Cleveland-Columbus-Cincinnati
High-Speed Rail Study

Final Report

July 2001

Prepared for:
Ohio Rail Development Commission

Presented by:
Transportation Economics & Management Systems, Inc.

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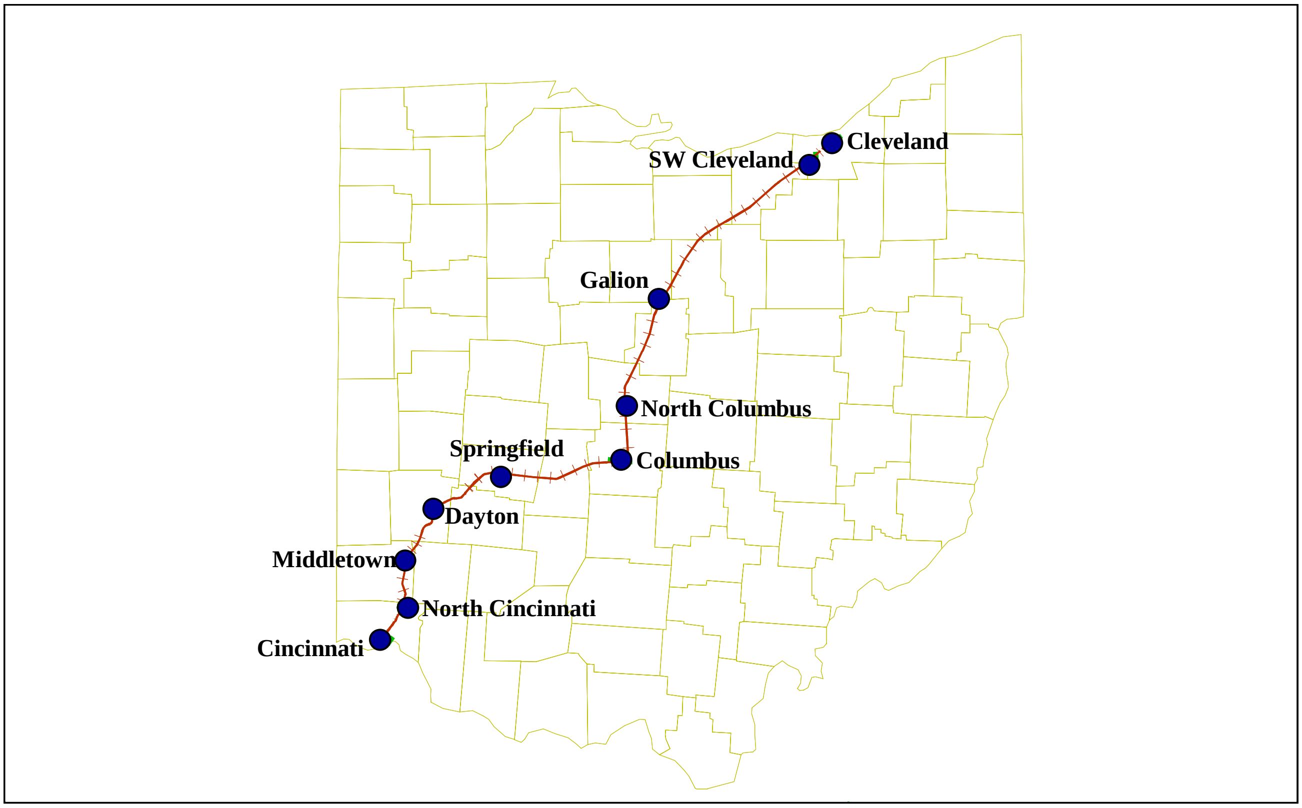
1.0 EXECUTIVE SUMMARY

In the past five years, the evaluation of different high-speed rail (HSR) studies in the Midwest has resulted in a realization that high speed rail, with speeds greater than 110 miles per hour, is too expensive in the short term to be implemented in the lower-density markets of the Midwest. However, given that the perennial issues of highway and airport congestion and environmental pollution remain problematic, a fresh approach to the development of passenger rail systems has been proposed. The new approach is based on an incremental investment in existing regional railroad systems with the planned maximum passenger train speeds being 110 miles per hour (mph). The premise of the new approach results from a revolution in train technology that has lowered operating costs and improved train performance on less-than-perfect track. Key to the new approach is that it minimizes capital costs and offers the opportunity to provide rail service without an operating subsidy.

The purpose of this study is to provide an evaluation of the potential for implementing a high-speed rail service with maximum speeds of 110 mph between Cleveland and Cincinnati through Columbus and Dayton (the 3C HSR Corridor). See Exhibit 1. The study contemplates the introduction of a modern rail service utilizing the latest equipment and technology to provide a very high quality of service. The scope of the study is to assess the potential for rail service by evaluating the following:

- Capital and operating costs
- Likely ridership and revenues
- Financial and economic returns.

Exhibit 1: 3C Corridor Proposed Station Map



The evaluation found that the 3C Corridor offers an exceptional opportunity for the incremental development of 110 mph passenger rail service. The ridership and revenue forecasts reveal the potential for a 3C passenger service to capture a significant share of the travel market, large enough to cover all of the estimated rail service operating costs. The study clearly suggests that a 3C train will be successful, but it must be fast, reliable, and convenient, and provide transit times that compete effectively in the market.

The optimal corridor service level, as suggested in the study, requires eight train frequencies (round trips) every day. At this level, the annual operating costs for 3C rail service are estimated at $31.55 million. The travel time on an express train from Cleveland to Cincinnati would be 3 hours and 28 minutes with the average one-way ticket costing about $90.00, or about $0.35 per mile.

The study forecasts a Year 2010 annual corridor ridership of 1.2 million passenger trips, which generates a farebox revenue of $39 million. With the addition of parcel revenue and on-board food services, total 3C revenue is estimated at $44.8 million. The study assumes that the 3C Corridor would be developed in conjunction with the Midwest Regional Rail System (MWRRS)[1] and would benefit from the economies of scale that it provides. The 3C Corridor would provide passenger connections to the MWRRS lines from Chicago to Cleveland and from Chicago to Cincinnati.

A key measure of success of a passenger rail service is its ability to operate without a subsidy or achieve an operating ratio of at least one; the 3C Corridor achieves this objective with a year 2010 operating ratio of 1.42. Under this scenario, for every dollar spent on operating the 3C Corridor, the service will return $0.42 in profit. (This is calculated by dividing the revenue, $44.8 million, by the operating costs, $31.55 million.)

The 3C Corridor capital costs include rolling stock and infrastructure costs. The proposed operating plan requires 7 modern train-sets, which will cost $66.5 million. The capital cost to improve the existing railroad along the 3C Corridor is estimated at $645 million. The total project cost, for 3C equipment and capital improvements, is estimated at $711 million. This estimate is based on a comprehensive engineering analysis, but was developed without input from the railroads. It is important to remember that the 3C Corridor is privately owned and all capital improvements and operational issues will be resolved through negotiations and agreements with the railroads.

In terms of capital costs, the study assumes that the development of the system would be based on an 80-percent Federal grant and a 20-percent State and local match. As a result, the capital cost to Ohio of developing the 3C Corridor would be around $143 million for both infrastructure and rolling stock.

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[1] The MWRRI is an ongoing effort to develop an improved and expanded passenger rail system in Illinois, Indiana, Michigan, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin. This system would use existing rail right-of-way shared with freight and commuter rail trains. The Ohio Rail Development Commission and Ohio DOT participate as planning study partners to determine ridership forecasts, service options, revenue, and capital and operating costs. The MWRRI Executive Report was made available in March 2000.

The 3C Corridor passenger rail services will provide a wide range of benefits which will contribute to the economic growth of Ohio, and will improve mobility between the major business and population centers - particularly between the State capital and the State's largest cities. The 3C Corridor will generate resource savings in automobile operating costs and highway congestion relief, and reduced energy usage and exhaust emissions. The passenger rail service and the connectivity that it provides to the MWRRS will afford an attractive travel choice that could result in reduced automobile trips for commuting, business, and leisure purposes.

The benefits-to-costs analysis indicates that over the 30-year project life cycle, the 3C Corridor is expected to have a positive impact on Ohio's economy and could generate more than $1.27 billion in economic benefits to the State. These benefits will appear in the form of new development within the areas near rail stations, the creation of hundreds of new jobs, and the increased economic activity associated with the implementation of new transportation services.

The rehabilitation and construction of new railroad track and sidings will help improve efficiency and expand capacity of the 3C Corridor, both for freight and passenger trains. Additionally, the safety of the highway/railroad crossings along the line will be significantly enhanced through a program of crossing upgrades and crossing consolidation.

2.0 THE TEMS APPROACH TO THE DEVELOPMENT OF RIDERSHIP AND REVENUE FORECASTS

The Transportation Economics & Management Systems, Inc. (TEMS) approach to the development of ridership and revenue forecasts, and the operating and capital costs for a 110-mph 3C HSR Corridor involved the use of a range of software tools, and databases that were adopted for the development of the MWRRI. TEMS' *COMPASS-R©* model was used for forecasting the corridor ridership and revenue. The *COMPASS-R©* system was developed by TEMS, Inc., and has been successfully applied in planning numerous rail, highway, air, and transit passenger systems. The *COMPASS-R©* model that has been utilized by the study team provides a rigorous framework that has been tested and validated throughout North America and Europe. It has been accepted by railroads, airlines, bus companies, investment banks, and government institutions as a sound and proven software tool. The core of the ridership estimation approach incorporates the *COMPASS-R©* passenger demand forecast model working interactively with the technology and operations plans. (See the Appendix for *COMPASS-R©* model description.)

The TEMS' *LOCOMOTION©* and *TRACKMAN©* models were applied to develop the operating plan for the proposed corridor. The *LOCOMOTION©* system provides a facility for optimizing train timetables in relation to given civil engineering or signaling work programs. The system estimates new train schedules for different rail technologies using train performance, engineering track geometry, and train control input data. *LOCOMOTION©* also provides milepost-by-milepost graphic output of train performance based on the characteristics of the track. The system will evaluate train interaction, provide stringline output for new and existing services, and identify any capacity restraints. In conjunction with *TRACKMAN©*, *LOCOMOTION©* can estimate the capital costs of improving train speeds and eliminate any capacity constraints. The system has been used in conjunction with rail development programs for Amtrak; the Federal Railroad Administration (FRA); Greater Rockford Airport Authority, Illinois, Minnesota, New York, and Wisconsin Departments of Transportation; London Transport; Burlington Northern Railroad; and Ontario/Quebec Rapid Train Task Force.

The *TRACKMAN©* program is designed to build an infrastructure database and provide graphic review capabilities for a given railroad route. Using condensed profile, engineering information, and even track car data, *TRACKMAN©* develops a milepost-by-milepost database of the physical infrastructure of the route, including gradients, curves, bridges, tunnels, yards, and signaling systems. This data is displayed along with maximum permissible train speed to provide input to the *LOCOMOTION©* program that calculates the performance of trains and potential train interaction for the track.

Feedback from *LOCOMOTION©* to *TRACKMAN©* provides the track engineer with an understanding of which track sections are limiting train performance and allows the engineer to develop a shopping list of track improvements that will usefully raise maximum permissible speeds. Using either specific engineering cost data or default unit costs, the proposed shopping list can be costed and a cost-per-minute saved priority ranking generated for each of the shopping list track improvements. In this way, *TRACKMAN©* and *LOCOMOTION©* provide a powerful analysis of engineering improvement needs and ensure that the most effective engineering improvements are made to maximize the value of capital investments and improve the operating plan for passenger and freight service.

The *TRACKMAN*© program has been used extensively by TEMS in its rail planning projects, including the Midwest Regional Rail System Study, Tri-State High Speed Rail Study, Rockford Rail Link Study, Virginia Passenger Rail Study, Minnesota Intrastate Rail Study, and Illinois Rail Plan and Service Improvement Study.

3.0 THE OPERATING PLAN

A key input to the ridership forecasts is the operating plan. The operating plan for this analysis is based on the assumption of a maximum speed of 110 mph and adoption of a Talgo train technology as a “generic technology” since it provides all the capabilities of a “modern train.” The Talgo offers high-quality on-board services, and critical performance characteristics such as tilt (9 degrees) and steerable trucks. It is also a low-cost, locomotive-hauled train that is well suited for operations along corridors with medium population density such as the 3C HSR Corridor.

For this study, other potential technologies such as those considered by the MWRRI, include Adtranz North American Diesel Multiple Unit (DMU) technology, which would be slightly lower in capital and operating costs, but is not locomotive-hauled; and the Bombardier Gas Turbine locomotive-hauled train, which would be faster than the Talgo or DMU technology, but is likely to be more expensive in terms of both capital and operating cost. Any of these trains—or indeed any of a wide range of trains that are manufactured worldwide—could be used as a generic example. (See Exhibit 2 for illustrations of modern train technologies.)

Exhibit 2: Types of Train Technology Considered in the Study

Talgo

Adtranz Flexliner DMU

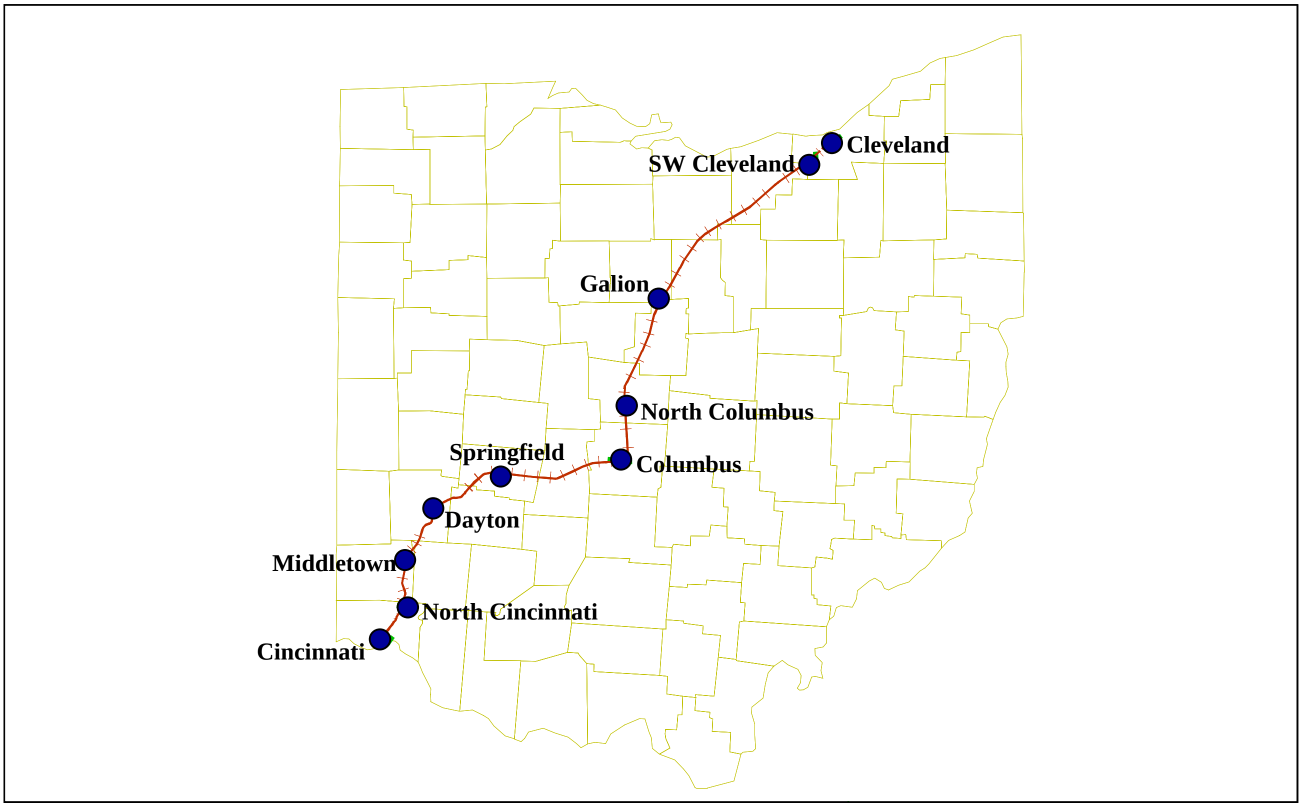
Bombardier’s American Eagle

Regardless of the specific technology utilized, research clearly indicates that, for rail service to be competitive in the 21st century, a new level of service must be established. This new level of service will use modern trains that provide the customer with the amenities that they expect in a 21st century transportation mode. Seats are wide and comfortable with such first-class amenities as electrical outlets and modem jacks (See Exhibit 3). The train must be fast and reliable and provide transit times that compete effectively in the market. Stations also need to be modern, comfortable, safe, and well located to encourage development and provide efficient interconnection to other modes of transportation as well as downtown business centers.

