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FINAL REPORT

REROUTING AND SPEED REDUCTION OF HAZARDOUS MATERIAL TRAINS IN SELECTED CONRAIL CORRIDORS

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16. Abstract

Rerouting and speed reduction of trains carrying hazardous materials shipments are analyzed so as to determine effects on railroad operations and costs and population exposure. A case study format was utilized on two corridors within the Conrail system.

Segments of mainline which are in proximity to population concentrations were identified. On those segments, the analysis assumed that hazardous materials traffic would be either prohibited - thus causing rerouting or would be carried at reduced speed.

Implications of the two policies (prohibit and reduce speed) are discussed.

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PREFACE

The study herein reported was conducted for the National Transportation Research Division of the Transportation Systems Center under sponsorship by the Office of Safety of the Federal Railroad Administration. Ms. Donna Woodman and Dr. Theodore Glickman of TSC and Mr. William A. Black and Mr. Michael Child of FRA were the monitors of the study.

This study addresses the question of effectiveness and cost of rerouting and speed reduction of trains carrying hazardous materials when in proximity to population centers. It focuses on particular movements in two case study corridors within the Conrail system. It is a companion to a macro-level study of routing of hazardous materials trains, which was conducted by the same agencies.

The study would not have been possible without the provisions of data on train operations and traffic movements, and certain other information provided by Conrail. Mr. J.B. Stauffer, Director of Operations Technology and Mr. John Hitchcock of the Transportation Department, both of Conrail, were particularly helpful in providing key assistance on the study.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

1.0 INTRODUCTION

There has been considerable concern in recent years about the safety of transporting hazardous materials (HM by railroad due to several serious incidents in which injuries have occurred and communities have undergone the disruption of evacuation.* Incidents within the past two years have taken place at Mississauga (near Toronto), Ontario and Boston, Massachusetts, resulting in increased concern over the possibility of HM releases in heavily populated areas.

Within the Federal government, the responsibility for the regulation of HM rail transportation rests with the Federal Railroad Administration (FRA) within the Department of Transportation (DOT). Working with the Transportation Systems Center (TSC), the FRA has commissioned this research project to analyze the impacts of operating restrictions on HM railroad traffic normally routed through population centers. Since macro-level analysis using the national railroad network and the One-Percent (railroad) Waybill Sample cannot adequately describe railroad operations which affect railroad routing and population exposure, this research has focused on a detailed analysis of actual train movements in populated corridors through a case study approach.

Five primary objectives have influenced the direction of this analysis. They are the following:

1. Identify a limited number of readily implementable policies (i.e., prohibit, reduce speed ...) to improve the safety of HM transportation;

2. Outline possible operational responses to these policies by the affected carrier(s);

3. Estimate the effects of these operational changes on delay, car-hours, train-hours and other operating characteristics;

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*For the purposes of this report hazardous materials (HM) are those transported commodities covered by 49CFR172.101; this involves all "placarded" rail cars, including placarded empty tank cars as required by the regulations.

4. Measure the costs incurred by the affected carrier(s) due to implementation of the safety policies; and

5. Indicate the effects of policies on risk factors such as population exposure to HM.

With these objectives, CONSAD analyzed the impacts of safety policies on railroad operations for two case study sites. The results of this analysis are presented in this report.

Chapter 2 describes the range of options available to Federal rail safety officials which would work to affect the routing of HM traffic away from populated areas. The options analyzed in detail, prohibition and reduced speed, and the basis for their selection, are described.

The cases selected for detailed analysis are then described. In Chapter 3, the selection of the carrier of interest is treated, while the selection of the two specific cases analyzed is covered in Chapter 4.

The analysis of the first case study, Indianapolis - Columbus, is covered in Chapter 5. Both descriptions of the methods employed and the results of those methods on that case are given.

The analysis of the second case study, Pittsburgh-Harrisburg, is provided in Chapter 6.

Finally, comparisons of the two case studies and observations on the results of the study are covered in Chapter 7.

2.0 SELECTION OF REGULATORY OPTIONS FOR ANALYSIS

A necessary component of the study was to identify implementable regulatory options which would result in improved safety in the railroad transportation of hazardous materials. The study also identified the laws and regulations which provide the bases for these options. In light of both of these concerns, discussions were held with representatives of the:

- FRA Office of Chief Counsel;
- FRA Office of Standards and Procedures;
- AAR Safety and Special Services Division; and
- AAR Bureau of Explosives.

The comments received are presented below for each of the possible options. However, a number of general observations were also made.

In discussing regulatory options for enhanced safety, representatives indicated that specifying a "designated route" for the movement of HM is likely to be a sensitive political issue. It was felt that few, if any, individuals would readily accept the rerouting of HM trains through their community. They also indicated that policies should not be subject to broad interpretation by the railroads to avoid placing the FRA in an "adjudicatory position". Therefore, the purposes of the policy should be obvious and self-implementing allowing a railroad to readily determine how to comply with the intent of the law.

The following regulatory options were initially identified for further consideration:

- Prohibit;
- Reduce speed;
- Emergency response capability of railroad train crews and other personnel;
- Yard handling restrictions; and
- Enhanced compliance.

2.1 Prohibit

This policy specifies "highly populated" routes over which HM shipments would be excluded, except for on-route pick-ups and deliveries, considered non-prohibitable since shippers and receivers located on these routes cannot be denied rail transport. Where possible alternative routes do exist for on-line shipments, they would be utilized.

Based upon the interviews, a prohibit option is legal and implementable; threshold levels defining "highly populated" rail lines must be established.

2.2 Reduce Speed

This policy requires that trains carrying HM on designated "high population" routes travel at speeds not to exceed the FRA posted speed limit of the next lower track class. The reduced speed should further decrease the possibility of an accident as well as decrease the possibility of a HM release in the event of an accident.

One concern with this policy was its effect on total throughput of the railroad system. The slower speeds of trains carrying HM is likely to significantly affect other trains in the corridor, although the degree of this influence depends upon various operational and physical factors, such as number of trains, percent carrying HM, and frequency and length of passing sidings on particular corridors. However, most of the transit time for railroad traffic occurs in yards and terminals, on which a reduction in line-haul speed would liekly have no effect.

Reducing speed within certain defined limits is not a policy subject to broad interpretation. In addition, it provides the benefit of providing the railroads a choice of routes (either the present route at a lower speed or a rerouting away from population).

2.3 Other Policy Options

A third option was that of "Emergency Response Capability of Railroad Personnel". Trains carrying hazardous materials would be required to be equipped with reliable communications devices for both train-to-train and train-to-dispatcher communications. This option might go so far as to have a crew member on-board who is familiar with the handling of HM spills.

Two general comments were offered in response to this policy. First, interviewees felt that the principal responsibility of the crew should be restricted to notifying the appropriate authorities in the event of a derailment. Second, there was general uncertainty as to the degree to which emergency response capabilities improve safety.

Another policy placed restrictions on the number of yard handlings for HM cars. Several points were made in response to this policy. It was recognized that the policy might not be implementable due to the need to switch cars into outbound and out of inbound trains. Also identified was the necessity of interchanging cars between railroads. The conclusion was made that only under a very special case, where large numbers of cars would be moved directly from shipper's siding to receiver's siding, would this policy be feasible.

The last policy considered was "Enhanced Compliance" requiring that all railroads carrying HM over the specified route be subject to increased and more stringent inspection. The point was made that this policy should attempt to achieve compliance with general safety regulations. The degree to which a higher level of inspection would affect the rate of HM spills would be very difficult to derive. Furthermore, compliance has been and will continue to be a major on-going effort for the FRA and the railroad industry.

2.4 Summary

Of the five possible regulatory options mentioned, only two, Prohibit and Reduce Speed were felt to be readily implementable and therefore of primary interest in this study. In addition, both options can have a positive impact on safety: the Prohibit policy through the requirement that railroads reroute trains away from heavily populated areas thereby reducing the number of individuals exposed to HM; Reduce Speed by the improvement of safety through reducing the severity of accidents. The other three options were eliminated from further analysis.

3.0 SELECTION OF CARRIER FOR STUDY

The procedure for the selection of the case study sites involved two phases of analysis. The first was the identification of an appropriate railroad on which the case study would be conducted. The second involved the specification of case study sites.

The selection of a carrier focused on four measures:

- Car-miles of HM;
- Population exposure to HM;
- Accident rates; and
- Feasibility of alternative routings.

3.1 Car-Miles

A recent study by Hornung and Kornhauser* focused upon 41 railroads carrying HM in 1977. Those 41 railroads accounted for almost 4.8 million car-miles of HM shipments; 11 were responsible for almost 90% of the 1977 total. Statistics for these 11 railroads are shown in Table 1.

3.2 Exposure

Hornung and Kornhauser also analyzed population exposure to HM for each railroad. Annual exposure was defined as the number of persons residing within a quarter mile band along each section of track, times the number of HM cars moving along the track. The levels of exposure that the authors found are shown in Table 2. As in the case of HM car-miles, the same 11 railroads accounted for almost 90 percent of total exposure. It was also noted that Conrail had high levels of both HM car-miles and exposure.

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*Hornung, M.A. and Kornhauser, A.L. "Population Avoidance Routing of Hazardous Materials Traffic on the U.S. Railroad System", A.L. Kornhauser & Associates, Princeton, N.J. October 30, 1979.

Table 1: Hazardous Material Car-Miles for the Eleven Major Carriers

Railroad	1977 Car-Miles (103)	Percent of Total
ATSF	683.5	14.1
BN	246.1	5.1
CO	242.8	5.0
CR	510.0	10.6
ICG	306.1	6.3
MP	574.9	11.9
NW	115.5	2.4
SCL	583.4	12.1
SP	523.8	10.8
SOU	319.0	6.6
UP	230.6	4.8
Sub-total	4,335.7	89.7
Other	496.0	10.3
Total	4,831.7	100.0

SOURCE: Hornung, M.A. and Kornhauser, A.L. "Population Avoidance Routing of Hazardous Materials Traffic on the U.S. Railroad System," A.L. Kornhauser and Associates, Princeton, NJ, October 30, 1979.

Table 2: Hazardous Material Exposure for the Eleven Major Carriers, 1977

RR	Exposure* (x 10^6)	Percent of Total
ATSF	28.8	8.2
BN	11.0	3.1
CO	29.0	8.3
CR	101.1	28.8
ICG	18.3	5.2
MP	32.7	9.3
NW	11.3	3.2
SCL	21.1	6.0
SP	31.7	9.0
SOU	22.1	6.3
UP	7.5	2.1
Sub-total	314.6	89.6
Other	36.7	10.4
Total	351.3	100.0

*Exposure = Residential population living within ¼ mile of rail line times annual number of HM cars passing over the line.

Source: Hornung, M.A. and Kornhauser, A.L. "Population Avoidance Routing of Hazardous Materials Traffic on the U.S. Railroad System" A.L. Kornhauser and Associates, Princeton, NJ, October 30, 1979.

3.3 Accidents

CONSAD Research Corporation assembled data on accident rates through the use of the Federal Railroad Administration's "Railroad Safety Statistical Report".* The accident rates in terms of accidents per million car-miles for the 11 railroads are shown in Table 3. While the railroads tend to cluster, the ICG, SCL, and Conrail are shown as having relatively high accident rates.

3.4 Feasibility of Alternative Routes

The availability of alternative routes within the system of a given carrier was evaluated in several ways. The first approach involved an examination of certain results reported by Hornung and Kornhauser. After assigning traffic to estimate historical flows, the authors conducted an experiment in which HM traffic was assigned to the railroad network so that total population exposure was minimized. The resulting changes in car-miles and exposure relative to historically observed values are shown in Tables 4 and 5.

Of the 11 railroads considered, Conrail exhibited the largest absolute increase in HM car-miles as well as the largest absolute decrease in exposure. This analysis suggested that Conrail would be a most interesting road for the case study.

The second approach to case study selection utilized graphic representations of Hazmat flows for each of the 11 railroads. Through the visual inspection of data from the "Railroad Safety Statistical Report", in the form of graphic displays of HM flows, it was found that Conrail moves large volumes of HM traffic on various routes. The data also showed that Conrail

*"Railroad Safety Statistical Report", FRA, Office of Safety, Washington, D.C., March 1979.

Table 3: Accident Rates for Eleven Major Carriers, 1977

Railroad	Accident per Million Car-Miles
ATSF	.136
BN	.240
CO	.372
CR	.392
ICG	.499
MP	.162
NW	.142
SCL	.482
SP	.184
SOU	.233
UP	.128

Source: "Railroad Safety Statistical Report", Federal Railroad Administration, Office of Safety, Washington, DC, March 1979, p.72.

Table 4: Hazardous Material Car-Miles for Eleven Major Carriers for a Minimum Population Exposure Route Assignment (Historical Junctions Preserved)

Railroad	Historically Observed Hazmat Car-Miles (10^3)	Reassignment Hazmat Car-Miles (10^3)	Absolute Change in Hazmat Car-Miles (10^3)	Percent Change in Car-Miles
ATSF	683	766	83	+ 12
BN	246	331	85	+ 35
CO	243	274	31	+ 13
CR	510	663	153	+ 30
ICG	306	354	48	+ 16
MP	575	657	82	+ 14
NW	116	122	6	+ 5
SCL	583	720	137	+ 23
SP	524	594	70	+ 13
SOU	319	378	59	+ 18
UP	231	241	10	+ 4
Subtotal	4,446	5,100	764	+ 18
Other	496	569	73	+ 15
Total	4,832	5,669	837	+ 17

Source: Hornung, M.A. and Kornhauser, A.L. "Population Avoidance Routing of Hazardous Materials Traffic on the U.S. Railroad System", A.L. Kornhauser and Associates, Princeton, NJ, October 30, 1979.

Table 5: Exposure for Eleven Major Carriers for a Minimum Population Exposure Assignment (Historical Junction Preserved)

Railroad	Historically Observed Exposure 10^6	Reassignment Exposure (10^6)	Absolute Change in Exposure (10^6)	Percent Change in Exposure
ATSF	29	27	- 2	- 7
BN	11	7	- 4	- 36
CO	29	23	- 6	- 21
CR	101	61	- 40	- 40
ICG	16	14	- 2	- 13
MP	33	30	- 3	- 9
NW	11	10	- 1	- 9
SCL	21	16	- 5	- 24
SP	32	27	- 5	- 16
SOU	22	13	- 9	- 41
UP	8	7	- 1	- 13
Subtotal	313	235	- 78	- 25
Other	38	30	- 8	- 21
Total	351	265	- 86	- 25

Source: Hornung, M.A. and Kornhauser, A.L. "Population Avoidance Routing of Hazardous Materials Traffic on the U.S. Railroad System", A.L. Kornhauser and Associates, Princeton, NJ. October 30, 1979.

carried significant HM flows in the most highly populated region of the United States. Further, inspection of Conrail's system map revealed that many alternative routings exist for the rerouting of traffic on HM within the Conrail system.

3.5 Summary

CONSAD's analysis showed that Conrail met the requirements for the case study with high levels of HM car-miles, population exposure, and a high accident rate relative to the other carriers. In addition, Conrail possessed a variety of alternative routes for the movement of HM traffic. Therefore, the carrier was chosen for study and steps were taken to identify candidate case study sites. Conrail was contacted directly and approval was given to study certain Conrail corridors in-depth. In addition, Conrail agreed to provide CONSAD with necessary data on train operations, HM flows and physical characteristics of trackage.

