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JOURNAL OF THE TRANSPORTATION RESEARCH FORUM

WIRELESS COMMUNICATIONS AND FREEWAY INCIDENT REPORTING

by ***Renatus N. Mussa,**** ***Judson S. Matthias,***** *and* ***Jonathan E. Upchurch*******

ABSTRACT

The research study evaluated a driver-initiated incident detection system that is based on the principle that drivers will report incidents to the responsible highway agency by using in-vehicle communications equipment. A FRESIM model was used to simulate four types of incidents occurring in light, moderate, and congested traffic flow. The results showed that all simulated incident types occurring in light, moderate, or congested traffic were detected quickly with high probability of detection. The performance of the proposed Driver-based Incident Detection System was compared to that of the conventional Highway-based Incident Detection System that relies on loop detectors and the California algorithm. The comparison indicated that the Driver-based Incident Detection System was superior as it detected most incidents in a shorter time. This paper also describes the wireless communication technologies that can support the Driver-based Incident Detection System and how the system can be incorporated into evolving Intelligent Transportation Systems.

INTRODUCTION

The continued improvement in wireless communications and the desire to solve urban transportation problems by advanced technologies is creating new avenues for bettering incident detection on urban freeways. A freeway incident is defined as any extraordinary event that causes congestion or delay by restricting normal traffic flow or posing safety hazards to the freeway users. Thus, incidents include events such as disabled vehicles on traveled way or shoulders, accidents, spilled loads, debris on the roadway, etc.

The Intelligent Transportation Systems (ITS) technologies that are being implemented by many highway agencies in the U.S. can enable drivers to initiate an incident detection process. Using wireless communications, drivers can communicate, by voice or digitally, either directly or indirectly, the location of an incident to the center. The wireless communications technologies that can be used by drivers to report an incident and its location include cellular telephones, vehicle-to-roadside communications (VRC) system, and Global Positioning System (GPS).

Cellular telephones have been used – on a limited basis – for many years to report incidents. Increased usage in recent years is due to many highway agencies establishing cellular call-in programs to facilitate incident reporting. Some of the cellular call-in telephone numbers around the United States are *999 in Chicago, Illinois; #777 in Maryland and Northern Virginia; *FHP in Florida; cellular 911 in Los Angeles County, and Bay Area, California (Christenson, 1995). The efficacy of a cellular telephone reporting system can be further enhanced with the improvement of digital and geolocation technologies. In recent years, cellular carriers have been changing from analog to digital technology. Likewise, as a result of the Federal Communications Commission (FCC) mandate that the cellular industry must be able to trace the origin of emergency cellular calls by year 2001, extensive geolocation experimentations are now being undertaken by the cellular industry. One example of a cellular location method under development is the triangulation method that uses at least three cellular antennas to determine the origin of the call by calculating very precisely the time a signal arrives at each antenna. This triangulation system was field tested in Washington, D.C. The system after automatically detecting that a phone call was being initiated located the vehicle position on the freeway within a matter of a few seconds. The system then periodically plotted the car's location in order to assess speed and advise travelers of travel speed (Robinson *et al.*, 1994).

Once an incident is reported to a highway agency's Traffic Operations Center, the driver's vehicle location can be automatically triangulated and displayed to an operator on a freeway electronic wall map. The operator can then zoom in using a closed circuit television (CCTV) camera to verify the incident. The simplicity of using digital and geolocation technologies would be that a driver the operator to describe the location of the incident, and correspondingly a highway agency does not have to hire many operators to answer calls.

While cellular telephone systems allow drivers to communicate directly to the highway agency, a vehicle-to-roadside communications (VRC) system represents an indirect method of incident reporting. A VRC system utilizes radio frequency communications between a tag (sometimes called a transponder) installed in a vehicle and a roadside reader. Where the VRC system is used for electronic toll collection purposes or commercial vehicle operations purposes, the readers are usually placed in strategic locations such as toll plazas, truck checkpoints, and motor carrier terminals. Tags, usually about the size of a bar of soap, contain information such as the user's toll collection account, fleet and driver information for weigh station bypass, or details about the contents of a shipment. The reader captures information contained in the tag and downloads it to a host computer by means of wirelines, wireless spread spectrum modems, or other communications infrastructure.

The VRC system can also be used to track vehicles for the purpose of collecting traffic information. Indeed, such a system has been installed on Interstate 10, Interstate 45 and US Highway 290 in Houston, Texas. The system is comprised of 161 roadside readers installed about every three to four miles in the outlying portion of the urban area and at shorter spacings (i.e. one mile apart) near Houston's central business district. In 1995 there were over 26,000 tags in use in the Houston urban area (Larue, 1995). As the tags pass each reader, information on location and time are collected. This information is used to assess delays and travel speeds. Travelers are then informed of traffic conditions through the use of variable message signs or local commercial radio reports.

A VRC system, such as this one installed in Houston, can also be used for incident detection. For vehicles installed with tags that have emergency messaging system activation buttons, a driver can activate the system when he or she sees an incident. When a button is activated, a precoded digital signal is relayed to the roadside reader and then to the highway agency through landlines or wireless connections. Since the location of the reader is known, the highway agency operator can pinpoint exactly where the message originated and take appropriate action – such as verifying the incident through a CCTV camera or sending a crew to the site.

The Global Positioning System (GPS) is applications including tracking public transit fleets, rail cars, long haul motor carriers, and for in-vehicle navigational systems. In the future, the GPS system is expected to be used extensively for "May Day" or emergency locating systems. When a vehicle is equipped with a two-way radio, a modem, or a cellular phone, the GPS can be used to deliver location information of an incident.

Certainly, wireless communications technologies are changing very fast and it is reasonable to fathom that in the future there will be numerous technologies that could enable a driver to report incidents involving themselves or others. An extensive discussion on wireless communications and incident detection can be found in Mussa (1996).

This paper explores the effectiveness of a Driver-based Incident Detection System that relies on wireless communications technologies. The hypothesis of the research was that a driver-initiated incident detection process would improve detection of random freeway incidents on urban and inter-urban freeway networks. This hypothesis is supported by the good results of the cellular call-in program in Chicago where it was found that major incidents are frequently being detected through this program (McLean, 1991). The hypothesis is also supported by a widespread acceptance of these technologies and the prospect that in the future many drivers will be equipped with one form or another of a wireless communications system. This paper also compares the detection performance of the proposed Driver-based Incident Detection System to that of the conventional Highway-based Incident Detection System.

RESEARCH APPROACH

An analytical method was used to assess the ability of a driver-initiated detection process to improve two incident detection parameters – the probability of detection and detection time. Two models were sequentially used. The first model was a simulation model, which generated the required incident data. The second model was a probability model that was applied to the generated incident data to determine the measures of effectiveness mentioned above, i.e. probability of detection and detection time. A discussion of two models and values used in this study follows.

Simulation model

The FREeway SIMulation (FRESIM) program (Halati *et al.*, 1990) was used to simulate data of individual vehicles arriving on the upstream side of an incident. Four types of incidents occurring in light, moderate, and congested traffic flow were simulated on a straight section of a three-lane one-direction freeway. The types of incidents simulated were: a shoulder incident, an incident blocking one lane, an incident blocking two lanes, and an incident blocking all three lanes. The volumes chosen for light, moderate, and congested traffic flow were *700*, *1550*, and *2000* vehicles per hour per lane, respectively.

FRESIM is a microscopic, time stepping stochastic freeway simulation model. Incidents occurring in the traveled way are simulated by decelerating one vehicle to a complete stop. The user specifies a time, a lane, and a longitudinal position in that lane. The vehicle, which next crosses that position in the designated lane after the designated time, is the incident vehicle, which is decelerated to a stop. The built-in mechanism for lane changing causes the congestion to spread to the other lanes (Halati *et al.*, 1990).

Shoulder incidents are simulated by reducing the capacity of the affected lanes. In a shoulder incident situation, a typical driver will slow down as the incident comes into view. The driver then maintains this reduced speed until he or she passes the incident location, whereupon the driver accelerates back to or even exceeds his or her upstream speed. This phenomenon is commonly called "rubbernecking" or "gawking". FRESIM simulates shoulder incidents by letting the user specify a "rubbernecking" factor that is used to increase the distance at which vehicles follow each other. Consequently, the speeds of all vehicles traversing a segment in the affected lanes are reduced; in so doing, the capacity of the affected lanes is also reduced. In this simulation, a rubbernecking factor of 10 percent was used to reduce by 10 percent the capacity of the through lanes for the whole period of incident simulation.

Probability Model

A probability model was applied to the vehicle arrivals data generated by the simulation model to determine the incident detection time and the probability of detection. The detection time (t) was defined as the elapsed time from the occurrence of an incident to the time the incident is reported to the highway agency. The assumption was that a freeway incident on a relatively straight section could be fairly visible to an approaching motorist within 100 feet, measured from the upstream end of the incident. Evidently, the greater the visible distance, the better will be the detection performance. Thus, time (t) is a sum of two components:

$$t = t_1 + t_2 \qquad \text{(i)}$$

The component t_1 is the time lapse from the start of an incident to the time a driver arrives within the visible distance of an incident. In this simulation it was assumed that an incident would be fairly visible to an arriving driver within 100 feet. The component t_2 is the time taken by the driver to activate the in-vehicle communication device to transmit a message or a coded signal to the highway agency. This time (t_2) depends on the type and set-up of the communication device the driver has in the vehicle. In case of a cellular telephone with a preprogrammed (highway agency) telephone number or in case of a VRC system, the time t_2 is approximately zero. For a non-preprogrammed telephone number, t_2 could be a few seconds up to a minute. In this modeling, incident reporting was assumed to be by digital messaging with a preprogrammed telephone number. Hence, $t_2 = 0$. (The time it takes for a digital signal to travel to the highway agency's Traffic Operations Center is assumed to be negligible. The time it takes for the operator to orient the CCTV camera to verify the incident or the time it takes to respond to the incident site are part of the post-detection activities and was not a subject of this research).

A binomial probability model was used to determine the probability of incident detection. The binomial model and its parameters are defined below.

$$P(X=x) = \binom{n}{x}^{x} \tilde{p}(1-\tilde{p})^{n-x},$$

$$x = 0, 1, 2, \ldots, n \qquad \text{(ii)}$$

$P(X=x)$ = the probability of arrival within the 100-feet detection zone in time t_1 of exactly x drivers who would report the incident.

n = the total number of drivers (with and without in-vehicle communication devices) arriving within the detection zone in time t_1. The FRESIM model generated this data as was previously discussed.

$\tilde{p}$ = proportion of drivers who are willing to report the incident.

Thus, $\tilde{p}$ is a product of two probabilities: the probability of an arriving driver having a communication device, p_1, and the probability of an arriving driver reporting the incident given that the driver has a communication device, p_2. The probability (p_2) of a driver using the in-vehicle communication device to report the incident represents the reporting propensity of drivers in the general driving public. A driver's willingness to report an incident can be influenced by factors such as the driver's awareness of why, how, and who to report to, whether the driver is the one involved in the incident, the driver's engagement with other tasks, the severity of the incident, how the driver perceives the effect of the incident on his or her travel time, driver's perception of privacy, etc. Though a literature search did not reveal any study documenting the relationship between reporting propensity and the above factors, the experience in Chicago shows that launching a publicity campaign can raise reporting propensity. When the Illinois Department of Transportation launched a publicity campaign comprised of freeway signing, cellular phone company billing notices, and video/radio advertising, they found that cellular calls to the *999 Dispatch Center increased significantly (McLean, 1991).

The probability of incident detection was equated to the probability of a driver reporting an incident. For an incident to be detected only one driver who has a communication device and is willing to use it has to arrive within the visible zone of an incident, defined previously as a 100-foot zone. Thus, the probability of detection is equal to the probability of arrival of one or more drivers willing to report an incident and was calculated from the cumulative binomial distribution as follows:

$$P(X \geq 1) = 1 - (1 - \tilde{p})^n \qquad \text{(iii)}$$

where all the parameters are as defined in equation (ii).

RESULTS AND DISCUSSION

The analysis of the results involves determining how the performance of the Driver-based Incident Detection System changes by varying the levels of various input variables. Some input variables were varied during the FRESIM simulation while other input variables were varied while applying the probability model on the simulation data. The following sections discuss the results from the sequential application of the two models. Of importance was the influence on detection performance by the following factors: (1) increasing proportion of ownership of in-vehicle communication medium, (2) incident type, and (3) the prevailing traffic volume at the time of the incident.