Exhibit 3: Examples of Modern Train Amenities

Ten stations (Cincinnati, North Cincinnati, Middletown, Dayton, Springfield, Columbus, North Columbus, Galion, Southwest Cleveland, and Cleveland) are proposed along the 258-mile route. (See Exhibit 4.)

Exhibit 4: 3C Corridor Proposed Stations Map



The operating time schedules for the 8 and 10 daily round trips, with express and local stopping patterns, are illustrated in Exhibits 5 and 6. These exhibits show that the travel time between Cleveland and Cincinnati is expected to be 3 hours and 49 minutes, and 3 hours and 28 minutes for local and express options, respectively. Exhibit 7 illustrates the average speed estimates for the corridor (including dwell times, acceleration, and deceleration). The speed profile for the 3C HSR Corridor is presented in Exhibit 8. A speed profile shows a graphical relationship between the speed of a train over a traveled distance. It illustrates the impacts of various infrastructure features such as curvature, diamonds, signaling, etc. along the track at the achievable speeds.

Exhibit 5

Travel Time

Ohio - Route 3C - 8 Frequencies

Simulation		With Recovery Time		Train Number		Schedule Time	2500	2000	2002	2004	2006	2008	2010	2012
Local	Express	Local	Express	Station	Milepost		Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
0:00	0:00	0:00	0:00	Cincinnati	0	0:00		6:30	7:30	9:30	12:00	15:00	17:30	18:30
0:16	0:16	0:18	0:18	North Cincinnati	14	0:18		6:48	7:48	9:48	12:18	15:18	17:48	18:48
0:33		0:36		Middletown	31	0:36			8:06		12:36			19:06
0:53	0:47	0:58	0:52	Dayton	53	0:58		7:22	8:28	10:22	12:58	15:52	18:22	19:28
1:15		1:23		Springfield	77	1:23			8:53		13:23			19:53
1:48	1:37	1:59	1:47	Columbus	122	1:59	6:00	8:17	9:29	11:17	13:59	16:47	19:17	20:29
2:00		2:12		North Columbus	133	2:12			9:42		14:12			20:42
2:30		2:45		Galion	177	2:45			10:15		14:45			21:15
3:14	2:55	3:33	3:12	SW Cleveland	245	3:33	7:24	9:42	11:03	12:42	15:33	18:12	20:42	22:03
3:28	3:09	3:49	3:28	Cleveland	258	3:49	7:40	9:58	11:19	12:58	15:49	18:28	20:58	22:19

Simulation		With Recovery Time		Train Number		Schedule Time	2501	2001	2003	2005	2007	2009	2011	2013
Local	Express	Local	Express	Station	Milepost		Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
0:00	0:00	0:00	0:00	Cleveland	0	0:00		6:30	8:40	9:40	12:00	14:00	17:00	18:30
0:13	0:13	0:15	0:15	SW Cleveland	13	0:15		6:45	8:55	9:55	12:15	14:15	17:15	18:45
0:58		1:04		Galion	80	1:04			9:44		13:04			19:34
1:29		1:38		North Columbus	125	1:38			10:18		13:38			20:08
1:41	1:30	1:51	1:39	Columbus	135	1:51	6:30	8:09	10:31	11:19	13:51	15:39	18:39	20:21
2:14		2:27		Springfield	181	2:27			11:07		14:27			20:57
2:36	2:20	2:52	2:34	Dayton	205	2:52	7:24	9:04	11:32	12:14	14:52	16:34	19:34	21:22
2:55		3:12		Middletown	227	3:12			11:52		15:12			21:42
3:11	2:51	3:30	3:09	North Cincinnati	244	3:30	7:59	9:39	12:10	12:49	15:30	17:09	20:09	22:00
3:30	3:10	3:51	3:29	Cincinnati	258	3:51	8:20	9:59	12:31	13:09	15:51	17:29	20:29	22:21

Note: - 10% Recovery Time is included.
- Performance is based on the Talgo technology used for the MWRRS Phase 3B

Trainsets	
1	2500 - 2003 - 2008
2	2000 - 2007 - 2010 - 2503
3	2002 - 2009 - 2012
4	2501 - 2004 - 2011
5	2001 - 2006 - 2013
6	2005 - 2502
7	Protect

Exhibit 6

Travel Time

Ohio - Route 3C - 10 Frequencies

Simulation		With Recovery Time		Train Number		Schedule Time	2500	2000	2002	2004	2006	2008	2010	2012	2014	2016	2502
Local	Express	Local	Express	Station	Milepost		Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
0:00	0:00	0:00	0:00	Cincinnati	0	0:00		6:30	7:30	8:50	10:29	12:30	15:00	16:30	17:30	19:25	21:00
0:16	0:16	0:18	0:18	North Cincinnati	14	0:18		6:48	7:48	9:08	10:47	12:48	15:18	16:48	17:48	19:43	21:18
0:33		0:36		Middletown	31	0:36			8:06		11:05		15:36			20:01	21:36
0:53	0:47	0:58	0:52	Dayton	53	0:58		7:22	8:28	9:42	11:27	13:22	15:58	17:22	18:22	20:23	21:58
1:15		1:23		Springfield	77	1:23			8:53		11:52		16:23			20:48	22:23
1:48	1:37	1:59	1:47	Columbus	122	1:59	6:30	8:17	9:29	10:37	12:28	14:17	16:59	18:17	19:17	21:24	22:59
2:00		2:12		North Columbus	133	2:12			9:42		12:41		17:12			21:37	
2:30		2:45		Galion	177	2:45			10:15		13:14		17:45			22:10	
3:14	2:55	3:33	3:12	SW Cleveland	245	3:33	7:54	9:42	11:03	12:02	14:02	15:42	18:33	19:42	20:42	22:58	
3:28	3:09	3:49	3:28	Cleveland	258	3:49	8:10	9:58	11:19	12:18	14:18	15:58	18:49	19:58	20:58	23:14	

Simulation		With Recovery Time		Train Number		Schedule Time	2501	2001	2003	2005	2007	2009	2011	2013	2015	2017	2019
Local	Express	Local	Express	Station	Milepost		Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
0:00	0:00	0:00	0:00	Cleveland	0	0:00		6:00	7:30	8:30	10:00	11:55	14:30	16:30	17:30	18:30	22:00
0:13	0:13	0:15	0:15	SW Cleveland	13	0:15		6:15	7:45	8:45	10:15	12:10	14:45	16:45	17:45	18:45	22:15
0:58		1:04		Galion	80	1:04			8:34		11:04		15:34			19:34	23:04
1:29		1:38		North Columbus	125	1:38			9:08		11:38		16:08			20:08	23:38
1:41	1:30	1:51	1:39	Columbus	135	1:51	6:00	7:39	9:21	10:09	11:51	13:34	16:21	18:09	19:09	20:21	23:51
2:14		2:27		Springfield	181	2:27			9:57		12:27		16:57			20:57	
2:36	2:20	2:52	2:34	Dayton	205	2:52	6:54	8:34	10:22	11:04	12:52	14:29	17:22	19:04	20:04	21:22	
2:55		3:12		Middletown	227	3:12			10:42		13:12		17:42			21:42	
3:11	2:51	3:30	3:09	North Cincinnati	244	3:30	7:29	9:09	11:00	11:39	13:30	15:04	18:00	19:39	20:39	22:00	
3:30	3:10	3:51	3:29	Cincinnati	258	3:51	7:50	9:29	11:21	11:59	13:51	15:24	18:21	19:59	20:59	22:21	

Note: - 10% Recovery Time is included.
- Performance is based on the Talgo technology used for the MWRRS Phase 3B

Trainsets	
1	2500 - 2007 - 2010
2	2000 - 2009 - 2012
3	2002 - 2011 - 2016
4	2501 - 2004 - 2013 - 2502
5	2001 - 2006 - 2015
6	2003 - 2008 - 2017
7	2005 - 2014 - 2019
8	Protect

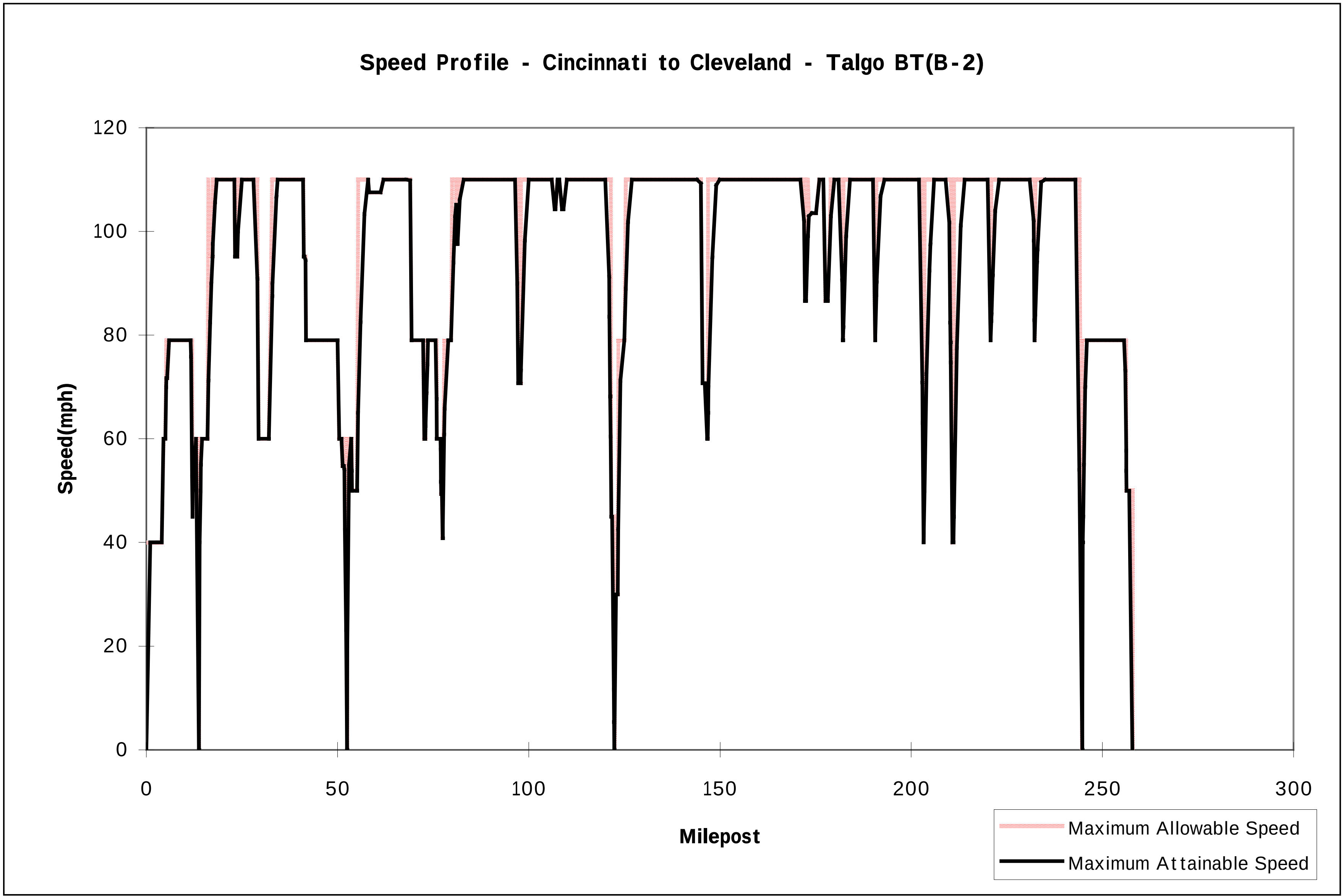
Exhibit 7

Ohio - Route 3C (average speeds)

Simulation		With Recovery Time		Train		Schedule Time	2500	2000	2002	2004	2006	2008	2010	2012	2502
Local	Express	Local	Express	Station	Milepost		Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
0:00	0:00	0:00	0:00	Cincinnati	0										
0:16	0:16	0:18	0:18	North Cincinnati	14			44.90	44.90	44.90	44.90	44.90	44.90	44.90	44.90
0:33		0:36		Middletown	31				56.59		56.59			56.59	56.59
0:53	0:47	0:58	0:52	Dayton	53			67.76	59.60	67.76	59.60	67.76	67.76	59.60	59.60
1:15		1:23		Springfield	77				58.99		58.99			58.99	58.99
1:48	1:37	1:59	1:47	Columbus	122			76.25	76.15	76.25	76.15	76.25	76.25	76.15	76.15
2:00		2:12		North Columbus	133				48.40		48.40			48.40	
2:30		2:45		Galion	177				79.94		79.94			79.94	
3:14	2:55	3:33	3:12	SW Cleveland	245		86.49	86.49	83.41	86.49	83.41	86.49	86.49	83.41	
3:28	3:09	3:49	3:28	Cleveland	258		49.64	49.64	49.64	49.64	49.64	49.64	49.64	49.64	
							2:56	0:53	15:00	0:53	15:00	0:53	0:53	15:00	5:39

Simulation		With Recovery Time		Train		Schedule Time	2501	2001	2003	2005	2007	2009	2011	2013	2503
Local	Express	Local	Express	Station	Milepost		Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
0:00	0:00	0:00	0:00	Cleveland	0										
0:13	0:13	0:15	0:15	SW Cleveland	13			51.73	51.73	51.73	51.73	51.73	51.73	51.73	51.73
0:58		1:04		Galion	80				81.77		81.77			81.77	81.77
1:29		1:38		North Columbus	125				78.67		78.67			78.67	78.67
1:41	1:30	1:51	1:39	Columbus	135			86.92	48.99	86.92	48.99	86.92	86.92	48.99	48.99
2:14		2:27		Springfield	181				75.20		75.20			75.20	
2:36	2:20	2:52	2:34	Dayton	205		76.62	76.62	60.00	76.62	60.00	76.62	76.62	60.00	
2:55		3:12		Middletown	227				62.43		62.43			62.43	
3:11	2:51	3:30	3:09	North Cincinnati	244		67.06	67.06	57.44	67.06	57.44	67.06	67.06	57.44	
3:30	3:10	3:51	3:29	Cincinnati	258		40.02	40.02	40.02	40.02	40.02	40.02	40.02	40.02	

Exhibit 8


Speed Profile - Cincinnati to Cleveland - Talgo BT(B-2)
Speed(mph)
120
100
80
60
40
20
0
0
50
100
150
200
250
300
Milepost
Maximum Allowable Speed
Maximum Attainable Speed

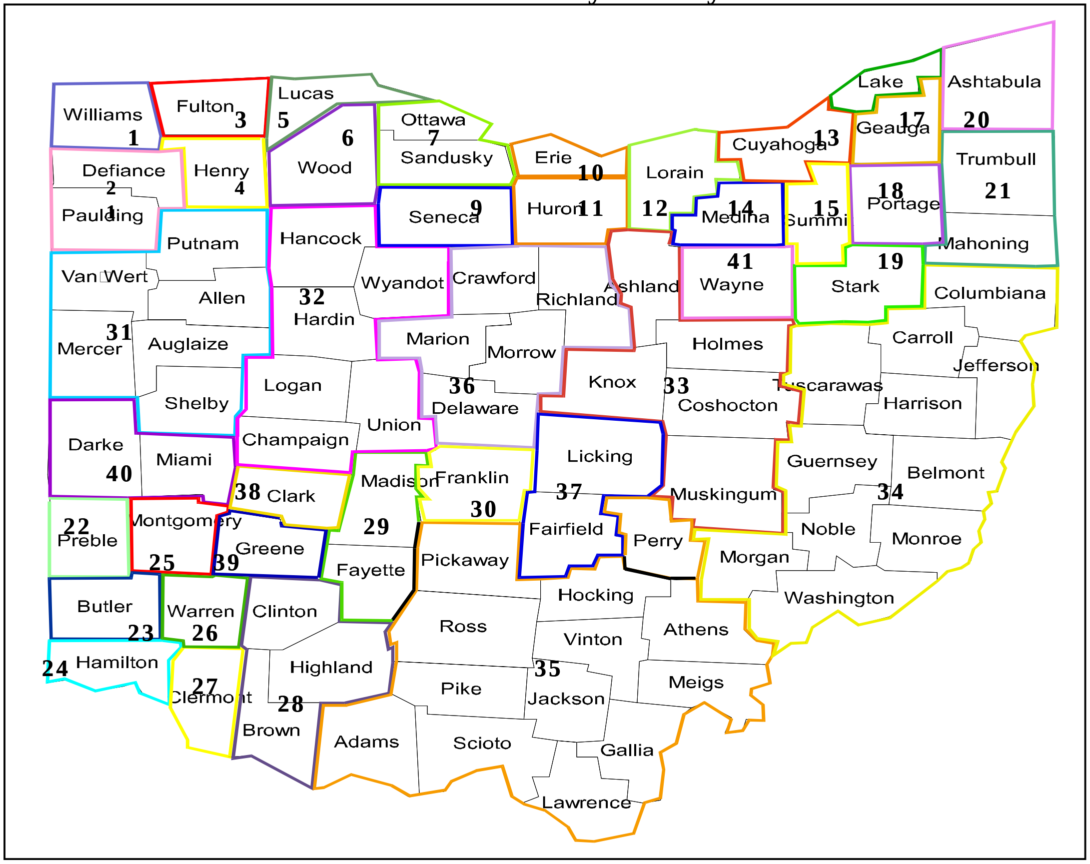
4.0 *COMPASS-R*© DEMAND MODEL DATABASE DEVELOPMENT

The *COMPASS-R*© model incorporates zone systems, origin-destination and network data, information compiled from stated-preference surveys, and socioeconomic statistics. This section describes these inputs to the model.

