regional Commission for proposed service between Boston and New York City. Furthermore, legislation has been passed by Congress establishing a quasi-public corporation to provide or ensure the continuation of high-quality, perhaps high-speed, intercity rail passenger service in certain heavily traveled corridors.

High-speed rail service is often recommended because it can provide direct service between downtown areas of the cities served. Also, because high-speed rail service could probably utilize existing rail rights-of-way, new and costly rights-of-way would not have to be constructed, and transportation-related air pollution could likely be reduced. Because travelers would be diverted from other modes, congestion on other

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modes and facilities would be lessened, and, ideally, a more balanced transportation system would be created.

It is likely that many agencies will conduct concept or preliminary feasibility studies to evaluate the applicability of high-speed rail service within their particular corridors. Anticipated use is one of the basic parameters that these studies must estimate so that feasibility or, at least, the promise, of high-speed rail service can be determined. The purpose of this paper is to present a diversion model for estimating high-speed rail use that can be used in studies that attempt to identify corridors that would likely support such service and in studies that attempt to verify that proposed high-speed rail service in a particular corridor demonstrates sufficient potential to justify additional expenditures on detailed feasibility studies. This model was developed for use in a concept study of high-speed rail service in New York State (1, 2).

Use estimates are a necessary input for estimating operating revenues and costs, user benefits and costs, and other significant factors affecting the feasibility of new or improved rail service. When combined with an evaluation of equipment alternatives, operational problems, needs for physical facilities, and alternative means of financing and implementing the service, this information provides a sound basis for determining the feasibility of high-speed rail service in heavily traveled corridors.

DIVERSION MODEL TO ESTIMATE HIGH-SPEED RAIL USE

A diversion model was used to estimate high-speed rail use in a concept study of such service in New York State. Five factors were explicitly considered in the model: travel time, travel cost, trip purpose, destination location, and, for automobile trips, group size of intercity trips. The formulation of the diversion model and the data used to apply it are given in this section. The objective of the study in which the model was used is also discussed. Estimated high-speed rail use for 1968 will be discussed later for 3 travel corridors in New York State.

The objective of the New York State study was to determine whether the high-speed rail service concept merited further study and, if so, the appropriate geographic extent of subsequent detailed market and engineering feasibility studies, leading to the possible implementation of such service. This determination was based on order of magnitude estimates of ridership for 1968 and on the corresponding direct and indirect benefits and costs of implementing high-speed rail service in 3 key overlapping travel corridors of New York State (Fig. 1): (a) New York City to Buffalo via Albany, (b) New York City to Montreal via Albany, and (c) New York City to Albany.

Diversion Model

Potential high-speed rail ridership in the 3 New York State corridors was estimated in 2 steps. First, the total number of intercity trips made on each nonrail mode between each city pair in the corridors was stratified into market segments by using trip characteristics identified in other studies as important determinants of modal split (3, 4, 5, 6, 7). This was necessary because the attractiveness of high-speed rail service is likely to vary among different segments of the intercity travel market. Second, the market segments for each mode were analyzed in conjunction with travel time and cost data for high-speed rail and each competing mode to determine which segments are likely to divert to high-speed rail service. This determination was made by using a set of reasoned decision rules sensitive to the previously mentioned determinants of modal split.

The 3 factors used to segment the intercity trips on each nonrail mode are shown in Figure 2. Because of the city-center nature of the proposed rail service, it is important to separate trips destined to the CBD from those destined to non-CBD locations. The distinction is also made between business and nonbusiness trips because business and nonbusiness travelers generally value their time and the cost of a trip differently. Furthermore, when estimates are made of diversions from automobile to high-speed rail service, it is important to distinguish between single- and multi-person trips. Multi-person trips are less likely to divert from automobile because of the additional cost incurred when two or more persons use public transportation.