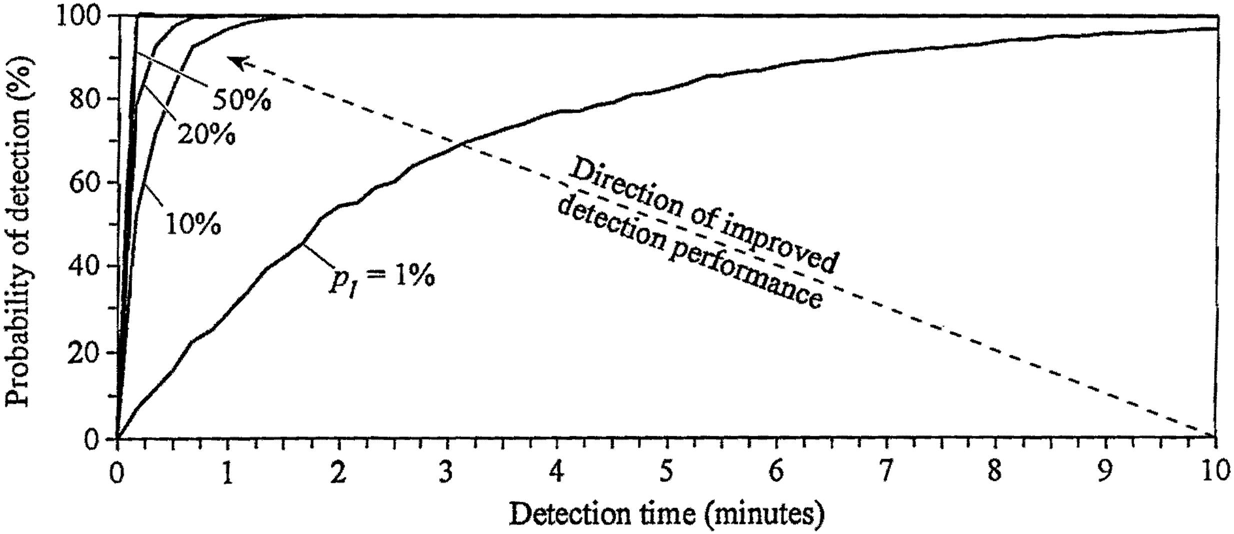
Growth of Ownership of Communication Device

Figure 1 shows the influence of the growth of ownership of in-vehicle communication devices on incident detection performance for a shoulder incident occurring in light traffic *(V=700 veh/hr/lane)*. The reporting propensity (p_2) was set at 100 percent. This figure reveals that there is a significant improvement in detection performance with an increase in ownership of in-vehicle communication devices (p_1). For instance, when 10 percent or more of drivers own an in-vehicle communication device, all incidents are assured of detection in less than a minute.

The same results were found for all four simulated incident types and for all three simulated traffic flow levels. The improvement in detection performance due to the growth of ownership of in-vehicle communication devices is particularly encouraging since the 1996 Cellular Telecommunication Industry Association (CTIA) statistics show that there was an 18 percent growth in cellular telephone ownership in the United States between 1994 and 1995 (CTIA, 1996). At the end of 1995, there were 33.8 million cellular telephone users in the U.S.; approximately one cellular telephone user per five licensed drivers. If this ratio were to be maintained in real life on a freeway, Figure 1 shows that a 100 percent detection rate in less than 40 seconds is attainable as long as drivers are willing to report incidents.

Further analysis was conducted to assess how drivers' willingness to report incidents affects the detection performance. This was achieved by setting values of p_2 at 20, 40, 60, 80, and 100 percent. Because of interchangeability between p_1 and p_2 (recall that $\tilde{p} = p_1 \times p_2$), the curves produced had trends similar to Figure 1. The analysis showed that the direction of improved detection performance was also the direction of increased driver reporting propensity.

The degree of reporting propensity can be improved by a publicity campaign soliciting support from the public to report freeway incidents. Previous experience has shown that a good publicity campaign can result in higher incident reporting. Following a publicity campaign, the Illinois Department of Transportation (IDOT) received 115,845 cellular calls reporting freeway incidents



Probability of detection (%)
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
Detection time (minutes)
50%
20%
10%
$p_l = 1\%$
Direction of improved
detection performance

and other non-freeway incidents in a one-year period. IDOT found that over 95 percent of all incoming calls were not from the involved motorist, but rather from "good Samaritans". Despite having a Highway-based Incident Detection System, IDOT found that frequently cellular calls were the first notification of major incidents on the Chicago freeway system (McLean, 1991).

The "good Samaritan" factor experienced in Chicago is particularly promising because it shows that motorists are willing to report incidents even if an incident does not involve their own vehicle. This suggests that a good publicity campaign can have a positive influence on the detection performance of a Driver-based Incident Detection System.

Incident Severity

Figure 2 illustrates the effect of different incident types on detection performance of this system. The values used in deriving Figure 2 are as shown below:

	V	P_1	P_2
Shoulder incident	2,000 veh/hr/lane	20%	10%
Incident blocking one lane	2,000 veh/hr/lane	20%	15%
Incident blocking two lanes	2,000 veh/hr/lane	20%	25%
Incident blocking all lanes	2,000 veh/hr/lane	20%	95%

The congested traffic level (i.e., V=2,000 veh/hr/lane) was chosen because it is in congested traffic conditions that quicker detection of incidents is of paramount importance. The proportion of drivers with an in-vehicle communication device in the general driving public (p_1) was chosen as 20 percent (or 1 out of 5) to mirror the 1996 *CTIA* statistics that showed that there was one cellular telephone user per five licensed drivers.

A literature search did not reveal any study documenting the relationship between the severity of an incident and the drivers' reporting propensity (p_2). Therefore, the above p_2 values are arbitrary but are based on the notion that severe incidents (e.g., an incident blocking all lanes) would generate more calls than less severe incidents (e.g., a disabled vehicle on the shoulder).

Figure 2 shows that the probability of detection increases logarithmically with the passage of time and approaches 100 percent asymptotically. The probability of detection remains high for all incident types even when the drivers' reporting propensity is low. The figure shows that over 80 percent of all four incident types can be detected in less than one minute. Further analysis of the detection performance at moderate flow (V=1,550 *veh/hr/lane*) and light flow (V=700 *veh/hr/lane*) showed that the detection performance was comparable to that of Figure 2 except for a slight decrease in the probability of detection with the decrease in traffic volume. This phenomenon can be explained by the fact that as the traffic volume decreases fewer vehicles pass the incident. Thus, the likelihood of a driver with a communication device passing the incident is also smaller, hence the lower probability of detection.

The results in Figure 2 when analyzed in combination with those of Figure 1 suggest that the continued growth in ownership of in-vehicle communication devices could have a significant impact on incident detection on freeways. Unlike current detection systems which detect some incidents some of the time at certain traffic flow volumes, this system has the potential of performing well for all incident types occurring across all traffic flow volumes.

Comparison Between Driver-based and Highway-based Incident Detection

The automatic incident detection system, which for the purpose of this paper is called *Highway-based Incident Detection System*, started in the early 1960s following the advent of vehicle detection systems such as loop detectors. In this system, vehicle detectors electronically monitor the freeway traffic flow continuously. The detector data is fed to a computer incident detection algorithm that checks for the probable presence of an incident.

The detection performance of the Driver-based Incident Detection System was compared to that of the conventional Highway-based Incident Detection System that uses the California algorithm for incident detection. It is noteworthy that some highway agencies in the U.S. use different detection algorithms, but most agencies use a variation of the California algorithm. Figure 3 shows the result of this comparison.

It is evident from Figure 3 that the Driver-based Incident Detection System is superior both in the detection rate and detection time. The maximum achievable detection rate by the Highway-based Incident Detection System is about 50 percent (at a false alarm rate of 1.00 percent) while a 100 percent detection rate is achievable by the Driver-based Incident Detection System. The detection rate of the Highway-based Incident Detection System is even lower at lower false alarm rates. False alarm

Figure 2. Railroad Pricing with a Natural Monopoly and with Intermodal Competition

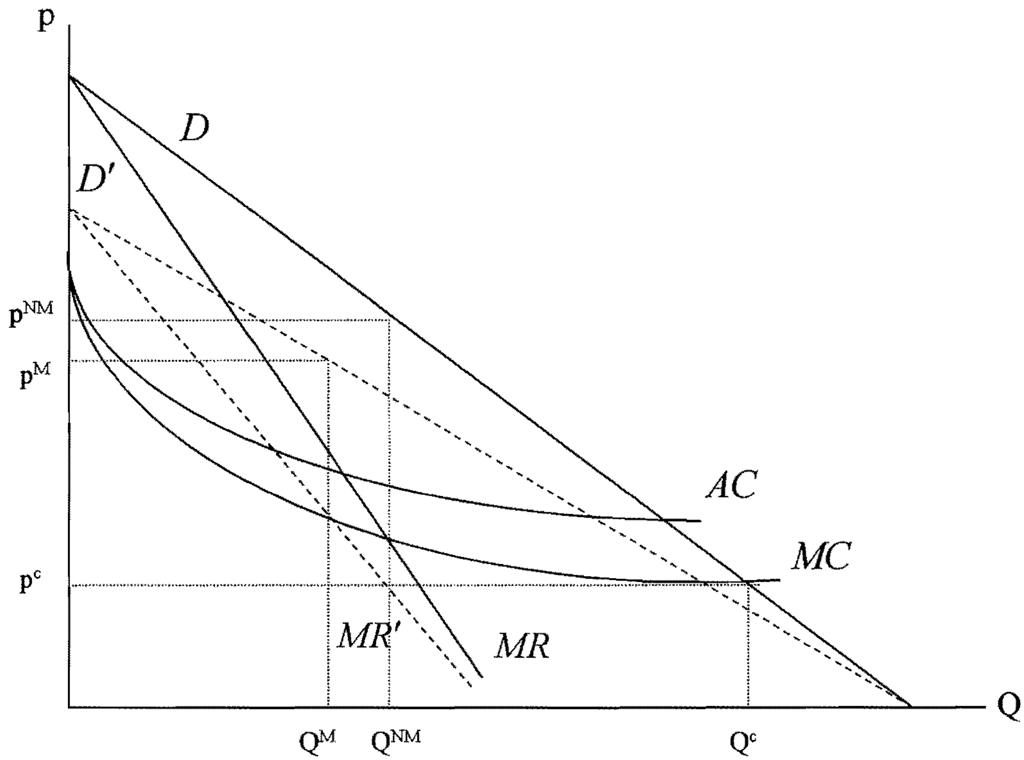
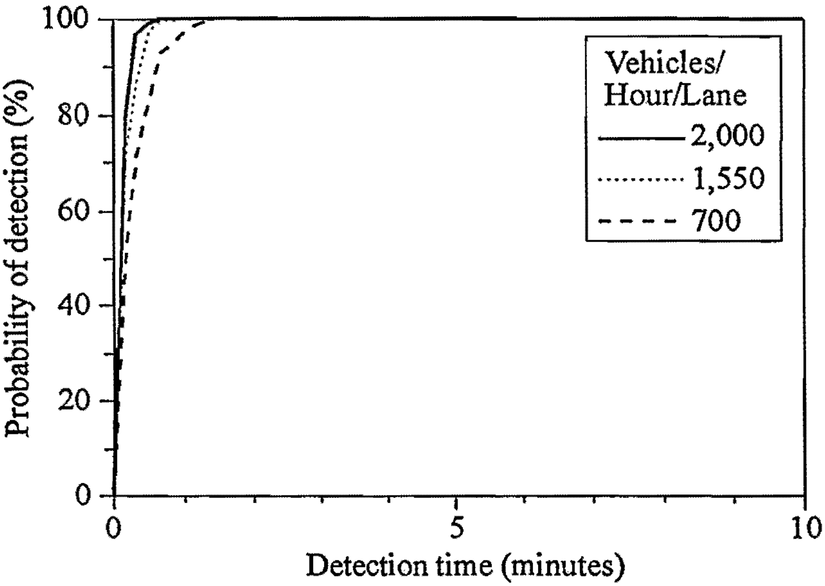
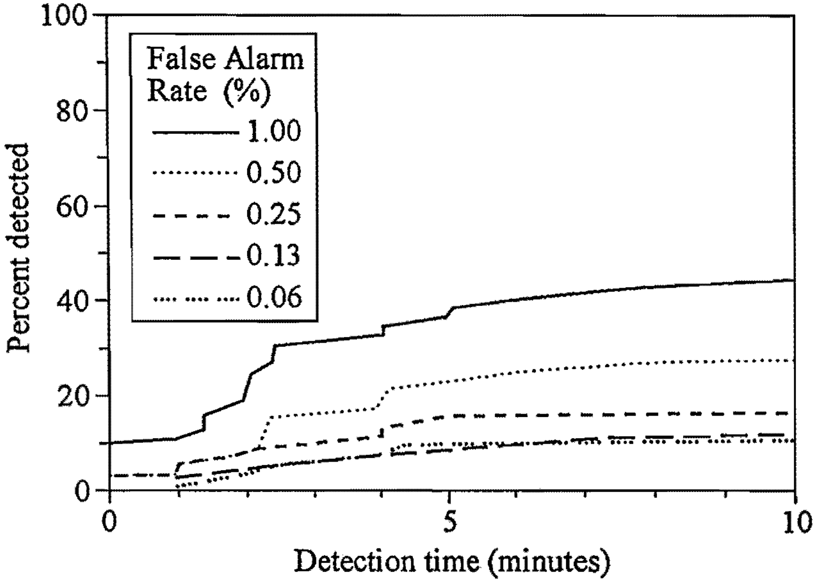