4.1 ZONE SYSTEM

One of the first steps in generating ridership and revenue forecasts for the study was to delineate geographic units ("zones") that are relatively homogenous with regard to their socioeconomic characteristics. The MWRRI zone system provided a base for the system used in this study. The critical factor in developing the zone system was to ensure that access times, which are key to any form of public transportation, were sufficiently representative of a given area. After modification to project specifications, 41 Ohio statewide zones were created (Exhibit 9).

Exhibit 9: Ohio Study Zone System



4.2 ORIGIN-DESTINATION DATA

The origin-destination (O-D) travel data was based on annual passenger trips between zone pairs for each mode and trip purpose. The MWRRI database provided primary sources of trip data. The data from these sources had to be modified (aggregated, disaggregated, and/or synthesized) in order to make the trip file project specific in terms of the zone system, trip purposes, and transportation modes.

4.3 NETWORK DATA

Transportation networks for base and forecast years were developed for auto, rail, and bus based on data from the MWRRI database. The *COMPASS*© model requires travel times, travel costs, and levels of service (reliability, schedules) for the base year to be considered in order to evaluate perceived competitiveness (Exhibit 10).

Exhibit 10: Parameters Used in the Demand Estimation Model

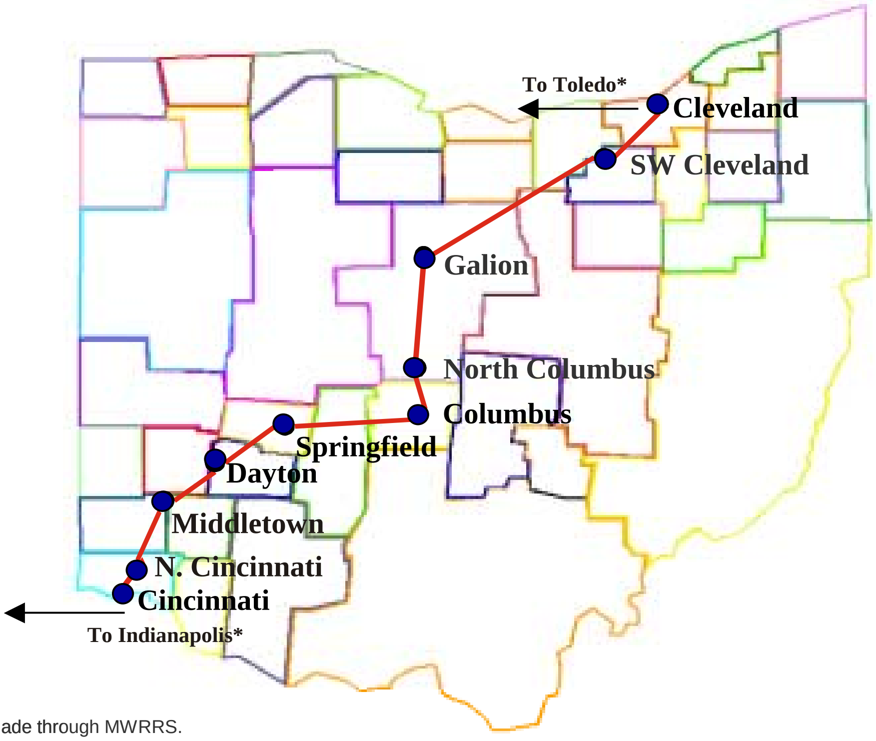
	PUBLIC MODES	AUTO
Time	• In-vehicle time • Access/egress times • Number of interchanges • Connection wait times	• Highway time • Access/egress times
Costs	• Fares • Access/egress costs	• Operating costs • Tolls
Reliability	• On-time performance	
Schedule	• Frequency of service • Convenience of times	

Based on estimates from the American Automobile Association, the operating-cost assumption for auto trips was $0.30 per mile for business, and $0.08 per mile for non-business (i.e., commuters, tourists, resident leisure/social travelers) trip purposes. Fares and access/egress costs are given similarly weighted values for each of the three trip purposes.

The access/egress attributes in the network account for the local accessibility characteristics to the respective modal transfer facilities. For example, in the case of the auto mode, local congestion within a county is reflected by a higher access/egress travel time impedance required to connect to the highway network, thus city zones are likely to have higher access/egress impedances than regional zones given the same distance.

The base railway and highway networks are illustrated in Exhibits 11 and 12.

Exhibit 11: The Base Railway Network



* Connections made through MWRRS.

Exhibit 12: The Base Highway Network

4.4 STATED-PREFERENCE SURVEYS

To accurately forecast ridership, stated-preference surveys were conducted throughout the Midwest states including Ohio in a manner designed to reach a broad sample of potential users of the passenger system: commuters, business travelers, tourists, and social/recreational travelers. Approximately 3,000 surveys were completed using self-administered mail-out, handout, and interview approaches. Each form collected information on origin-destination, trip purpose, demographics, values of time (VOT) for travel modes, and values of frequency (VOF) for the public modes.

Travel options were organized in a manner that enabled respondents to consider trade-offs among travel attributes. These were presented in such a way as to induce individuals to give a realistic response to the options without bias to a specific mode of travel. This process minimized the gap between “saying” and “doing.” For example, a problem frequently encountered is that many more people say they will use a service (e.g., a new train line) than actually do. Some positive responses come from the desire to please the person taking the survey, while others represent an optimistic assessment of the service itself; once the service is introduced, though, many will continue using their previous mode. Stated-preference surveys ask travelers to choose between a hypothetical cost and another value, such as travel time and service frequency. The trade-off analysis isolates the main characteristics for travel choice without revealing what the “correct” answer might be. The VOTs and VOFs are components of the generalized costs part of the model as described in the Appendix. Exhibit 13 illustrates values of time and frequency for different modes of travel and trip purposes.

Exhibit 13: Summary of Attitudinal Parameters Used in the Analysis

a) Values of Time ($/hr)

Trip Purpose	**Mode**			
	Auto	**Bus**	**Rail**	**Air**
Business	$23	-	$30	$67
Non-Business	$17	$12	$19	$44

b) Values of Frequency ($/hr)

Trip Purpose	**Mode**		
	Bus	**Rail**	**Air**
Business	-	$9	$34
Non-Business	$4	$7	$23

4.5 SOCIOECONOMIC DATA

Another step in the process of forecasting ridership involved the establishment of a socioeconomic database for the study area. The variables used to forecast ridership demand in this study were population, employment, and per capita income. A socioeconomic database for the base and forecast years was established using data from the U.S. Bureau of the Census and the Bureau of Economic Analysis. The forecasts of growth rates for the three variables for the aggregate of the zones between 2000 and 2040 are presented in Exhibit 14. Exhibits 15 through 17 illustrate the growth trends of the three socioeconomic variables over time.

Exhibit 14: Forecasted Socioeconomic Growth in the Study Area (2000 - 2040)

	2000	**2010**	**2020**	**2030**	**2040**
Population	11,407,083	11,888,369	12,589,047	13,266,311	13,980,571
Employment	7,120,086	7,700,289	7,933,095	8,228,838	8,535,932
(Per Capita) Income	$26,728	$30,007	$32,696	$35,571	$38,698

Exhibit 15: Forecasted Population Growth in the Study Area (2000 – 2040)

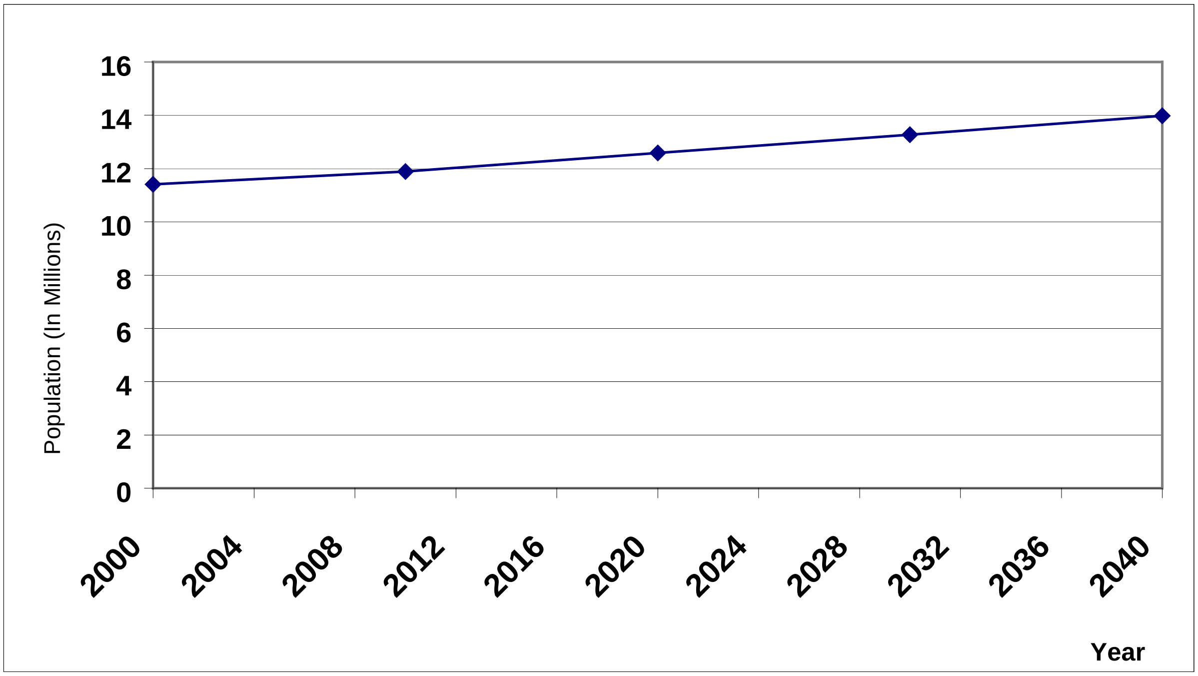


Exhibit 16: Forecasted Employment Growth in the Study Area (2000 – 2040)

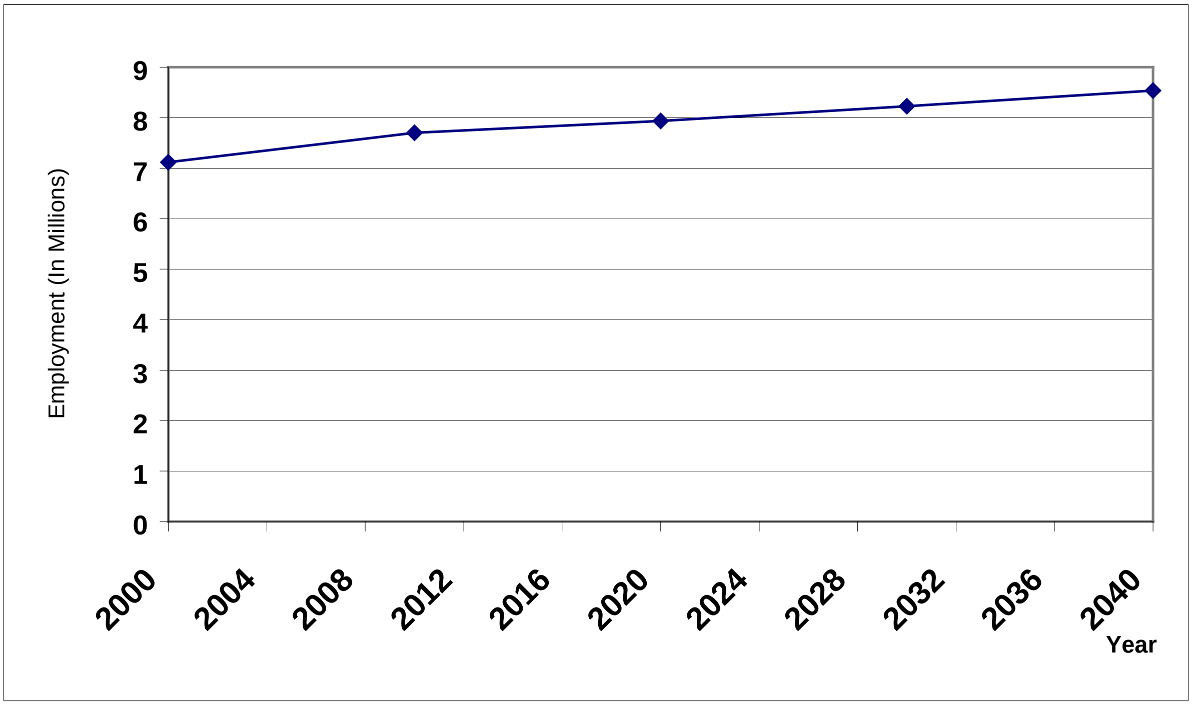
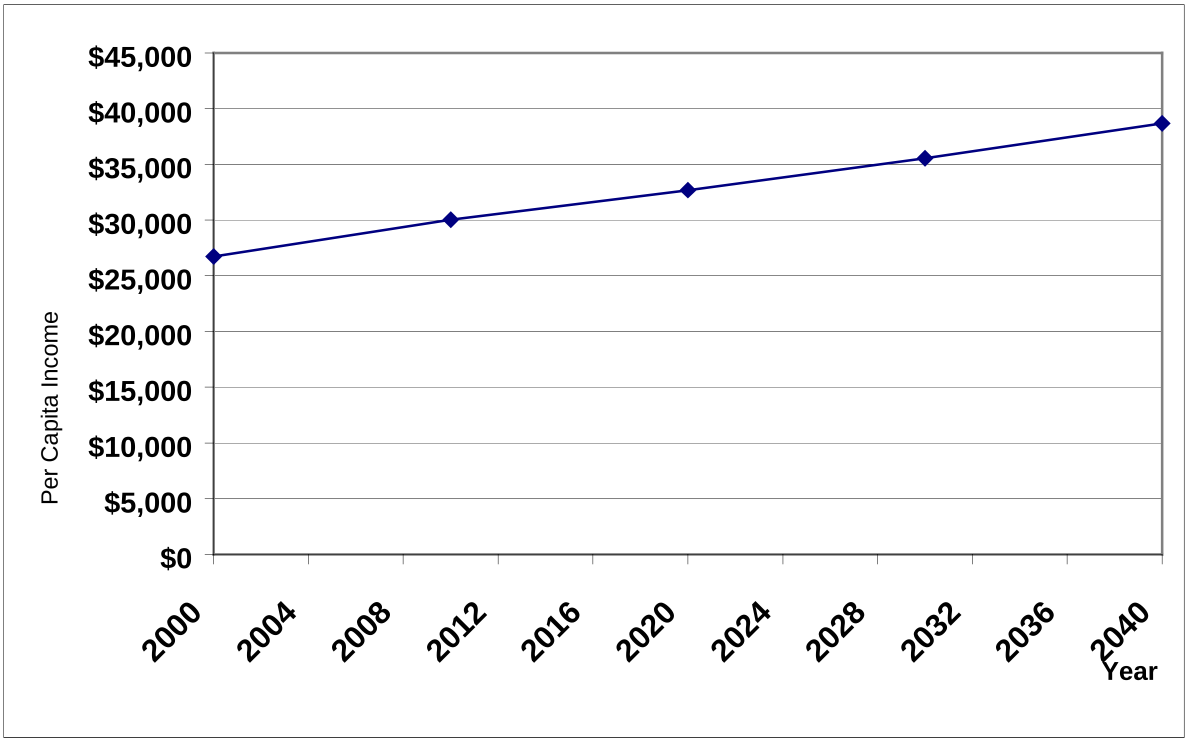


Exhibit 17: Forecasted Per Capita Income Growth in the Study Area (2000 – 2040)



5.0 RIDERSHIP AND REVENUE FORECASTS

Ridership and revenue forecasts were prepared for the 3C HSR Corridor using the *COMPASS-R*© model with the inputs described in Section 4 and the operating plan described in Section 3. A detailed description of the *COMPASS-R*© model is provided in the Appendix.