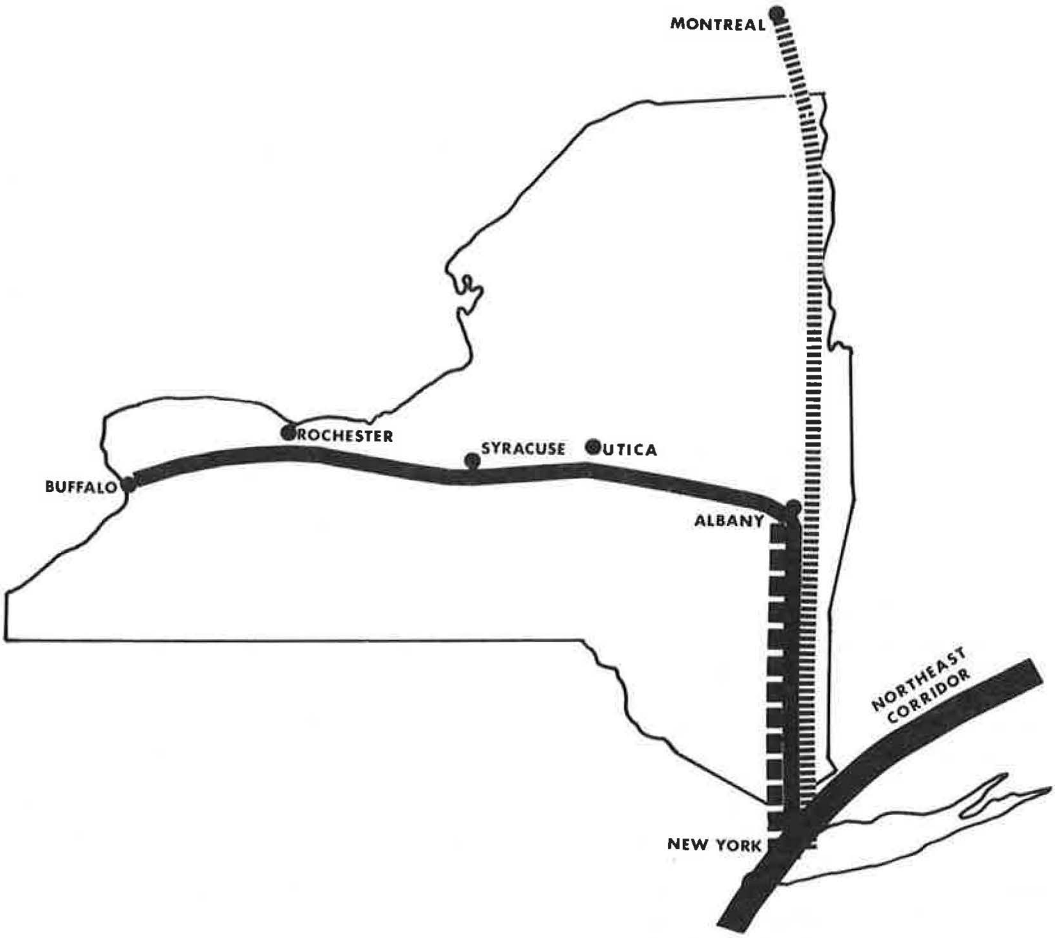


Figure 1. Alternative high-speed rail corridors in New York State.

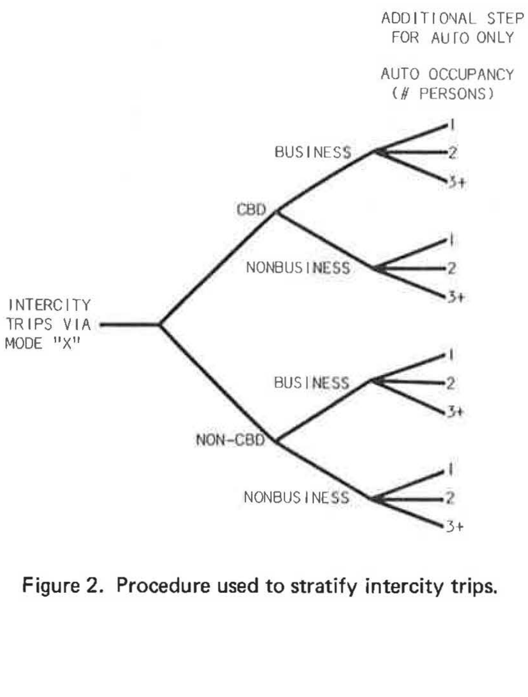


Figure 2. Procedure used to stratify intercity trips.