FIGURE 3



(a) Detection of a lane-blocking incident in moderate traffic by the Driver-based Incident Detection System $\{ p_1 = 10\%, p_2 = 100\% \}$



(b) Detection of incidents by a Highway-based Incident Detection System which utilizes the California algorithm (*Adapted* from Payne *et al.* 1975)*

*A total of 51 incidents were used in the Payne *et al.* Study. Twenty-one of these incidents were traffic collisions, 23 were disabled vehicles, 5 gawking, 1 spilled load, and one in which there was no apparent reason for the incident. These incidents occurred in traffic volumes ranging from light to congested traffic.

rate is defined as the ratio of incident signals to the total number of tests for incidents. To put these false alarm rates in a better perspective, Payne and Knobel (1976) reported that when false alarm rate is 0.002 or higher it can be safely assumed that 90 percent or more of the incident indications are false. The false alarm rates shown in Figure 3 are thus operationally undesirable. Lower false alarm rates are desirable because at higher false alarm rates highway agency operators are forced to respond to false alarms more frequently.

The false alarm for this system would be defined as reporting of an incident when no incident has occurred or when an incident disappeared before verification. The false alarm rate for the Driver-based Incident Detection System was undeterminable under simulated conditions. However, a field study on I-880 freeway in the Bay Area, California, found a cellular false reporting rate of about 8 percent (Skabardonis *et al.*, 1997). However, because false reports were defined as incidents that could not be verified, it is likely that this rate might be actually lower since some incidents are usually too short-lived to be verified.

In addition, if incident reporting were to be by digital signal (through a cellular or a VRC system), a highway agency can mitigate false reporting by requiring multiple reports be received before an alarm is sounded. This strategy would be similar to a "persistence check" method that has been successfully employed by the California algorithm.

Figure 3 also shows that the Driver-based Incident Detection System detects incidents faster than the Highway-based Incident Detection System. All incidents can be detected in under a minute (at the given p_1 and p_2 values) by the Driver-based Incident Detection System. The Highway-based Incident Detection System can detect only up to 50 percent of all incidents at an unacceptably large false alarm rate (1 percent) and the time-to-detection of 10 minutes.

CONCLUSIONS

The analysis of the Driver-based Incident Detection System revealed the potential this system has in improving freeway incident detection. The results showed that fast incident detection times with high detection rates were achieved across light, moderate, and high traffic volumes. The same trend was sustained across all four simulated incident types. Equally important is the fact that shoulder incidents were quickly detected. This is an important finding because even though incidents occurring and/or ending on shoulders may not significantly reduce capacity, they nevertheless pose a safety hazard. It is imperative that these incidents be detected quickly to reduce hazards to the motorists involved and to passing motorists as well. Unless there is "gawking" which significantly reduces capacity, the Highway-based Incident Detection System generally does not detect incidents occurring on shoulders because sensing devices usually are not placed on shoulders.

The results further showed that when one out of five drivers or more owns an in-vehicle communication device, all incidents are almost assured of detection in less than 40 seconds from the time of incident occurrence, regardless of the incident type or the prevailing traffic volume. (This result assumes a 100 percent reporting propensity). The CTIA statistics show that there were close to 40 million cellular telephone users at the end of 1995; a ratio of one cellular telephone user per five licensed drivers. If the simulation results reported herein were to correctly represent motorist behavior, a significant improvement in incident detection is achievable with the current level of ownership of cellular telephones in the U.S.

Despite the promising positive results, this research study had some limitations. Only a basic freeway segment that is straight, level, and does not have on-ramps and off-ramps was modeled. Obviously, most freeway incidents are likely to occur where weaving, diverging, or merging maneuvers are frequent – such as in sections leading to and from off-ramps, on-ramps, lane drops, curved sections, grades, etc.

Additional qualifications are in order. The research study assumed that drivers sending a voice or digital signal to a highway agency to report an incident would do so in the vicinity of the incident, thus allowing a highway agency operator to zoom-in in the area with CCTV camera to verify the incident. It is highly conceivable that some drivers would report the incident way after they have passed the incident; still, some drivers might report incidents that occur in the opposite direction from which they are traveling. Only a field study can quantify the magnitude and assess the likely solutions for these phenomena.

RECOMMENDATIONS

The simulation results of this study have shown the prospect of improving freeway incident detection through a driver-initiated detection process. Drivers on the freeway can report incidents either (1) directly using cellular telephones, two-way radio, etc., or (2) indirectly using a vehicle-to-roadside communications (VRC) system. The continued improvement in wireless communications technologies will enable more drivers in the future to have even better in-vehicle communication devices such as the Personal Communications System (PCS) telephones now under development.

A driver-initiated detection process can not become a reality unless the Intelligent Transportation Systems (ITS) that many highway agencies are implementing take into account the potential of this system. For example, without the establishment of a line of communications between the highway agency and the driver on the freeway (such as the free *999 number in Chicago), the capability for drivers to report incidents would be low. Similarly, the current VRC systems that are operational (e.g., in Houston) or are being installed (e.g., in San Antonio) are not capable of allowing a driver in distress (or a good Samaritan) to send an emergency signal to the responsible highway agency. It is therefore imperative that highway agencies be proactive in shaping ITS to allow incident reporting by drivers. Indeed, this research underscores the need to continuously explore and build open system architecture in the ITS environment to allow new technologies to be easily implemented.

Further research is needed to see how digital and geolocation technologies can be used to automate a driver-initiated incident detection process. When a driver dials a dedicated highway agency number or a cellular 911 number, his or her location should automatically be displayed to the operator on the freeway electronic wall map. Therefore, there exists an interesting opportunity for research collaboration between highway agencies and the cellular industry to extend the current emergency geolocation experimentations to freeway incidents.

REFERENCES

Cellular Telecommunications Industry Association (1996) *Semi-Annual Industry Survey.* Washington, D.C., March.

Christenson, R.C. (1995) *Evaluation of Cellular Call-In Programs for Incident Detection and Verification.* Department of Civil Engineering, Texas A&M University, College Station, Texas, August.

Halati, A., Torres, J.F., and Mikhalkin, B. (1990) FRESIM Technical Report. *Final Report - FHWA Contract DHFH61-85-C-00094,* JFT Associates, Pacific Palisades, California, February.

Larue, P. (1996) Traffic Monitoring and Traveler Information in a Metropolitan Area. *Traffic Technology International* magazine, UK & International Press, 68-72.

McLean, C.H. (1991) Cellular Phones - A Key Traffic Management Component. *ITE 1991 Compendium of Technical Papers,* Institute of Transportation Engineers, Washington, D.C.

Mussa, R. (1996) Evaluation of Driver-based Freeway Incident Detection. *Ph.D. Dissertation,* Department of Civil and Environmental Engineering, Arizona State University, Tempe, Arizona.

Payne, H.J., Goodwin, D.N., and Teener, M.D. (1975) Evaluation of Existing Incident Detection Algorithms. *FHWA Report Number FHWA-RD-75-39,* Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.

Payne, H.J., and Knobel, H.C. (1976) Development and Testing of Incident Detection Algorithm, Volume 3. *FHWA Report Number FHWA-RD-76-21,* Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 28.

Robinson, J.R., Ewald, R.C., Gravely, T.B. and Carter, E. (1994) Capital IVHS Operational Test. *ITE 1994 Compendium of Technical Papers,* 255-259.

Skabardonis, A., Chavala, T.C, and Rydzewski, D. (1997) *The I-880 Field Experiment: Effectiveness of Incident Detection Using Cellular Phones.* Paper Presented at the 77th Annual Meeting of the Transportation Research Board, Washington, D.C., January.

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PRODUCTIVITY AND PRICES IN THE U.S. RAIL INDUSTRY: EXPERIENCE FROM 1965 TO 1995 AND PROSPECTS FOR THE FUTURE

*by Carl D. Martland**

ABSTRACT

This paper documents the major changes in rail freight service productivity and the overall changes in rail prices over the period 1965 to 1995. Over this period, productivity improvements produced annual savings approaching $25 billion by 1995, with most of the savings achieved after 1983. Despite these dramatic improvements, the profitability of the industry never returned to the peak level of 1966, as the great majority of the savings were passed on to customers in the form of lower rates. A major concern is that the recent rate of productivity improvement will be very difficult to sustain into the 21st century, while the pricing pressures unleashed by deregulation will only grow stronger. The industry may therefore face significant financial problems in the not too distant future.

BACKGROUND

A combination of structural, technological, regulatory, and environment changes propelled the U.S. rail industry from the brink of bankruptcy in the late-1960s and 1970s to apparent financial prosperity in the 1990s. This transformation was especially remarkable since most of the dramatic productivity savings were passed on to customers in the form of lower rates. However, the industry did not survive intact, as railroads exited many markets, rationalized their networks, and focussed on high density, heavy haul operations. The rail industry in the mid-1990s was therefore smaller than it was in the mid-1960s, and it was a much smaller piece of the growing freight transportation marketplace. The shrinkage of the rail industry has been masked by inflation, the continued growth in bulk traffic and the surge in intermodal traffic following the introduction of doublestack trains. While ton-miles and tonnage continued to set records, revenue and profitability in the mid-1990s were nowhere near their highs. When NROI (net railway operating income) is expressed in real terms, 1966 emerges as the most profitable year of the last three decades, as shown in Figure 1. While there are other ways of looking at financial performance[1] and there are accounting intricacies that could alter the shape of the figure,[2] Figure 1 certainly challenges some of the accepted mythology of the rail industry. The collapse of the Penn Central in 1970, which triggered the Northeast Rail Crisis, clouds our perspective and obscures the bright prospects that were actually then apparent for a time. The "wreck of the Penn Central" just 871 days after the merger was as spectacular as it was unexpected:

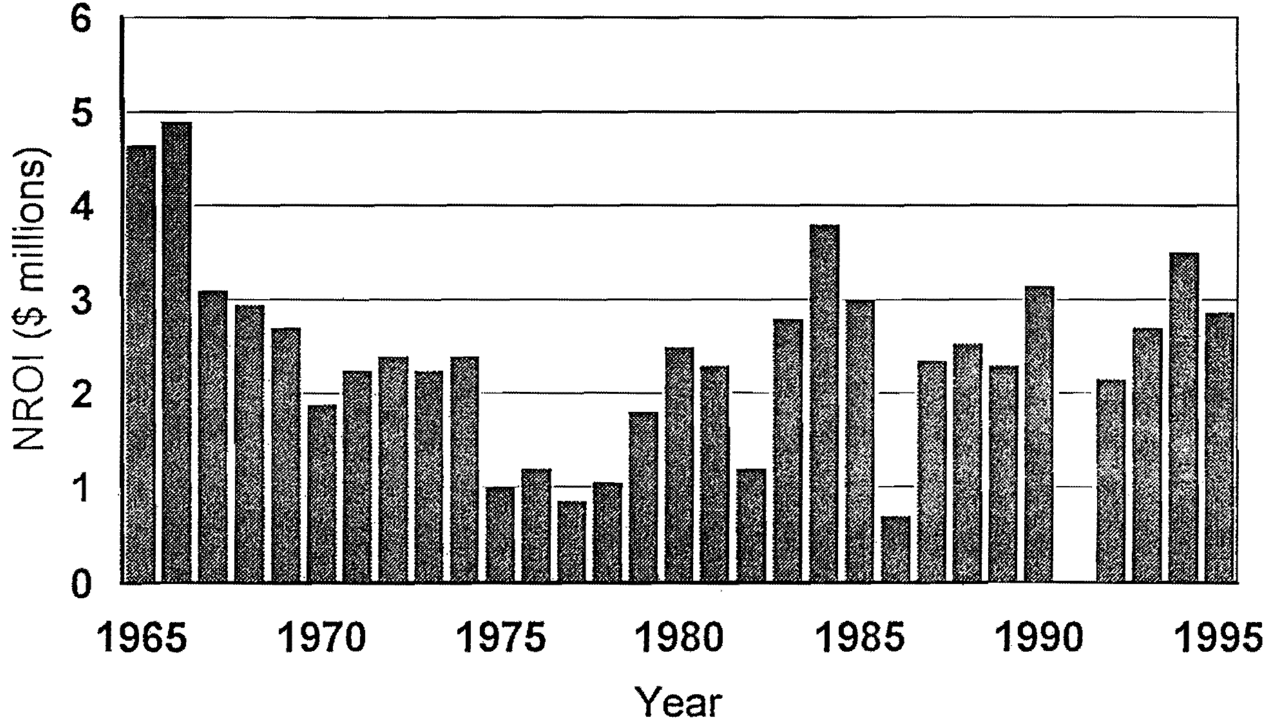
> "Problems that nobody foresaw or bothered about on opening day swelled to unmanageable proportions. On June 21, 1970, with a sickening crash that frightened Wall Street, jarred both the United States economy and its government, and scared off foreign investors, the nation's largest railroad went broke. The history of American Railroading is marked by wildly cyclical ups and downs, but never before had there been a cataclysm as stunning as this." [Daughen and Binzen, 1971, p. 12]

In February 1968, when the Penn Central was formed, however, it was not apparent that it would fail. Indeed, it was viewed as "the most ambitious merger in railroad history, ... a truly awesome monument to the free enterprise system" [Daughen and Binzen, 1971, p. 206]. To understand why this was the case, let's begin by looking more closely at that peak year of 1966, a point of time when the rail industry earned NROI that, in real terms, would not be matched in the next 30 years. Yet, as we now know, the industry at that time was perched on the brink of disaster.

THE RAIL INDUSTRY IN 1966

The industry as a whole in 1966 had revenues of $10.6 billion and net railway operating income (NROI) of $1.05 billion, enough for a return on investment of 3.9% during a period of low

Figure 1: U.S. Class I Railroad Net Railway Operating Income
CPI-Adjusted Constant 1995 Dollars
(Adapted from Chapman & Martland, 1996)



inflation and low interest rates.[3] Furthermore, 1966 was not an outlier, but the culmination of a 5-year period during which both NROI and ROI doubled. Nor were the railroads in the northeast excluded: for the Eastern District, which included the roads that would merge to form the Penn Central, the NROI was nearly $400 million. Using constant dollars will put these numbers into sharper perspective. The $10.6 billion operating revenues of 1966 would amount to $45 to $50 billion in 1995, i.e. 50% to 60% greater than the 1995 operating revenues of $32 billion. And we have already seen in Figure 1 that the average NROI in 1965 and 1966, when expressed in real terms, was roughly twice the average NROI from 1990 to 1995.

Of course, the outlook for the industry in 1966 was not entirely rosy. Inflation, competition for merchandise traffic, passenger service deficits, light density operations, and many of the other problems that would dominate the public policy debates in the 1970s were beginning to be evident at that time:

> **Inflation**: while railroad material prices and wage rates rose only about 2% per year from 1961 to 1964, they rose 5% in from 1965 to 1966 (and would rise more than 8% per year for the next 7 years).
>
> **Merchandise Traffic and Light Density Lines**: the depression and the travel restrictions during World War II masked the competitive advantage of trucking for many years, but trucking's market share of intercity freight rose from about 5% during the war to about 22% by 1966. The obvious targets were the general merchandise customers on light density lines who received costly and unreliable service; as traffic dried up, rail losses on these lines grew. In many locations, railroads introduced intermodal operations to keep customers affected by line abandonments and service cutbacks. From 1957 to 1966, piggyback loadings increased at 18% per year, from 0.25 million to 1.2 million. (However, by 1966 the rate of growth was slowing, and the number of piggyback carloadings would actually drop back to 1.2 million in the recession of 1971).
>
> **Passenger Deficits**: The passenger service deficit was $400 million in 1966, which was a 5% improvement from 1965 and typical of the early 1960s; of this total, only $31 million was considered to be solely related to passenger operations, as the $1.02 billion in passenger revenues nearly covered the direct expenses of these operations. As airlines and the interstate highway system were continuing to grow, the rail passenger market was clearly in decline in the late 1960s. (The solely related deficit would grow rapidly to $252 million in 1970, eventually forcing the creation of Amtrak as a way to retain passenger service while alleviating the freight railroads of the rising deficits.)
>
> **Labor Productivity**: labor strife was common in the 1960s as the railroads pushed hard to reduce crew consists, to eliminate restrictive work rules, and to modify the basis of pay. The unions resisted strenuously, and it was clear by 1966 that it would be very difficult to achieve any rapid breakthroughs in labor productivity.

The importance of these problems was abruptly brought into the public eye with the collapse of the Penn Central in 1970. For 10 years thereafter, the industry, labor unions, congress, DOT, the ICC, USRA, state governments, shipper organizations grappled with these and other problems. The formation of Amtrak and Conrail, the continuation of the merger movement, establishment of procedures for and alternatives to rail line abandonment, and significant regulatory reform were some of the fruits of these efforts.[4] In a strategic sense, however, the fact that the industry had so many problems was an advantage, because it was possible to identify opportunities for overcoming the problems and improving performance. Even though much of the rail industry was still on the verge of bankruptcy for much of the 1970s, major efforts were underway to rationalize the network, improve equipment management, increased labor productivity, upgrade the track structure, improve the regulatory environment and to focus marketing activities on profitable traffic (e.g. Task Force on Railroad Productivity, 1973; Secretary of Transportation, 1978). These efforts led to remarkable productivity improvements in many areas, as discussed in the next section.

PRODUCTIVITY IMPROVEMENT AND COST SAVINGS, 1965 TO 1995

Changes in Traffic Mix

Four trends in rail traffic mix tended to eliminate high cost shipments and encourage low cost shipments. First, boxcar traffic declined dramatically, with some traffic shifting to intermodal and more shifting to truck. Second, bulk traffic rose dramatically, to the extent that coal and farm products accounted for 50% of the tons hauled in 1995. Third, bulk traffic shifted away from single- and multi-car shipments to unit trains. Fourth, the average length of haul5 increased from 500 miles in the mid-1960s to 615 miles in 1980 and to 843 miles in 1995.

From 1965 to 1973, the trends toward larger cars and an increasing percentage of bulk traffic were just beginning. From 1973 to 1985, many dramatic institutional changes took place - the formation of Conrail, the Railroad Revitalization and Regulatory Reform Act in 1976, and the Staggers Act in 1980 - but the productivity was roughly the same in 1983 as it was in 1973 [Martland, 1989]. The greatest underlying factor during this period was the shift away from boxcar traffic toward bulk traffic, which resulted in lower prices for transporting heavier cars. After 1983, the dominant trend was no longer the elimination of light density box car traffic, but the achievement of even further productivity gains for bulk unit-train traffic.

Exhibit 1a shows some of the key service units for 1965, 1978, 1983, and 1995. Exhibit 1b restates the service units as percentages of the base year. The output index (freight service revenue deflated by a price index[6]) was roughly constant over the first half of the period, rising from 96.3 in 1965 to 100 in 1978. Output fell to 76.5 in 1983, but then rose substantially, reaching 147.2 in 1995.

If there were no changes in productivity and no changes in traffic mix, then we would expect to find service units changing in proportion to output. In fact, revenue ton-miles (at 146% of the base year) and gross-ton-miles (152.2%) did grow as fast as the output index. However, road train-miles, car-miles, and revenue carloads all increased less than 10%, while yard switching hours continued to decline, indicating dramatic changes in productivity. With fewer service units per unit of output, substantial cost savings were achieved, as shown in Exhibit 1c.[7] From 1978 to 1983, when traffic was in decline, service units declined, but not as fast as traffic, so that the service unit effect was negative. However, before and after that period, the service unit effect was very strong leading to annual savings of approximately $7.5 billion overall in 1995 compared to 1965.

Maintenance of Way

A recent study [Chapman and Martland, 1996] estimated that improvements in track productivity save the industry on the order of $7 billion annually (in 1995 dollars). Annual maintenance of way (MOW) expenditures[8] increased only 6% in constant dollars from the mid-1960s to the mid-1990s, despite a 73% increase in revenue ton-miles and an increase of 31% in average axle loads. The MOW expense per 1000 GTM declined 28% in real terms over this period, with all of the decline coming after 1986. The productivity savings were attributed to economies of density ($2.6 billion), track technology ($1.8 billion), network rationalization ($1.5 billion), and equipment productivity ($1.3 billion).

Train Crew Costs

During the 1980s, the railroads finally achieved a breakthrough with the United Transportation Union (UTU) concerning crew consist. Rather than arguing the effects of reduced crews on workload or safety, management offered financial incentives and the unions agreed to allow crews with a conductor and an engineer on most line and many yard jobs. Exhibit 2 shows that the annual impact is approximately $4 billion. Exhibit 2a shows the basic factors related to wages and crew productivity. Train-miles were fairly constant over the entire period shown, but the train and enginemen (T&E employees) dropped 60%. As a result, T&E employees per 10,000 train miles dropped from 3.8 in 1965 to 1.39 in 1995, with the largest drop occurring after 1983. Some of this reduction in train T&E undoubtedly reflects the shift from slow local freights to faster through freights, but the dominant factors are believed to be smaller crew consists and longer crew districts.

The total compensation for train T&E employees rose from $2.6 billion in 1965 to $3.6 billion in 1983, then stayed at that level in 1995 despite the increase in train-miles. The total T&E wages per 10,000 train-miles was the same in 1995 as it was in 1978, despite the fact that the average wage rose from $24 to $57 thousand. The 136% increase in the average wage reflects in part an increase in wage rates, but also the addition of incentive payments for working on reduced crews as well as the shift from brakemen to higher paid conductors and engineers.[9]

Exhibit 2b translates the productivity gains into cost savings. Total crew costs were estimated under two sets of assumptions. First, the current employees per train-mile were used with the 1978 T&E wages. In this calculation, crew costs are directly proportional to train miles and vary very little over the entire period. The next portion of the table calculates crew costs based upon the current year wage rates and the base year employees per train mile. With this calculation, crew costs would have been $8.5 billion in 1995.