4.0 SELECTION OF CASE STUDY SITES

Selection of the case study sites proceeded by first identifying major flows of hazardous materials on the Conrail system. In order to identify these flows, Conrail provided CONSAD with the results of a computer simulation providing an approximation of Conrail train and tonnage movements (for both HM and non-HM traffic) on a representative day. A description of the simulation model is supplied in Section 5.2.3. Major railroad yards through which heavy HM flows travelled were noted.

Approximately ten possible railroad yard pairs (two yards connected by a Conrail mainline) were initially identified through the use of the Conrail simulation model (for HM flows), the Conrail System Map (for identification of mainlines) and Conrail's Manifest Train Schedule (for identification of yards and trains operating between yards). Of these, however, only four pairs appeared to have both heavy HM flows and feasible rerouting options. The four yard pairs considered were:

- Avon Yard (Indianapolis, IN) to Buckeye Yard (Columbus, OH);
- Buckeye Yard (Colubus, OH) to Conway Yard (Pittsburgh, PA);
- Collinwood Yard (Cleveland OH) to Bison Yard Buffalo, NY); and
- Conway Yard (Pittsburgh, PA) to Enola Yard (Harrisburg, PA).

Upon review of data from the Conrail simulation model, it was discovered that the mainline from Conway Yard to Enola Yard carried the largest volume of HM traffic (in tonnage). Table 6 shows that approximately 17,000 gross tons of hazardous materials moved daily between these two yards. Similarly, of the four yard pairs, the mainline from Conway to Enola carried the largest number of trains with HM. The second largest values were for the mainline from Avon to Buckeye Yard.

Based on discussions with representatives of Conrail and review of the Conrail System Map, it was found that alternative routings exist for traffic

Table 6: Hazmat Flows, 1979

Yard Pairs	Approximate Hazmat Tonnage Carried on Main Line (gross tons per day)	Approximate Average Number of Trains Carrying Hazmat on Main Line (trains/day)
Avon Yard (Indianapolis) to Buckeye Yard (Columbus)	10,000	12
Buckeye Yard (Columbus) to Conway Yard (Pittsburgh)	9,000	10
Collinwood Yard (Cleveland) to Bison Yard (Buffalo)	9,000	11
Conway Yard (Pittsburgh) to Enola Yard (Harrisburg)	17,000	18

Source: Information presented in this table was compiled by CONSAD Research Corporation from simulation model results supplied by Conrail.

moving between all four yards. Each alternative route: had lower population densities than the main route; currently handled trains which could accommodate rerouted HM cars; and, would enable any rerouted train or car to arrive at its destination as directly as possible. At least three such rerouting options were identified between Avon and Buckeye Yards. No more than two were available for the three remaining yard pairs.

Review of the information on hazardous material flows, population densities and reroute options showed that the Conway to Enola Yard pair provided an opportunity to dramatically reduce population exposure with an uncomplicated rerouting scheme. The Avon to Buckeye Yard pair allowed analysis of a much more complicated, hence a more realistic situation which could be faced by the railroads. For these reasons the Conway to Enola and Avon to Buckeye Yard pairs were chosen as the most appropriate for further analysis given the objectives and constraints of the study.

Table 7: Population Densities, 1979

Railroad Yard Pairs	Population Density (Persons per Mile of Track)		
	Current Main Line	Obvious Reroute	Percent Change
Avon Yard (Indianapolis) to Buckeye Yard (Columbus)	622	465	- 25
Buckeye Yard (Columbus) to Conway Yard (Pittsburgh)	641	822	+ 28
Collinwood Yard (Cleveland) to Bison Yard (Buffalo)	1,036	618	- 40
Conway Yard (Pittsburgh) to Enola Yard (Harrisburg)	683	254	- 60

Source: Information presented in this table was compiled by CONSAD Research Corporation from the computer tape of "U.S. Rail Link Population Densities", November 1979, supplied by TSC.

5.0 INDIANAPOLIS-COLUMBUS CASE STUDY

5.1 Description

Conrail's mainline from Avon to Buckeye Yard connects two large urban areas which act as major hubs on the Conrail network. The railroad distance between the yards is approximately 194 miles. The mainline extends easterly from Avon Yard through the City of Indianapolis, then in a northeasterly direction through several small cities and the larger cities of Anderson and Muncie, Indiana. The line continues easterly through Union City (at the Indiana-Ohio line) and Urbana, Ohio to Buckeye Yard located west of Columbus, OH. Figure 1 is a schematic representation of Conrail showing the corridor.

5.1.1 Trackage and Train Operations

Data has been collected on physical characteristics of the main and alternative line. Table 8 contains information on link length, number of tracks, track class, and major yards on the mainline. This particular line is a high density double track mainline.

Utilizing the information provided by Conrail, CONSAD identified all HM and non-HM trains on the mainline. Figure 2 is a schematic representation of this information. This traffic was then rerouted on a number of available alternative routes.

5.1.2 Population Methodology

Estimates of the population residing along the mainlines and secondary lines were obtained from two sources: (1) The City County Data Book;* and (2) United States Geological Survey (U.S.G.S.) quadrangle maps (available from the United States Geological Survey, Reston, Virginia).

The following methodology was used to estimate the resident population directly at risk from accidents involving trains carrying Hazmat on the mainline.

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*1977 County and City Data Book, U.S. Department of Commerce, Bureau of Census, Washington, D.C.

Figure 1: Schematic of Case Study Corridor From Indianapolis to Columbus Showing Alternate Rates

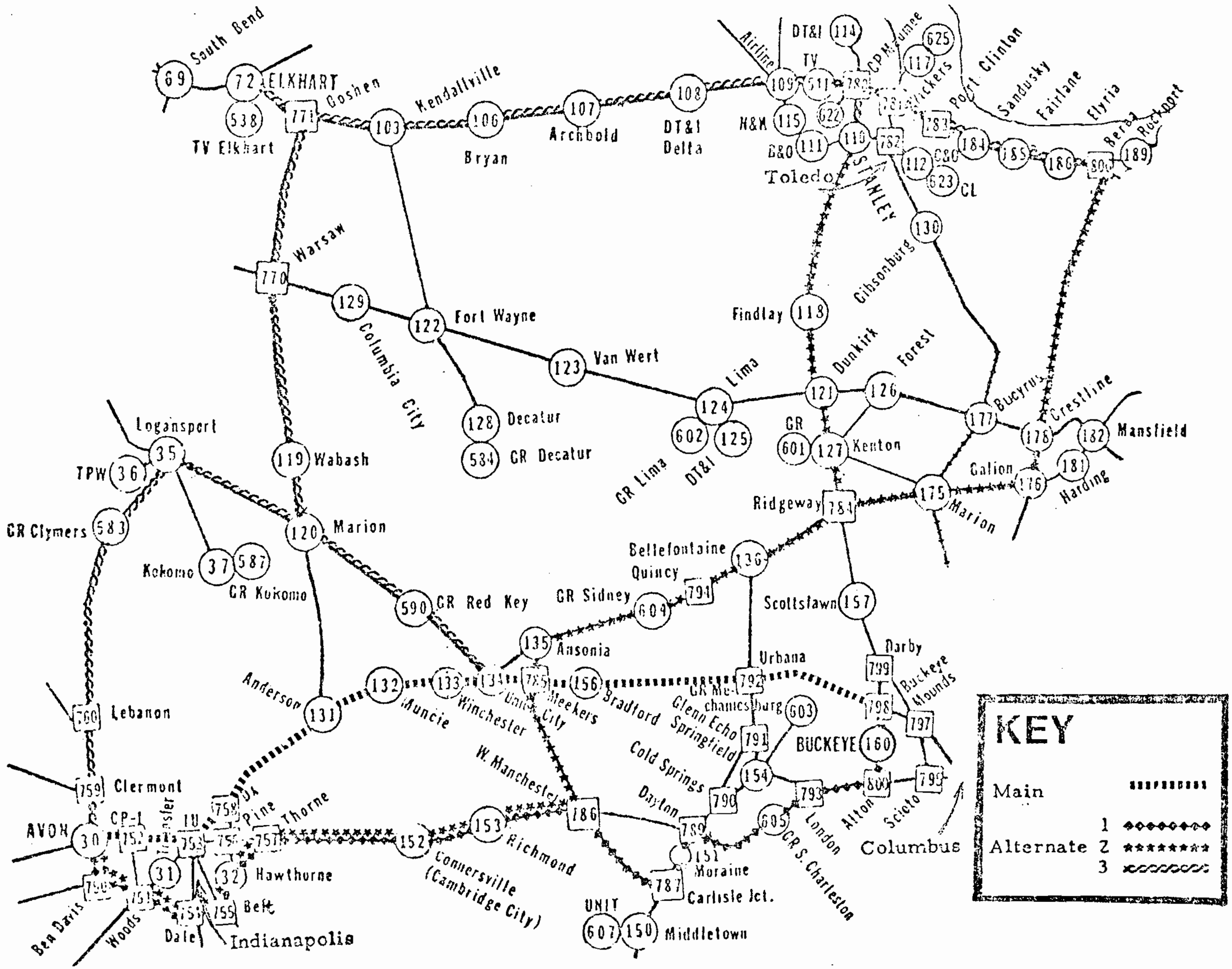


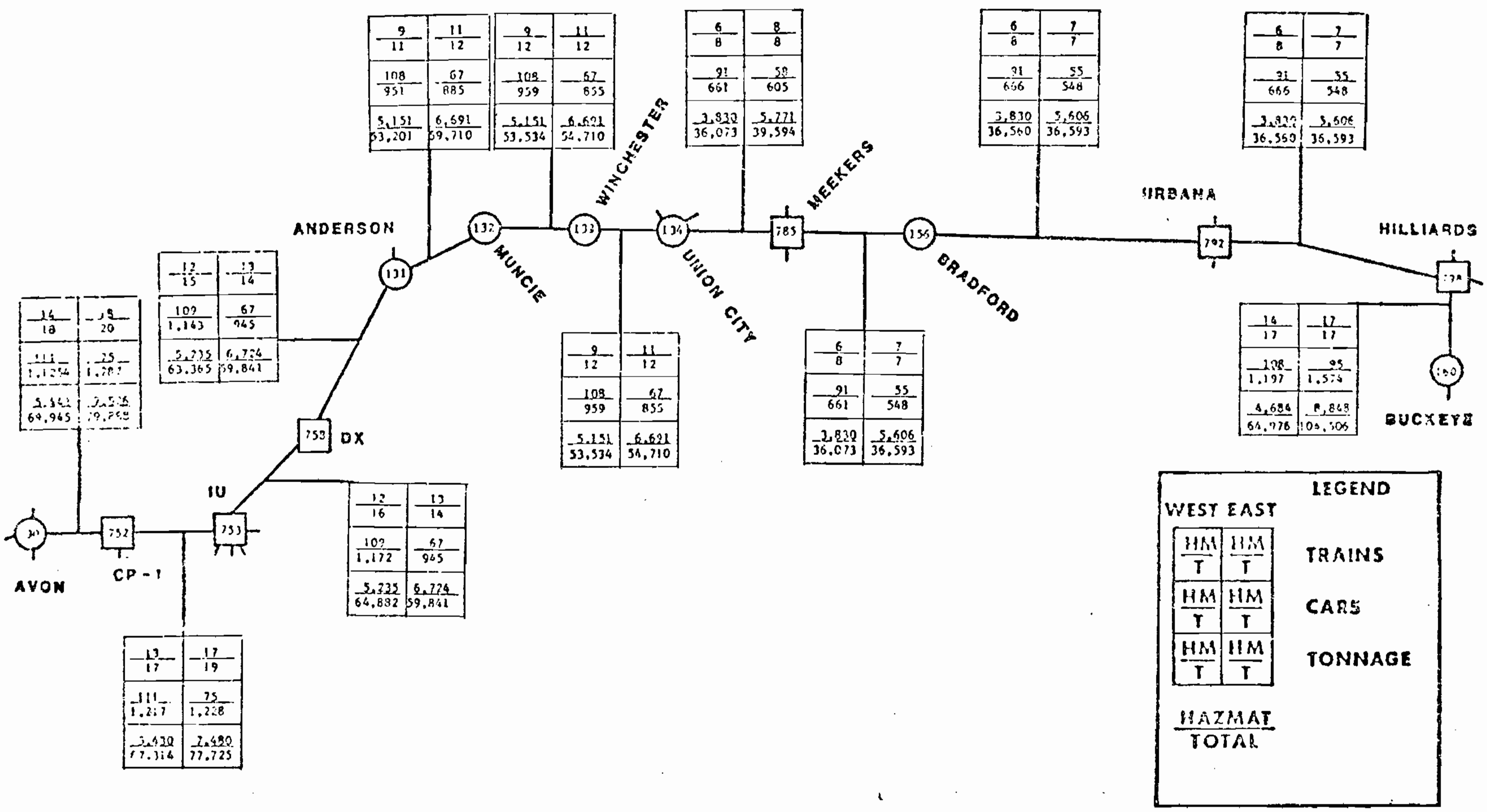
Table 8: Physical Characteristics of Main Line: From Indianapolis To Columbus

Link No.	Length (Miles)	No. of Tracks	Speed Limit Max.	Speed Limit Min.	Track Class	Major Yards
						Avon
30-752	10.9	1,2	50	40/30*	IV/III	
752-753	1.6	2	40	15	III/II	
753-758	3.2	2	50	15	IV/II	
758-131	32.9	2	50	20	IV/II	
						Anderson
131-132	17.7	2	50	20	IV/II	
						Muncie
132-133	21.6	2	50	50	IV	
						Winchester
133-134	10.2	2	50	50	IV	
						Union City
134-785	8.9	1	50	50	IV	
785-156	11.9	2	50	30*	IV/II	
						Bradford
156-792	36.2	2	50	25*	IV/II	
792-798	36.7	2	50	35*	IV/III	
789-160	2.3	2	50	45*	IV	
						Buckeye

Source: CONSAD Research Corporation

*Point speed restrictions.

Figure 2: Trains and Traffic Operating Over the Indianapolis to Columnus Case Study Corridor



For rural areas, a one-half mile wide band (one-quarter mile on each side of the track) was constructed on a set of contiguous U.S.G.S. quadrangle maps (7½ minute series). The number of dwellings (which are shown on the maps as darkened squares) within the band were counted for each county. A county-specific estimate of persons per dwelling unit* was multiplied by the number of dwelling units (recorded from the maps) for the county, to obtain a population estimate within the one-half mile wide band.

For urbanized areas, U.S.G.S. maps generally do not identify dwelling units; rather the area is shown shaded (usually pink). In the shaded areas a one-half mile band was constructed along the rail line. Using data from the 1977 County and City Data Book, average population density values for individual political jurisdictions were estimated.** These jurisdiction-specific population densities were then multiplied by the shaded area (square miles) within the one-half mile band, with the resulting value being total population for the area of interest.

Population estimates for both rural and urban areas were summed to obtain total population within a one-half mile band width along the mainline from Avon to Buckeye Yard. Similar estimates were made for other lines over which traffic was rerouted.