For each city pair, each identified market segment was classified into 1 of 3 diversion categories by applying the following set of reasoned decision rules:

1. A market segment is considered to be completely divertible to high-speed rail service if the train is faster and less expensive than the mode used at that time.

2. A market segment is considered to be nondivertible to high-speed rail service if the train is slower and more expensive than the mode used at that time.

3. A market segment is considered to be possibly divertible to high-speed rail service (a) if the train is faster and more expensive than the mode used at that time or (b) if the train is slower and less expensive than the mode used at that time.

TABLE 1

DATA USED TO DEVELOP AND APPLY THE DIVERSION MODEL

Item	Automobile	Bus	Air	Rail
Travel volume (person trips)	x	x	x	x
CBD and non-CBD split	x		x	
Trip purpose	x	x	x	
Car occupancy	x			
Door-to-door travel time				
Main line	x	x	x	x
Terminal		x	x	x
Access		x	x	x
Fare	x[a]	x	x	x
Service frequency		x	x	x

[a]Automobile operating cost.

The reasoned decision rules form the basis of the diversion model.

To develop and later apply the diversion model required that data be obtained describing the service provided by each existing intercity mode serving the corridors and the nature and number of trips made between each city pair on each mode. These data were collected from a wide variety of secondary sources; no new surveys were conducted for this study. Air-travel data were obtained from carrier ticket records, passenger surveys, and schedules. Automobile-travel data were obtained from files of earlier urban transportation surveys in the major cities of the state and from other travel data records maintained by the Department of Transportation. Intercity bus and rail companies provided travel-volume data for their respective modes. In some instances, travel data for the base year (1968) were not available, making it necessary to factor the next most recent information to the base year. Several travel volumes between smaller upstate cities were estimated to complete the city-pair trip matrices needed for the analysis of potential ridership.

Table 1 gives a summary of the items of information collected for this study. Travel volumes, in terms of person trips, between each city pair were gathered for each mode. Information was also obtained on the CBD and non-CBD orientation of air and automobile trips, trip purpose of nonrail travelers, and, for automobile trips, the size of the group traveling together (i.e., automobile occupancy). Door-to-door travel times between each city pair on each mode were estimated by aggregating 3 components: main-line time, from published schedules of the common carriers, and typical terminal access and delay times for each end of the trip. Fare and frequency of service data were tabulated by mode for each city pair.

To estimate the number of travelers likely to use high-speed rail service required the formulation of a set of high-speed rail service characteristics for each New York State corridor. These service characteristics included travel time, fare, frequency of service, and amenities of the high-speed rail service (e.g., food service, terminal parking, and attractiveness of equipment).

Door-to-door travel time via the high-speed train between each city pair was developed by adding typical ground access and terminal delay times for each end of the trip to the main-line (station-to-station) time. Station-to-station times were taken from a simulation of high-speed rail service between New York City and Buffalo developed by the United Aircraft Corporation (8). The simulation was made for the existing right-of-way by using a maximum speed of 120 mph, and it reflects all the physical restraints on train speed (e.g., tunnels, curves, and bridges). The resulting rail speeds represent an increase of approximately 50 percent over those of conventional rail service. Travel times between major cities are expected to be reduced as follows: between New York City and Albany by approximately 1 hour, between New York City and Buffalo by approximately 3 hours, and between New York City and Montreal by approximately 4 hours.

High-speed rail fares were assumed to be in the general range of present rail fares—lower than air fares, but higher than bus fares. Pinpointing future fares exactly is not only very difficult but also unnecessary for this model; future fares depend on equipment costs, physical improvements, operating costs and revenues, competition, possible government support, and other economic factors.

The following frequency-of-service guidelines were adopted for this study. First, future high-speed rail service is expected to be more frequent than present rail service with its 2-hour minimum headway between New York City and Albany. The hourly service anticipated in the Northeast Corridor is viewed as a feasible upper limit of service frequency. Service is expected to be as frequent as that of alternative modes. Consequently, frequency of service has not been accounted for explicitly in estimating the potential passenger market for high-speed rail service. The amenities of high-speed rail service were assumed to be of high quality, comparable to those of air and high-speed rail service now available in the Northeast Corridor.