5.1 ADDITIONAL ASSUMPTIONS

Fares: A critical assumption of the ridership forecasts is the fare to be charged for using the system. Exhibit 18 shows the fares proposed for the station-to-station segments. The total fare between Cincinnati and Cleveland is assumed to be $90.27, with an average per-mile fare of about $0.35, consistent with that of MWRRI.

Exhibit 18: 3C Corridor Proposed Fares

City Pair	Fare
Cleveland to Southwest Cleveland	$4.60
Southwest Cleveland to Galion	$23.56
Galion to North Columbus	$15.58
North Columbus to Columbus	$3.68
Columbus to Springfield	$15.82
Springfield to Dayton	$8.65
Dayton to Middletown	$7.49
Middletown to North Cincinnati	$6.06
North Cincinnati to Cincinnati	$4.83
Total between Cleveland and Cincinnati	**$90.27**

Congestion: Highway congestion is another important factor that affects the ridership estimates. Forecasts were run *without* (additional) congestion and *with* congestion scenarios. The latter case was obtained, after discussions with the Study Steering Committee, Ohio DOT, and others, by assuming increasing congestion levels relative to the existing highway congestion. Specifically, highway congestion is assumed to be increasing by 1 percent annually. This provides an approximation of what may happen when road improvements cannot keep pace with increasing vehicular traffic. It also adds to the possible benefits of the system to timesavings that are not apparent with the present conditions.

5.2 FORECASTS

For comparison purposes, the ridership and revenue forecasts were developed for both the *without* and *with* congestion scenarios; however, the latter scenario was deemed to be more realistic and therefore served as the base on which the following analysis was performed.

The annual ridership of the 3C HSR Corridor is estimated to be 1,080,006 trips in 2005 (the assumed first year of operations), rising by about 56 percent to 1,681,884 in 2035 for the eight daily frequencies. The forecasts were conducted for a 30-year period, consistent with the MWRRI study. This produces corresponding revenues of $35.47 million and $56 million, respectively. All dollar amounts are expressed in $1998, consistent with the MWRRI study. More details are shown in Exhibits 19 through 21. The projected total demand for the four intercity modes in the corridor in year 2010 is displayed in Exhibit 22. High-speed rail is estimated to account for about 2 percent of the overall corridor demand.

Exhibit 19: Ridership and Revenue Forecast Summary

Year	**Ridership** (Annual Trips)		**Revenue** (Millions of 1998$)	
	8 Daily Runs	**10 Daily Runs**	**8 Daily Runs**	**10 Daily Runs**
2005	1,080,006	1,160,905	$35.47	$38.21
2010	1,183,535	1,271,281	$39.03	$42.01
2020	1,385,681	1,485,346	$46.09	$49.46
2035	1,681,884	1,802,686	$55.98	$60.07

Exhibit 20: System Ridership Growth (2005-2035, Eight Daily Frequencies)

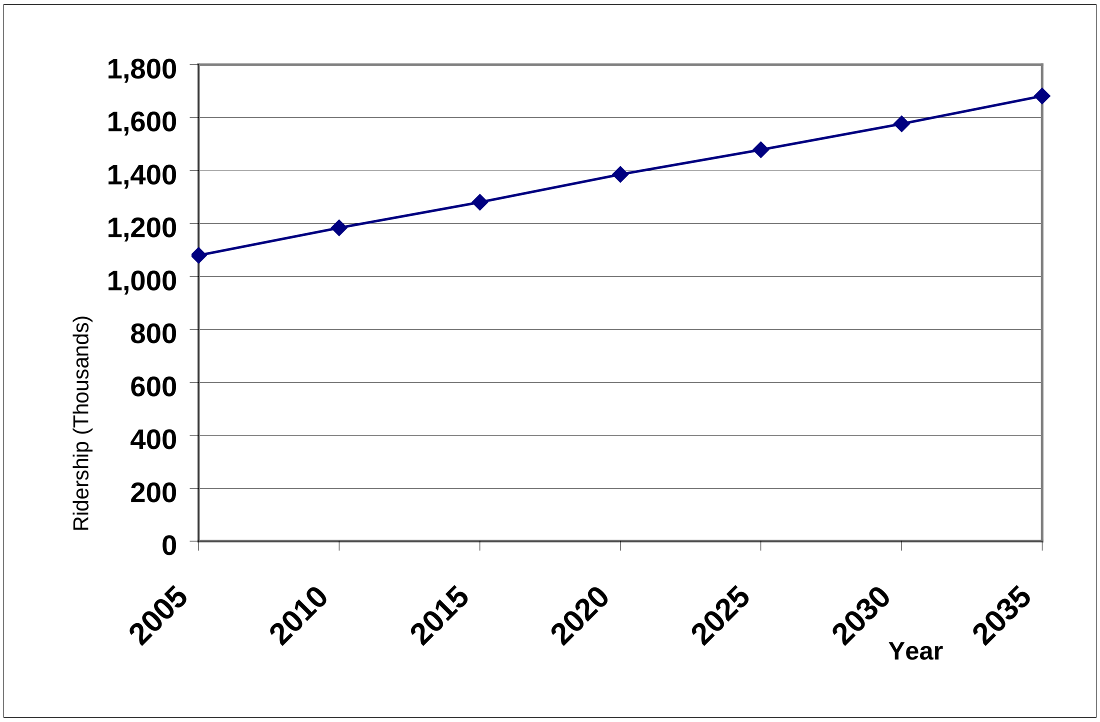


Exhibit 21: System Revenue Growth (2005-2035, Eight Daily Frequencies)

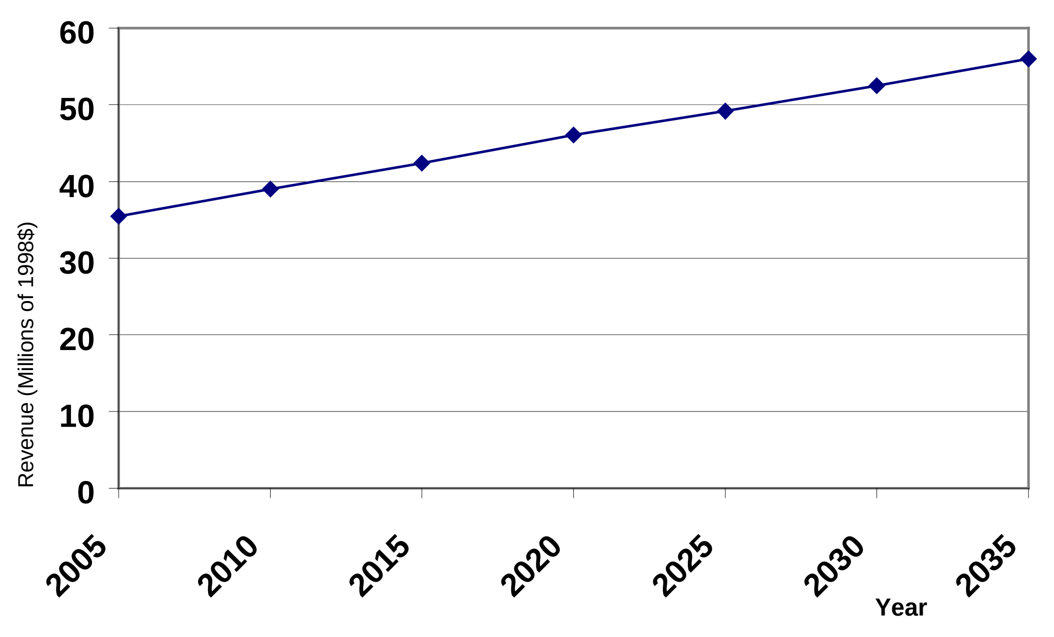


Exhibit 22: Total Corridor Demand Forecast Summary (2010, Eight Daily Frequencies for HSR)

Mode	Total Trips	Modal Split
Auto	57,502,272	96.30%
Bus	425,723	0.71%
Air	599,042	1.00%
High-Speed Rail	1,183,532	1.98%
Total Corridor Demand	59,710,569	

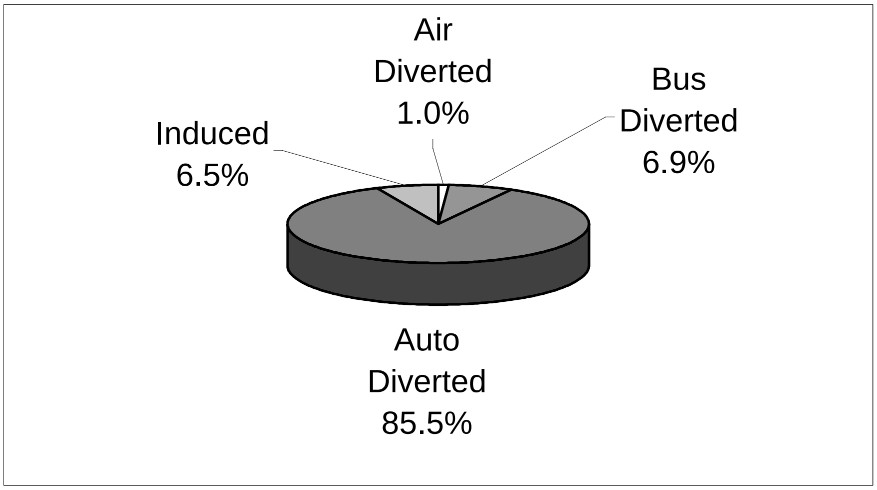
The *COMPASS*© model calculates total ridership by demand type (diverted, induced, and/or natural growth); trip purpose; transportation mode; and city pairs.

Diverted trips (made by users who previously used a different mode) for the system in 2010 accounted for about 93.5 percent of total system demand. Induced demand represents new trips taken because of improvements to the transportation network – such as those that would be created by the proposed 3C high-speed rail service – that otherwise would not have occurred. Induced demand is estimated to account for about 6.5 percent of total demand in 2010. Exhibits 23 and 24 depict the breakdown of the forecasted system demand.

Exhibit 23: System Demand Breakdown by Type (2010, Eight Daily Frequencies)

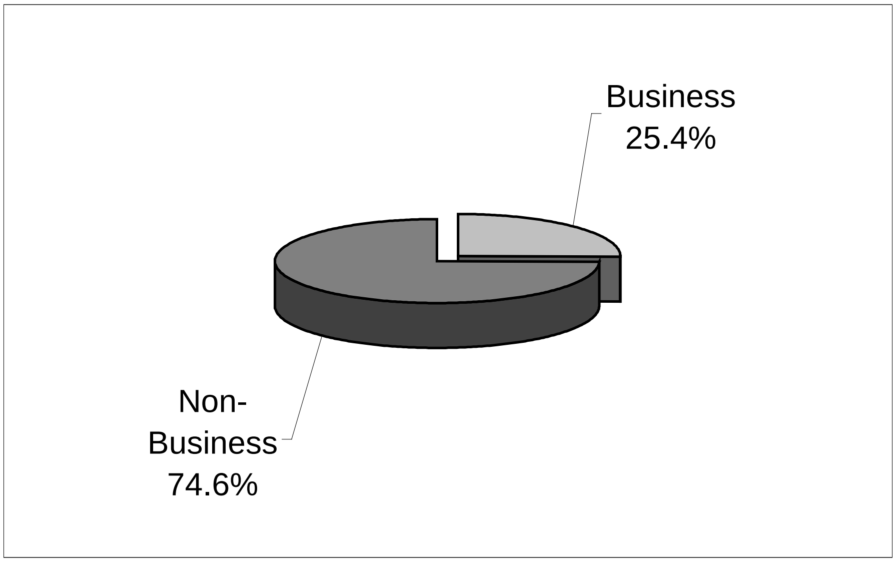
	Diverted Trips	Diverted Share
Auto Diverted	1,011,737	85.5%
Bus Diverted	82,087	6.9%
Air Diverted	12,297	1%
Induced	77,412	6.5%
Total HSR Ridership	1,183,533	

Exhibit 24: System Demand Breakdown by Type (2010, Eight Daily Frequencies)



The trip purpose distribution analysis shows that the most dominant forecasted trip purpose in 2010 will be non-business (including tourists, social/recreational travelers, and commuters) at about three quarters of all riders, with business travelers accounting for the remaining quarter of the ridership. The trip purpose breakdown for 2010 is shown graphically in Exhibit 25.

Exhibit 25: Trip Purpose Breakdown (2010, Eight Daily Frequencies)



The ridership estimate from the *COMPASS*© model also generated ridership by city pairs and station volumes in the corridor—as illustrated in Exhibits 26 and 27. The ridership volumes indicate a strong interconnection of the 3C Corridor with locations outside of Ohio (quarter of the total) through the MWRRS.

Exhibit 26: City Pair Annual Ridership (2010, Eight Daily Frequencies)

	Cincinnati	N. Cincinnati	Middletown	Dayton	Springfield	Columbus	Galion	SW Cleveland	Cleveland	North Ohio	Indianapolis	Other States	Totals
Cincinnati		33,235	2,264	14,136	6,110	19,170	5,267	5,160	41,733	14,004	0	0	141,079
N. Cincinnati			3,136	52,408	10,766	52,494	13,023	8,863	86,446	24,694	18,794	161,042	431,666
Middletown				3,297	2,648	3,811	2,289	1,319	10,866	4,986	326	6,378	35,920
Dayton					7,328	52,634	9,708	7,830	100,974	24,066	3,226	66,363	272,129
Springfield						10,636	4,160	3,099	40,749	15,973	0	0	74,617
Columbus							6,624	7,224	98,512	27,462	0	0	139,822
Galion								684	9,958	4,482	0	0	15,124
SW Cleveland									7,172	3,435	0	11,419	22,026
Cleveland											2,150	0	2,150
Totals	**0**	**33,235**	**5,400**	**69,841**	**26,852**	**138,745**	**41,071**	**34,179**	**396,410**	**119,102**	**24,496**	**245,202**	**1,134,533**

Exhibit 27: Station Volumes by Trip Purpose (2010, Eight Daily Frequencies)

	Business	**Non-Business**	**Total**
Cincinnati	36,426	136,703	173,129
North Cincinnati	138,743	325,969	464,712
Middletown	7,840	33,403	41,243
Dayton	86,198	255,666	341,864
Springfield	17,609	83,804	101,413
Columbus/North Columbus	78,787	199,739	278,526
Galion	11,401	44,777	56,178
Southwest Cleveland	11,604	44,552	56,156
Cleveland	180,082	585,330	765,412

Fare Sensitivity was tested for the system. The results, illustrated in Exhibit 28, show the expected inverse relationship between ridership and fare. Ridership goes down with higher fares. The overall revenue rises with increases in fare from about $29.5 million at $0.20 per mile to $39 million when the fare is at $0.35 – as in the case of the MWRRI.