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*Using the 1977 County and City Data Book, 1980 estimates (by county) of population and dwelling units were made by extrapolating 1975 values provided in that report. The 1975 value for population was extrapolated to 1980 by applying the reported percentage change from 1970 to 1975. For dwelling units, reported 1975 and 1976 two-year new housing starts were multiplied by five to arrive at the approximate number of housing strats from 1970 to 1980. This value was added to the total number of dwelling units reported for 1970. The calculated 1980 population estimate was divided by the calculated 1980 estimate of dwelling units to obtain a ratio of persons per dwelling unit by county.

**The population density value for jurisdictions without detailed coverage of dwelling units by the U.S.G.S. was calculated by dividing total estimated population by land area in square miles. Land area was obtained from the 1977 County and City Data Book; 1980 population was extrapolated by applying percentage change in population from 1970 to 1975 to jurisdiction specific 1975 recorded population. The 1980 estimate for population was divided by land area to obtain a population per square mile value.

Population estimates are shown in Table 9. Approximately 49,000 persons are estimated to reside within one-half mile of the mainline from Avon to Buckeye Yard. Of the 49,000, 30,000 persons (61% of the total population) live between Avon Yard and Union City. A population profile is presented in Figure 3 for both the main and alternate routes.

Union City is approximately 98 railroad miles (over 50 percent of the total 194 miles of the mainline) from Avon Yard. The mainline from Avon Yard to Union City passes through heavily populated areas of Indianapolis, Anderson, and Muncie. The remaining portion of the line from Union City to Buckeye passes through smaller communities and does not enter Columbus, OH (Buckeye Yard being west of Columbus). Because the majority of population is located between Avon and Union City, it was determined that all policies aimed at improving safety should apply to that portion of the mainline. Since Union City is a junction point for trains entering and leaving the mainline, it is a logical terminus point in terms of railroad operations. Thus, for purposes of the analysis of the Prohibit policy, all Hazmat traffic (other than on-line originating or terminating Hazmat traffic) will be prohibited from moving on the portion of the mainline from Avon to Union City (Conrail links 30-752-753-758-131-132-133-134). The Avon to Union City segment is also the portion of the mainline to which the Reduce Speed option will be applied.

5.2 Prohibit Hazmat Traffic

After review of the specific train and traffic movements over the prohibit segment of the mainline, it became evident that there are several possible rerouting alternatives available including:

1. From Avon: south of Indianapolis to Thorne, IN: thence easterly through Richmond, IN. to West Manchester OH; at West Manchester traffic could move either north to Meekers City and east on the Avon to Buckeye Yard mainline, by-passing Dayton, OH, toward Buckeye Yard (and the reverse for westerly traffic from Buckeye Yard) or south to Carlisle Junction through London to Buckeye.

Table 9: Population Along Main Line from Avon to Buckeye Yard

Conrail Segment	Community	Population (within ½ mile band of track)	Percent of Total
30-752	Avon Yard to West Indianapolis	3,429	7
752-753*	West Indianapolis to Indianapolis	521	1
753-758*	Indianapolis to East Indianapolis	3,522	7
758-131	East Indianapolis to Anderson, IN	8,907	18
131-132	Anderson to Muncie, IN	5,510	11
132-133	Muncie to Winchester, IN	6,280	13
133-134	Winchester to Union City, IN	1,785	4
134-785	Union City, IN to Meekers, OH	750	2
785-156	Meekers to Bradford, OH	1,245	2
156-792	Bradford to Urbana, OH	10,421	21
792-798	Urbana to N. Buckeye Yard	6,817	14
798-160	N. Buckeye Yard to Buckeye Yard	49	0
Total		49,236	100

Source: CONSAD Research Corporation

*Segments 752-753-758 pass through Indianapolis and total only 4.8 miles.

2. From Avon: continuing as in the first alternative route to West Manchester; then north to Ansonia and on to either Stanley or Berea, as the final destination dictates.

3. From Avon: north to Logansport, IN; then southeast to Marion toward Union City; at Union City traffic would continue on the mainline to Buckeye Yard. Or from Marion would travel north to Elkhart and then if necessary on to Stanley or Berea.

There are numerous other routes available for the movement of HM traffic prohibited on the portion of trackage from Avon to Union City. CONSAD determined that it would be unwise and unrealistic to specify any of the above as the alternative route for two reasons:

- First, certain HM traffic on the line from Avon to Union City does not continue on the mainline to Buckeye Yard (Refer to Figure 2), but moves north to various yards on Conrail. Thus the specification of an alternative from Avon to Buckeye Yard would not address or accommodate HM traffic which is not constrained to reach Buckeye.

- Second, not all HM traffic moving between Avon and Buckeye Yard has the same origin and destination on Conrail. Therefore, it might be advantageous for Conrail to reroute traffic bound for various locations by a number of routes. By not specifying an alternative route for prohibited HM, CONSAD has allowed Conrail considerable routing flexibility as a more realistic approach to the rerouting of traffic around a prohibited segment of trackage.

5.2.1 Rerouting as a Response to Prohibition

As previously described, all HM traffic (except that which originates or terminates on-line) would be prohibited from moving over the Avon Yard to Union City mainline segment and no singular alternative route for this traffic has been specified. For simplicity of analysis, the following constraints were imposed concerning the rerouting of HM traffic;

- Only HM traffic moving on the trackage from Avon Yard to Union City will be rerouted.

Non-HM traffic will continue to move on the line if it is to Conrail's advantage to do so.

- HM traffic originating and/or terminating on the prohibited trackage will, by necessity, continue to move on the line. Conrail will continue to serve shippers and receivers located on the line.

- Conrail may choose to reroute HM around the prohibited portion, but back on to the mainline at Union City.

- The ultimate origin and destination (on Conrail) of the HM traffic will not be altered by the Prohibit policy. HM traffic between two points will continue to move between those points, but by an altered route.

- Traffic moving east from Avon Yard will be rerouted beginning, not prior to, Avon Yard. Traffic moving west from Buckeye Yard will be rerouted beginning at Buckeye Yard.

5.2.2 Operating Rules for Rerouting Under Prohibition

While the above assumptions establish boundaries within which the rerouting can occur, considerable latitude as to specific response to prohibition remains. Therefore, CONSAD has defined four Operating Rules to represent the range of responses that may occur.

> Operating Rule A. Present train patterns and schedules will not be altered. All Conrail trains will continue to move on their current routes at scheduled times. HM traffic on the prohibit segment will be switched at Avon or Buckeye onto existing trains which do not operate on the prohibited segment. HM cars may be switched as often as is necessary to deliver them to their destination.
>
> This rule restricts the rerouting, or altering of schedules, of existing trains for the purpose of picking up HM traffic. All HM traffic must, therefore, be dropped off at yards or junction points serviced by existing trains. In order to deliver HM to its point of destination, it may be necessary to move a HM car on two or more consecutive trains. In order for this to take place, there will be no restriction on the number of HM cars a train may pick-up.

CONSAD anticipates that under the constraints of this operating rule, HM car-miles, car-switches, and car-hours will increase. It is expected that HM cars will wait in yards and at junction points for pick-up.

Operating Rule B. All HM traffic on the prohibited segment must be rerouted on existing trains. If a train on the prohibited segment currently contains more than 20 percent HM cars, that train will be rerouted. However, no other trains may be rerouted or rescheduled.

This Operating Rule is identical to A, except for the stipulation that any HM trains on the prohibited segment which carry more than 20 percent HM would be rerouted. As in A, HM cars will be moved from yard to yard until they reach their ultimate destination.

CONSAD expects that the results of B will yield increases in car-switches which will be less than those in A. Obviously, there will be increases in train-hours, locomotive unit-hours, crew-hours, caboose-hours, train-miles and locomotive unit-miles since whole trains, not just HM cars, will be rerouted. Operating Rule B will tend to cause a less significant increase in car-hours for HM cars on rerouted trains, since they will no longer be held over in yards, waiting for a scheduled train to pick them up, however, non-HM cars will now be rerouted causing increase in both car-miles and car-hours. The final net increases in both car-miles and car-hours cannot then be determined and could either be greater or less than that for A, depending on the alternate route chosen. Obviously, car-miles will increase over those in Rule A since non-HM and HM cars are being rerouted in all trains carrying 20% hazardous materials.

Operating Rule C. All HM traffic must be rerouted on trains carrying more than 20 percent HM. HM cars will be held in yards until enough cars are available to add to and comprise at least 20% of an existing train scheduled to move on the prohibited segment. The train will then be rerouted.

While HM cars are held for pick-up (wait may be measured in days), the train to be rerouted will continue to operate on the prohibited route carrying its non-HM cargo (HM cars will be dropped off for pick-up later). When sufficient HM cars are assembled, the next scheduled train will be rerouted.

An example of application of this Operating Rule might involve a hypothetical train called SLIO which operated daily from Avon to Buckeye Yard carrying 11 HM and 80 non-HM cars. On day one, SLIO would continue to operate on the prohibited route but would only carry 80 non-HM cars. The 11 HM cars would remain at Avon Yard. On day two SLIO enters Avon Yard with 11 new HM and 80 non-HM cars. It picks up the 11 HM cars waiting from day one and the train is then rerouted since it now consists of more than 20% HM cars (22 HM and 80 other cars).

Operating Rule C is substantially different from A and B in that HM cars can be rerouted on any existing train not moving on the prohibited route. HM cars do not have to wait until a train with 20 percent HM cars can be assembled. In C, however, HM cars do not move until a train (which currently operates on the prohibit route) is assembled with more than 20 percent HM; that train is then rerouted away from the prohibited segment. We would therefore expect that delay times would be greater in C than in A or B. However car-switches should be less since the only additional switch in C would be to put the car into the rerouted train, where in A and B HM cars would be switched from train to train.

Operating Rule D. This is the most straightforward Operating Rule. HM cars will be held in yards or at junctions until solid HM trains of 50 cars or more can be assembled. These HM trains will be rerouted and will drop off cars at the appropriate destinations. The new HM trains will be rerouted daily (if there is sufficient HM traffic to meet the minimum requirement of 50 cars) with their own itineraries and schedules.

This rule is different from C in that it requires the creation of new HM consists, not just the rerouting of existing trains. Also, the new trains carry only HM. In addition, all HM on the prohibited route must move only on solid HM trains.

Rule D will cause overall increases in train-hours, crew-hours, caboose-hours, locomotive unit-hours, train-miles and locomotive unit-miles, since new trains will be created. However, these increases will probably be less than those in Rules B or C, where more trains are rerouted but greater than in A where only cars are rerouted. Increases in car-miles will most likely be identical to those in A, while switches will be less and car-hours probably less since there will no longer be waits in yards along the alternate routes. Car switches will be greater than those in Rules B or C since all HM-cars will need to be switched.

5.2.3 Data Used in the Analysis

As noted above, Conrail provided CONSAD with printouts from computer runs of the Conrail simulation model. That model merges actual 1979 fourth quarter carload traffic data with a Conrail blocking and scheduling strategy specifying how traffic will move through the Conrail system. Traffic and train volumes data is tabulated from the model.

Conrail also provided CONSAD with the operating results of the equivalent of a single day's traffic movements. This was done by loading the fourth quarter 79 data, running the model, and adjusting the results to 1/75th of the quarter's total. The 1/75th represents a typical day of the fourth quarter since Conrail calculations are based on the assumption of 25 typical days/month (300 per year) in the three month period.

Conrail staff indicated that the computer printouts do not precisely duplicate a day of actual traffic movements on the system. The data was for the fourth quarter of 1979, unadjusted for seasonal fluctuation.

The data provided contain information on train and traffic movements (both HM and non-HM) by each Conrail train on the system by name. Data on the origin and termination of the train, the number and itinerary of the locomotives, the number of cars on the train (HM and non-HM can be specified), and the major locations (usually yards or junctions) through which the train passes (including arrival and departure time) are also provided. In addition, specific information is provided on blocks (a group of cars with the same origin and destination which are moving together). For each block, data are given on the origin and destination (on Conrail) of the block, the number of cars and tonnage, and the point and time of pick-up (receiving a car from a yard) and/or set-off (leaving a car at a yard). Using this data, it is possible to follow the movement of a block from the time it joined a train until it leaves that train.

Unfortunately, the block specific data do not identify blocks by name. Therefore, if a block is dropped from a train, there is no easy way to determine which train picked up that block. This means that if a block is not carried by a single train from origin to termination on Conrail, it is impossible to follow that block beyond the portion of its journey on that train.

The data provided also give summary performance data on all Conrail trains. Each train's symbol is given with accompanying information on train-miles, car-miles, train-hours, car-hours, and gross ton-miles. Thus summary data can be assembled on train performance.

Both sets of data have a very useful purpose. For the Avon to Union City corridor for example, information on current operations can be compiled very rapidly. Knowing the name of all trains on the prohibited trackage, it is possible to identify all HM blocks moving on the line (as well as itineraries and other data on HM cars).

Conrail identified all trains operating on the prohibited trackage as well as the trains operating into and out of major yards, based on the Conrail Manifest Freight Train Schedule. CONSAD therefore was able to identify scheduled trains on the entire Conrail system.

In addition, Conrail provided copies of regional time tables containing data on the physical characteristics of all trackage within the system. Mainlines are listed by name with information on mile post locations and stations along the line. Certain sections also contain data on number of tracks, speed limits, signalization, weight restrictions, and other physical characteristics.

5.2.4 Rerouting Methodology

The methodology for identifying HM traffic, compiling statistics on current operations, and hypothetically rerouting HM traffic on the prohibited route involved a number of steps.

- All trains operating over any portion of the prohibited trackage were identified;
- Data was collected from computer printouts on current train operations consisting of information on origin and destination of HM and non-HM traffic, train arrival and departure times, and various other information on train and car movement data;

- Tabulations were created showing the itinerary of each train including arrival and departure time. Each individual HM block was identified and flagged for rerouting;

- HM cars (blocks) were grouped by terminating locations on the Conrail system, assuming that blocks bound for the same location would be routed together; and

- Summary statistics were compiled which presented information on train-miles, train-hours, car-hours, car-miles, etc., for each train and for all affected trains.

The HM traffic was rerouted according to each of the Operating Rules. The following steps were taken:

1. All blocks bound for the same destination on Conrail were given an identifier.

2. A list of the different destinations of each of the groups of blocks was compiled.

3. Conrail system maps were studied and alternative routes for the HM traffic were found. As stated earlier, the Manifest Freight Train Schedule was referred to in order to identify trains for re-routed traffic.

4. Blocks of HM traffic were switched from current trains (on the prohibited route) onto existing trains bound for the appropriate destination. In some instances, cars were late for train connections and therefore were forced to wait a day or two for pick-up by trains on alternative routes. Since the model gives times at intermediate points, CONSAD was able to estimate delay times for all HM blocks.

5. In rerouting cars, CONSAD made the assumption that the shortest possible route should be taken. Further, re-routing constraints described in section 5.2.1 were taken into consideration.

6. Hazardous material cars were rerouted under each of the four Operating Rules. For Rule A, all HM cars were assigned to appropriate trains. For Rule B, HM cars were assigned to trains; in addition, trains on the prohibited route with 20 percent HM were rerouted.

Under C, HM cars were assigned to trains such that the train to be rerouted had more than 20 percent HM. Trains were rerouted and all HM cars were delivered. Solid HM trains were created under Operating Rule D, and all HM cars were delivered.