Estimation of Diversions From Air Travel

The model for estimating the number of air travelers likely to divert to high-speed rail service is shown in Figure 3. The branch diagram shown in Figure 3 illustrates how intercity air trips were stratified into market segments.

An analysis of air fares relative to high-speed rail fares indicated that air fares were greater than or equal to rail fares for all city pairs. This finding provided one of the 2 basic inputs needed to determine the diversion category of each market segment.

Because the model is applied to many city pairs, door-to-door travel time via high-speed rail service can be faster or slower than air service. For each travel-time condition, a market segment is classified into one of the 3 diversion categories by applying the reasoned decision rules mentioned previously. The reasons for classifying each market segment into a particular diversion category are also shown in the last column of Figure 3.

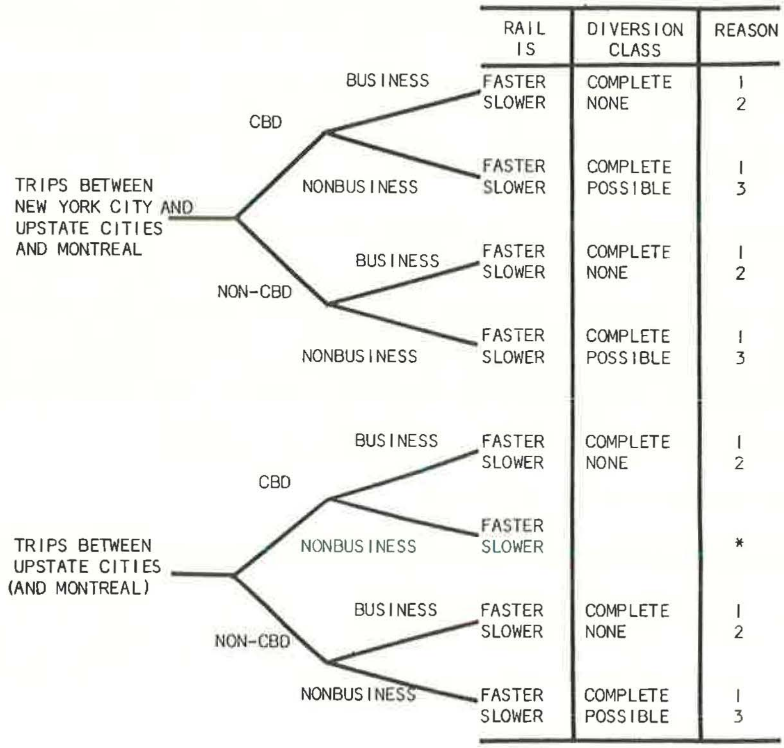
The set of diversion guidelines applied to air as well as to other trips originating or terminating in New York City was slightly different from the set applied to trips made solely between upstate New York cities. This refinement was made because of the considerably different terminal access characteristics in New York City relative to the smaller cities in upstate New York and because more detailed trip data were available for the New York City area.

In several instances, the diversion rules originally adopted were modified by judgment. For example, the non-CBD business market segment was considered nondivertible if the train was slower than air. Although this segment would have been considered as possibly divertible to high-speed rail service if the diversion classifications were strictly applied, it was classified as nondivertible because most business travelers would likely be willing to pay the premium fare for the time saved.

Estimation of Diversions From Automobile Travel

The model for estimating the number of automobile travelers likely to divert to high-speed rail service is given in Figure 4. Diversion guidelines for automobiles were developed in essentially the same manner as those for air travel, with 1 important difference. A comparison of the costs of intercity travel by automobile and by high-speed rail service showed that for a single-person trip the cost on each mode was essentially equal but that for a multi-person trip the cost of automobile travel was much less expensive than rail for all city pairs. This finding is reflected in the diversion guidelines.