Exhibit 1
Reductions in Service Units per Unit of Output

a. Total Quantity of S.U. (millions, except where indicated)

	1965	1978	1983	1995
Road train-miles	421	433	346	458
Yard switching hours (note 6)	34	27	15	11
Total car-miles (billions)	29	29	21	30
Gross ton-miles (billions)	1680	1836	1698	2680
Revenue ton-miles (billions)	698	858	828	1306
Revenue carloads	28	23	19	24

b. Index (1978 = 100)

	1965	1978	1983	1995
Road train-miles	97%	100%	80%	106%
Yard switching hours	126%	100%	54%	41%
Total car-miles	101%	100%	73%	105%
Gross ton-miles	92%	100%	93%	146%
Revenue ton-miles	81%	100%	97%	152%
Revenue carloads	121%	100%	80%	102%
Output index	96%	100%	77%	147%

c. Savings from Reduction in S.U. per Unit of Output (1995 $)

		1965 to 1978	1978 to 1983	1983 to 1995	Total
Road train-miles	@ $5	$22	($97)	$1,036	$961
Yard switching hours	@ $10	$839	$473	$1,692	$3,004
Total car-miles	@ $0.0	$89	$86	$623	$798
1000 Gross ton-miles	@ $2.5	($226)	($1,157)	$1,467	$84
Revenue carloads	@ $15	$913	($175)	$1,866	$2,604
Total		$1,637	($869)	$6,684	$7,452

Exhibit 2
Changes in Train & Enginemen Expense, 1965 to 1995

	1965	1978	1983	1995
a. T&E Wages and Productivity				
Train-miles (millions)	421	433	346	458
T&E, Train Employees	160,180	141,220	95,168	63,831
Total compensation (millions)	$2,611	$3,393	$3,634	$3,611
Average wage	$16,300	$24,026	$38,185	$56,571
Employees/10,000 train-miles	3.80	3.26	2.75	1.39
Actual T&E Wages/10,000 train-miles	$62,019	$78,378	$105,059	$78,791
b. Labor Costs Under Various Assumptions:				
Current employees per train-mile and 1978 T&E wages per train-mile	$3,300	$3,393	$2,711	$3,592
1978 employees per train-mile and current wages per train-mile	$2,239	$3,393	$4,309	$8,458
c. Estimated Savings:				
Reduction based upon 1978 employees per train-mile and current wages per train-mile	($372)	$0	$675	$4,847
Productivity savings attributable to reduction in crew consist and longer crew districts (estimated as 80% of the total savings)	($298)	$0	$540	$3,877

The estimated savings are shown in Exhibit 2c. The first row shows the difference between the actual crew cost and the crew cost projected with current wages and the base year crew consist. In 1995, the savings amount to $4.8 billion relative to 1978. Given that some of this may relate to the shift away from local switching services rather than productivity improvements on through trains, the savings are estimated to be 80% of this, or $3.9 billion over all. Relative to 1965, the savings are estimated to be $4.2 billion.

Computers and the Elimination of Clerks and Managers

Railroads have clearly benefited along with the rest of the economy from the technological improvements in communications and office automation. By 1995, most of the clerical, car management, and customer service functions were automated and centralized. As a result, the category of employees called "Professional, clerical, and general" declined from over 130 thousand in 1965 to 108 thousand in 1978, 68 thousand in 1983, and 27 thousand in 1995. The average annual compensation for this category of employees was $43,893 in 1995, so that the benefits of just the reductions from 1983 totaled $1.8 billion, even without taking into account the 25% increase in carloads over that period. For the entire period, the savings are estimated to be $4.7 billion.

Fuel Efficiency

Fuel consumption is proportional to the work that is done in moving trains, which is commonly expressed in terms of gross ton-miles. Given total GTM, total fuel cost depends upon fuel efficiency and the price of fuel. Over the period in question, fuel efficiency measured as GTM per gallon of fuel improved, especially after 1983, with an annual benefit of $1.33 billion in 1995 prices (Exhibit 3).

Summary -- Total Productivity Savings

If we add up the productivity savings discussed in this section, we quickly come to a very impressive number, nearly $25 billion annually, most of which have been achieved just since 1983 (Exhibit 4). It is beyond the scope of this paper to try to provide a complete discussion of the sources of productivity benefits, and there surely could be differences of opinion as to the best way for calculating each area of benefits. However, it is absolutely clear that the net effect of productivity improvements has been dramatic. If the 1995 traffic were moved on the 1966 network with 1966 performance capabilities, the actual 1995 expenses of $31.4 billion would have increased more than 75% to $55 billion!

Exhibit 5 summarizes the productivity changes over this period. Productivity is measured as the ratio of an index of railroad freight volume to an index of the inputs used in rail freight transportation. From 1965 to 1978, the output index was relatively stable (rising from 96 to 100), while the input index declined steadily from 130 to 100. As a result, productivity rose by a third, from 0.74 to 1.00, or just over 2% annually. Productivity held steady through 1983, as both outputs and inputs fell. After 1983, productivity rose rapidly, from 1.02 to 2.43, which is equivalent to productivity improvement of nearly 8% annually. This extremely rapid rate of productivity improvement might well be dismissed as way out of line for a major industry over a 12-year period were it not for the specific improvements already documented in this section.

PRICES AND PROFITABILITY

Unfortunately for the rail industry, the revenue side of the picture is as dismal as the productivity side is bright. For whatever reason, essentially none of the multibillion dollar annual cost savings have survived. A decade of cost-cutting has had little or no effect on NROI. In fact, three tumultuous decades have simply reduced the size of the industry. As shown above in Figure 1, the constant dollar NROI was essentially the same in 1995 as it was in 1983, when it was barely half the NROI in 1966. What happened to the savings? To answer this question, we need to look at trends in prices and costs. Improvements in productivity lead to greater profits only if prices at least keep pace with costs. As shown in Exhibit 5, that did not happen. The price index rose steadily from 1965 through 1978, increasing by 220%, but the cost index rose by just over 300% The one third improvement in productivity offset some of the cost increases, but much of the industry still fell into bankruptcy over this period. From 1978 to 1983, a period of rapid inflation in the country and a period of great public concern about the rail industry, prices actually rose faster than costs. This is evident in the column that shows the ratio of the price index to the cost index, which rose from 0.89 to 0.94 during this period of highly focussed attention on the rail industry. It is no coincidence that this was the period when the industry's NROI rebounded. After 1983, costs continued to rise, albeit less rapidly, but

Exhibit 3
Effects of Changes in Fuel Efficiency and the Price of Fuel, 1965 to 1995

	1965	1978	1983	1995
GTM (billions)	1680	1836	1698	2680
Gallons (millions)	3592	3898	3112	3480
Cost/gallon ($/gallon)	$0.09	$0.38	$0.83	$0.60
Total fuel cost ($ billion)	$0.33	$1.48	$2.57	$2.09
1000 GTM/gallon	0.47	0.47	0.55	0.77
Index, 1978 = 100	0.99	1.00	1.16	1.64
Gallons, at 1978 consumption rate	3568	3898	3606	5691
Efficiency savings (million gallons)	-24	0	494	2211
Efficiency savings ($ billion):				
At current prices	($0.00)	$0.00	$0.41	$1.33

Exhibit 4
Summary of Annual Cost Reductions Resulting From Productivity Improvements, US Class I Railroads
(Billions of 1995 $)

Area of Savings	1965 to 1978	1978 to 1983	1983 to 1995	Overall
Reductions in Service Units per unit of Output (Heavy Haul)	$1.6	($0.9)	$6.7	$7.5
MOW Productivity (a) and Network Rationalization	$1.0	$1.0	$5.0	$7.0
Office Technology	$1.7	$1.1	$1.8	$4.7
T&E Employees	$0.3	$0.5	$3.3	$4.2
Fuel Efficiency	$0.0	$0.4	$0.9	$1.3
Total	$4.6	$2.2	$17.7	$24.6

(a) The MOW savings were predominantly achieved during the last 12 years, and the entire benefits were distributed as shown to approximate this assessment

Exhibit 5
Productivity, Price and Cost Changes, and Net Freight Revenues

	Freight Revenues	Price Index	Output Index	Freight Service Cost	Cost Index	Input Index	Productivity	Ratio of Price to Cost	Revenue/ Ton-mile
Est. 196	$8.8	77	96	$8.6	62	130	0.74	1.24	1.27
Est. 196	$10.6	79	111	$10.1	77	123	0.90	1.03	1.35
1972	$12.6	100	105	$12.0	100	113	0.93	1.00	1.62
1978	$20.2	169	100	$20.2	190	100	1.00	0.89	2.36
1983	$25.8	282	77	$23.9	300	75	1.02	0.94	3.12
1995	$31.4	178	147	$27.9	433	61	2.43	0.41	2.40

Notes: The BLS Price Index for Railroad Freight was used for 1972 to 1983; the Surface Transportation Board's Price Index for Class I Railroads was used to compare 1983 to 1995.

The RR Cost Recovery Index extends back only to 1976; prior to that, the Index of charge-out prices and wage rates was used (where the wage rate includes supplements)

The freight service costs for 1965 and 1969 were estimated as total operating expense minus passenger revenues minus the solely related passenger deficit.

Revenues, costs, net freight revenues, and revenue/ton-mile are current dollars.

prices began to fall and the ratio of prices to costs declined precipitously.

In short, a serious pricing problem emerged after 1983, presumably in response to the pricing freedoms and competitive pressures resulting from deregulation of the rail and trucking industries. Using the Surface Transportation Board's Index of Class I Railroad Prices, real prices fell (from 100 in 1982) to 92.7 in 1983 to 58.5 in 1995 [Office of Economics, 1998]. If the prices had remained at the 1983 level, the revenue would have been $50 billion rather than $31 billion. If real prices had remained at the 1965 level, total 1995 revenues would have been $53 billion. The $19 billion in price cuts from 1983 to 1995 and the $22 billion for the entire period are equivalent to the cost savings summarized in Exhibit 4, i.e. the cost savings were almost entirely passed on to the customers. Despite the very impressive gains in productivity, especially over the 1983 to 1995 period, the net effect for the rail industry was simply to reduce the size of the industry by 50%, without any increase at all in profitability. The industry was unable to retain the savings that it worked so hard to gain through productivity improvements.[10]

THE RAIL INDUSTRY IN 1996

Stable Finances

By 1996, the RR industry was in its best financial shape since 1966, with NROI in the range of $2-3 billion annually and return on shareholders equity in the range of 8-10%. Despite all of the very significant achievements, the industry was still not quite revenue adequate.

Diminishing Opportunities for Productivity Improvement

By 1995, the industry had addressed its serious structural problems. It had upgraded its track and equipment; it had resolved the crew consist dispute and made headway on other major labor issues; and it had taken advantage of significant technological advances in track and equipment. Opportunities for further improvement still remained, of course, but the industry would suffer from declining returns. Future increases in car capacity will not be as dramatic as the 43% increase from the 200,000 pound car of the 1960s to the 286,000 pound car of the 1990s. Going from a 2-person crew to even a no-person crew provide lower savings, in absolute terms, than going from the 5-man crew of the 1950s to the 2-person crew of the 1990s. Doubling the life of rail components has decreasing returns because of the time value of money. Eliminating branchlines and consolidating duplicate facilities, long a major source of productivity improvements, offers fewer opportunities for the future and the industry is now in the position of adding rather than eliminating capacity. Sustaining productivity improvements for another decade at the 8% annual rate achieved from 1983 to 1995 would seem to be a very difficult feat given the emergence of severe capacity and service problems.

Increasing Pressures on Pricing

In the old regulated environment, a common complaint was that the ICC was slow to allow rate increases that would allow revenue to keep pace with inflation. Nevertheless, from 1969 to 1983, a period of high inflation, rail prices did in fact keep pace with inflation. In the deregulated environment, there is no longer an ICC, there is no longer a floor for rail prices, and prices can be raised only in the context of a highly competitive freight transportation market. With nearly two decades experience of pricing under deregulation, it is evident that it is now very difficult to raise prices. In general, customers did gain the advertised benefits of deregulation, while the railroads barely managed to retain enough profit to approach revenue adequacy. It is also worthwhile to recall that railroads fared quite well under deregulation relative to their motor carrier competitors. The motor carriers were plagued by bankruptcies and enormous operating deficits for most of the years following deregulation of their industries. The main problem was that intense competition resulted in a level of price discounting that "clearly exceeded even the fondest dreams of deregulators and has reflected the worst fears of the proregulators" [Glaskowsky, 1990, p. 12].

The motor carrier industry differs from the rail industry in that entry of new firms is relatively easy, since firms only have to worry about equipment and operations, not about the right-of-way. Even in the highly capitalized LTL industry, where entry is more difficult, all of the carriers have access to all of the customers over the same highway system, which heightens the competitive atmosphere. Railroads thus far have retained control over most of their network, and they have not been subjected to cutthroat competition from aggressive, new, non-union carriers. However, the experience of these other transportation industries should serve as a reminder that the effects of deregulation could, eventually, become much worse for the rail carriers.

Strategic Problems

Today, the rail industry faces a variety of strategic problems, some of which are new and some of which are very old:

Capacity: as a result of continued traffic growth during an era of network rationalization, line and terminal capacity are again becoming concerns.[11]

Bridges: the industry is aware that bridges could be a major annual expense of $500 million or more at some time in the not-too-distant future, when it finally becomes necessary to upgrade or replace thousands of 80-100 year old bridges [Sweeney et al., 1996].