5.2.5 Method for Cost Estimation

After all HM cars were hypothetically rerouted, CONSAD estimated the change in cost to Conrail of the Prohibit policy under each Operating Rule. Only variable line-haul costs that would change as a result of changes in operations were estimated. Line-haul costs have been broken down into six major components: maintenance of way (MOW) costs; maintenance of equipment (MOE) cost; equipment cost; transportation costs; switching costs; and car costs.

Maintenance of Way. Maintenance of Way (MOW) costs which vary with gross ton-miles include: ties, rail, other track material, ballast, track laying and surfacing, roadway machines and fringe benefits associated with the labor associated with these costs.* CONSAD developed MOW costs per gross ton-mile for Conrail by reviewing expenditures for MOW from 1976 to 1979 for each of the accounts mentioned previously. The dollar values were inflated to 1979 dollars and summed to total dollars spent on maintenance of way (for each year). Total expenditures for each year were divided by gross ton-miles to yield 0.0017 dollars per gross ton-mile for Conrail MOW. To calculate the change in line-haul MOW costs, this factor was multiplied by the change in gross ton-miles due to the Prohibit policy.

Maintenance of Equipment. Equipment maintenance cost was calculated as a function of train-miles. The following ICC R-1 accounts were included: administration, locomotive repairs, machinery repairs, fringe benefits, and casualty and insurance. These costs were adjusted to 1979 values, summed, and divided by total train miles for Conrail to obtain a cost of $6.91 per train-mile.

Equipment. CONSAD did not rely on ICC accounts to calculate the costs of owning equipment. The annual cost of equipment (locomotives and cabooses) was calculated (using the practice preferred by railroads of replacement cost)

*Annual Report to the Interstate Commerce Commission, Conrail. R-1 Reports for Class I Railroads, 1976 to 1979.

as the fully financed equivalent annual payment necessary to replace the equipment, as follows:

Given:

Purchase Cost ($)	=	PC
Life (years)	=	n
Interest Rate (Cost of Capital)	=	i
Salvage Value ($)	=	SV

The equivalent Annual Payment (EAP) is equal to:

$$EAP = \frac{i(PC) - i[SV/(1+i)^{n}]}{1 - (1+i)^{-n}}$$

Discussion with various suppliers of locomotives and related equipment indicated that the average cost of a six axle locomotive is approximately $642,300, with an average life of 30 years and an approximate salvage value of $64,230. Assuming a ten percent interest rate, the equivalent annual payment for a locomotive would be:

$$\frac{.1\ (642,300) - 0.1\ [64,230/(1.1)^{30}]}{1 - (1.1)^{-30}} = \$67,744$$

Dividing this annual figure by 4,164, the average annual number of locomotive service hours on the Conrail system, yields an hourly cost of $16.27 for ownership of a six-axle locomotive.

The ownership cost of a caboose was developed by the same method. An average 1978 purchase price of $53,239 was obtained from Railway Age and updated to 1979 using an index of railroad prices (1.095). Assuming a 30 year life, with a ten percent rate of interest, the annual cost of a caboose was calculated as $6,149. Using an average utilization rate for a caboose of 2,237 hours per year results in a unit cost of $2.75 per train hour (assuming one caboose per train).

Transportation. Transportation costs include all of the elements required to operate the trains including dispatching, clerical and accounting, grade crossing protection and inter-locking protection, and loss and damage. In calculating the cost impact of implementing each policy option, CONSAD included only those costs that were expected to vary in the short-run with the rerouting of trains. Assuming that many of the costs listed above vary only in the long-run, transportation expenses such as crew costs, fuel costs, and locomotive servicing accounting for 60 percent of total transportation costs were the only items used in CONSAD's calculations.

Crew costs are directly related to train-hours of operation. An hourly wage plus fringe benefits cost of $62.69 was obtained from Conrail for a five-man crew as follows:*

Four-man crew		$297.33
Fireman		74.18
Total wages		371.50
Fringes at 35 Percent		130.02
Total (8 hour shift)		$501.52
	=	$ 62.69 per hour

This $62.29 value can be directly applied to train hours to obtain total crew costs.

Fuel costs were based on recently estimated energy efficiencies for freight transportation.** Rail freight requires 667 BTU's per ton-mile. Assuming 138,700 BTU's per gallon of diesel fuel, it requires 4.81 gallons of diesel fuel for every 1,000 gross ton-miles. Using $0.82 per gallon, a figure provided by Conrail, a fuel cost of $0.00396 per GTM was derived. Multiplying this factor by the increase in gross ton-miles for the Prohibit policy results in the incremental increase in fuel costs.

The annual cost of servicing locomotives was obtained directly from Conrail. The cost for calendar year 1979 was $9.21 per operating hour.

Since published data does not provide details on intra-line switching costs, a value of $12.05 per car-switch supplied by Conrail was used in this analysis.

Similarly, for car costs, quotations from Conrail of $0.04 per car-mile plus $0.25 per car-hour for the average cost for the total Conrail car fleet were used for non-HM cars.

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*CONSAD was informed by Conrail that virtually all trains on the corridors of interest operate with five man crews.

**Transportation Energy Conservation Data Book, Edition 3, Oak Ridge National Laboratory, 1979.

For HM tank cars, however, a higher, more realistic leasing rate of $0.62 per car-hour was used in the cost calculations.

In rerouting the HM traffic under each operating rule, CONSAD estimated changes in gross ton-miles, train-miles, car-miles, car-hours, locomotive-hours, caboose-hours, crew-hours, and car-switches. The cost relationships applied were the following:

Maintenance of way	=	$0.0017 per gross ton-mile
Maintenance of Equipment	=	$6.91 per train-mile
Equipment Cost	=	$16.27 per locomotive-hour plus $2.75 per caboose-hour
Transportation Cost	=	$62.29 per crew-hour plus $0.00396 per gross ton-mile plus $9.21 per locomotive-hour
Car Cost	=	For HM Cars: $0.62 per car-hour For Non-HM Cars: $0.25 per car-hour plus $0.04 per car-mile
Switching Cost	=	$12.05 per car-switch

The total cost associated with the rerouting option, for each Operating Rule, is obtained by summing the product of each of the above six cost elements and the observed operating changes.

5.2.6 Results of Rerouting

Using information provided by Conrail, CONSAD identified the traffic and trains moving over the prohibited segment from Avon to Union City.

Table 10 summarizes this data, including traffic carried (carloads and empties) for all commodities and for HM, the gross tonnage moved, train-miles, car-miles, and gross ton-miles. Fifty-three HM trains per day operate over some portion of the segment, with their HM cars accounting for 17,000 gross tons. However, not all 53 trains operate on the entire prohibited segment.

Changes in Operating Statistics. The results of the rerouting are shown in Table 11 giving changes in operations, due to the four options, relative to the current situation. For four of the six operating statistics presented car-miles, gross ton-miles, car-hours, and car-switches - Operating Rule A, which calls for no change in train patterns, shows the greatest increase, all due to HM-car reroutes. Similarly, Rule D (solid HM trains) results in the greatest increase in train miles. Operating Rule C, on the other hand, produces the smallest increases in car-miles, gross ton-miles, car-hours, and car-switches.

In Table 11 a number of negative values (decreases in operating statistics) appear. In some instances, HM cars were rerouted in a manner which was actually shorter than the current route, resulting in a net decrease for mileage-related statistics. As shown in Figure 1, new routes are not necessarily longer than the current route. Therefore, the direction of change (either positive or negative) for operating statistics can not be precisely predicted and will vary according to the physical characteristics of the individual case study site.

Solely on the basis of minimizing impacts on operating statistics, operating Rule C appears to be the most attractive. Total delay under this rule increases by 2,305 car-hours for 197 cars for the one day of operations, a mean increase of 11.7 hours per car. However, the median increase is 16 hours per car. For cars with less than the mean delay, the delay is primarily due to rerouting travel time. For cars with longer delay times, the vast majority of delay is due to schedule differences.

Table 10: Summary Measures of Current Operations on the Indianapolis to Columbus Corridor

	Prohibited Portion From Avon to Union City	Mainline from Avon to Buckeye
No. Trains		
All	40	63
Hazmat	33	53
No. Cars		
All	2,622	4,371
Hazmat	193	251
Gross Tons		
All	153,580	260,040
Hazmat	12,980	17,470
Train-Miles		
All	2,692	4,197
Hazmat	2,289	3,588
Car-Miles		
All	196,730	314,960
Hazmat	17,340	31,510
Gross Ton-Miles		
All	11,668,000	18,933,000
Hazmat	1,428,000	2,117,000

Source: CONSAD Research Corporation.

Table 11: Changes in Operating Statistics for a Typical Day on the Indianapolis to Columbus Case Study Corridor

Operating Rule	Change in Operating Statistics								
	Train-Miles	Car-Miles	Gross Ton Miles (10^3)	Train-Hours	Car-Hours	Car-Switches	Loco-Hours	Total Cars Rerouted	Total HM Cars Rerouted
PROHIBITION - Avon to Union City									
A Eastbound	0	4,929	536	0	3,939	250	0	77	77
Westbound	0	7,948	379	0	6,601	237	0	116	116
TOTAL	0	12,877	915	0	10,538	477	0	193	193
B Eastbound	6	3,606	365	0.3	2,456	150	1.0	194	77
Westbound	12	5,404	309	0.7	3,393	133	2.0	277	116
TOTAL	18	9,010	674	1.0	5,849	283	3.0	477	193
C Eastbound	- 16	- 729	- 10	3.8	1,091	82	11.4	261	77
Westbound	8	1,709	167	2.3	1,214	50	4.6	325	116
TOTAL	- 8	980	157	6.1	2,305	132	16.0	541	193
D Eastbound	214	44	32	1.0	1,011	106	2.0	77	77
Westbound	18	2,515	140	3.1	1.568	117	9.4	116	116
TOTAL	232	2,559	172	4.1	2,579	223	11.4	193	193

Source: CONSAD Research Corporation

Operating Costs. The costing methodology previously described was applied to the change in operating statistics shown in Table 11. By simply multiplying the results in that table by the appropriate dollar factor from page 5.19, the increases in daily operating costs shown in Table 12 were obtained.

Cost impacts are the greatest for Operating Rule A, with a daily increase of over thirteen thousand dollars. However, if Operating Rule C were implemented, total costs would increase by $3,856 per day, the least of the four Operating Rules.

Population Exposure. For the Avon to Union City case study, CONSAD has used as a measure of risk the "person-gross-tons-per-day" exposed to HM, defined as the total number of persons living along the one half-mile band around the trackage in question multiplied by the gross tons of HM traversing that route per day. Although the level of risk is also a function of time on route, number of handlings, and train speed, this study observes population exposure before and after rerouting as a simple measure of the level of risk associated with rail movements of hazardous materials.

The methodology used in calculating exposure consisted first of estimating the population within a one-half mile band width of the trackage along the prohibited segment as well as along all possible alternative routes by the methodology described in Section 5.1.2. Each HM car currently operating on the Prohibit segment was identified and the Conrail links over which is traversed (both on the prohibited and non-prohibited portions of the route) were recorded. For each of the Operating Rules, the links over which the HM cars were rerouted were tabulated. All links which were the same under current and rerouted operations were ignored. Only links which differed were ultimately used in the calculation of exposure. For each of these links, the number of HM tons traveling on the link was multiplied by the estimated population. The values obtained (in person-gross-tons) were summed for all links traversed by HM for current and reroute operations. The difference in person-tons for the base case (current operations) and reroute operations, provides an estimate of the change in exposure.

Table 12: Increase in Daily Operating Costs for the Indianapolis to Columbus Case Study

Operating Rules	Line Haul Cost								Car Costs			SWITCHING COSTS TOTAL	TOTAL COSTS
			Equipment		Transporation								
	MOW	MOE	LOCO	CAB	CREW	FUEL	LOCO SER	TOTAL	HRS	MIL	TOTAL		
PROHIBITION Avon to Union City													
A Eastbound	911	0	0	0	0	2,123	0	3,034	984	197	1,181	2,894	7,109
Westbound	645	0	0	0	0	1,502	0	2,147	1,650	318	1,968	2,853	6,968
TOTAL	1,556	0	0	0	0	2,625	0	4,181	2,634	515	3,149	5,747	13,077
B Eastbound	620	41	16	1	21	1,445	9	2,153	614	144	758	1,810	4,721
Westbound	526	83	33	2	41	1,225	18	1,928	848	216	1,064	1,600	4,592
TOTAL	1,146	124	49	3	62	2,670	27	4,081	1,462	360	1,822	3,410	9,313
C Eastbound	-17	-110	187	11	239	-38	105	377	273	-29	244	987	1,608
Westbound	285	55	75	6	144	663	43	1,271	304	68	372	605	2,243
TOTAL	268	- 55	262	17	383	625	148	1,648	577	39	616	1,592	3,856
D Eastbound	54	1,479	33	3	62	127	18	1,776	253	2	255	1,281	3,312
Westbound	239	124	154	9	196	557	87	1,366	392	101	493	1,410	3,269
TOTAL	293	1,603	187	12	258	684	105	3,142	645	103	748	2,691	6,581

Source: CONSAD Research Corporation.

Table 13 shows the changes in population exposure due to the rerouting of hazardous materials cars currently operating on the prohibited section. Operating Rule B produces the greatest reduction in exposure, over 55 million person-gross-tons per day. The rerouting in B requires the shuttling of HM cars over many alternative routes. In most instances these routes are not high density mainlines and do not pass through heavily unbanized areas, thus accounting for the large decreases in exposure.

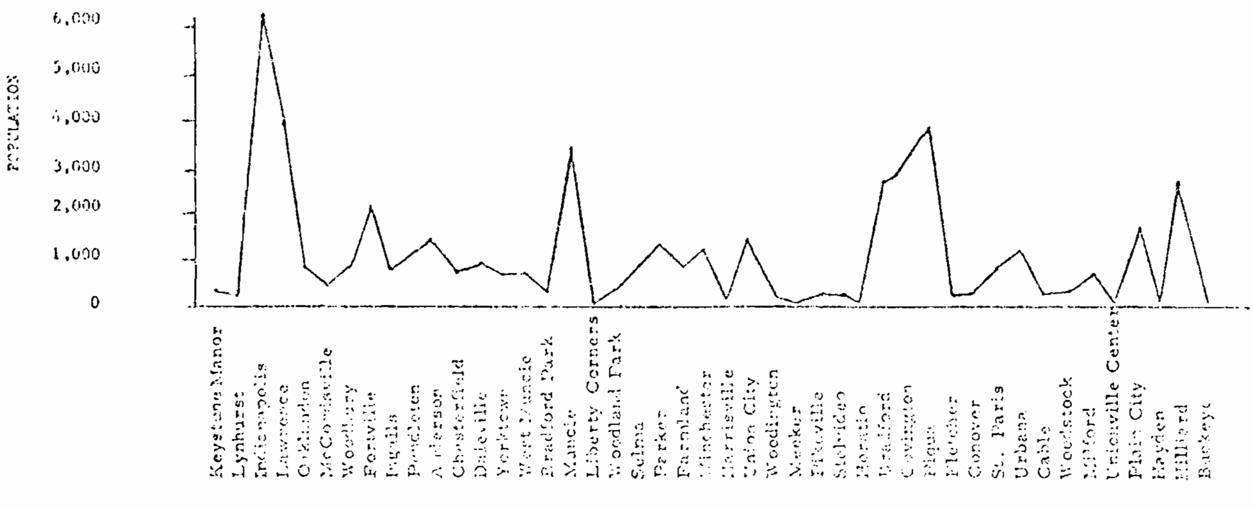
For the other Operating Rules the reduction in exposure was less significant due to the fact that HM trains as well as cars were rerouted. When trains were rerouted, the reroutings were generally shorter than in B and through more moderately populated areas, accounting for the smaller reductions in exposure. If C or D were adopted, the total exposure would be reduced by only 220,000 and 400,000, respectively. Although Operating Rule C has the least impact on railroad operations, and therefore costs, the reductions in exposure are minimal.