In this study, 2-person automobile trips for business purposes to CBD and non-CBD locations in New York City were considered completely divertible if the train was faster than the automobile. Even though the train fare was more expensive than the



1. RAIL IS FASTER AND LESS EXPENSIVE THAN AIR, AND RAIL SERVICE IS SIMILAR IN QUALITY TO AIR SERVICE.

2. A BUSINESS TRAVELER NOW USING AIR IS NOT LIKELY TO DIVERT IF THE TRAIN IS SLOWER.

3. RAIL IS SLOWER BUT LESS EXPENSIVE THAN AIR, SO DIVERSIONS DEPEND ON HOW A NONBUSINESS TRAVELER VALUES HIS TIME.

* ALL AIR TRIPS TO CBD LOCATION IN UPSTATE NEW YORK CITIES AND IN MONTREAL WERE ASSUMED TO BE BUSINESS TRIPS.

Figure 3. Procedure used to estimate diversions from air to high-speed rail.

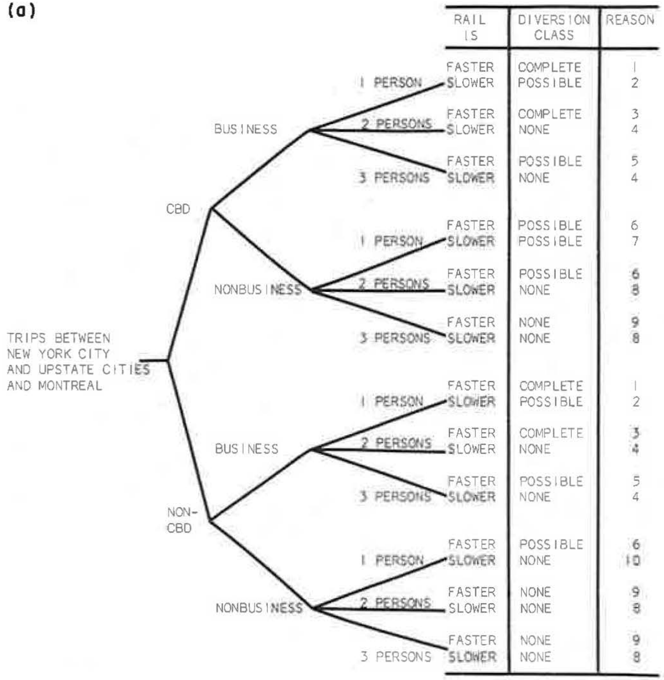
automobile in this case, it was assumed that the business traveler would be willing to pay the additional cost for reduced travel time.

Estimation of Diversions From Bus Travel

Figure 5 shows the model for estimating diversions from bus service to high-speed rail service. The guidelines for making these estimates were developed and applied in the same manner as those discussed for air and automobile trips, with 1 exception. All bus trips were assumed to originate and terminate in the CBD of the city pairs under study because both bus service and rail service are generally provided between these points. Differences in travel time and cost between bus and rail modes are considered to be a result of the line-haul portion of the trip and not of the ground-access portions.

There are no completely divertible bus passengers. Although high-speed rail service is generally faster than bus service, the latter is always less expensive. The number of diversions from bus to high-speed rail service will depend on how travelers

(a)



1 RAIL IS FASTER AND ONLY SLIGHTLY MORE EXPENSIVE. A BUSINESSMAN WILL AVOID CBD AUTO CONGESTION AND CAN WORK ON THE TRAIN.