Exhibit 28: Fare Sensitivity Summary (2010, Eight Daily Frequencies)

Per Mile Fare	Annual Ridership	Annual Revenue ($Millions)
$0.20	1,377,126	$29.49
$0.25	1,308,417	$33.36
$0.30	1,244,150	$36.51
$0.35	*1,183,534*	*$39.03*

6.0 COST ESTIMATES

6.1 CAPITAL COSTS

The capital cost estimates for the 3C Corridor are based on a comprehensive engineering review of the existing right-of-way and infrastructure. This analytic process is identical to that used in the development of the Midwest Regional Rail Initiative, and it utilizes the same unit costs for all of the various infrastructure components. The major capital improvements include right-of-way modification to track and track alignments to support 110-mph train speeds, and additional capacity for freight and passenger operations. The cost estimates also include upgrades to existing stations, construction of new stations, bridge construction and rehabilitation, highway/railroad grade crossings, and signaling and communications systems.

The basic capital costs for the 3C Corridor are shown in Exhibit 29. They are estimated at around $711 million and $720 million for the seven- and eight-trainset options, respectively. This cost includes double-tracking a majority of the 3C Corridor. A less expensive single-track system, which would include long passing sidings, may offer adequate freight and passenger train capacity at a significantly reduced capital cost. However, for the purposes of developing a conceptual estimate, this study has assumed that the more expensive double-tracking of the corridor would be required. It is important to remember that the 3C Corridor is privately owned and operated by the railroads and all of the capital improvements and operational issues must be resolved through negotiations and agreements with the railroads.

6.2 OPERATING COSTS

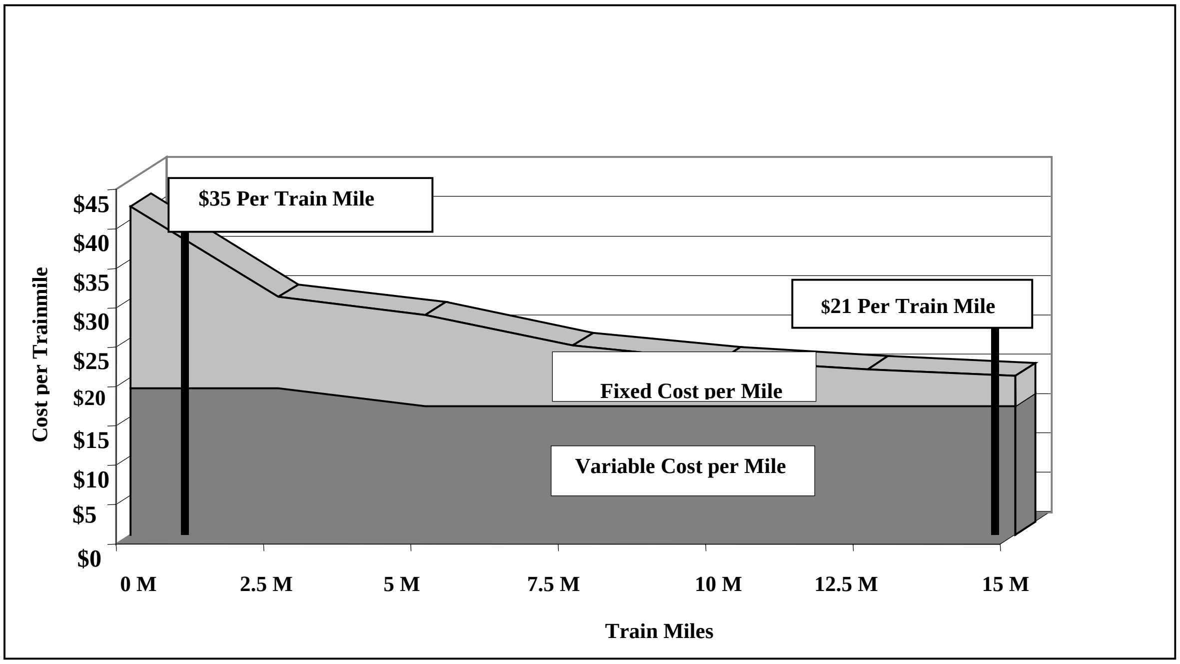
The operating costs for the system are highly dependent on the level of service offered, the train technology selected, and the character and size of the proposed operation. In terms of the frequency of service, the two operating scenarios were assessed. With respect to train technology, the Talgo has been used as the “generic” example of a modern train.

The other key factor in the operating costs is the scale of the operation proposed. Linking the 3C HSR Corridor to a larger existing rail system has many benefits, because operating costs fall dramatically as the train miles of the operation increase. This is one of the economies of scale that prompted the creation of the Midwest Regional Rail Initiative. (See Exhibit 30.) If the 3C Corridor is linked to the fully-implemented MWRRI, assuming a Talgo train set, the operating cost per mile would be similar to the values shown towards the right side of Exhibit 30, with a cost per train mile of $21. If the 3C service were operated as a freestanding system, the operating costs would be substantially higher at around $35 per train mile or more. Note the higher values on the left side of Exhibit 30.

Exhibit 29: Capital Cost Estimates

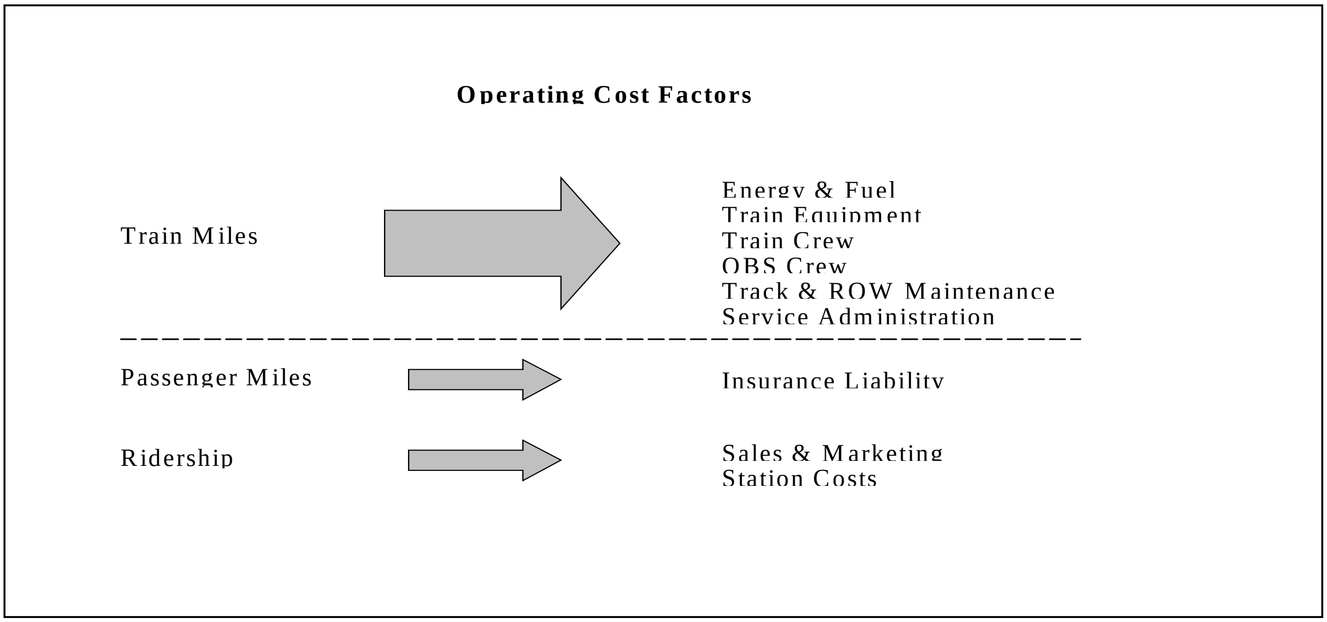
3-C Route, 258 miles	**110-mph**	
	Express	Local
Running Times (minutes)	205	229
Running Times (hours)	3:25	3:49
Average Speed (mph)	75.5	67.6
Frequencies	**8**	**10**
Capital Improvements		
Right-of-Way		
Infrastructure		
Track (includes double track)	$277,633,000	
Turnouts	$4,440,000	
Bridges Under	$140,290,000	
Bridges Over	$0	
Curve Upgrade	$8,470,000	
Signals	$193,662,000	
Train Control	$91,684,000	
Highway Crossing Protection	$101,978,000	
Structures	$20,000,000	
Stations	$10,000,000	
Maintenance/Other Stations	$10,000,000	
Total Infrastructure	**$644,495,000**	
	7 Trainsets	**8 Trainsets**
Rolling Stock	$66,500,000	$76,000,000
Grand Total	**$710,995,000**	**$720,495,000**

Exhibit 30: Variable and Fixed Cost Per Mile Volume Relationship



In evaluating the 3C Corridor service option, the significant factors increasing operating costs are related to the increase in train miles from additional frequencies (fixed costs) and the increase in ridership and passenger miles (variable costs). Exhibit 31 identifies the operating cost drivers as they relate to the operating cost elements.

Exhibit 31: Operating Cost Drivers Related to Operating Cost Elements



The operating cost estimates are based on the trip distance (516 miles for a roundtrip), daily frequencies (8 and 10 trip options), and the cost per trainmile ($21). This cost per trainmile was derived from the MWRRI study and assumes economies of scale in the overhead costs for the system. It also excludes train depreciation costs. The breakdown of operating costs per mile, based on the MWRRI study, is shown in Exhibit 32. As presented in Exhibit 33, the annual operating costs are projected to be around $31.55 million and $39.44 million for the 8 and 10 daily frequencies, respectively.

Exhibit 32: Operating Costs Components Breakdown (based on MWRRI)

Amtrak/Private
Train Crew/OBS: $4.74/mile

3rd Party (fuel/ROW): $5.22/mile
Amtrak/Private $4.67/mile

Amtrak/Private (Stations, Sales, Marketing): $2.94/mile

Amtrak/Private (Administration, other): $3.66/mile

Total Operating Cost: $21.23/mile

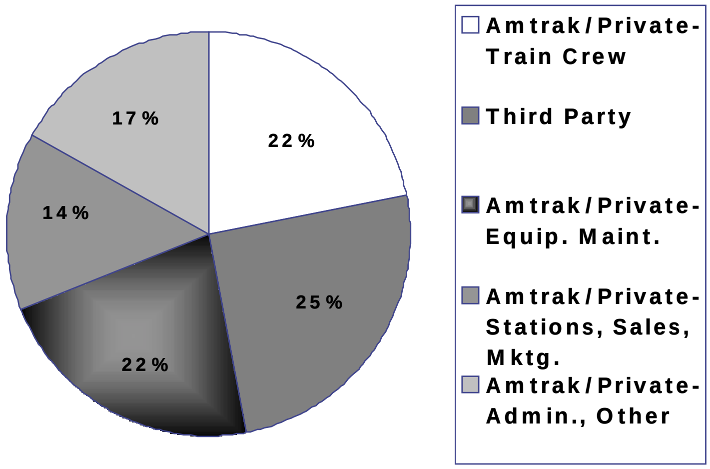


Exhibit 33: Operating Costs Estimates

Trainmiles and Cost Assessment		
	8 Frequencies	**10 Frequencies**
Corridor Distance	258	258
Round-Trip Distance	516	516
Daily Frequency	8	10
Daily Trainmiles	4,128	5,160
Annual Trainmiles	1,502,592	1,878,240
Cost Per Trainmile	$21.00	$21.00
Total Annual Operating Costs	$31,554,432	$39,443,040,

7.0 MEASURES OF FINANCIAL SUCCESS

A key measure of the success of a passenger rail corridor for the 3C HSR service is its ability to achieve an operating ratio of at least one. Exhibit 34 shows that of the 3C Corridor achieves this objective with an operating ratio of at least 1.42 for eight daily frequencies in 2010. It should be noted that the revenue side (numerator) of the operating ratios, as in the MWRRI case, includes (in addition to farebox revenue) other sources of operating revenue such as parcel revenue and on-board services. The estimates for these two categories were obtained by applying the per train mile unit revenues of $2.24 for parcels and $1.6 for on-board services (consistent with the MWRRI) to the annual train mileage for the system.

Exhibit 34: Summary Operating Ratios

Year	**Operating Revenue*** ($ Millions)		**Operating Cost** ($ Millions)		**Operating Ratio**	
	8 Daily Runs	**10 Daily Runs**	**8 Daily Runs**	**10 Daily Runs**	**8 Daily Runs**	**10 Daily Runs**
2005	$41.24	$45.42	$31.55	$39.44	1.31	1.15
2010	$44.80	$49.22	$31.55	$39.44	1.42	1.25
2020	$51.86	$56.67	$31.55	$39.44	1.64	1.44
2035	$61.75	$67.28	$31.55	$39.44	1.96	1.71

* Operating revenue includes: farebox, parcel, and on-board services revenues.

The financial results for the study show that in 2010 a better operating ratio (1.42) is obtained by the eight-daily-frequencies scenario than the 10-daily-frequencies scenario (1.25). This option requires less capital investment than the 10-daily-frequencies scenario while still providing good service and operating ratio(s).

In terms of capital costs, the MWRRI assumes that the development of the system would be based on an 80-percent Federal Grant and a 20-percent State and local match. As a result, should the corridor become part of the MWRRI, the capital cost to Ohio of developing the 3C Corridor would be around $143 million for both infrastructure and rolling stock.

8.0 ECONOMIC BENEFITS

The 3C Corridor passenger rail services will provide a wide range of benefits which will contribute to the economic growth of Ohio, and will improve mobility between the major business and population centers—particularly between the State Capital and the State's largest cities. The 3C Corridor will generate resource savings in automobile operating costs and highway congestion relief, as well as reduced energy usage and exhaust emissions. The passenger rail service and the connectivity to the Midwest Regional Rail System will provide an attractive travel choice that could result in reduced automobile and air trips for commuting, business, and leisure purposes.

This section of the report defines, quantifies, and evaluates the economic benefits that will be achieved through the development and operation of the 3C HSR Corridor. These benefits will appear in the form of users' consumer surplus, system revenues, airport delay savings, highway delay savings, and emissions savings. The economic forecasting and assessment techniques used here have been approved and employed by the Federal Railroad Administration (FRA). In addition this process has been accepted by other Federal, State, and local governmental authorities and has been employed throughout the transportation planning industry as a proven economic forecasting and assessment technique.

8.1 COMMERCIAL FEASIBILITY STUDY (CFS)

The Commercial Feasibility Study (CFS) produced by the FRA investigated investment needs, operating performance, and benefits of high-speed ground transportation (HSGT) corridors to transportation users. The CFS compares the economic benefits and costs of implementing different technology options, such as high-speed rail. This comparison takes two basic forms: subtraction (benefits less costs) and ratio (benefits divided by costs).

8.1.1 CFS EVALUATION TOOLS AND STRATEGIES

Contrasting a "no-build" strategy with a "build" strategy generated benefit-cost comparison measures. Passenger traffic growth, with and without high-speed rail (HSR), was estimated using the *COMPASS-R*© model. This comparison provided the basis for evaluating the projected levels of user and public benefits resulting from the implementation of the HSR system in line with the CFS methodology. The *COMPASS-R*© model is described in detail in the Appendix.

8.1.2 TOTAL BENEFITS VERSUS TOTAL COSTS

A summary of the benefits and costs relating to the CFS is provided in Exhibit 35.

In many cases, the comparison of benefits to the public-at-large with publicly-borne costs tends to portray HSGT less favorably than does the comparison of total benefits with total costs. This comparison reflects the absence of the users' consumer surplus from the benefits to the public-at-large, and its inclusion in total benefits. In economic terms, when publicly-borne costs exceed the benefits to the public-at-large, the consumer surplus may be regarded as a subsidy enjoyed by the users. This is typically the case in highway projects, such as interstates and bridges, where users seldom pay the full cost of public projects.