Figure 3 provides a population profile for the prohibited route and the various reroutes for the HM traffic, indicating that the highest population density exists along the prohibited segment of the Avon to Buckeye mainline. Although population densities vary on each of the reroutes, they are generally less than those on the prohibited route.

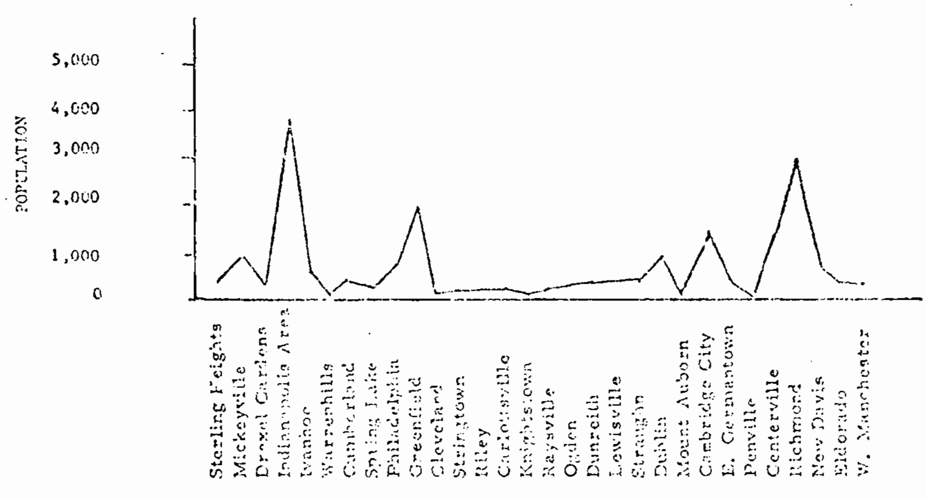
5.3 Reduce HM Train Speed

Reducing the speed limit of HM trains to that of the next lowest track class on the high density portion (Avon to Union City) of the Indianapolis to Columbus mainline was the second safety option considered. This option is based on the rationale that reduced speed will mitigate accident severity. CONSAD identified all HM trains operating on any portion of the mainline from Avon to Union City and gathered data on total travel time (train-hours), car-hours, and delays for these trains. CONSAD then estimated the additional time to traverse the Avon to Union City portion of trackage under the Reduce Speed option. Delays and other non-running times were factored out of the

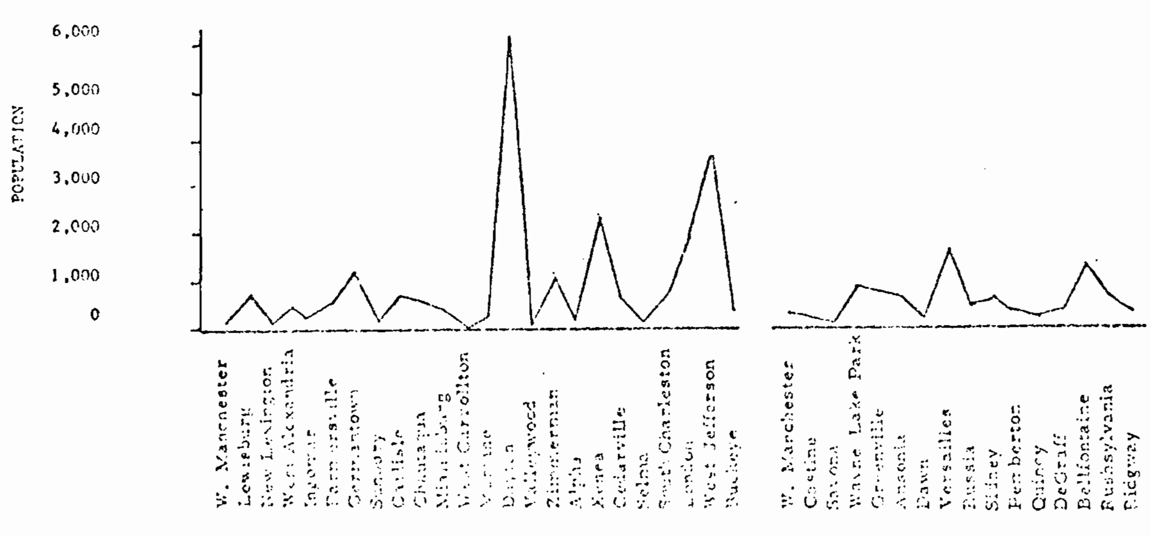
Figure 3: Representation of Population Along Main and Alternate Routes For the Indianapolis to Columbus Case Study Corridor* (Keyed to Route Numbers on Figure 1)



POPULATION CENTERS ALONG THE MAIN ROUTE



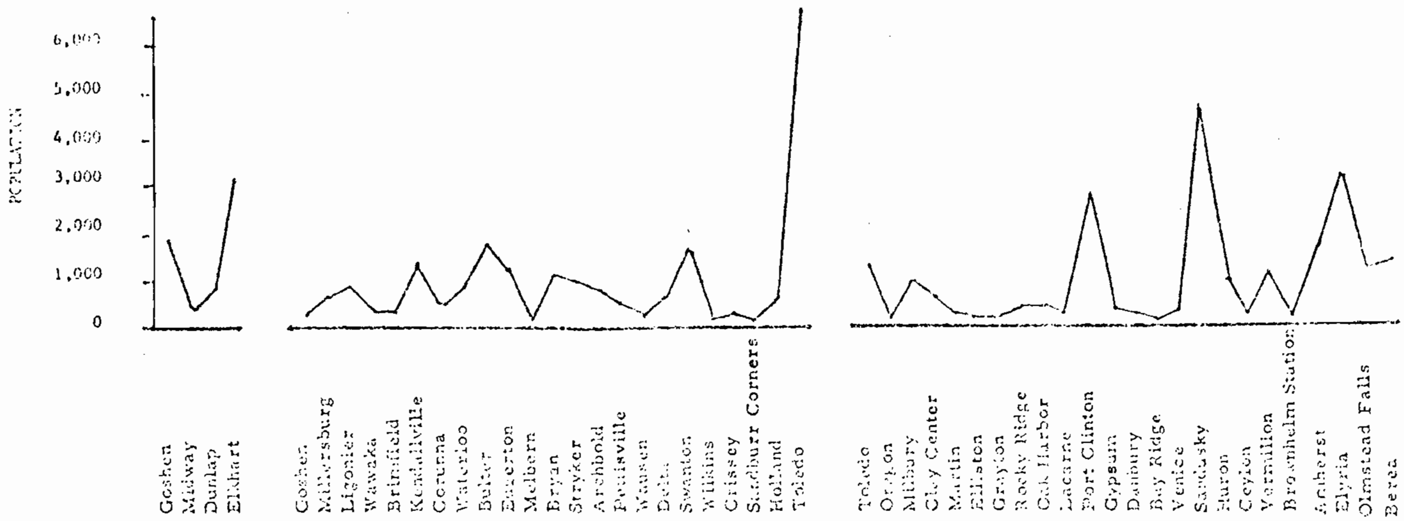
POPULATION CENTERS ALONG THE ALTERNATE ROUTE 3



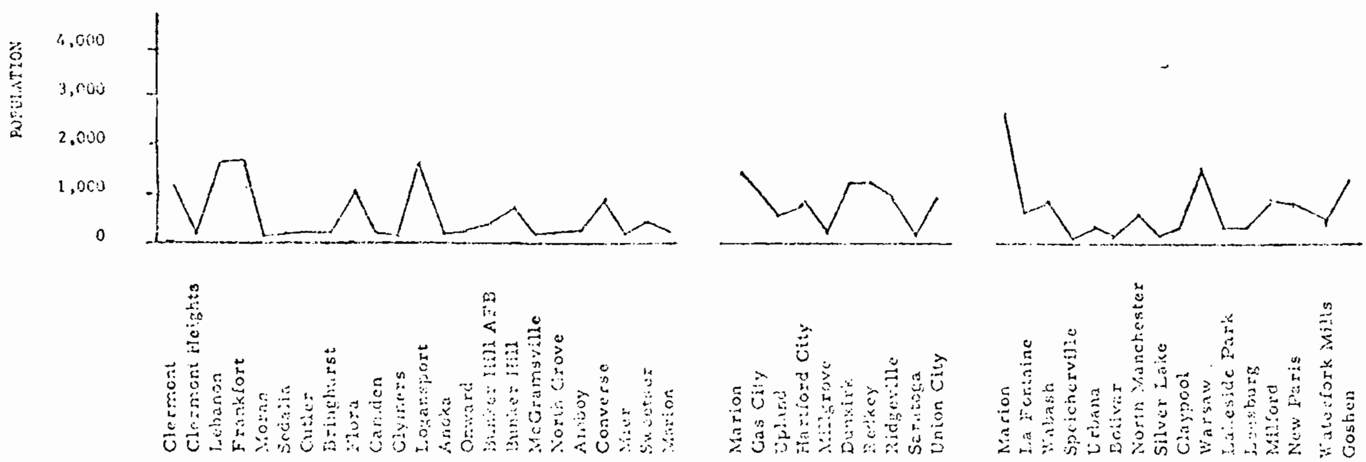
POPULATION CENTERS ALONG ALTERNATE ROUTE 3

*Note: Non-uniform horizontal scale.

Figure 3: Representation of Population Along Main and Alternate Routes For the Indianapolis to Columbus Case Study Corridor (Continued)



POPULATION CENTERS ALONG
ALTERNATE ROUTES 1,2



POPULATION CENTERS ALONG THE
ALTERNATE ROUTES 1,2

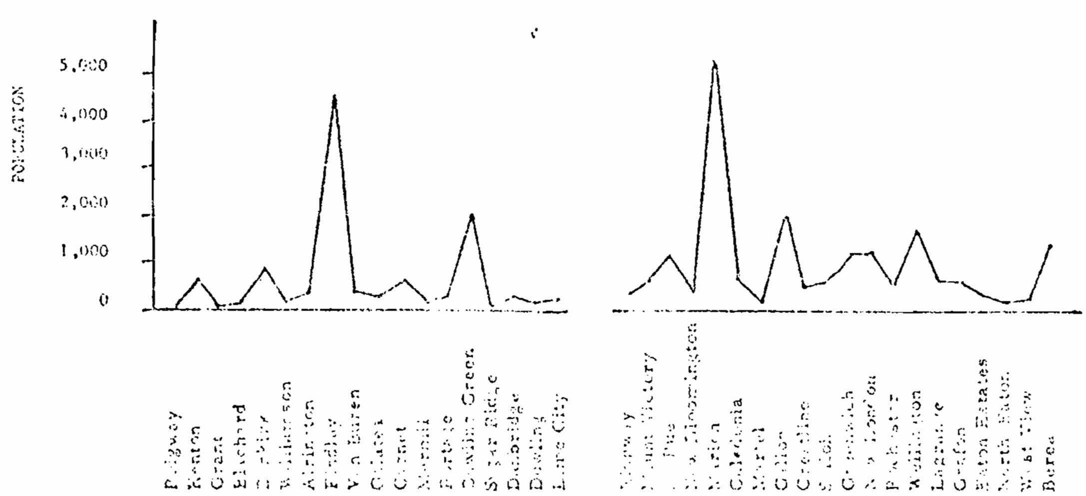


Table 13: Population Exposure from Avon to Buckeye

Population* Exposure	Prohibit Handling Assumptions (Millions of Person Gross-Tons)			
	A	B	C	D
Current	542	542	542	542
Prohibit	496	486	541	541
Percent Change	-8.5	-10.3	-.2	-.2

*Exposures levels are attributed to hazardous material traffic which currently operates on prohibited segment.

analysis to estimate only the change in running time due to a reduced speed policy using the following procedure:

- The length of each link from Avon to Union City was obtained from the time tables.

- For each of these links the maximum speed limit (as identified in the time table) was converted to track class using Table 14. Thus a current track class was determined for each link in question.

- Average running speeds (for a typical train) by link were obtained from Conrail's Division Engineer for the Indianapolis region. These running speeds do not include delay and are an average for freight trains. Time table speed limits were also verified.

- For each link, an average running time for current operations was calculated. This was done by dividing link length by the average running speed quoted by the engineer, in the following manner:

  For example: 11 miles $\div$ 45 m/hr = .244 hours

- Time table speed limits (for reduced speed) were established by reducing current track classes by one class.

- Average running speeds (for reduced speed) were set equal to the reduced speed limits. Under current operations, most of the trains were observed to approach current time table speed limits. If speed limits were reduced one track class, it was assumed that trains would slow down to the upper limit of the revised speed limit (reduced speed) in order to minimize time lost due to running at slower speeds.

- For each link, revised average running time (for reduced speed operations) were calculated by dividing average running speed into link length.

- Current average running time was subtracted from reduced speed running times to obtain the difference in running times due to implementation of the policy.

- Since changes in running times due to reduced speeds were assumed to be the only delay due to the policy, changes in time related statistics were calculated by

Table 14: Conversion from Speed Limits to Track Class

Maximum time Table Speed Limit	Track Class
50	IV
40	III
25	II
10	I

Source: CONSAD Research Corporation.

multiplying by the change in running time. Car-miles and train-miles would not change since the routings remain the same.

- Changes in operating statistics were added to the operating statistics obtained from the original Conrail data in order to estimate total car-hours, train-hours, etc. for each train affected. In doing this, all delays, etc., were added back into the operating statistics.

A number of simplifying assumptions underlie this methodology. First, it is assumed that delays at yards and on line (due to interference, etc.) are not changed if train speeds are reduced. They are estimated in the simulation model and are simply added back in after changes in running times are calculated. It was also assumed that although initially the reduction in speed for HM trains would not significantly slow non-HM trains, in the long run any trains traversing a particular segment of track over which HM train speeds are reduced will be similarly slowed. Therefore, the slowing of all trains on the prohibited segment is taken into account in the cost estimation of the Reduce Speed policy. One final consideration is the problem of freight trains undergoing harmonic roll while travelling at speeds of 17-22 mph on jointed track. For consistency in speed reduction this possible problem was ignored; however, if such an alternative were to be adopted this fact must be considered in setting operating speeds.

Table 15 provides the changes in daily operating statistics as a result of reducing speeds of HM trains and slowing of all trains. Running time increases by only 0.45 hours for the portion from Avon to Union City, but total car-hours increases by 956 per day. Also, train hours for all HM trains, will increase by 13 hours per day.

The costing method described in Section 5.2.5 was applied to the changes in operating statistics shown in Table 15 to obtain estimates of increased costs due to the Reduced Speed policy. These costs and total costs on a daily basis. As shown in Table 16, the reduced speed option increases Conrail's daily costs by approximately $1,900. Of that amount, over 87 percent is due to increases in line-haul costs (crew costs, equipment costs, etc).