2 RAIL IS SLOWER AND SLIGHTLY MORE EXPENSIVE. HOWEVER, CBD AUTO CONGESTION IS AVOIDED AND WORK CAN BE DONE ON THE TRAIN.

3 RAIL IS FASTER AND MORE EXPENSIVE BUT OFFERS THE BUSINESSMAN THE SAME ADVANTAGES NOTED IN REASON 1.

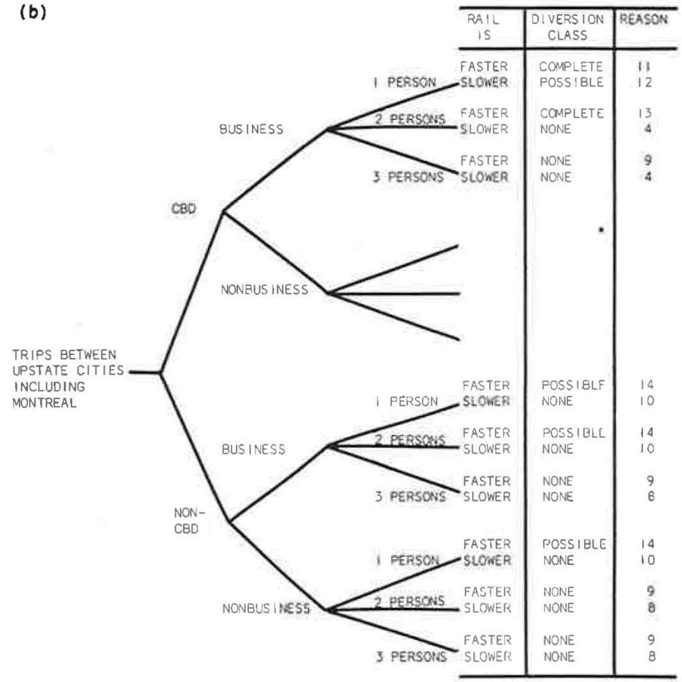
4 MULTI-PERSON BUSINESS TRIPS ARE UNLIKELY TO DIVERT IF RAIL IS SLOWER AND MORE EXPENSIVE.

5 RAIL IS FASTER, BUT SIGNIFICANTLY MORE EXPENSIVE. HOWEVER, RAIL OFFERS THE BUSINESSMAN THE SAME ADVANTAGES NOTED IN REASON 1.

6 RAIL IS FASTER AND MORE EXPENSIVE. THE NUMBER OF DIVERSIONS DEPENDS ON HOW NONBUSINESS TRAVELERS VALUE THEIR TIME.

7 RAIL IS SLOWER AND SLIGHTLY MORE EXPENSIVE. THE NUMBER OF DIVERSIONS DEPENDS ON HOW NONBUSINESS TRAVELERS VALUE THEIR TIME. AUTO CONGESTION IS AVOIDED.

(b)



* THE NUMBER OF INTERCITY AUTO TRIPS MADE FOR NONBUSINESS PURPOSES TO THE CBD'S OF UPSTATE CITIES AND MONTREAL WERE ASSUMED TO BE NEGLIGIBLE.

8 RAIL IS SLOWER AND SIGNIFICANTLY MORE EXPENSIVE FOR A MULTI-PERSON TRIP.

9 RAIL IS FASTER, BUT SIGNIFICANTLY MORE EXPENSIVE FOR A MULTI-PERSON TRIP.

10 RAIL IS SLOWER AND MORE EXPENSIVE. CONGESTION IS LESS OF A PROBLEM.

11 RAIL IS FASTER AND ONLY SLIGHTLY MORE EXPENSIVE. A BUSINESSMAN CAN WORK ON THE TRAIN.

12 RAIL IS SLOWER AND SLIGHTLY MORE EXPENSIVE. HOWEVER, A BUSINESSMAN CAN WORK ON THE TRAIN.

13 RAIL IS FASTER AND MORE EXPENSIVE, BUT OFFERS THE SAME ADVANTAGES DESCRIBED IN REASON 1.

14 RAIL IS FASTER BUT SLIGHTLY MORE EXPENSIVE. AUTO TRAVELERS DESTINED TO NON-CBD LOCATIONS MAY BE WILLING TO DIVERT TO RAIL.

Figure 4. Procedure used to estimate diversions from automobile to high-speed rail (a) with New York City as 1 end of the trip and (b) for all other city pairs excluding New York City.

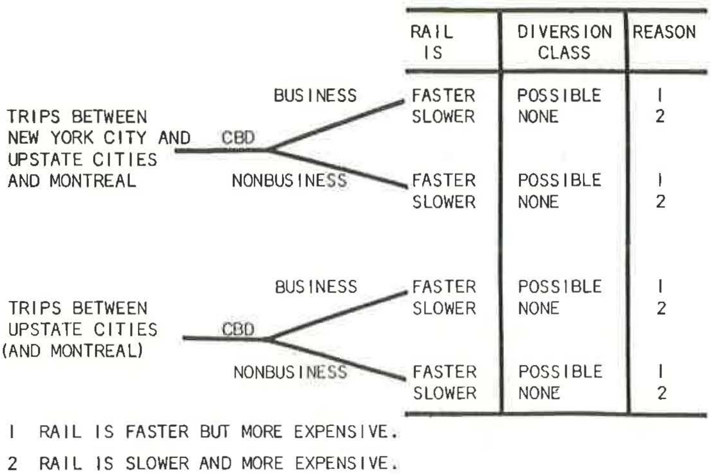


Figure 5. Procedure used to estimate diversions from bus to high-speed rail.