Service: for the most part, service capabilities for general merchandise, single-car shipments are still as slow and unreliable or inefficient as they were 20 years ago [Kwon et al, 1995]. Equipment utilization and terminal performance remain major problems; in fact, the benchmarks for hump yard performance date back to the 1970s or to hump yards in other countries [Martland et al., 1994].

Competition: deregulation has certainly promoted competition. Railroads face stronger interroad competition for bulk traffic, continued competition for merchandise traffic from efficient truckload carriers, and increasing competition for intermodal traffic. With competition among rival partnerships, intermodal prices will tend to drop to the marginal costs of a service involving double-stack container trains. As Glaskowsky [1990, p.96] noted in his study of the effects of deregulation on LTL carriers, "larger shippers will never lose all of their rate advantage unless re-regulation of interstate LTL rates occurs". Unlike motor carriers, who serve all types of customers, the rail industry deals almost exclusively with "larger shippers", perhaps explaining why prices have fallen so much.

Trucking productivity: continued productivity improvements in trucking are possible in the areas of fuel consumption, size and weight restrictions, and especially in the use of information technology. Information technology will provide some efficiency at tolls, borders, weigh stations, as well as offering a better customer interface and possibilities for improved utilization of equipment and drivers.

Pressure for open access: as the number of carriers decline, shippers and state agencies are likely to push for some sort of open access to promote price competition.[12]

Pressure for passenger service: as highways and airports become more congested, and as population and travel continue to grow, pressure will continue to mount for better commuter, traditional inter-city, and high-speed rail service. These pressures will become stronger, and increased passenger operations will contribute to concerns regarding capacity.

Deregulation of the electric utilities: deregulation of the electric power utilities may put serious pressure on unit coal train rates and on the use of coal for generating electricity. At the very least, utilities will be pressing much harder for lower rates.

None of these problems are insurmountable, but they will require innovative and informed responses over the next ten to twenty years.

Outlook

Projecting the general pattern of the past 30 years out for another decade or two points to a declining traffic base, greater focus on bulk traffic and very large customers, and falling prices. With fewer obvious opportunities for productivity improvement today, the prospects for productivity improvement are much diminished. Therefore, we can envisage a scenario where price pressures prove more powerful than productivity improvements, forcing the rail industry once again into serious financial problems. But this time around, there will be fewer, more difficult options for recovery. The future is of course not entirely dismal, and there are opportunities for railroads to prosper. Railroads could do more for merchandise customers in terms of equipment and service and they could do more for bulk customers in terms of heavy haul technology. All customers could benefit from precision train control systems, efficient terminal operations, and better use of information technology. All of these possibilities will require innovation, planning, technological development, and leadership on the part of the railroads.

It will also be important for railroads to avoid strategic marketing mistakes as the industry introduces new services and more efficient equipment. Senior management must pay special attention to the implications of its marketing and pricing strategies in the light of projected operating conditions and technological opportunities. As capacity problems become evident on many routes, a more aggressive pricing strategy and a deeper consideration of technological options would both seem to be appropriate.

REFERENCES

AAR (1974, 1978, 1983, and 1996) *Railroad Facts*, Association of American Railroads, Washington DC

Chapman, J.D. and Martland, C.D. (1996) "Technology and Railroad Track Costs: A Historical Perspective", Massachusetts Institute of Technology, AAR Affiliated Lab Working Paper 96-1, MIT, Cambridge, MA

Daughen, J.R. and Binzen, P. (1972) *The Wreck of the Penn Central*, Little, Brown and Company, Boston Glaskowsky, Nicholas A. Jr. (1990) *Effects of Deregulation on Motor Carriers*, 2nd edition, Eno Foundation for Transportation, Westport, CT

Kwon, Oh Kyoung, Martland, C.D., Sussman, J.M. and Little, P. (1995) "Origin-to-Destination Trip Times and Reliability of Rail Freight Services in North American Railroads," *Transportation Research Record*, No. 1489, pp. 1-8

Martland, C.D. (1989) "Improving Railroad Productivity: Implications of U.S. Experience for Canadian Railroads", *Journal of the Transportation Research Forum*, Vol. XXIX, No. 2, pp. 427-433

Martland, C.D., Little, P., Duffy, M. and Dong, Y. (1994) "Benchmarks for Rail Hump Yard Performance", AAR Affiliated Lab Working Paper 94-3, MIT, Cambridge, MA

Office of Economics, Environmental Analysis, and Administration, "Rail Rates Continue Multi-Year Decline", Surface Transportation Board, Washington, DC, February 1998

Secretary of Transportation (1978) "A Prospectus for Change in the Freight Railroad Industry", U.S. Department of Transportation

Sweeney, Robert A., Oommen, G. and Le, H. (1996) "A Summary of Seven Years of Railway Bridge Testing at Canadian National Railway", AREA Bulletin, Vol. 97, #756, pp. 333-347

Task Force on Railroad Productivity (1973) "Improving Railroad Productivity", Final Report to the National Commission of Productivity and The Council of Economic Advisers

Watson, Rip (1998) "NIT League wants big changes in board approach to rail service", *Journal of Commerce*, March 1998

ENDNOTES

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1. Figure 1 would be little changed if another price index were used. With the GDP price index, for example, prices increase by a factor of 4.3 from 1965 to 1995, compared to a factor of 4.8 using the CPI index. The shape of the chart would be basically the same using either index.
2. Figure 1 does not take into account all of the accounting changes that took place over this period, nor does it show the effect of special charges and adjustments. During the late 1980s, for example, the industry incurred significant special charges related to the implementation of new crew consist agreements. These charges were included in current expenses, having the effect of depressing NROI. For example, the special charges in 1986 were $1.8 billion, which explains the dip in NROI in that year. If NROI before special charges were graphed, then the recovery of the 1980s would look better, but the stabilization in the 1990s would be little changed.
3. Except where otherwise noted, the financial information, service units and operating statistics used in the Exhibits and cited in the text are taken from *Railroad Facts*, published annually by the Association of American Railroads.
4. The Northeast Rail Crisis, the creation of Amtrak, the formation of Conrail and the other elements of the "Northeast Rail

Crisis" are all well-documented [Secretary of Transportation, 1978].

5. The figures on average carload used here are based upon the ratio of ton-miles/car mile, rather than "tons originated/carload" as published in *Railroad Facts* [AAR, various years].

6. The level of output is dependent upon the price index that is used. For the 1983 to 1995 period, an index published by the Surface Transportation Board was used [Office of Economics, 1998]. The BLS Price Index was based upon the 1% waybill sample and went back as far as 1969. The prices for 1965 were estimated by extrapolating changes in proportion to changes in revenue per ton-mile. During this time period, inflation was relatively low and general price increases were allowed by the ICC, so that revenue per ton-mile did reflect inflation to some extent.

7. The unit costs were assumed to be the same in 1995 as in 1978, as dramatic changes in productivity have offset equally dramatic changes in the underlying wage rates. The service unit cost for train-miles, for example, is basically the cost of the crew. In 1978, the average crew had more than 4 people; today it is down close to 2. Likewise, the breakthroughs in maintenance have extended the life of track components and reduced the costs of materials. As a result, there was no need to update these unit costs, as they remain approximately valid today.

8. Chapman combined capital and operating expenditures in his study in order to overcome the problems caused by the shift from betterment to depreciation accounting in 1983. The assumption was that the same total amount of work was being done, with only the accounting changed.

9 These other factors are believed to be much smaller than the increase in wages, as the increase in wages for other transportation employees was 133% over the same period and the increase for all railroad employees was 137%. There is also the matter of how to deal with the substantial payments to UTU members who agreed to take buyouts. Since those payments were concentrated in the period 1984 to 1991 or so, those payments do not affect the years examined in this table.

10. As a final note on profitability, consider the effect of Conrail on the industry's performance. Conrail's NROI was $0.34 billion in 1995, whereas Conrail suffered losses of $0.5 billion or more in the late 1970s. Hence, Conrail's NROI increased by roughly $1 billion per year over this period, accounting for well over a quarter of the industry's overall gain in NROI. Since Conrail only accounted for 12% of the industry's revenue in 1995, it had achieved far more than its share of the NROI improvements.

11. This was written in May 1997, somewhat before the UP capacity crisis became front page news. A "capacity crisis" is a logical end result of 15 years of downsizing and price-cutting; downsizing eliminates the excess capacity, while price cutting attracts more business.

12. Pressure has mounted dramatically for re-regulation and open access as a result of UP's capacity problems and concerns about high prices and poor service: "Another key complaint was the National Industrial Traffic League's view that the Surface Transportation Board accepted flawed arguments by the railroads that real rates had fallen precipitously in the past two decades" [Watson, 1998]. Given the evidence for dramatic productivity improvements as presented in this paper, it would appear that the STB is much closer to the truth than the NIT League.

RAILROAD MONOPOLY IN GRAIN TRANSPORTATION?

*by **Jean-Philippe Gervais*** and **C. Phillip Baumel****

ABSTRACT

The rail industry is under intense scrutiny as a result of very serious service problems in portions of the United States. This paper provides a theoretical and empirical assessment of the railroad intramodal and intermodal railroad monopoly power in grain transportation. Railroads face both intramodal and intermodal competition for grain still on the farm. However, once the grain arrives at most grain elevators, intramodal competition disappears. Railroads still face intermodal competition from trucks hauling grain from elevators to barge terminals, grain processors and feeder markets. There is a negative relationship between rail rates and truck competition. Surveys in Iowa and in the U.S. indicate that intermodal competition is strong in the grain industry.

INTRODUCTION

The Union Pacific Railroad has faced numerous, well publicized problems in digesting the purchase of the Southern Pacific Railroad. Among the charges levied against the Union Pacific are mismanagement of the integration of the two railroads, poor service resulting in failure to meet the common carrier obligation and monopoly pricing practices. Shipper groups have complained vigorously about alleged mistreatment by railroads. Wilner (1998) reports numerous complaints, summarized by the following quote: "the vast majority of rail shippers are served by a single railroad. If the shipper, the customer of the railroad, is unsatisfied with the rail service or price, he or she cannot call another railroad. In all other modes of transportation, shippers have service providers competing for their business." An executive committee member of the Alliance for Rail Competition (ARC) states that "the only long-term solution to ARC's concerns about rates and service quality is free market competition." [Whiteside (1998)]. ARC recommendations for increasing rail competition include forced access, prescribed "reasonable rates", more rigorous merger conditions, full access by short line carriers and redress for ineffective service.

On the other hand, railroads insist that what shippers and the ARC have in mind is re-regulation that "would take us back to the dark days of bankrupt railroads and standing derailments." [Wilner (1998)]. The Association of American Railroads has argued in a statement to the Surface Board of Transportation that: "direct rail-to-rail competition yields rates far lower than those needed on average to cover a railroad's total costs. ... and unless there is meaningful progress toward or achievement of full cost recovery, railroads will not make necessary investments in rail infrastructure."

The debate between the railroad industry and the Alliance for Railroad Competition and others rests largely on the degree of monopoly power of the railroad industry. The Attorney Generals States of Ohio-Illinois-Iowa-Texas argue in a statement before the Surface Transportation Board that: "Still two questions that premise the current investigation remain: is there sufficient evidence of railroad monopoly power to warrant a departure from the current regulatory course and, if so, is competitive access the most efficient method for assuring adequate surface freight transportation?"

The purpose of this paper is to provide a theoretical and empirical assessment of the state of railroad intramodal and intermodal competition in grain transportation. The paper is organized as follows: The first section reviews theoretical concepts on natural monopoly and introduces the intermodal competition framework to analyze competition between railroads and trucks in grain transportation. The second section builds a theoretical model to explain the impact of trucking market competition on railroads in grain transportation. The next section presents empirical evidence from the state of Iowa and the U.S. that any railroad intramodal monopoly power quickly vanishes in an intermodal framework. Finally, we present some concluding remarks along with a description of the future of railroads in grain transportation.

RAILROAD MONOPOLY FROM AN INTRAMODEL PERSPECTIVE

Several researchers have successfully shown theoretically and empirically that railroads constitute a natural monopoly [See Bitzan (1997) for a thorough survey]. This conclusion is drawn strictly from an intramodal competition framework.

Following Berg and Tschirhart (1988), a necessary and sufficient condition for an industry to be a natural monopoly is for its cost structure to be subadditive. Two important concepts in production theory need to be introduced to fully understand the concept of subadditivity.