Table 15: Changes in Daily Operating Statistics on Avon to Union City Route Due to Reduce Speed Option

Link	Length (miles)	CURRENT OPERATIONS				REDUCE SPEED OPERATIONS				CHANGE IN OPERATING STATISTICS			
		Speed Limit	Track Class	Average Running Speed	Average Running Time (Hrs.)	Speed Limit	Track Class	Average Running Speed	Average Running Time (Hrs.)	Change in Running Time	Change in Car-Hours	Change in Train-Hours	Change in Locomotive Hours
30-752	11	50	IV	45	.24	40	III	40	.28	.03	78.77	1.12	2.57
752-753	2	15	II	15	.13	10	I	10	.20	.07	163.82	2.41	5.55
753-758	4	25	II	15	.27	10	I	10	.40	.13	281.36	3.99	9.18
758-131	32	50	IV	45	.71	40	III	40	.80	.09	185.83	2.58	5.94
131-132	18	50	IV	45	.40	40	III	40	.45	.05	90.30	1.15	2.64
132-133	22	50	IV	45	.49	40	III	40	.55	.06	110.65	1.46	3.36
133-134	9	50	IV	45	.20	40	III	40	.22	.02	45.35	.60	1.38
TOTAL	98				2.44				2.90	.45	956.28	13.31	30.62

Source: CONSAD Research Corporation, 1981.

Table 16: Change in Daily Operating Costs for Reduced Speed Policy
Avon to Union City

Indianapolis to Union City	TOTAL LINE HAUL COSTS								CAR COSTS			Total Switching Costs	TOTAL COSTS
	Maintenance of Way	Maintenance of Equipment	Locomotive Costs	Caboose Costs	Crew Costs	Fuel Costs	Locomotive Servicing	Total	Per Hour	Per Mile	Total		
East	0	0	248.28	18.23	415.63	0	140.54	822.68	112	0	112.06	0	934.74
West	0	0	249.91	18.37	418.77	0	141.47	828.52	127	0	127.01	0	955.53
TOTAL	0	0	498.19	36.60	834.40	0	282.01	1,651.20	239	0	239.07	0	1,890.27

Source: CONSAD Research Corporation, 1981.

5.4 Summary

Table 17 summarizes the changes in operating statistics found in this case study for both the Prohibit and Reduce Speed options. For all statistics except train-hours, the reduced speed policy results in the smallest increases, since the HM traffic will continue to move on the current route with only a small reduction in running speeds. The Prohibit policy, however, involves switching and yarding of cars producing delays as well as increased mileage.

Table 18 summarizes information on the effect of each policy on the cost of moving the traffic. Reduced speed is the least costly of the policies followed by Operating Rule C of the Prohibit policy. Operating Rule A which requires the rerouting of HM cars only is the most costly of all the alternatives because of the circuity involved in the rerouting.

Operating Rule A results in the greatest reduction in exposure but also the greatest increase in total costs. Of the remaining Prohibit options, Operating Rule C results in the smallest decrease in exposure but also the smallest increase in total costs. The Reduce Speed policy is by far the least costly of all but there is no reduction in exposure. However, to the extent that safety is improved by reducing speed, this alternative is also attractive due to the relatively low cost of implementation.

Table 17: Changes in Daily Operating Statistics for The Indianapolis to Columbus Case Study

	DAILY CHANGES IN OPERATING STATISTICS					
Policy	Change in Train-Miles	Change in Car-Miles	Change in Gross ton-Miles (10^3)	Change in Train-Hours	Change in Car-Hours	Change in Car Switches
Prohibit						
Operating Rule A	0	12,877	915	0	10,538	477
Operating Rule B	18	9,010	674	1	5,849	283
Operating Rule C	-8	980	157	6	2,305	132
Operating Rule D	232	2,559	172	4	2,579	223
Reduced Speed	0	0	0	13	956	0

Source: CONSAD Research Corporation, 1981.

Table 18: Changes in Daily Operating Costs of Each Policy (1979 Dollars) For The Indianapolis to Columbus Case Study

Policy	Line Haul Costs	Car Costs	Switching Costs	Total Costs
Prohibit				
Operating Rule A	$4,181	3,149	5,747	$13,077
Operating Rule B	4,081	1,822	3,410	9,313
Operating Rule C	1,648	616	1,592	3,856
Operating Rule D	3,142	748	2,691	6,581
Reduced Speed	1,651	239	0	1,890

6.0 PITTSBURGH-HARRISBURG CASE STUDY

6.1 Description

The second case study site is Conrail's mainline between Conway Yard (near Pittsburgh, PA) and Enola Yard (Harrisburg, PA). The railroad distance between the two classification yards is approximately 270 miles with the line passing easterly through heavily populated areas of Pittsburgh as well as through Pitcairn, Greensburg, Johnstown, and Altoona. The corridor of interest is graphically depicted in Figure 4. Unlike the Indianapolis-Columbus study area, one alternative route can be defined and is also indicated in Figure 4.

6.1.1 Trackage and Train Operations

Data has been collected on the physical characteristics of the main and alternative line. Table 19 contains information on speed limits, number of tracks, link length, and major yards on the mainline, a relatively high speed portion of trackage with between three and four tracks.

Utilizing the information provided by Conrail, CONSAD identified all HM and non-HM trains operating on the mainline. Figure 5 summarizes trains and traffic on the mainline and the alternative route. The portion of trackage from Conway to Conpit has a minimum of 27 trains per day (of which 20 carry HM), and over 115,000 gross tons per day (of which 6,000 are HM); the alternative route has considerably less tonnage and fewer train operations.

6.1.2 Population

Estimates of the population residing within a one-half mile bandwidth of the line were obtained from several sources using the methodology presented in Section 5.1.2. Population estimates are shown in Table 20, while Figure 6 provides a population profile of the main and alternate routes.

The total population along the mainline from Conway to Enola is 117,400. Of this total, over 76,000 (65 percent) are located on the 86 mile segment between Conway and Conpit. CONSAD therefore determined that restrictions

Figure 4: Schematic of Case Study Corridor from Pittsburgh to Harrisburg Showing Alternate Route

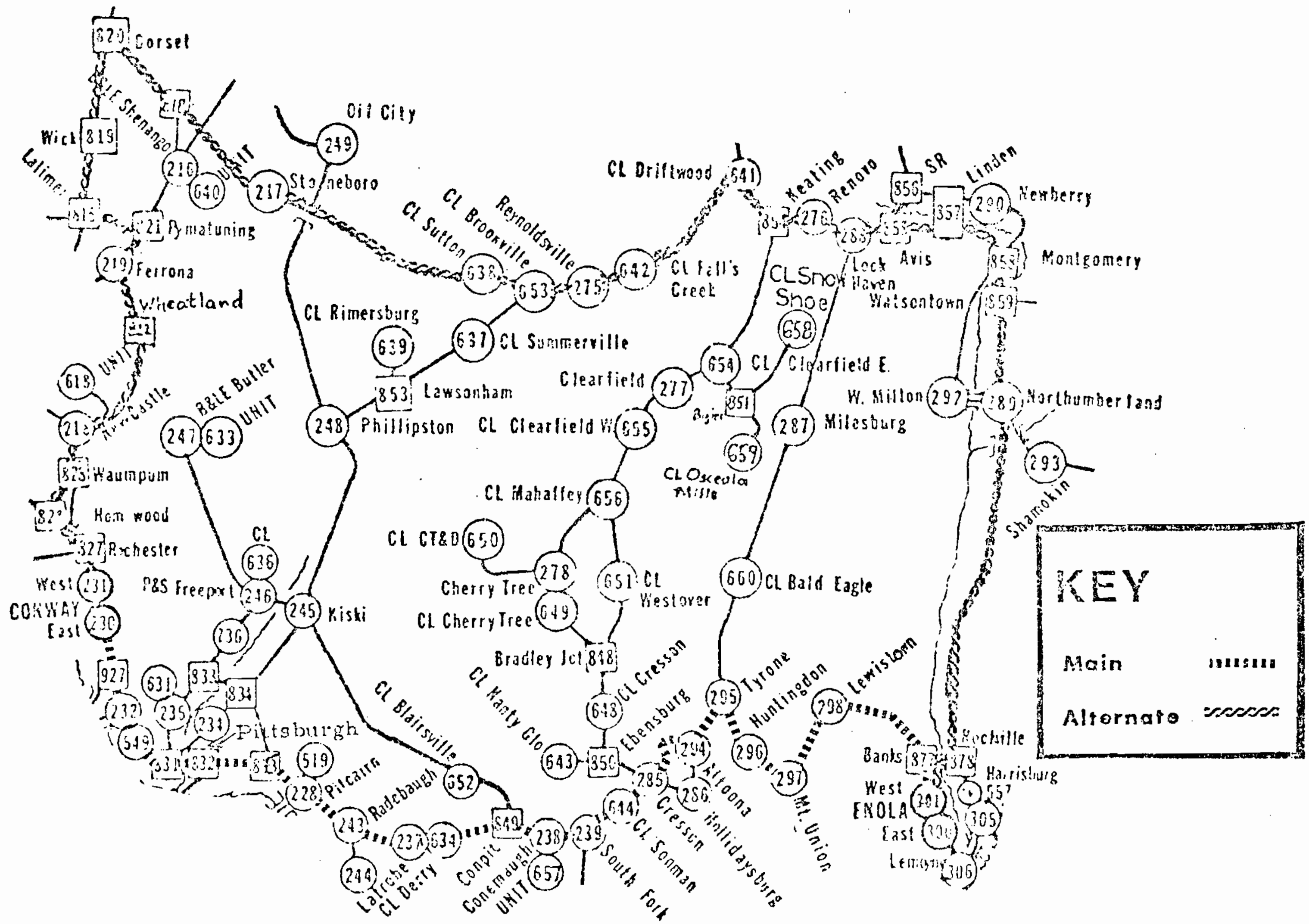


Table 19: Physical Characteristics of Pittsburgh to Harrisburg Main Line

Link No.	Length (Miles)	No. of Tracks	Speed Limit Max	Speed Limit Min	Track Class	Major Yards
						Conway East
230-927	18	4	50	50	IV	
927-232	1	4	40	40	III	
						Island Avenue
232-549	1	2	20	20	II	
						Federal Street
549-831	2	4	20	20	II	
831-832	1	4	20	20	II	
832-835	5	2	30	15	III/IV	
835-228	10	3	45	35	IV/III	
						Pitcairn
228-243	13	3	50	45	IV	
						Radebaugh
243-237	13	3	50	45	IV	
						Latrobe
237-634	5	3	50	45	IV	
						Derry
634-849	17	3	50	45	IV	
849-238	18	4	45	30	III	
						Conemaugh
238-239	5	4	50	45	IV	
						South Fork
239-644	10	4	45	30	III/IV	
						Sonman
644-285	6	4	45	40	IV/II	
						Cresson
285-294	15	4	45	15	IV/II	
						Altoona
294-295-	14	4	50	40	IV/III	
						Tyrone
295-296	20	4	50	40	IV/III	
						Huntingdon
296-297	12	3	50	40	IV/III	
						Mt. Union
297-298	25	3	50	35	IV/III	
						Lewistown
298-877	54	3	50	40	IV/III	
877-301	2	4	50	35	IV/III	
						Enola West

Source: CONSAD Research Corporation.

Figure 5: Trains and Traffic Operating Over the Pittsburgh to Harrisburg Case Study Corridor

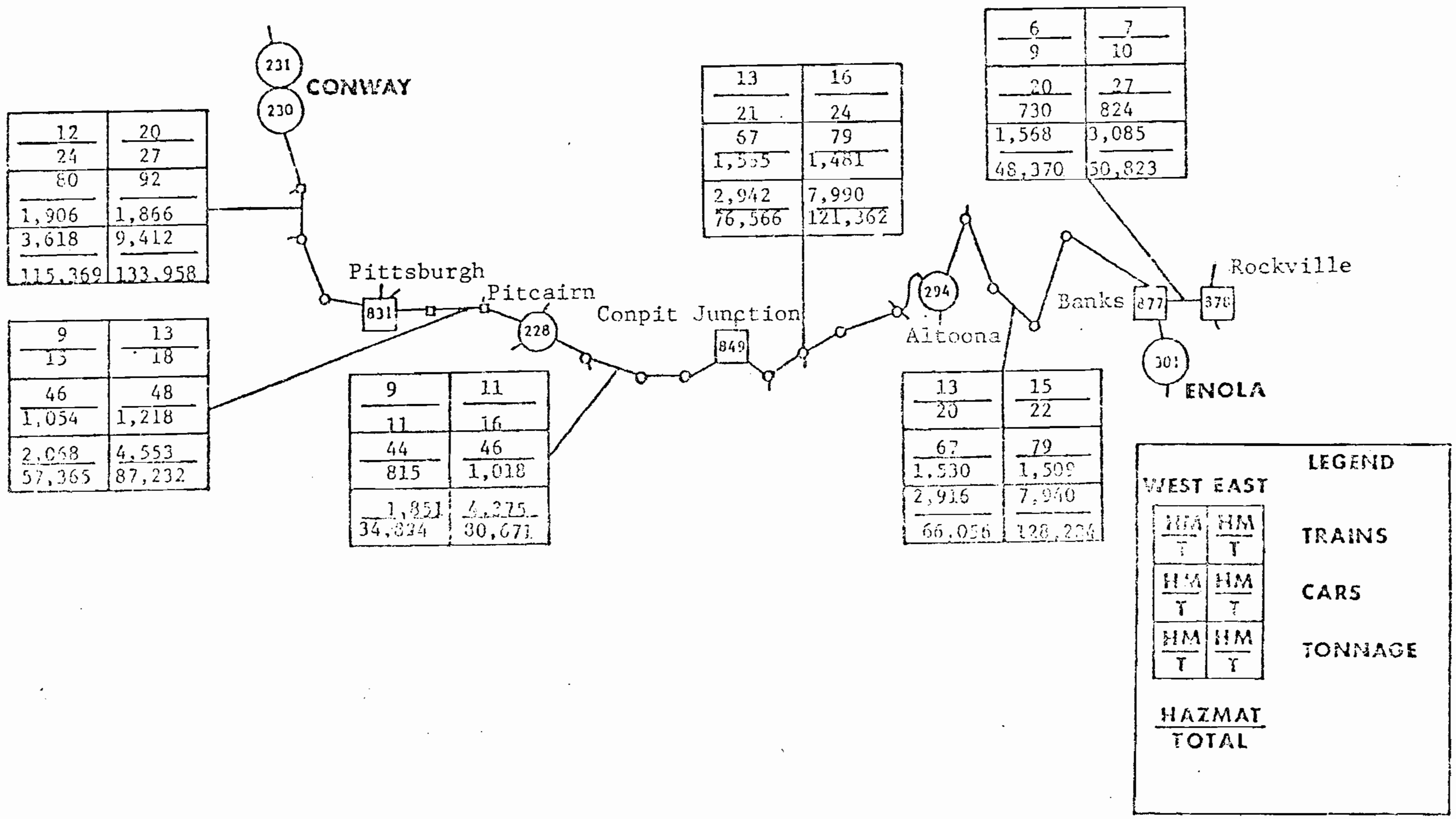
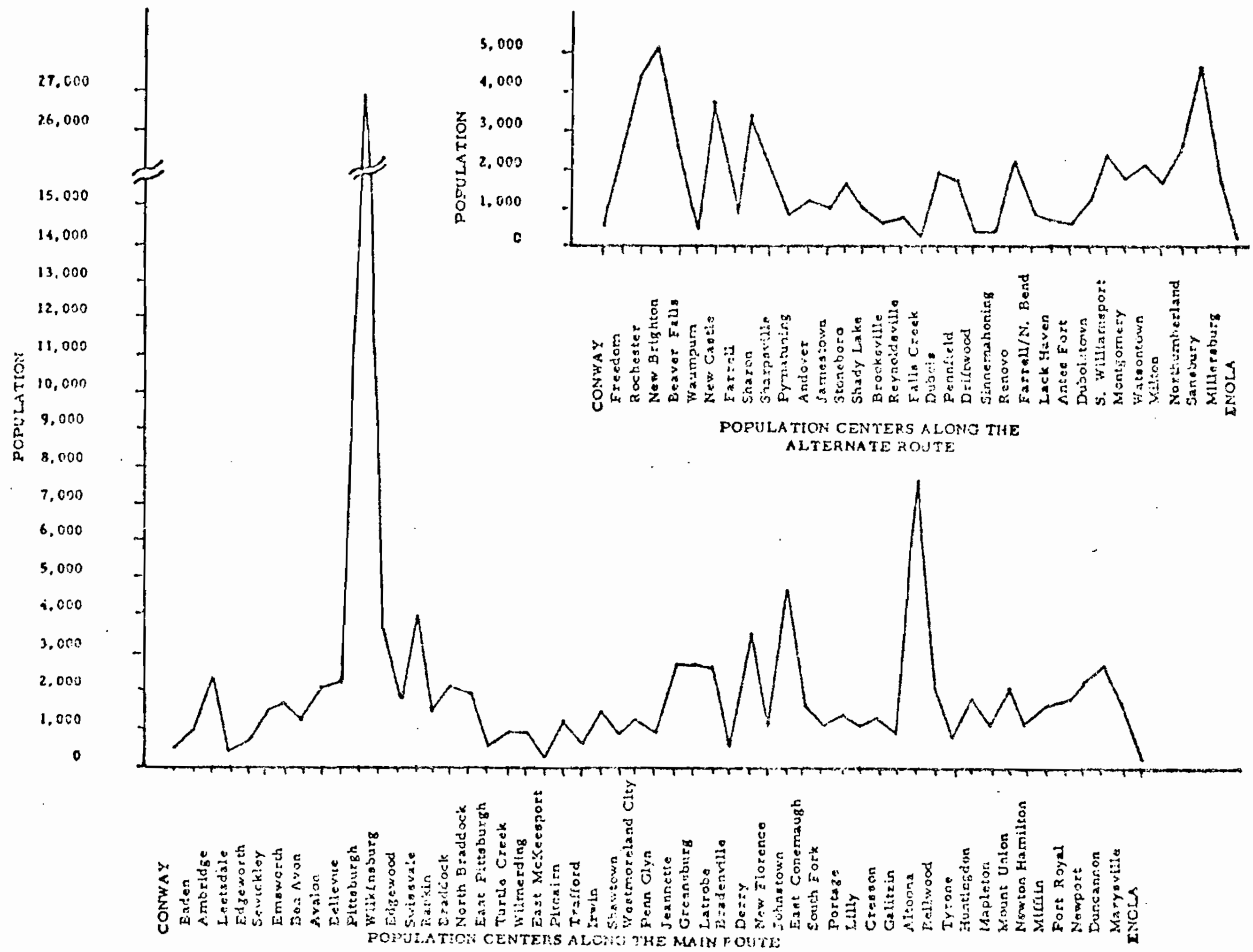