evaluate the trade-off between time and cost. Consequently, the estimated number of diversions from bus to rail is likely to be conservative, particularly because certain market segments, such as business travelers, may be attracted to improved rail service.

Estimation of Diversions From Existing Rail Service

All travelers using existing rail service in the 3 New York State corridors are expected to divert to high-speed rail service because this service is expected to be faster and more frequent than conventional rail service and similar in cost. It was assumed, when estimating high-speed rail ridership in a particular corridor (e.g., New York City-Albany), that conventional rail service would continue in adjoining corridor segments (e.g., Albany-Buffalo, Albany-Montreal). Consequently, transfers from conventional rail to high-speed rail service (but no transfers from other modes) were expected to occur between corridor segments at Albany—the city common to all corridors. The number of such transfers is noted in sample ridership estimates given in the next section.

HIGH-SPEED RAIL USE FOR 1968—AN APPLICATION OF THE MODEL

The diversion model was used to estimate high-speed rail use for 1968 for the 3 proposed rail corridors in New York State (Table 2). The high-speed rail service characteristics used in this test are those described in the previous discussion of the diversion model.

In terms of completely divertible travelers, high-speed rail ridership is highest in the New York City-Buffalo corridor and lowest in the New York City-Albany corridors. The same ranking of corridors is indicated by the possibly divertible ridership figures.

Approximately 60 percent of the completely divertible riders in each corridor are automobile travelers, approximately 35 percent are travelers using conventional rail service, and approximately 6 percent are air travelers. All bus passengers were classified as possibly divertible because, although high-speed rail service would be faster than bus service, it was assumed that high-speed rail service would also be more expensive.

The complete diversion figures show that high-speed rail service would increase annual rail ridership by 1,010,000 trips (183 percent) in the New York City-Buffalo

TABLE 2

ESTIMATED 1968 HIGH-SPEED RAIL RIDERSHIP AND TRAVEL VOLUMES

Item	New York City-Buffalo	New York City-Montreal	New York City-Albany
High-speed rail ridership by corridor[a]			
Completely divertible travelers from			
Existing rail, within corridor	471,000	232,000	134,000
Existing rail, transfer	80,000	209,000	289,000
Air	106,000	55,000	54,000
Automobile	904,000	542,000	497,000
Bus	0	0	0
Total	1,561,000	1,038,000	974,000
Possibly divertible travelers from			
Existing rail	0	0	0
Air	698,000	337,000	51,000
Automobile	2,385,000	1,072,000	985,000
Bus	1,220,000	874,000	534,000
Total	4,303,000	2,283,000	1,570,000
Total travel			
Existing rail	551,000	441,000	423,000
Air	2,511,000	2,366,000	2,355,000
Automobile	16,032,000	11,605,000	8,895,000
Bus	1,368,000	1,061,000	958,000
Total	20,462,000	15,473,000	12,631,000

[a]High-speed rail ridership in the New York City-Albany corridor is included in the ridership estimates for both other corridors.

corridor, by 597,000 trips (135 percent) in the New York City-Montreal corridor, and by 551,000 trips (130 percent) in the New York City-Albany corridor. For these same corridors, rail ridership would increase by an additional 4,303,000, 2,283,000, and 1,570,000 trips if all trips in the possibly divertible category were to use high-speed rail service.

Approximately 7 percent of all intercity trips in each corridor are classified as completely divertible to high-speed rail service (Table 3). If all the possibly divertible travelers were also to use the train, they would constitute an additional 21.0 percent of all intercity trips made in the New York City-Buffalo corridor, 14.8 percent in the New York City-Montreal corridor, and 12.4 percent in the New York City-Albany corridor.