Exhibit 35: Commercial Feasibility Study - Subcategories of Benefits and Costs

Types of Benefits and Costs	Related Analytical Components
Benefits to HSGT Users:	
• Benefits that HSGT users pay directly	⇒ System revenues
• Benefits that HSGT users do not pay directly	⇒ Users' consumer surplus
Benefits to Other Travelers:	
• Airport congestion delay savings	⇒ Airline and air passenger savings from reduced air traffic
• Highway congestion delay savings	⇒ Highway users' time savings from reduced auto traffic
• Emission savings	⇒ Difference in emissions rates per passenger mile between the HSR-build and no-build cases
Costs:	
• Capital investment	⇒ Infrastructure and rolling stock
• Operating and maintenance expense	⇒ Ongoing operations

8.2 EVALUATION OF THE OUTPUTS

8.2.1 OVERVIEW OF THE OUTPUTS

Benefit and cost calculations were performed in accordance with the FRA's CFS methodologies. Exhibit 36 details the benefits, costs and investments, and the methods of analyzing their relationships.

Exhibit 36: Overview of the Outputs

Type of Benefits	Costs and Investments	Analysis Outputs
• Users' consumer surplus • System revenues • Airport delay savings • Highway delay savings • Emission savings	• Investment costs • Operations and maintenance expenses	• Benefit-cost ratio • Net present value

8.2.2 METHODOLOGY FOR USERS’ BENEFITS OUTPUTS

The benefits to users of the HSR are the sum of consumer surplus and system revenues.

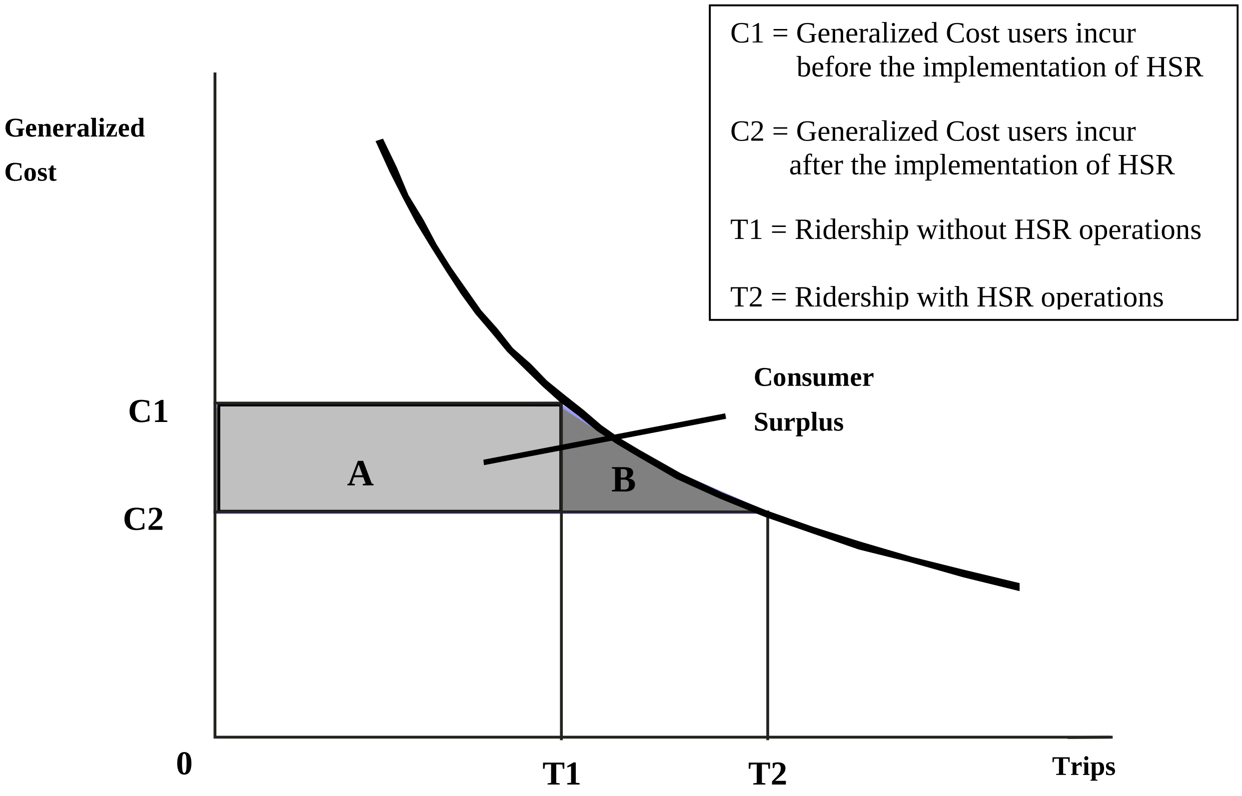
8.2.2.1 Consumer Surplus

Consumer surplus measures users’ benefits. A transportation improvement is seen as providing users’ benefits in terms of time and costs savings, as well as convenience, comfort, and reliability to users of the mode. For the HSR, trips will be either induced (i.e., users who previously did not make a trip) or diverted (users who previously used a different mode).

In consumer surplus analysis, improvements in service (for all modes of transportation in the corridor) are measured by improvements in generalized cost. In some cases, individuals may pay higher fares (for example, current bus and rail users), but it is likely that other aspects of the improvement will compensate for the increased fare.

To calculate consumer surplus, the number of trips and generalized cost of travel without HSR were compared to the number of trips and generalized cost of travel with HSR. In Exhibit 37, the shaded area represents improvements in the generalized cost of travel for induced or diverted users (the consumer surplus). The shaded area is defined by the points (0, C_1), (0, C_2), ($T_{1,}$ C_1) and (T_2 C_2). The equation assumes that area *B* is a triangle, and the arc of the demand curve is a straight line. Equation 1 measures consumer surplus.

Exhibit 37: Consumer Surplus Graphically



Equation 1

$$CS = [(C_1 - C_2)\ T_1] + [(C_1 - C_2)(T_2 - T_1)(0.5)]$$

Where:

CS = Consumer Surplus
Rectangle = $(C_1 - C_2)\ T_1$
Triangle = $(C_1 - C_2)(T_2 - T_1)(0.5)$

The *COMPASS-R*© demand model estimates consumer surplus by calculating the increase in regional mobility (i.e., induced travel) and traffic diverted to HSR (area B in Exhibit 37), as well as the reduction in travel costs, measured in terms of generalized cost, for existing system users (area A). The reduction in generalized cost generates the increase in users' benefits. Consumer surplus consists of the additional benefits derived from savings in time, fares, and other utility improvements. The users' consumer surplus, therefore, is the difference between the amount an individual would be willing to pay for HSR service, and the fare required to use the HSR system; in other words, the additional benefit, or surplus, individuals receive from the purchase of the service. Consumer surpluses exist because individuals receive more perceived benefit or utility from a service than the actual dollar price paid.

8.2.2.2 System Revenues

Revenues are another benefit to users of the HSR system, a benefit for which they pay directly. Fares charged multiplied by the number of riders equals system revenues. Methodology pertaining to revenue forecasting is included in the Ridership and Revenue part of this report (See section 4 and the Appendix.)

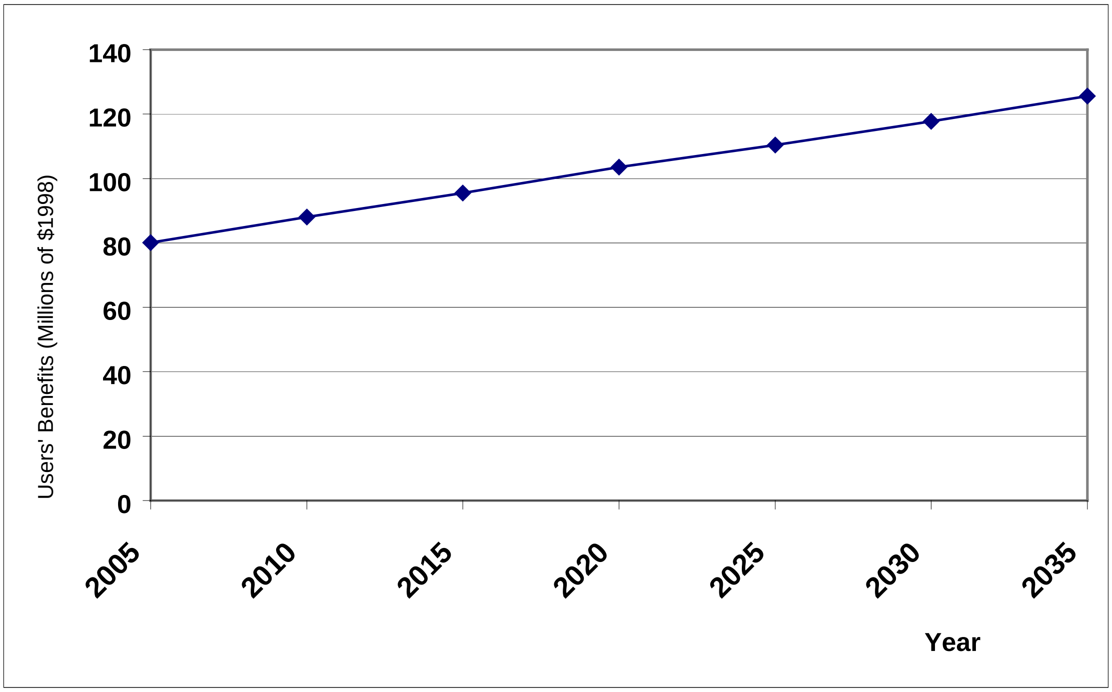
8.2.2.3 User Benefits Related *COMPASS-R*© Model Forecasts

Benefits to users (Exhibits 38 and 39) of the 3C HSR Corridor service are measured by the sum of system revenues and consumer surplus. System revenues are calculated at around $35 million in 2005, rising to $56 million in 2035. Consumer surplus is a direct output of the *COMPASS*© model for each of the forecast years. It is estimated to be $44.61 million in 2005, rising to almost $70 million in 2035. All amounts in the analysis are in constant (1998) dollars. The total of users' benefits is consequently estimated at $80 million in 2005, increasing to $125 million in 2035.

Exhibit 38: 3C Corridor High Speed Rail Service Users' Benefits
(Eight Daily Frequencies)

	2005	**2010**	**2020**	**2035**
Users' Benefits				
System Revenues	$35.47M	$39.03M	$46.09M	$55.98M
Consumer Surplus	$44.61M	$48.98M	$57.42M	$69.61M
Total Users Benefits	**$80.08M**	**$88.00M**	**$103.51M**	**$125.59M**

Exhibit 39: Summary of Users' Benefits (Eight Daily Frequencies)



8.2.3 *BENEFITS TO USERS OF OTHER MODES*

In addition to rail-user benefits, travelers using other modes will also benefit from the 3C Corridor as the system will contribute to highway congestion relief and reduced travel times for users of these other modes. For purposes of this analysis, these benefits were measured by identifying the estimated number of air and auto passenger trips diverted to rail and multiplying each by the benefit levels used in the FRA/USDOT study, *High-Speed Ground Transportation in America*. Exhibit 40 summarizes the estimates of the non-user benefits.

Exhibit 40: Summary of the Estimated Non-User Benefits (in 2010, Eight Daily Frequencies)

	$Millions in 2010
Benefits to Users of Other Modes	
Airport Congestion Savings	$0.54
Highway Congestion Savings	$23.76
Subtotal of Benefits to Users of Other Modes	$24.29
Resource Benefits	
Air Carrier Operating Costs Savings	$0.29
Emissions Savings	$18.14
Subtotal of Resource Benefits	$18.43
Total of Non-User Benefits	**$42.72**

8.2.3.1 Airport Congestion

Using projections from the *COMPASS*© model, benefits to air travelers resulting from reduced air congestion were identified by estimating the number of passenger air trips diverted to rail in 2010. The air-connect model estimates that 12,297 air trips will be diverted to the 3C HSR Corridor.

The FRA calculated travel time saved by air passengers (those not diverted to rail) due to reduced congestion, deviations from scheduled flight arrival and departure times, and additional time spent on the taxiway or en route. For each major airport, average delays were capped at 15 minutes per operation. From the FRA calculations, the benefit unit estimate of $43.64 per diverted passenger air trip was obtained. This value, multiplied by the estimated air trips diverted to the 3C Corridor yields air-congestion savings of more than $536,000 in 2010.

8.2.3.2 Highway Congestion

There will be somewhat reduced congestion and delays on highways due to auto travelers diverting to the 3C Corridor, relative to the levels that would take place without the implementation of high-speed rail. It is estimated that 1.01 million auto trips will be diverted.

The FRA calculated the travel time saved when traffic volumes are reduced on major highways between city pairs. From the FRA calculations, the benefit unit estimate of $23.48 per diverted passenger auto trip was obtained. This value, multiplied by the estimated auto trips diverted to the 3C Corridor yields highway-congestion savings of $23.76 million in 2010.

For comparison purposes, the distances and in-vehicle travel times for HSR and auto modes for sample city pairs in the 3C are presented in Exhibit 41. Generally, in terms of generating time savings versus auto, the 3C Corridor HSR line appears to be less successful on the southern part of the corridor than it is on the northern part.

Exhibit 41: In-Vehicle Time Savings from Implementing HSR (sample city pairs)

City pair	Auto		Rail		Time Savings (minutes)
	In-Vehicle Time (minutes)	Distance (miles)	In-Vehicle Time (minutes)	Distance (miles)	
Cleveland-Columbus	183	148	104	136	79
Cleveland-Dayton	260	215	161	206	99
Cleveland-Cincinnati	291	234	217	258	74
Columbus-Dayton	77	67	57	70	20
Cincinnati-Dayton	64	55	56	52	8

8.2.4 RESOURCE BENEFITS

The implementation of any transportation project has an impact on the resources used by travelers. The 3C HSR Corridor service and the consequent reduction in airport congestion will result in resource savings to airline operators and reduced emissions of air pollutants for all non-rail modes.

8.2.4.1 Air-Carrier Operating Costs

Benefits to air carriers in terms of operating cost savings resulting from reduced congestion at airports are calculated in much the same way as the time savings benefits to air travelers. For its study corridors, the FRA study estimated the benefits to air carriers by multiplying the projected reduction in the number of aircraft hours of delay by the average cost to the airlines for each hour of delay. As noted above, average delays were capped at 15 minutes per operation. From the FRA calculations, the benefit unit estimate of $23.46 per diverted passenger air trip was obtained. This value, multiplied by the estimated air trips diverted to the 3C Corridor yields air-carrier-operating-costs savings of over $288,000 in 2010. The dollar amounts of savings related to both airport congestion and air-carrier operating costs for the corridor are relatively low because of rather short distances and infrequent air service between the cities along the corridor.

8.2.4.2 Emissions

The diversion of travelers to rail from the auto and air modes generates emissions savings. The FRA calculated emissions savings based on changes in energy use with and without the proposed rail service. Their methodology took into account the region of the country, air quality regulation compliance of the counties served by the proposed rail service, the projection year, and the modes of travel used for access/egress as well as the line-haul portion of the trip. For the 3C Corridor, it was assumed that emissions savings would be proportional to the number of diverted auto vehicle miles. For both the FRA and 3C Corridor analyses, the number of vehicle-miles saved was calculated by multiplying the number of diverted auto trips times and the average trip length divided by an average vehicle occupancy factor. The resulting auto vehicle-miles saved was divided by the estimate of emissions benefit, yielding a FRA-estimated benefit of $0.02 per vehicle mile. This value, multiplied by the number of vehicle-miles saved by implementation of the 3C Corridor, yields a benefit of over $18 million in 2010.

As previously illustrated in Exhibit 40, the total non-user benefits generated by the 3C Corridor in 2010 are projected to amount to over $42 million.

9.0 BENEFITS TO COSTS COMPARISONS

The values of the benefits and costs presented in this section are based on an analysis of discounted cash flow (DCF). The DCF is an extended stream of cash flows, as in Equation 2.

Equation 2

$$PV = \Sigma C_t / (1 + r)^t$$

where
PV = Present value
C_t = Cash flow
r = Opportunity cost of capital
t = Time period

Discounted cash flows are calculated over the project life of 30 years. For financial comparisons, capital, operating and maintenance costs are compared to revenue streams. The discount rate is the financial return foregone by investing in a project (such as the proposed system), rather than in securities. A seven-percent rate (consistent with the MWRRI study) was used for the discount rate in this study.