Table 20: Population Along Mainline from Conway to Enola Yard

Conrail Segment	Community (all within PA)	Population (within ½ mile band of track)	Percent Of Total
230-927	Conway to Pittsburgh	13,104	11
927-232	Pittsburgh	3,547	3
232-831	Pittsburgh	3,233	3
831-832	Pittsburgh	2,286	2
832-835	Pittsburgh	13,740	12
835-228	Pittsburgh to Pitcairn	22,526	19
228-243	Pitcairn to Radebaugh	8,488	7
243-237	Radebaugh to Latrobe	4,944	4
237-634	Latrobe to Derry	1,749	1
634-849	Derry to Conpit Jct.	2,948	3
849-238	Conpit Jct. to Conemaugh	6,614	6
238-239	Conemaugh to South Fork	831	1
239-644	South Fork to Sonman	3,092	3
644-285	Sonman to Cresson	2,290	2
285-294	Cresson to Altoona	6,492	5
294-295	Altoona to Tyrone	4,338	4
295-296	Tyrone to Huntingdon	1,561	1
296-297	Huntingdon to Mt. Union	3,095	3
297-298	Mt. Union to Lewistwon	2,560	2
298-877	Lewistown to Banks	9,809	8
877-301	Banks-West Enola	181	0
Total		117,425	100

Source: CONSAD Research Corporation

Figure 6: Representation of Population Along Main and Alternate Routes In the Pittsburgh to Harrisburg Case Study*



*Note: non-uniform horizontal scale

on HM traffic would be on this line segment (links 230-927-232-549-831-832-835-228-243-237-634-849).

Unlike the Indianapolis-Columbus case study, over 90 percent of all trains operating on the restricted trackage travel the entire line between Conway and Enola. Further, the only logical alternative routing for HM traffic is a line from Conway to New Castle, north to Dorset, then east to Newberry passing through Reynoldville and Driftwood, and finally south through Northumberland to Enola. Whereas there are a multitude of reroute possibilities for the first case study, the specifics of this site limit feasible reroutes to only one (links 218-219-821-820-653-641-857-858-878-301).

6.2 Prohibit Hazmat Traffic

Under the Prohibit option, all HM traffic which does not include that which originates or terminates on line would be restricted from moving on the mainline between Conway and Conpit and would be rerouted over the one designated alternative route described above. The methodology and assumptions for rerouting the HM traffic are identical to those described in Section 5.2.

As in the previous case study, HM was rerouted according to the four operating rules which are repeated below.

6.2.1 Operating Rules

<u>Operating Rule A</u>. Present train patterns and schedules will not be altered. HM traffic will be switched onto existing trains moving over the alternative route.

<u>Operating Rule B</u>. All HM traffic moving on the prohibited route must be routed on existing trains operating on the alternative route, but if a train on the prohibited route currently carries more than 20 percent HM, that train will be rerouted.

<u>Operating Rule C</u>. All HM must be rerouted on trains currently operating on the prohibited route so that upon rerouting (to the alternative route), the train will carry greater than 20 percent HM. Therefore, HM cars will wait in yards or junctions until a train (currently moving on the prohibited route) can be rerouted.

Operating Rule D. HM cars will be held in yards until a solid HM train of at least 50, but not more than 150, cars can be created.

The data on HM traffic used in the rerouting procedure is described in Section 5.2.3 and was collected for current train operations on the segment of trackage from Conway to Conpit. The data for this particular case study are presented in Table 21. The traffic was then rerouted using the same methodology and assumptions as those in the Indianapolis-Columbus case study; the costs under each operating rule were estimated.

6.2.2 Results

Changes in Operating Statistics. Table 22 summarizes the changes in operating statistics due to rerouting for each of the four Operating Rules. Under Operating Rule C (which calls for the holding of HM until a train having more than 20 percent HM can be rerouted) three of the six operating statistics (car-miles, gross ton-miles, and train-hours) show the greatest increases because trains with non-HM cars are rerouted. It should be noted that the results in this case study differ greatly from those in the Indianapolis-Columbus one where Operating Rule C had the least impact on the car-mile and gross ton-mile statistics due to the fact that the alternate route is shorter than the main route. In the Pittsburgh-Harrisburg case, however, the alternative route is longer.

Operating Rule D, involving the assembly of solid HM trains, produces the least total delay to traffic (in car-hours) with an increase of 2,456 car-hours for 88 affected HM cars, or a mean of 28 hours per car. Generally the delay is due to rerouting travel time for cars with less than the mean delay time and schedule differences for those with delays greater than the mean. Under Rule A, car-related statistics of car-hours and car switches show the greatest increases. This is due to the fact that rerouted HM cars must be held over (often for more than a day) in yards along the alternative route while waiting for a scheduled train to pick them up and move them further toward their destination. This is due to the fact that some segments of the alternate route carry very little scheduled traffic.

Table 21: Summary Measures of Current Operations on The Pittsburgh to Harrisburg Corridor

	Prohibited Portion From Pittsburgh To Conpit Junction	Mainline From Pittsburgh To Harrisburg
No. Trains		
All	59	183
HM	40	42
No. Cars		
All	5,987	14,987
HM	88	93
Gross Tons		
All	299,323	928,410
HM	9,231	9,832
Train-Miles		
All	9,240	12,152
HM	6,265	6,731
Car-Miles		
All	731,764	993,790
HM	13,782	14,906
Gross Ton-Miles		
All	46,877,000	65,906,000
HM	1,457,000	1,576,000

Table 22: Changes In Operating Statistics Due to Rerouting

Operating Rule		Changes in Operating Statistics: Train-Miles	Car-Miles	Gross Ton-Miles	Train-Hours	Car-Hours	Car Switches	Loco-Hours	Total Cars Rerouted	Total Haz Mat Cars Rerouted
A:	East	0	12,566	1,542,152	0	12,191	438	0	73	73
	West	0	2,580	511,700	0	5,385	105	0	15	15
	Total	0	15,136	2,053,852	0	17,576	543	0	88	88
B:	East	172	32,852	3,029,436	19	10,141	264	51.	191	73
	West	0	2,580	511,700	0	5,385	105		15	15
	Total	172	35,432	3,541,136	19	15,526	369	51.	206	88
C:	East	516	49,020	3,704,020	57	5,710	65	153	285	73
	West	172	8,256	759,036	20	1,104	10	54	48	15
	Total	688	57,276	4,463,056	77	6,814	75	207	333	88
D:	East	439	12,556	1,542,152	19	2,012	73	51	73	73
	West	439	2,580	511,700	20	444	15	54	15	15
	Total	878	15,136	2,053,852	39	2,456	88	105	88	88

Source: CONSAD Research Corporation, 1981.

*All values in this table (except those in the cars or Hazmat cars affected columns) represent net incremental changes relative to current operations. Any car which is rerouted is considered an affected car, even if the car is non-Hazmat.

Table 23: Changes in Daily Operating Costs for the Prohibit Policy

Operating Rules		Line Haul Costs							Car Costs			Switching Costs	Total Costs
				Equipment		Transportation			Non-HM				
		MOW	MOE	LOCO	CAB	CREW	FUEL	LOCO	Car	HM Car	Total	Total	
A.	East	2,621.66	0	0	0	0	6,106.92	0	0	7,558.42	7,558.42	5,277.90	21.656.
	West	869.88	0	0	0	0	2,026.33	0	0	3,338.70	3,338.70	1,265.25	7,500.
	TOTAL	3,491.55	0	0	0	0	8,133.25	0	0	10,897.12	10,897.12	6,543.15	29,065.
B.	East	5,150.04	1,188.52	834	52.25	1,191.11	11,966.57	472.47	2,378.12	2,403.05	4,781.17	3,181.20	28,848.
	West	869.89	0	0	0	0	2,026.33	0	0	3,338.70	3,338.70	1,265.25	7,500.
	TOTAL	6,019.93	1,188.52	834	52.25	1,191.11	14,022.90	472.47	2,378.12	5,741.75	8,119.87	4,446.45	36,348.
C.	East	6,296.83	3.565.49	2,503.95	156.75	3,573.33	14,667.92	1,417.42	2,520.42	906.79	3,427.21	783.25	36.392.
	West	1,290.36	1,188.52	878.58	55.00	1,253.80	3,005.78	497.34	227.04	213.90	440.94	120.50	8,731.
	TOTAL	7,587.20	4,754.08	3,382.53	211.75	4,827.13	17,673.70	1,914.76	2,747.46	1,120.69	3,868.15	903.75	45,123.
D.	East	262.06	3,033.49	834.65	52.25	1,191.11	6,106.92	472.47	0	1,247.44	1,247.44	879.65	14,080.
	West	869.89	3,033.49	878.58	55.00	1,253.80	2,026.33	479.34	0	275.28	275.28	180.75	9,070.
	TOTAL	1,131,95	6,066.98	1,713.23	107.25	2,444.91	8,133.25	969.81	0	1,522.72	1,522.72	1,060.40	23,150.

Operating Costs. The costing methodology described in Section 5.2.5 was applied to the changes in operating statistics. The increase in daily operating costs for line haul, car hire and switching are presented in Table 23.

Operating Rule C is the most costly with an increase of over $45,000 per day resulting from large increases in line-haul costs. The high relative cost of Operating Rule C in the Pittsburgh-Harrisburg case (in contrast to the first case study where it was the least costly of the operating rules under Prohibition) illustrates that the length of the alternative route is a critical variable governing the impact of the Rule.

Operating Rule D is the least costly. There are high volumes of HM in this corridor therby minimizing time involved in assembling HM trains. In addition, since the majority (over 90 percent) of HM traffic moves from Conway to Enola Yard, it is not necessary to drop off cars along the alternative route. Therefore, train delay and car hours are minimized. Because of the unique characteristics of this case study site, it is more efficient to create new trains than to switch the HM traffic from train to train on the alternative route.

Population Exposure. As in the Indianapolis-Columbus case study, CONSAD used the number of person-gross-tons per day as the measure of exposure as described in Section 5.1.2.

Table 24 presents the impact of the rerouting of Hm traffic on population exposure. The first column gives the absolute exposure on the mainline under both current and Prohibit operations, as well as the percent decrease in exposure due to the rerouting of traffic. The second column provides exposure levels for the alternative route which already includes some HM traffic. With the rerouting of HM off of the Conway to Conpit track segment, additional traffic will move on the alternative route. Column three presents exposure summary data. The Prohibit policy results in a net decrease of 347,000 person gross-tons.

Unlike the Indianapolis to Columbus case study site (see Table 13,

Table 24: Population Exposure from Conway to Enola Yard

	Population Exposure (Millons of Persons-Gross Tons)		
	Main	Alt	Total
Current Operations	1,065	138	1,203
Prohibit Operations	19*	837	856
Percent Change	-98%	+50%	-29%

*Exposure on the main line will not be reduced to zero due to the presence of on-line Hazmat deliveries which will continue to move even under the Prohibit policy.

Source: CONSAD Research Corporation.

p. 5.27), the reduction in exposure is the same for all operating rules since only one alternative route is used. Although the HM will be handled differently under each operating rule, it will move on the same alternative route (for each operating rule), thereby exposing the same number of people to the hazardous material traffic.

Figure 6 (page 6.6 -- above) provides a population profile along the main and alternative route. The highest population exists on the main route. Populations are less on the alternative route.

6.3 Reduce Speed Conway to Conpit

The methodology for estimating the impacts of reducing speeds from Conway to Conpit is explained in Section 5.3. Table 25 shows changes in operating statistics due to this option. Running time increases by 0.29 hours resulting in an increase of 719 car-hours, and ten train-hours per day.

Having applied the costing methodology to the changes in line-haul, car-hire, and switching presented in Table 25, the changes in costs are shown in Table 26. If the reduced speed option is implemented, the daily costs to Conrail will be approximately $1,500. Of that amount, over 87 percent is attributable to changes in line haul costs.