As the sample results show, the diversion model provides a range of estimated high-speed rail ridership when applied to a potential corridor. The minimum level of estimated ridership in each corridor is the number of completely divertible travelers; the maximum level is the sum of complete and possible diversions. However, only a small portion of the possibly divertible travelers are expected to divert to high-speed rail service. The model does not provide an estimate of the exact size of this portion.

DISCUSSION OF THE DIVERSION MODEL

A "reasoned" diversion model was used to estimate high-speed rail use because there is some question as to whether a statistically calibrated modal-split model

TABLE 3

ESTIMATED 1968 HIGH-SPEED RAIL RIDERSHIP AS A PERCENTAGE OF TOTAL INTERCITY TRAVEL

Diversion Class	New York City-Buffalo (percent)	New York City-Montreal (percent)	New York City-Albany (percent)
Completely divertible	7.6	6.7	7.7
Possibly divertible	21.0	14.8	12.4

developed with travel volumes and service characteristics for existing rail service can accurately estimate high-speed rail use. This concern arises mainly because travel times, service frequency, and amenities of the proposed rail service are significantly different from those of existing rail service. It is possible that a traveler's implied weighting of travel time, cost, or service frequency in a mathematical model, based on present rail data, may not accurately represent the weighting of these factors for the proposed service.

A problem related to using a mathematical model based on data for existing rail service is that the model will likely have to be extrapolated beyond the range of data points used for calibration. For example, if the ratio of rail to automobile travel time is used as an independent variable in a model, the numerical values of this variable would likely change from 1.0 or slightly greater for present rail service to as low as 0.5 for the proposed rail service. Service frequency ratios and other travel time ratios, which are commonly used independent variables in modal-split models, would also change significantly for high-speed rail service. A potential solution to these problems is the use of an attitudinal modeling approach to estimate high-speed rail use.

Although the diversion model is elementary, it permits estimates to be made of high-speed rail use as a function of 5 important factors affecting modal split. Furthermore, the model produces reasonable preliminary estimates of high-speed rail use. Another reason for using this model in preliminary studies of high-speed rail service is that it does not have to be statistically calibrated. This reduces the time and expense of conducting a preliminary feasibility study.

An important property of the model is that it distinguishes between those travelers likely to be attracted to high-speed rail service as opposed to those travelers who may be attracted. This factor, together with its simplicity, makes the model more readily understood by decision-makers and the general public, an important consideration when the feasibility of new or improved forms of transportation is studied.

In the New York State study, the diversion model was not used to estimate future high-speed rail use. However, it could be used to prepare such estimates, provided that the necessary inputs to the model are projected into the future.

The formulation of the diversion model also has certain weaknesses. It does not account for travel generated or induced by the provision of high-speed rail service. Although these trips are likely to be small in number relative to diverted trips, they may be important in establishing the feasibility of high-speed rail service.

Another limitation of the model is that a range rather than a specific estimate of potential ridership is determined because the model has no explicit mechanism to trade off travel time and travel cost for the possibly divertible travelers. The problem can be minimized if a reasonable set of decision rules are formulated for various travel-time and travel-cost conditions and applied to the possibly divertible travelers. Decision rules of this type were not used in the New York State study in order to minimize subjectivity in the high-speed rail ridership estimates.

Frequency of service and amenities of the various modes are not explicitly accounted for in this diversion model. The model accounts only indirectly for these factors by assuming that they are equal for all common-carrier modes.

CONCLUSIONS

The diversion model presented here can be used to prepare preliminary estimates of high-speed rail use in intercity travel corridors. The approach outlined in this paper is particularly applicable both to initial feasibility studies of proposed high-speed rail service and to studies that attempt to identify corridors in which high-speed rail service may be justified.

High-speed rail use is estimated as a function of travel time, travel cost, trip purpose, destination location, and, for the automobile trips, group size of intercity trips. The diversion model is a set of reasoned decision rules that categorize travelers using modes of transportation other than high-speed rail as completely divertible, possibly divertible, or nondivertible to high-speed rail service. The model has been used successfully in a study of proposed high-speed rail service in New York State.

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