From the DCF of the costs and revenues, the net present value (NPV) was calculated. The NPV is the measurement of the combined worth of all the cash flows, positive and negative, associated with a project, at a given point in time. For this rail study, the NPV includes the different benefits, the operating and maintenance costs, and capital costs. Equation 3 states NPV in terms of cash flow.

Equation 3

$$NPV = C_0 + PV$$

where
C_0 = Initial cash outflow (capital)
PV = Present value of cost and revenue streams that result from the operation of the project

If an NPV is positive, then the investment it represents is worth more than it costs. If the NPV is negative, the investment costs more than the income it generates.

The calculation of the benefits-to-costs ratio is based upon net present value of total project benefits and costs. Costs and revenues are looked at in constant dollars. All costs and revenues are discounted at seven percent to the year 2000.

For the purposes of the analysis the implementation schedule with operations starting in 2005 following two years of construction was assumed here The capital costs used in this analysis included expenditures of around $711 million (undiscounted, and expressed in 1998 dollars) to be spent evenly in 2003 and 2004, resulting in an overall capital cost discounted present value of about $525 million. The operating and maintenance costs were assumed to be $31.5 million (undiscounted, in 1998 dollars) annually between 2005 and 2035, giving the discounted present value for the 30 years of $282 million. The sum of present value of the capital and operating and maintenance cost is forecasted at almost $807 million.

On the benefits side, the 30-year discounted present value of the revenues is estimated at $378 million, while the present value of consumer surplus is projected to be $473 million. Within the non-user benefits category, the present value of total air congestion savings is forecasted at $4 million, while highway congestion savings is at $235 million, air carrier operating cost savings is $2 million, and emission saving is $180 million. The savings from air-related traffic movement are relatively low compared to those based on highway traffic. The total present value of all benefits is estimated at $1.27 billion.

Exhibit 42 summarizes the present value of the benefit and cost items and the NPV of the benefit/cost comparison.

Exhibit 42: Benefits to Costs Comparison Summary (Eight Daily Frequencies)

3C Corridor Cost Benefit Parameters	**30-Year Net Present Value ($Millions)**
Benefits	
User Benefits	
Consumer Surplus	$473
System Revenues	$378
Other Mode User Benefits	
Airport Congestion Savings	$4
Highway Congestion Savings	$236
Resources Benefits	
Air Carrier Operating Costs Savings	$2
Emission Savings	$180
Total Benefits	***$1,274***
Costs	
Capital	$525
Operating and Maintenance	$282
Total Costs	***$807***
Total Benefits minus Total Costs	***$467***
Ratio of Benefits to Costs	***1.42***

A benefits-to-costs ratio of 1.42 is generated. This ratio of benefits to costs indicates that the 3C HSR Corridor is expected to have a positive impact on the state economy. The benefit analysis, which is based on criteria established by the FRA for passenger rail projects, estimates that implementation of the 3C Corridor will generate more than $1.27 billion in economic benefits to the state over the 30-year project lifecycle.

Appendix

COMPASS-R© Model Structure and Description

The *COMPASS*© Model System is a flexible multimodal demand-forecasting tool that provides comparative evaluations of alternative socioeconomic and network scenarios. It also allows input variables to be modified to test the sensitivity of demand to various parameters such as elasticities, values of time, and values of frequency.

The *COMPASS*© Model System is structured on two principal models: a Total Demand Model and a Hierarchical Modal Split Model. For this study, these two models were calibrated separately for two trip purposes, *i.e.*, business and non-business (commuter, personal, and social). Moreover, since the behavior of short-distance trip-making is significantly different from long-distance-trip-making, the database was segmented by distance and independent models were calibrated for long trips and short trips. For each market segment, the models were calibrated on origin-destination trip data, network characteristics, and base year socioeconomic data.

The models are calibrated on the base data. In applying the models for forecasting, an incremental approach known as the “pivot point” method is used. The “pivot point” method preserves unique travel flows present in the base data which are not captured by the model variables by applying model growth rates to the base data observations. Details on how this method is implemented are provided below.

Total Demand Model

The Total Demand Model, shown in Equation 1, provides a mechanism for assessing overall growth in the travel market.

Equation 1

$$T_{ijp} = e^{\beta 0p}(SE_{ijp})^{\beta 1p} e^{\beta 2p\ Uijp}$$

Where

T_{ijp} = Number of trips between zones i and j for trip purpose p

SE_{ijp} = Socioeconomic variables for zones i and j for trip purpose p

U_{ijp} = Total utility of the transportation system for zones i to j for trip purpose p

$\beta_{0p}, \beta_{1p}, \beta_{2p}$ = Coefficients for trip purpose p

As shown in Equation 1, the total number of trips between any two zones for all modes of travel, segmented by trip purpose, is a function of the socioeconomic characteristics of the zones and the total utility of the transportation system that exists between the two zones. For this study, trip purposes included business and non-business, and socioeconomic characteristics included population, employment, and per capita income. The utility function provides a logical and intuitively sound method of assigning a value to the travel opportunities provided by the overall transportation system.

In the Total Demand Model, the utility function provides a measure of the quality of the transportation system in terms of the times, costs, reliability and level of service provided by all modes for a given trip purpose. The Total Demand Model equation may be interpreted as meaning that travel between zones will increase as socioeconomic factors such as population and income rise or as the utility (or quality) of the transportation system is improved by providing new facilities and services that reduce travel times and costs. The Total Demand Model can therefore be used to evaluate the effect of changes in both socioeconomic and travel characteristics on the total demand for travel.

Socioeconomic Variables

The socioeconomic variables in the Total Demand Model show the impact of economic growth on travel demand. The *COMPASS*© Model System, in line with most intercity modeling systems, uses three variables (population, employment, and per capita income) to represent the socioeconomic characteristics of a zone. Different combinations were tested in the calibration process; and it was found, as is typically found elsewhere, that the most reasonable and stable relationships consists of the following formulations:

Trip Purpose	***Socioeconomic Variable***
Business	$E_iE_j(I_i+I_j)/2$
Non-Business	$P_iP_j(I_i+I_j)/2$

The business formulation consists of a product of employment in the origin zone, employment in the destination zone, and the average per capita income of the two zones. Since business trips are usually made between places of work, the presence of employment in the formulation is reasonable. The non-business formulation consists of a product of population in the origin zone, population in the destination zone, and the average per capita income of the two zones. Non-business trips encompass many types of trips but, the majority are home-based and thus, greater volumes of trips are expected from zones with higher population.

Travel Utility

Estimates of travel utility for a transportation network are generated as a function of generalized cost (GC), as shown in Equation 2:

Equation 2

$$U_{ijp} = f(GC_{ijp})$$

where

GC_{ijp} = Generalized cost of travel between zones i and j for trip purpose p

Because the generalized cost variable is used to estimate the impact of improvements in the transportation system on the overall level of trip-making, it needs to incorporate all the key modal attributes that affect an individual's decision to make trips. For the public modes (rail, bus, air), the generalized cost of travel includes all aspects of travel time (access, egress, in-vehicle times); travel cost (fares, tolls, parking charges); schedule convenience (frequency of service, convenience of arrival/departure times); and reliability.

The generalized cost of travel is typically defined in travel time (*i.*e., minutes) rather than dollars. Costs are converted to time by applying appropriate conversion factors, as shown in

Equation 3. The generalized cost (GC) of travel between zones i and j for mode m and trip purpose p is calculated as follows:

Equation 3

$$GC_{ijmp} = TT_{ijm} + \frac{TC_{ijmp}}{VOT_{mp}} + \frac{VOF_{mp} OH}{VOT_{mp} F_{ijm} C_{ijm}} + \frac{VOR_{mp} \exp(-OTP_{ijm})}{VOT_{mp}}$$

Where

TT_{ijm} = Travel time between zones i and j for mode m (in-vehicle time + station wait time + connection wait time + access/egress time + interchange penalty), with waiting, connect and access/egress time multiplied by a factor (greater than 1) to account for the additional disutility felt by travelers for these activities

TC_{ijmp} = Travel cost between zones i and j for mode m and trip purpose p (fare + access/egress cost for public modes, operating costs for auto)

VOT_{mp} = Value of Time for mode m and trip purpose p

VOF_{mp} = Value of Frequency for mode m and trip purpose p

VOR_{mp} = Value of Reliability for mode m and trip purpose p

F_{ijm} = Frequency in departures per week between zones i and j for mode m

C_{ijm} = Convenience factor of schedule times for travel between zones i and j for mode m

OTP_{ijm} = On-time performance for travel between zones i and j for mode m

OH = Operating hours per week

Station wait-time is the time spent at the station before departure and after arrival. Air travel generally has higher wait-times because of security procedures at the airport, baggage checking, and the difficulties of loading a plane. Air trips were assigned wait-times of 45 minutes while rail trips were assigned wait times of 30 minutes and bus trips were assigned wait times of 20 minutes. On trips with connections, there would be additional wait times incurred at the connecting station. Wait-times are weighted higher than in-vehicle time in the generalized cost formula to reflect their higher disutility as found from previous studies. Wait-times are weighted 70 percent higher than in-vehicle time for business trips and 90 percent higher for non-business trips.

Similarly, access/egress time has a higher disutility than in-vehicle time. Access time tends to be more stressful for the traveler than in-vehicle time because of the uncertainty created by trying to catch the flight or train. Based on previous work, access time is weighted 30 percent higher than in-vehicle time for air travel and 80 percent higher for rail and bus travel.

TEMS has found from previous studies that the physical act of transferring trains (or buses or planes) has a negative impact beyond the times involved. To account for this disutility, interchanges are penalized time equivalents. For both air and rail travel, each interchange for a trip results in 40 minutes being added to the business generalized cost and 30 minutes being added to the non-business generalized cost. For bus travel, the interchange penalties are 20 minutes and 15 minutes for business and non-business, respectively.

The third term in the generalized cost function converts the frequency attribute into time units. Operating hours divided by frequency is a measure of the headway or time between departures. It is this measure on which tradeoffs are made in the stated-preference surveys resulting in the value of frequencies. Although there may appear to be some double-counting (because the station wait time in the first term of the generalized cost function is included in this headway measure), it is not the headway time itself that is being added to the generalized cost. The third term represents the impact of perceived frequency valuations on generalized cost. TEMS has found it very convenient to measure this impact as a function of the headway.

The fourth term of the generalized cost function is a measure of the value placed on reliability of the mode. Reliability statistics in the form of on-time performance (fraction of trips considered to be on time) were obtained for the rail and air modes only. The negative exponential form of the reliability term implies that improvements from low levels of reliability have slightly higher impacts than similar improvements from higher levels of reliability.

Calibration of the Total Demand Model

In order to calibrate the Total Demand Model, the coefficients are estimated using linear regression techniques. Equation 1, the equation for the Total Demand Model, is transformed by taking the natural logarithm of both sides, as shown in Equation 4:

Equation 4

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

This provides the linear specification of the model necessary for regression analysis.

The segmentation of the database by trip purpose and trip length resulted in four sets of models. Trips that would cover more than 160 miles on the road are considered long trips. This cutoff was chosen because travel behavior switches significantly around this level with travelers considering faster modes such as air and high-speed rail over the automobile. In the base data, the average trip length for the short-distance model is approximately 80 miles, while the average trip length for the long-distance model is about 310 miles. The results of the calibration for the Total Demand Models are given in Exhibit A1.

In evaluating the validity of a statistical calibration, there are two key statistical measures: *t*-statistics and R^2. The *t*-statistics are a measure of the significance of the model's coefficients; values of 1.95 and above are considered “good” and imply that the variable has significant explanatory power in estimating the level of trips. The R^2 is a statistical measure of the “goodness of fit” of the model to the data; any data point that deviates from the model will reduce this measure. It has a range from 0 to a perfect 1, with 0.4 and above considered “good” for large data sets.

Based on these two measures, the total demand calibrations are excellent. The *t*-statistics are very high, aided by the large size of the Midwest data set. There are about five times as many long-distance observations as short-distance observations, resulting in higher *t*-statistics for the long- distance models. The R^2 values imply very good fits of the equations to the data.

As shown in Exhibit A1, the socioeconomic elasticity values for the Total Demand Model are close to 0.7, meaning that each one percent of growth in the socioeconomic term generates approximately a 0.7 percent growth in trips. Since each component of the socioeconomic term will have this elasticity, a one-percent increase in population (or employment) of every zone combined with a one-percent increase in income will result in a 2.1-percent growth in trips.

The coefficient on the utility term is not exactly elasticity, but it can be used as an approximation. Thus, the transportation system or network utility elasticity is higher for short distance-trips than long-distance trips, with each 1 percent improvement in network utility or quality as measured by generalized cost (*i.e.*, travel times or costs) generating approximately a 0.7 percent increase for long trips and 1.1 percent increase for short trips. The higher elasticity on short trips is partly a result of the scale of the generalized costs. For short trips, a 30-minute improvement would be more meaningful than the same time improvement on long trips, reflecting in the higher elasticity on the short-distance model.

Exhibit A1: Total Demand Model Coefficients(1)

Long-Distance Trips (*more than 160 miles driving distance*)

Business
$$\log(T_{ij}) = -13.4 + \underset{(146)}{0.710\ SE_{ij}} + \underset{(123)}{0.684\ U_{ij}} \qquad R^2=0.91$$

$$\text{where } U_{ij} = \log[\exp(-1.12 + 0.679\ U_{Pub}) + \exp(-0.00460\ GC_{Car})]$$

Non-Business
$$\log(T_{ij}) = -13.4 + \underset{(176)}{0.708\ SE_{ij}} + \underset{(172)}{0.744\ U_{ij}} \qquad R^2=0.92$$

$$\text{where } U_{ij} = \log[\exp(-2.77 + 0.685\ U_{Pub}) + \exp(-0.00557\ GC_{Car})]$$

Short-Distance Trips (*driving distance of 160 miles or less)*)

Business
$$\log(T_{ij}) = -11.4 + \underset{(15)}{0.759\ SE_{ij}} + \underset{(15)}{0.933\ U_{ij}} \qquad R^2=0.68$$

$$\text{where } U_{ij} = \log[\exp(-6.69 + 0.965\ U_{Pub}) + \exp(-0.0153\ GC_{Car})]$$

Non-Business
$$\log(T_{ij}) = -7.00 + \underset{(31)}{0.636\ SE_{ij}} + \underset{(31)}{1.231\ U_{ij}} \qquad R^2=0.63$$

$$\text{where } U_{ij} = \log[\exp(-7.73 + 0.658\ U_{Pub}) + \exp(-0.0155\ GC_{Car})]$$

---

(1) *t-statistics are given in parentheses.*

The utility functions are functions of the generalized costs of the modes of travel. In deriving the total utility term, a special "logsum" approach is used in which utilities are built up from individual modes in a recursive fashion. Further details are provided below. Thus, the total utility is derived from car generalized cost and the public mode utility which itself is derived from the generalized costs of its constituent modes (i.e., air, rail, bus). The exact form for the public mode utility function is determined from the calibration process for the modal split models to be described in the next section.