Under this option, costs would increase and exposure levels would remain unchanged since HM continues to move on the same route. Although population may be exposed for a longer period of time under this option, accident severity is expected to be less than under current operations.

6.4 Summary

The results of CONSAD's analysis for the Pittsburgh-Harrisburg case show that the reduced speed policy is the least costly alternative at $1,545 per day. Of the Prohibit policies, Operating Rule D is the least costly, at $23,150 per day, over 14 times more expensive than reduced speed.

The Prohibit policies do, however, reduce exposure by 347 million person-gross-tons. Although the improvement in safety under reduced speed has not been quantified, this option is attractive due to its relatively low cost.

Table 27 compares the changes in daily operating statistics for each alternative while Table 28 presents the cost increases caused by these operating statistic changes.

Table 25: Changes in Operating Statistics

Link	Length	Speed Limit	Track Class	Average Running Speed	Average Running Time (hrs.)	Speed Limit	Track Class	Average Running Speed	Average Running Time (hrs.)	Change in Running Time	Change in Car-Hours	Change in Train Hours (Crew &Caboose)	Change in Locomotive Hours
230-927	18	50	IV	45	.400	40	III	40	.450	.050	186.45	2.5	6.75
927-232	2	40	III	40	.050	25	II	25	.080	.030	104.16	1.35	3.64
232-549	1	30	III	30	.033	25	II	25	.040	.007	26.27	.36	.96
549-831	1	30	III	30	.033	25	II	25	.040	.007	25.94	.35	.94
831-832	1	15	II	15	.067	10	I	10	.100	.033	74.97	1.06	2.85
832-835	5	30	III	25	.200	25	II	25	.200	0	0	0	0
835-228	10	45	III	45	.222	40	III	40	.325	.036	63.62	.97	2.62
228-243	13	50	IV	45	.289	40	III	40	.325	.036	65.99	.97	2.62
243-237	13	50	IV	45	.289	40	III	40	.325	.036	64.37	.97	2.62
237-634	5	50	IV	45	.111	40	III	40	.125	.014	24.67	.38	1.02
634-849	17	50	IV	45	.378	40	III	40	.425	.047	82.72	1.22	3.30
Total					2.07				2.36	.29	719.16	10.08	27.19

Source: CONSAD Research Corporation, 1981.

Table 26: Changes in Daily Operating Costs for Reduced Speed Policy From Conway Yard to Conpit Junction

Conway to Conpit	TOTAL LINE HAUL COSTS								CAR COSTS				
	Maintenance of Way	Maintenance of Equipment	Locomotive Costs	Caboose Costs	Crew Costs	Fuel Costs	Locomotive Servicing	Total	Per Hour	Per Mile	Total	Switching Costs	Total Costs
East	0	0	242.91	15.18	346.05	0	137.51	741.65	99.60	0	99.60	0	841
West	0	0	199.47	12.54	285.87	0	112.91	610.79	92.96	0	92.96	0	703
TOTAL	0	0	442	28	632	0	250	1,352	193	0	193	0	1,545

Source: CONSAD Research Corporation, 1981.

Table 27: Changes in Daily Operating Statistics for the Pittsburgh to Harrisburg Case Study

	DAILY CHANGES IN OPERATING STATISTICS					
Policy	Change in Train-Miles	Change in Car-Miles	Change in Gross ton-Miles (10^3)	Change in Train-Hours	Change in Car-Hours	Change in Car Switches
Prohibit						
Operating Rule A	0	15,136	2,054	0	17,576	543
Operating Rule B	172	35,432	3,541	19	15,526	369
Operating Rule C	688	57,276	4,463	77	6,814	75
Operating Rule D	878	15,136	2,054	39	2,456	88
Reduced Speed	0	0	0	10	719	0

Source: CONSAD Research Corporation, 1981.

Table 28: Changes in Daily Operating Costs of Each Policy (1979 Dollars) for the Pittsburgh to Harrisburg Case Study

Policy	Line Haul Costs	Car Costs	Switching Costs	Total Costs
Prohibit				
Operating Rule A	11,625	10,897	6,543	29,065
Operating Rule B	23,782	8,120	4,446	36,348
Operating Rule C	40,351	3,868	904	45,123
Operating Rule D	20,567	1,523	1,060	23,150
Reduced Speed	1,352	193	0	1,545

7.0 COMPARISON OF CASE STUDY RESULTS AND CONCLUSIONS

Due to the variety of geography, traffic patterns, and train operations on the national railroad system, great care must be taken in generalizing the findings of these two case studies. Nevertheless, it is useful to compare the impacts on railroad operations and costs observed in these two sites.

7.1 Definition of Unit Measures of Impact

The magnitudes of changes in operating statistics and costs of the Prohibit and Reduce Speed Options are given in Chapters 5 and 6. To evaluate these magnitudes, it is necessary to reduce them to unit measures. However, there are three possible bases by which to derive such measures. The first basis is all cars moving over the restricted high population density segment. However, under certain of the Prohibit Options only a portion of the traffic would be affected directly. Therefore, the second possible basis is the number of affected cars. Finally, the third basis for deriving unit measures is the number of HM cars moving daily over the restricted segment.

The number of cars in each of the three categories for the two case studies is shown in Table 29. In deriving unit measures of impact, the distinction must be made as to whether the basis is all cars, referred to as "per-car"); only cars which are affected, either by rerouting or reducing speed ("per-affected-car"); or only HM cars ("per-affected-HM-car"). The comparisons which are made later in this chapter are careful to distinguish among the three bases.

Table 29: Number of Cars Operated Daily on Restricted Segment

	Total Cars	Hazardous Materials Cars
Indianapolis-Columbus:		
Avon-Union City		
Current Operations	2,622	193
Affected Traffic Under:		
Prohibit A	193	193
B	471	193
C	541	193
D	193	193
Reduce Speed	2,622	193
Pittsburgh-Harrisburg:		
Conway-Conpit Junction		
Current Operations	4,241	88
Affected Traffic Under:		
Prohibit A	88	88
B	206	88
C	333	88
D	88	88
Reduced Speed	4,241	88

7.2 Baseline Operations

In order to draw conclusions, it is also necessary to have clear definition of measures of performance of the "Baseline", i.e., the pattern of traffic and operations which exists in the absence of any restrictions as to handling of HM traffic. This issue raises a number of significant methodological questions. The original concept of the study focused on rerouting traffic moving on a mainline corridor between two major railroad classification yards. However, since HM traffic of interest often originates prior to one of the major classification yards and terminates beyond the second, carriers are likely to reroute prior to the restricted track segment. The traffic data used in the two case studies did not discriminate between traffic which originated or terminated at the classification yards defining the corridor from that which moves on or off prior to or after the yards of interest. Therefore, the base case could not, necessarily, incorporate traffic movements from origin to destination.

The definition of baseline traffic used by CONSAD focused on the points between which the rerouting diverges from the current route and converges back onto that route. Any change in operational measures which occurs with rerouting can be compared with this baseline measure.

For the Pittsburgh-Harrisburg case, the point of route divergence is at Conway Yard and convergence is at Enola. For the Indianapolis-Columbus case, a much more complex situation exists since the affected trains have numerous origin and destination combinations.

Table 30 gives the baseline daily operating statistics for the trains and traffic which would be affected by restrictions. It also provides an estimate of the operating costs for the traffic of interest. Note that the statistics provided do not account for movement between origin and destination points, but rather between points of route divergence and convergence.

Table 30: Current Daily Operating Statistics

Current Operations	Number of Cars	Train-Miles	Car-Miles	Gross Ton-Miles (1000's)	Train-Hours	Car-Hours	Total Operating Costs
Indianapolis-Columbus							
Eastbound	1,287	1,870	131,845	8,334	106	7,059	$ 80,247
Westbound	1,335	1,429	113,485	6,299	72	5,565	$ 60,353
Total	2,622	3,299	245,330	14,633	178	12,624	$140,600
Pittsburgh-Harrisburg							
Eastbound	2,795	4,982	369,664	30,163	196	13,069	$249,641
Westbound	3,192	4,258	362,100	16,714	150	11,302	$160,173
Total	5,987	9,240	731,764	46,877	346	24,371	$409,814

Source: CONSAD Research Corporation.

7.3 Comparison of Case Study Results

7.3.1 Operating Statistics

Operating statistics for car-miles, car-hours, and car-switches for the baseline and under restrictions on HM, for the two case studies, are given in Table 31. Both totals and unit measures are given. The unit values which represent the least adverse impact (increase) in the operating statistics are highlighted in the table. In both cases, the Reduce Speed restriction results in the least impact. For the Prohibit restriction, Operating Rule C shows the least impact for all measures in the Indianapolis-Columbus case and the greatest for car-miles in the Pittsburgh-Harrisburg case.

7.3.2 Operating Cost

The key measure of impact from the viewpoint of the railroad companies is operating cost. The comparative summary of unit cost impacts is shown in Table 32 with the lowest cost impacts highlighted. The Reduce Speed alternative is the least costly in all measures. Of the Prohibit restrictions, Operating Rule C is least costly for Indianapolis-Columbus and the most costly in the Pittsburgh-Harrisburg case. This again illustrates that it is difficult to predict the impact of an operating rule on cost without knowing the specific alternate route which will be chosen.

7.3.3 Population Exposure

A comparision of population exposure in the two cases is given in Table 33. It shows that the Prohibit alternative in the Pittsburgh-Harrisburg case promises a greater degree of reduction in exposure than was found in the Indianapolis-Columbus case study. For Operating Rules C and D for the Indianapolis-Columbus case, there is virtually no exposure reduction. Although trains are rerouted away from the population concentration between Avon and Union City over the best available alternative, the overall population exposure remains constant. However, there are less very highly populated areas along the alternative routes as shown by the population distribution profile on pages 5.25 and 5.26.

Table 31: Comparison of Unit Operating Statistics Between Case Studies

	CAR-MILES				CAR-HOURS				CAR-SWITCHES			
	Total	Per Car	Per Affected Car	Per Haz-Mat Car	Total	Per Car	Per Affected Car	Per Haz Mat Car	Total	Per Car	Per Affected Car	Per Haz-Mat Car.
Indianapolis-Columbus												
Baseline	245,330	94	94	94	12,624	4.8	4.8	4.8	*	*	*	*
Prohibit A	258,340	98	161	161	23,163	8.8	59.4	59.4	477	0.18	2.5	2.5
B	254,310	97	113	140	18,473	7.0	17.2	35.1	283	0.11	0.6	1.5
C	246,310	[94]	96	99	14,929	5.7	9.1	16.7	132	0.05	0.2	0.7
D	247,889	95	107	107	15,203	5.8	18.2	18.2	223	0.09	1.1	1.1
Reduce Speed	245,330	[94]	[94]	[94]	13,580	[5.2]	[5.2]	[9.7]	0	[0]	[0]	[0]
Pittsburgh-Harrisburg												
Baseline	669,529	158	158	158	20,890	4.9	4.9	4.9	*	*	*	*
Prohibit A	684,665	161	330	330	38,466	9.1	204.6	204.6	543	0.12	6.2	6.2
B	704,961	166	330	561	36,416	8.6	80.3	181.3	369	0.09	1.8	4.2
C	726,805	171	330	809	27,704	6.5	25.4	82.3	75	0.02	0.2	0.8
D	684,665	161	330	330	23,346	5.5	32.9	32.9	88	0.02	1.0	1.0
Reduce Speed	669,529	[158]	[158]	[158]	21,604	[5.1]	[5.1]	[13.0]	0	[0]	[0]	[0]

*Assumed to be zero.

Table 32: Comparison of Unit Operating Costs Between Case Studies

	LINE HAUL COSTS				CAR COSTS				SWITCHING COSTS				TOTAL COSTS			
	Total	Per Car	Per Affected Car	Per Haz Mat Car	Total	Per Car	Per Affected Car	Per Haz Mat Car	Total	Per Car	Per Affected Car	Per Haz Mat Car	Total	Per Car	Per Affected Car	Per Haz Mat Car
[illegible]																
[illegible]	$127,630	$48.68	$ 48.68	$ 48.68	$12,970	$ 4.95	$ 4.95	$ 4.95	*	*	*	*	$140,600	$53.63	$ 53.63	$ 53.63
[illegible] A	131,811	50.27	70.34	70.34	16,119	6.15	21.27	21.27	5,747	2.19	29.78	29.78	153,677	58.61	121.39	121.39
B	131,711	50.23	57.34	69.83	14,792	5.64	14.39	14.39	3,410	1.30	7.24	17.67	149,913	57.18	73.40	101.88
C	129,278	[49.31]	51.73	[57.22]	13,586	5.18	6.09	8.14	1,592	.61	2.94	8.25	144,456	55.09	60.76	73.61
D	130,772	49.87	64.96	64.96	13,718	5.23	8.83	8.83	2,691	1.03	13.94	13.94	147,181	56.13	87.73	87.73
[illegible]	129,281	[49.31]	[49.31]	57.23	13,209	[5.04]	[5.04]	[6.19]	0	[0]	[0]	[0]	142,490	[54.35]	[54.35]	[63.42]
[illegible]																
[illegible]	$271,570	$64.11	$ 64.11	$ 64.11	$33,204	$7.83	$ 7.83	$ 7.83	*	*	*	*	$305,074	$71.93	$ 71.93	$71.93
[illegible] A	283,495	66.85	196.21	196.21	44,101	10.40	131.66	131.66	6,543	1.54	74.35	74.35	334,139	78.79	402.21	402.21
B	295,651	69.71	179.55	334.35	41,324	9.74	47.25	100.10	4,446	1.05	21.58	50.52	341,422	80.50	248.38	484.98
C	312,221	73.62	185.28	522.64	37,072	8.74	19.45	51.78	904	0.21	2.71	10.27	350,197	82.57	207.43	584.69
D	292,437	68.95	297.82	297.82	34,727	8.19	25.14	25.14	1,060	0.25	12.05	12.05	328,224	77.39	335.00	335.00
[illegible]	273,222	[64.42]	[64.42]	[79.47]	33,397	[7.87]	[7.87]	[10.02]	0	[0]	[0]	[0]	306,619	[72.30]	[72.30]	[89.44]

Table 33: Comparison of Population Exposure Effects Between Case Studies

	Exposure (Millions of Person-Gross-Tons)	
	Total	Percent Change
Indianapolis-Columbus		
Baseline	542	———
Prohibit A	496	-8.5
B	486	-10.3
C	542	0
D	541	~0
Reduce Speed	542	0
Pittsburgh-Harrisburg		
Baseline	1,203	———
Prohibit A,B,C or D	856	-28.8
Reduce Speed	1,203	0

3. Carriers are likely to react to a Prohibition Policy by choosing the least cost alternative since all result in significant increases. In both case studies, forming solid HM trains was a relatively inexpensive option. The risk implications of a railroad choosing this strategy, however, have not been addressed in this study.

4. The impacts of an operating rule cannot always be predicted, as illustrated by Operating Rule C which was the least costly of the Prohibition options in the Indianapolis-Columbus case and the most expensive in the Pittsburgh-Harrisburg one. The critical determinant of the cost impact appears to be the availability and choice of alternate routes, of which there may be several.

5. A change in route does not necessarily lead to a change in population exposure. Unless an improvement in safety through population exposure reduction outweighs the costs, a Prohibition Policy may not be worth implementing.