First, for a single product firm, a production function f is said to exhibit increasing return to scale if, for all inputs $x \in R^n_+$, there exist constants $\lambda \geq 1$, and $0 < \mu \leq 1$, such that $f(\lambda x) \geq \lambda f(x)$ and $\mu f(x) \geq f(\mu x)$. This definition implies that if we increase (decrease) the input by a proportionality factor greater (less) than one, the output produced will increase (decrease) by more than the proportionality factor. However, it is often more convenient to look at the returns to scale by examining the firm's cost structure. The ratio of average cost (AC) to marginal cost (MC) provides a measure of the elasticity of scale ($\varepsilon = AC/MC$)) [Chambers (1988)]. The idea is that if AC is greater than MC, then marginal cost is below average cost, and so increasing output will lower average cost. In the single product case, increasing returns to scale is a sufficient condition for a natural monopoly to exist; thus making marginal cost pricing non-profitable for a firm.

While economies of scale explain cost changes that occur as output expands, there may also be changes in cost due to the product mix chosen. If there are cost advantages from the production of several products simultaneously as contrasted with their production in separate firms or processes, then economies of scope are said to occur.

In the multiproduct case, returns to scale is equal to the ratio of total cost to the inner product of the marginal cost vector and the output vector. Economies of scale and scope are not sufficient conditions for the existence of a natural monopoly. A sufficient condition for natural monopoly is cost subadditivity. The definition is for any and all outputs $y^1, \ldots, y^k$, with $y^j \neq y$, $j = 1, \ldots, k$ such that $\sum_{j=1}^{k} y_j = y$, $C(y) < \sum_{j=1}^{k} C(y_j)$. While this seems closely related to the idea of of scope economies, Baumol, Panzar and Willig (1982) have shown that multiproduct economies of scale and scope do not necessarily imply strict subadditivity of the cost function. Cost subadditivity implies that a natural monopoly will exist if the outputs can be produced at a lower cost by one firm than by any combination of firms.

Economies of scale can exist over some ranges of output but not others. For example, at low levels of output, scale economies may be present, while at larger production levels the opposite, *i.e.* diseconomies of scale, may occur. This is, in part, illustrated in Figure 1. Over the output range covered by the demand curve D, the firm's technology exhibits increasing returns to scale.

At the intersection where the marginal cost curve crosses the demand curve, the competitive equilibrium price and quantity are p^c and Q^c respectively. Since the equilibrium output is below the average cost, under competitive pricing, the area $defp^c$ represents the firm's operating losses. In contrast, the monopoly solution is represented by the equilibrium price and quantity p^{NM} and Q^{NM} respectively. At the monopoly equilibrium, the monopolist enjoys profits equal to the area $abcp^{NM}$.

The unanswered question in all the discussions on monopoly power of railroads is to what extent does competition from other modes of transportation impose limits on that degree of monopoly power. Assuming railroads are the sole mode of transportation for grain, adding another source of competition, like trucks, rotates the demand curve for rail cars inward, ceteris paribus. Therefore, railroads face a flatter demand curve (more elastic) as D' in Figure 2.[1]

The solution (P^{NM},Q^{NM}) represents the equilibrium price and quantity under the condition of a natural monopoly as described in Figure 1. Introducing trucking competition into the analysis flattens the demand curve faced by the monopolist railroad. However, both demand curves should cross the horizontal axis at the same point[2]. The monopoly solution with intermodal competition is where the marginal revenue curve crosses the marginal cost curve. The equilibrium price is P^M with quantity Q^M. The equilibrium price will always be lower under competitive pressure from trucks than in a pure monopoly structure ($P^M < P^{NM}$). Clearly, the monopoly power of a railroad over a fixed network is restricted if it faces competition from one or more other modes of transportation. The greater the competitive impact of the truck market for grain transportation, the more elastic the demand for rail transport; and thus the lower is P^M.

STRATEGIC INTERACTION BETWEEN RAILROADS AND ELEVATORS IN AN INTERMODAL TRANSPORTATION FRAMEWORK

Figure 2 assumes a single market and single shippers and strictly linear relationships. A more realistic assessment of the monopolistic power of the railroad would include multiple shippers, multiple receivers and non-linear relationships between all agents. It should also incorporate the non-cooperative bidding process leading to grain receipts and the sales decisions to markets.

Figure 1. Railroad Natural Monopoly

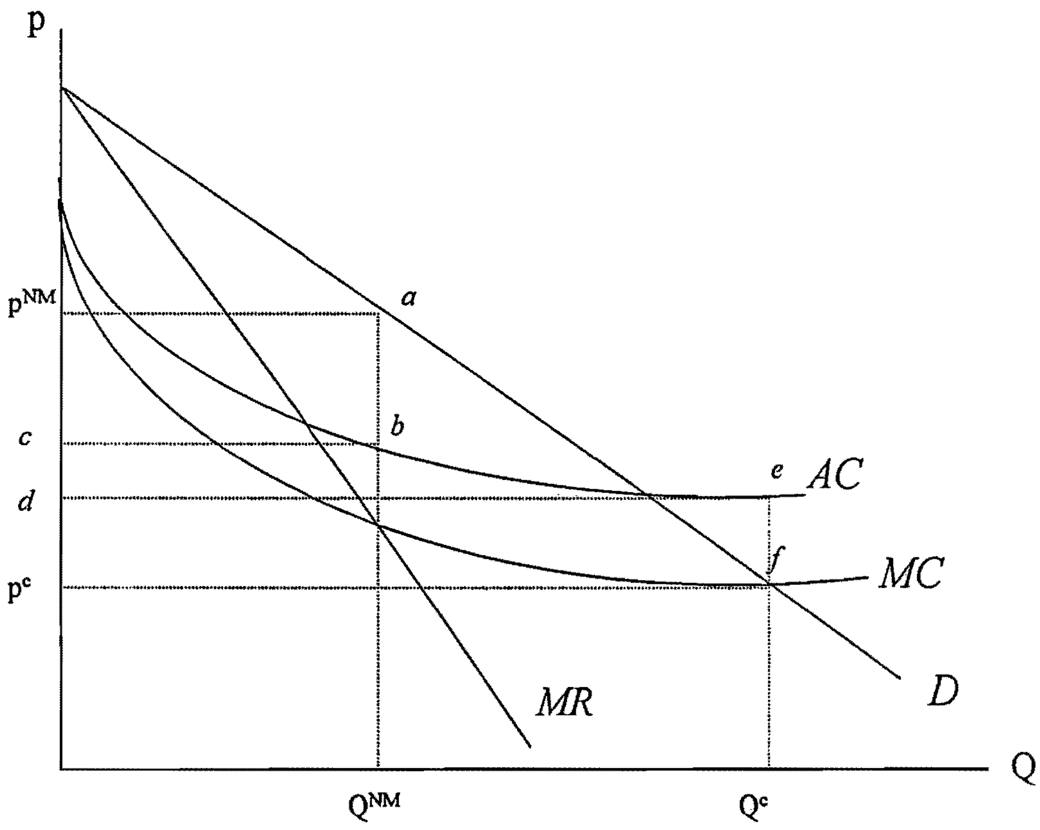
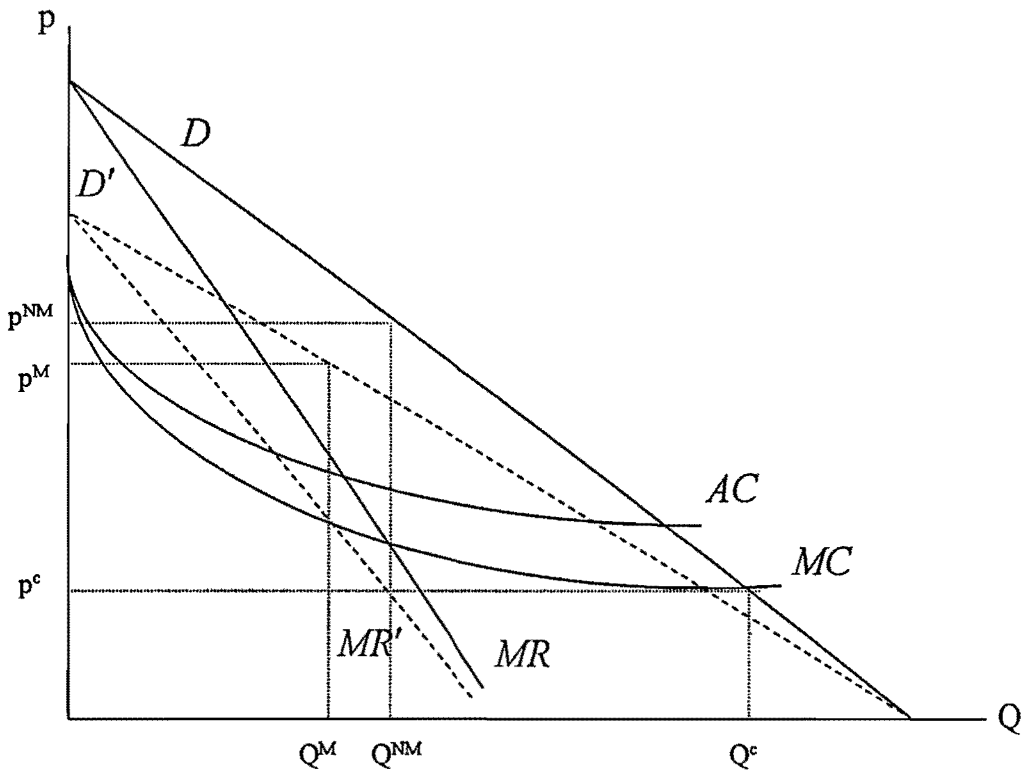


Figure 2. Railroad Pricing with a Natural Monopoly and with Intermodal Competition



To model the strategic impact of truck transportation on a railroad monopoly, we introduce a three-stage game. In the first stage, each grain elevator chooses its bid to grain producers non-cooperatively. In the second stage, railroads choose their supply of rail cars along with a price. In the last stage, grain elevators choose to haul their grain to market either by rail or truck. In this framework, railroads have an incentive to offer competitive rates for two reasons. First, the direct competition effect from the trucking industry in the third stage provides downward pressure on the rail rates. Second, railroads must offer competitive rates to attract grain to rail elevators. Grain elevator operators are rational forward-looking agents. Therefore, they have knowledge at the beginning of the game of the railroads' behavior in the second period. In order for the grain on the farm to reach a rail elevator, a sufficiently high farm bid must be offered by rail elevators. This is encouraged only if railroads offer competitive rail rates to the elevators.

Consider a model where there are N grain elevators. The elevators are divided into two subgroups, N^r and N^t, where N^r consists of elevators with access to rail transport and N^t includes all the elevators with no access to a railroad line. We suppose there are two grain markets in the model. One is a rail market that bids $\bar{p}$ for rail delivered grain, while the other market is a truck market (potentially a river terminal or grain processor) that bids $\bar{q}$ for truck delivered grain.

At the beginning of stage three, the supply of rail cars is known to elevators and they have already received the grain from farms. Profits of elevator $i \in N^r$ are:

$$\pi^i = (\bar{p} - r^i)y^{i,r} + (\bar{q} - \bar{t}^i)y^{i,t} - b^i y^i - \phi^r(y^{i,r}) - \phi^t(y^{i,r}) - \phi^t(y^{i,t}) \tag{1}$$

where r^i is the rail rate for shipping grain to the rail market from elevator i's origin, t^i is the truck transportation cost to the truck market from elevator i's origin, b^i is the elevator bid for grain paid to farmers by elevator i, $y^{i,r}$ and $y^{i,t}$ are the quantities of grain hauled to the rail market and the truck market respectively by elevator i and $\phi^t(y^{i,t})$ and $\phi^r(y^{i,r})$ are the elevator truck and rail handling cost functions respectively. Both cost functions are assumed to be convex in their own argument.