Incremental Form of The Total Demand Model

The calibrated Total Demand Models could be used to estimate the total travel market for any zone pair using the population, employment, income, and the total utility of all the modes. However, there would be significant differences between estimated and observed levels of trip-making for many zone pairs despite the good fit of the models to the data. To preserve the unique travel patterns contained in the base data, the incremental approach or "pivot point" method is used for forecasting. In the incremental approach, the base travel data assembled in the database are used as "pivot" points and forecasts are made by applying trends to the base data. The total demand equation as described in Equation 1 can be rewritten into the following incremental form which can be used for forecasting:

Equation 5

$$\frac{T_{ijp}^{\ f}}{T_{ijp}^{\ b}} = \left(\frac{SE_{ijp}^{\ f}}{SE_{ijp}^{\ b}}\right)^{\beta_{1p}} \exp(\beta_{2p}\ (U_{ijp}^{\ f} - U_{ijp}^{\ b}))$$

where

T^f_{ijp} = Number of trips between zones i and j for trip purpose p in forecast year

Se^f_{ijp} = Socioeconomic variables for zones i and j for trip purpose p in forecast year

U^f_{ijp} = Total utility of the transportation system for zones i to j for trip purpose p in forecast year

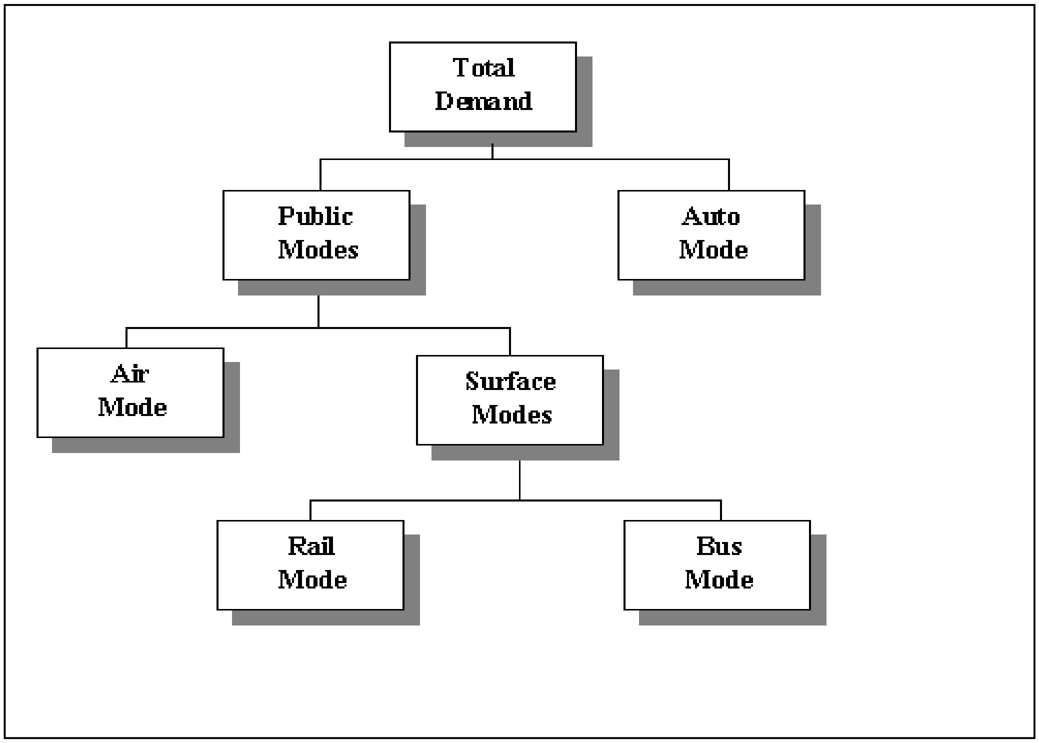
Note: Variables with superscript b refer to base year values.

In the incremental form, the constant term disappears, and only the elasticities are important.

Modal Split Model

The role of the Modal Split Model is to estimate relative modal shares, given the Total Demand Model estimate of the total market. The relative modal shares are derived by comparing the relative levels of service offered by each of the travel modes. The TEMS *COMPASS*© Modal Split Model uses a nested logit structure, which has been adapted to model the intercity modal choices available in the study area. As shown in ExhibitA2, three levels of binary choice were calibrated.

Exhibit A2: Hierarchical Structure of the Modal Split Model



The main feature of the Hierarchical Modal Split Model structure is the increasing commonality of travel characteristics as the structure is descended. The first level of the hierarchy separates private auto travel—with its spontaneous frequency, low access/egress times, low costs, and highly personalized characteristics—from the public modes. The second level of the structure separates air— the fastest, most expensive, and perhaps most frequent and comfortable public mode—from the rail and bus surface modes. The lowest level of the hierarchy separates rail—a potentially faster, more reliable, and more comfortable mode— from the bus mode.

Form of the Modal Split Model

To assess modal split behavior, the logsum utility function, which is derived from travel utility theory, has been adopted. As the Modal Split Hierarchy is ascended, the logsum utility values are derived by combining the generalized costs of travel. Advantages of the logsum utility approach are: (1) the introduction of a new mode will increase the overall utility of travel and; (2) a new mode can readily be incorporated into the Modal Split Model, even if it was not included in the base-year calibration.

As only two choices exist at each level of the modal split hierarchical structure, a Binary Logit Model is used, as shown in Equation 6:

Equation 6

$$P_{ijmp} = \frac{\exp(U_{ijmp}/\rho)}{\exp(U_{ijmp}/\rho) + \exp(U_{ijnp}/\rho)}$$

where

P_{ijmp} = Percentage of trips between zones i and j by mode m for trip purpose p

U_{ijmp}, U_{ijnp} = Utility functions of modes m and n between zones i and j for trip purpose p

ρ is called the nesting coefficient

In Equation 6, the utility of travel between zones i and j by mode m for trip purpose p is a function of the generalized cost of travel. Where mode m is a composite mode (*e.g.*, the surface modes in the third level of the Modal Split Model hierarchy, which consist of the rail and bus modes), the utility of travel, as described below, is derived from the utility of the two or more modes it represents.

Utility of Composite Modes

Where modes are combined, as in the upper levels of the modal split hierarchy, it is essential to be able to measure the "inclusive value" of the composite mode, *e.g.*, how the combined utility for bus and rail compares with the utility for bus or rail alone. The combined utility is more than the utility of either of the modes alone, but it is not simply equal to the sum of the utilities of the two modes. A realistic approach to solving this problem, which is consistent with utility theory and the logit model, is to use the logsum function. As the name logsum suggests, the utility of a composite mode is defined as the natural logarithm of the sum of the utilities of the component modes. In combining the utility of separate modes, the logsum function provides a reasonable proportional increase in utility that is less than the combined utilities of the two modes but reflects the value of having two or more modes available to the traveler. For example:

Suppose
Utility of Rail or $U_{rail} = + \beta GC_{rail}$
Utility of Bus or $U_{bus} = \beta GC_{bus}$
Then
Inclusive Utility of Surface Modes, or $U_{surface} = \log(e^{Urail} + e^{Ubus})$

It should be noted that improvements in either rail or bus will result in improvements to the inclusive utility of the surface modes.

In a nested binary logit model, the calibrated coefficients associated with the inclusive values of composite modes are called the nesting coefficients and take on special meaning. If one of these coefficients is equal to 1, then that level of the hierarchical model collapses and two levels of the hierarchy essentially become one. At this point, the Modal Split Model is a multinomial logit model that is analyzing three or more modes, *i.e.*, all the modes comprising the composite mode as well as the other modes in that level of the hierarchy. If one of the coefficients is greater than 1, then the hierarchy has been incorrectly specified and counterintuitive forecasts will result. Because of the assumptions behind the Modal Split Model, the coefficients must decrease as the modal split hierarchy is ascended or counterintuitive results will occur. Thus, the coefficients provide a check on whether the Modal Split Model hierarchy has been specified correctly.

Calibration of the Modal Split Model

Working from the bottom of the hierarchy up to the top, the first analysis is that of the rail mode versus the bus mode. As shown in Exhibit A3, the model was effectively calibrated for the two trip purposes and the two trip lengths, with reasonable parameters and R^2 and t values. All the coefficients have the correct signs such that demand increases or decreases in the correct direction as travel times or costs are increased or decreased, and all the coefficients appear to be reasonable in terms of the size of their impact. Rail travelers are more sensitive than bus travelers to time and cost. This is as expected, given the general attitude that travelers, and in particular business travelers, have toward the bus mode. The higher coefficients on the short-distance models are partly due to the scale effect where the same time or cost improvements would be more meaningful on shorter trips.

Exhibit A3: Rail versus Bus Modal Split Model Coefficients(1)

Long-Distance Trips (*more than 160 miles driving distance*)

Business $\log(P_{Rail}/P_{Bus}) = 3.76 - 0.00446\ GC_{Rail} + 0.00413\ GC_{Bus}$
$R^2=0.62$
(5.7) (7.7) (4.4)

Non-Business $\log(P_{Rail}/P_{Bus}) = 2.36 - 0.00297\ GC_{Rail} + 0.00196\ GC_{Bus}$
$R^2=0.40$
(11) (16) (9.5)

Short-Distance Trips (*driving distance of 160 miles or less)*)

Business $\log(P_{Rail}/P_{Bus}) = 3.12 - 0.00640\ GC_{Rail} + 0.00499\ GC_{Bus}$
$R^2=0.46$
(3.4) (5.2) (2.2)

Non-Business $\log(P_{Rail}/P_{Bus}) = 0.82 - 0.00445\ GC_{Rail} + 0.00352\ GC_{Bus}$
$R^2=0.42$
(2.2) (10) (9.4)

---

(1) t-statistics are given in parentheses.

The constant term in each equation indicates the degree of bias towards one mode or the other. Since the terms are positive in all the market segments, there is a bias towards rail travel that is not explained by the variables (times, costs, frequencies, reliability) used to model the modes. As expected, this bias is larger for business travelers who tend to have very negative perceptions of intercity bus.

For the second level of the hierarchy, the analysis is of the surface modes (rail and bus) versus air. Accordingly, the utility of the surface modes is obtained by deriving the logsum of the utilities of rail and bus. As shown in Exhibit A4, the model calibrations for both trip purposes are all statistically significant, with good R^2 and *t* values and reasonable parameters. As indicated by the air coefficients, short-distance travelers are less sensitive to changes in the air costs than long-distance travelers. One explanation is that some short-distance air trips are special trips responding to personal or business emergencies and are thus, cost insensitive. As indicated by the constant terms, there is a large bias towards air travel for long-distance trips. However, for short trips, there is only a small bias towards air for business travelers. For non-business travel, the bias—which is large—is actually towards the surface modes.

Exhibit A4: Surface versus Air Modal Split Model Coefficients(1)

Long-Distance Trips (*more than 160 miles driving distance*)

Business $\log(P_{Surf}/P_{Air}) = \underset{(13)}{-5.91} + \underset{(19)}{1.258}\, U_{Surf} + \underset{(12)}{0.00880}\, GC_{Air}$ $R^2=0.77$

where $U_{Surf} = \log[\exp(3.76 - 0.00446\, GC_{Rail}) + \exp(-0.00413\, GC_{Bus})]$

Non-Business $\log(P_{Surf}/P_{Air}) = \underset{(22)}{-3.22} + \underset{(29)}{1.051}\, U_{Surf} + \underset{(27)}{0.00536}\, GC_{Air}$ $R^2=0.48$

where $U_{Surf} = \log[\exp(2.36 - 0.00297\, GC_{Rail}) + \exp(-0.00196\, GC_{Bus})]$

Short-Distance Trips (driving distance of 160 miles or less)

Business $\log(P_{Surf}/P_{Air}) = \underset{(2.3)}{-1.10} + \underset{(7.3)}{1.078}\, U_{Surf} + \underset{(5.0)}{0.00380}\, GC_{Air}$ $R^2=0.53$

where $U_{Surf} = \log[\exp(3.11 - 0.00640\, GC_{Rail}) + \exp(-0.00499\, GC_{Bus})]$

Non-Business $\log(P_{Surf}/P_{Air}) = \underset{(8.5)}{3.01} + \underset{(14)}{1.387}\, U_{Surf} + \underset{(4.1)}{0.00155}\, GC_{Air}$ $R^2=0.55$

where $U_{Surf} = \log[\exp(0.82 - 0.00445\, GC_{Rail}) + \exp(-0.00352\, GC_{Bus})]$

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(1) t-statistics are given in parentheses.

The analysis for the top level of the hierarchy is of auto versus the public modes. The public modes are comprised of air and the surface modes (rail and bus). The utility of the public modes is obtained by deriving the logsum of the utilities of the air, rail, and bus modes.

As shown in Exhibit A5, the model calibrations for both trip purposes are all statistically significant, with good R^2 and *t* values and reasonable parameters in most cases. The R^2 value for the non-business, short-distance model is a bit low and marginally acceptable. Part of the reason for the poor fit is that local transit trips are not included in the public trip database causing some of the observations to deviate significantly from the model equation. The constant terms show that there is a bias towards the auto mode with the bias increasing with shorter trip length.

Exhibit A5: Public versus Auto Modal Split Model Coefficients(1)

Long-Distance Trips (*more than 160 miles driving distance*)

$$\begin{array}{llllllll} \text{Business} & \log(P_{Pub}/P_{Auto}) = & -1.12 & + & 0.679\ U_{Pub} & + & 0.00460\ GC_{Auto} & R^2=0.62 \\ & & (13) & & (46) & & (69) & \end{array}$$

where $U_{Pub} = \log[\exp(-5.91 + 1.258\ U_{Surf}) + \exp(-0.00880\ GC_{Air})]$

$$\begin{array}{llllllll} \text{Non-Business} & \log(P_{Pub}/P_{Auto}) = & -2.77 & + & 0.685\ U_{Pub} & + & 0.00557\ GC_{Auto} & R^2=0.66 \\ & & (55) & & (47) & & (96) & \end{array}$$

where $U_{Pub} = \log[\exp(-3.22 + 1.051\ U_{Surf}) + \exp(-0.00536\ GC_{Air})]$

Short-Distance Trips (*160 miles driving distance*)

$$\begin{array}{llllllll} \text{Business} & \log(P_{Pub}/P_{Auto}) = & -6.69 & + & 0.965\ U_{Pub} & + & 0.0153\ GC_{Auto} & R^2=0.51 \\ & & (24) & & (8.8) & & (15) & \end{array}$$

where $U_{Pub} = \log[\exp(-1.10 + 1.078\ U_{Surf}) + \exp(-0.00380\ GC_{Air})]$

$$\begin{array}{llllllll} \text{Non-Business} & \log(P_{Pub}/P_{Auto}) = & -7.73 & + & 0.658\ U_{Pub} & + & 0.0155\ GC_{Auto} & R^2=0.38 \\ & & (49) & & (12) & & (18) & \end{array}$$

where $U_{Pub} = \log[\exp(3.01 + 1.387\ U_{Surf}) + \exp(-0.00155\ GC_{Air})]$

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(1) *t-statistics are given in parentheses.*

Incremental Form of the Modal Split Model

Using the same reasoning as described above, the Modal Split Models are applied incrementally to the base data rather than imposing the model estimated modal shares. Different regions of the corridor may have certain biases toward one form of travel over another, and these differences cannot be captured with a single model for the entire Midwest Regional Rail System. Using the "pivot point" method, many of these differences can be retained. To apply the modal split models incrementally, the following reformulation of the modal split models is used:

Equation 7

$$\left(\frac{P^f{}_A}{P^f{}_B}\right) / \left(\frac{P^b{}_A}{P^b{}_B}\right) = e^{\beta(GC^f{}_A - GC^b{}_B) + \gamma(GC^f{}_B - GC^b{}_B)}$$

where

$P^f{}_A$ = Percentage of trips using mode A in the forecast year

$GC^f{}_A$ = Generalized cost for mode A in the forecast year

β,γ = Estimated coefficients

Note: Variables with superscript B refer to base year values

For Modal Split Models that involve composite utilities instead of generalized costs, the composite utilities would be used in the above formula in place of generalized costs. Once again, the constant term is not used and the drivers for modal shifts are changes in generalized cost from base conditions.

Another consequence of the "pivot point" method is that extreme changes from current trip-making levels and current modal shares are rare. Thus, since very few short-distance commuter trips are currently being made on Amtrak, the forecasted growth in these trips will be limited despite the huge auto market.

These calibrated models maximize the use of available local origin-destination data for the study area. The calibrated Total Demand and Modal Split Models appear very reasonable and compare well with models constructed for other transportation corridors. In general, the parameters were in good agreement with parameters from other models including:

- New York Corridor (Buffalo-Albany-New York City)
- North-South Station Rail Link Study (1997)
- Ontario-Quebec Corridor (Windsor-Toronto-Montreal-Quebec City)
- VIA Ridership Demand Forecasting Study (1994)
- Tri-State Corridor (Chicago-Milwaukee-Twin Cities)
- Tri-State High Speed Rail Study (1991)
- Illinois Corridor (Chicago-Springfield-St. Louis)
- Chicago-St. Louis Demand Forecast Study (1993)
- Virginia Corridor (Lynchburg-Richmond-Washington, D.C.), Virginia Passenger Rail Service Study (1995).