The decision problem for every rail elevator is to choose the quantity of grain $y^{i,r}$ and $y^{i,t}$ to ship. Equation (1) is maximized subject to the constraint that shipments in rail and trucks equal total grain received at the elevator in stage one, *i.e.* $y^{i,r} + y^{i,t} = y^i$. The Kuhn Tucker conditions for the maximization problem are:

$$\frac{\partial \pi^i}{\partial y^{i,t}} = \bar{q} - \bar{t}^i - b^i - \phi^t_y \le 0; \; y^{i,t} \frac{\partial \pi^i}{\partial y^{i,t}} = 0 \text{ if } y^{i,t} = 0 \tag{2}$$

$$\frac{\partial \pi^i}{\partial y^{i,r}} = \bar{q} - r^i - b^i - \phi^r_y \le 0; \; y^{i,r} \frac{\partial \pi^i}{\partial y^{i,r}} = 0 \text{ if } y^{i,r} = 0 \tag{3}$$

where ϕ^t_y and ϕ^r_y denote the first derivative of the cost function with respect to its own argument. Solving for equation (2) and (3) yields the optimal demand for truck transportation at the rail elevator $y^{i,t}(b^i, r^i, t^i, \boldsymbol{\beta})^*$ and the optimal demand for rail cars $y^{i,r}(b^i, r^i, t^i, \boldsymbol{\beta})^*$; for $i = 1, \ldots, N^r$. $\boldsymbol{\beta}$ is the vector of market prices $(\bar{p}, \bar{q})$. Denote by $\boldsymbol{x(b,r,t,\beta)}$ the vector demand of rail cars of dimension N^r x 1[3]. The bold variables $\boldsymbol{b}$, $\boldsymbol{r}$, and $\boldsymbol{t}$ represent vectors of dimension N^r x 1.

At the beginning of stage two, the railroad company must select the rates to offer each of the N^r elevators. The railroad's profit function is:

$$\pi^R = \boldsymbol{r}'\boldsymbol{x}(\boldsymbol{r}, \bar{\boldsymbol{t}}, \boldsymbol{b}, \boldsymbol{\beta}) - c(\boldsymbol{x}) \tag{4}$$

where $c(x)$ is the railroad convex cost function. For simplification, we assume that the railroad's cost function has the following structure: $\boldsymbol{c(x)} = \sum_{i=1}^{N} \gamma^i(y^{i,r}) + F$, where F represents fixed costs. This cost structure implies that the variable cost of providing cars to one elevator is independent of the variable cost of providing cars to another elevator; although variable costs may differ from one elevator to another since the variable cost function is indexed for each elevator. The first order condition for the maximization problem in (4) is:

$$\frac{\partial \pi^R}{\partial r^i} = \frac{\partial y^{i,r}(r^i, \bar{t}^i, b^i, \beta)}{\partial r^i} r^i + y^{i,r}(r^i, \bar{t}^i, b^i, \beta) - \frac{\partial \gamma^i(y^{i,r})}{\partial y^{i,r}} \frac{\partial y^{i,r}}{\partial r^i} = 0, \; i = 1, \ldots, N^r \tag{5}$$

Solving the set of first order conditions in (5) gives the optimal profile of rail rates offered to the grain elevators, $r^i(b^i, \bar{t}^i, \boldsymbol{\beta})^*$; $i = 1, \ldots, N^r$, assuming second order conditions are satisfied. Because of the particular cost structure, the rail rate offered to elevator i is independent of other elevators' truck rate or bid.[4]

In the first stage of the game, each grain elevator decides the bid it offers grain producers to attract grain at their facility. The maximization problem of rail elevator $i \in N^r$ is:

$$\pi^i = (\bar{p} - r^i - b^i)y^{i,r}(b^i, r^i, \bar{t}^i, \beta) + (\bar{q} - \bar{t}^i - b^i)y^{i,t}(b^i, r^i, \bar{t}^i, \beta) - \phi^r(y^{i,r}(b^i, r^i, \bar{t}^i, \beta)) - \phi^t(y^{i,t}(b^i, r^i, \bar{t}^i, \beta)) \tag{6}$$

Differentiate the profit function in (6) with respect to $y^{i,r}$, $y^{i,t}$, r^i and b^i to obtain:

$$d\pi^i = (\bar{q} - \bar{t}^i - b^i - \phi'^t)dy^{i,r} + (\bar{p} - r^i - b^i - \phi'^r)dy^{i,r} - (y^{i,r} + y^{i,t})db^i + [(\bar{p} - r^i - b^i - \phi'^r).\ \frac{\partial y^{i,r}}{\partial r^i} - y^{i,r} + (\bar{q} - \bar{t}^i - b^i - \phi'^t).\ \frac{\partial y^{i,t}}{\partial r^i} - y^{i,t}]dr^i = 0 \tag{7}$$

Equation (7) can be rewritten in a very simplistic way. From (2) and (3), we have respectively that $(\bar{q} - \bar{t}^i - b^i - \phi')$ and $(\bar{p} - r^i - b^i - \phi')$ equal zero. Therefore, assuming an interior solution, the first order condition of the maximization problem in (7) simplifies to:

$$\frac{\partial \pi^i}{\partial b^i} = (y^{i,r} + y^{i,t})(1 + \frac{\partial r^i}{\partial b^i}) = 0 \Rightarrow b^i = \eta^i r^i \tag{8}$$

where $\eta^i = -\frac{\partial r^i}{\partial b^i}\frac{b^i}{r^i}$ is the elasticity[5] of the rail rate with respect to the elevator bid b^i. Equation (8) states that every rail elevator sets its grain bid equal to the rail rate weighted by the elasticity of the rail rate with respect to the elevator's bid. Because of the perfect foresight assumption in our model, rail elevators correctly anticipate the rail rate chosen by the railroad at the next stage. Therefore, they set their bid to grain producers according to some mark-up pricing rule. Their bid is conditioned on the rail rate offered in the second stage. Equation (8) shows the interdependence between the railroad's profit maximization action and the rail elevator's optimal bid to grain producer.

Truck elevators choose their bid to grain producers non-cooperatively. The profit function of elevator $j \in N^t$ is:

$$\pi^j = (\bar{q} - \bar{t}^j - b^j)y^{j,t} - \phi^j(y^{j,t}) \tag{9}$$

The residual supply faced by the truck elevator h is:[6]

$$Q(b^1 - d^1, ..., b^{Nr} - d^{Nr}, b^{Nr+1} - d^{Nr+1}, ..., b^{Nr+Nt} - d^{Nr+Nt}, \beta) - \sum_{i=1}^{Nr} y^i(r^i, b^i, \bar{t}^i, \beta) - \sum_{j\neq h}^{Nt} y^{j,t} - y^{h,t} = 0 \tag{10}$$

where $Q(\bullet)$ is the aggregate grain producers' supply to elevators located at one area and d^i represents the distance from that origin to elevator $i = 1, \ldots, N^r + N^t$. Equation (10) is the behavioral equation of elevator h. Differentiate equation (10) taking as given the bid from other grain elevators to get:

$$Q_h(\bullet)db^h - dy^{h,t} = 0 \tag{11}$$

where Q_h is the partial derivative of the grain supply with respect to elevator h's bid. To optimize the profit function of elevator h, differentiate the profit function in (9) with respect to $y^{h,t}$ and b^h. Using (11), substitute for $dy^{h,t}$ in the preceding equation. Finally, to obtain the first order condition, divide both sides of the equation by db^h:

$$\frac{\partial \pi^h}{\partial b^h} = (\bar{q} - \bar{t}^h - b^h - \phi'^t)Q_j - y^{h,t} = 0 \tag{12}$$

Equation (12) yields the bid reaction function for elevator $h \in N^t$: $b^h = f(b^1, \ldots b^{Nr}, b^{Nr+1}, \ldots, b^{Nr+Nt}, \bar{\boldsymbol{t}}, \boldsymbol{\beta}, \boldsymbol{d})$, where $\boldsymbol{d}$ is the vector of distances from the grain origin to each elevator of dimension $(N^t + N^r)$x1. Imposing a Nash equilibrium,[7] the equilibrium bid of elevator h is: $b^h(\bar{\boldsymbol{t}}, \boldsymbol{\beta}, \boldsymbol{d})^*, h \in N^t$.

The purpose of our theoretical model is to look at the impact of exogenous variables on the equilibrium rail rate and grain bids. Specifically, we examined the impact of the truck market on the rail rates of the monopoly railroad. A measure of the truck competition is the cost of shipping to the truck market from an elevator. This can be answered by looking at the partial derivative of the optimal rail rate with respect to the truck transportation cost, $\bar{t}^i$. As the cost of shipping by truck $(\bar{t}^i)$ increases (decreases) for elevator i, the monopoly power of the railroad should increase (decrease), and therefore r^i should increase (decrease). Formally, define the first order condition in (7) as the function $J^i(r^i, \bar{t}^i)$. From the implicit function theorem:

$$\frac{\partial r^i}{\partial \bar{t}^i} = -J^i_{\bar{t}} / J^i_r = \frac{(r^i - \gamma^i)\partial^2 y^{i,r} / \partial r^i \partial \bar{t}^i + \partial y^{i,r} / \partial \bar{t}^i - \gamma''(\partial y^{i,r} / \partial r^i)(\partial y^{i,r} / \partial \bar{t}^i)}{-J^i_r} \tag{13}$$

Assuming the second order conditions of the maximization problem in (7) are satisfied, $J^i_r < 0$. Therefore, the sign of $\partial r^i / \partial \bar{t}^i$ is the same as the numerator in expression (13). Because of the monopoly structure, $(r^i - \gamma^i)$ is positive since the monopolist is pricing above marginal cost. Therefore, a sufficient condition for $\partial r^i / \partial \bar{t}^i$ to be positive is for the railroad to face a linear demand for rail cars or that $\partial y^{i,r} / \partial r^i / \partial \bar{t}^i \geq 0$. The result $\partial r^i / \partial \bar{t}^i > 0$ illustrates the negative impact of the truck market on the railroad's ability to price above marginal cost. A decrease in the price of trucking transportation lowers the *optimal* price charged by the railroad. This is the direct effect of the trucking market on rail rates.

Other significant conclusions can be drawn from our theoretical analysis. An increase in the bid for rail delivered grain ($\bar{p}$) will have a positive impact on the equilibrium rail rate. The partial derivative:

$$\frac{\partial r^i}{\partial \bar{p}} = -J^i_{\bar{p}} / J^i_r = \frac{(r^i - \gamma^i)\partial^2 y^{i,r} / \partial r^i \partial \bar{p} + \partial y^{i,r} / \partial \bar{q} - \gamma''(\partial y^{i,r} / \partial r^i)(\partial y^{i,r} / \partial \bar{p})}{-J^i_r} \tag{14}$$

Because the terms γ'', $(r^i - \gamma^i)$ and $\partial y^{i,r} / \partial \bar{p}$ are all greater than zero,[8] equation (14) is positive if $\partial y^{i,r} / \partial r^i \partial \bar{p} \geq 0$. Therefore, an increase in the bid for rail delivered grain will increase the equilibrium rail rate. Similarly, it can be proven that the partial derivative $\partial r^i / \partial \bar{q}$ is negative. An increase in the bid for truck delivered grain will cause a decrease in the equilibrium rail rate. The results are fairly intuitive. If the bid for rail delievered grain increases (decreases), the railroad's response is to increase (lower) its rate, leaving the elevator not worse off than before the change in $\bar{p}$. In a similar manner, following an increase (decrease) in the bid for truck delivered grain ($\bar{q}$), the optimal railroad's response is to decrease (increase) its rate. The change in the equilibrium rail rate is needed to make elevator shipments in rail more (less) profitable relatively to trucks following the change in $\bar{q}$.

The major conclusion to be drawn from the above results is that rail rates are determined in a general equilibrium framework. They are not solely determined by the railroad monopoly power (if any). Any significant analysis of the railroad monopoly in grain transportation has to include those factors into the argument to be close to reality.

EMPIRICAL EVIDENCE

Using published survey data of grain producers and country elevators, we argue that there is empirical evidence to support our theoretical claims. In a survey published by the National Grain and Feed Association, Keith (1983) has shown that 96 percent of country elevators in the United States served by rail are served by only one single railroad. Bitzan (1997) examined the cost structure of the Class I railroad industry. Using the empirical test of natural monopoly for the multiproduct firm developed by Shin and Ying (1988), Bitzan showed that railroads are natural monopolies compared to the alternative of having more than one firm serving the same market over duplicate trackage. The obvious reason that 96 percent of the country elevators served by rail are served by only one railroad is that railroad costs increase when a grain shipper is served by more than one railroad. This is the reason that railroads state that "direct rail-to-rail competition yields rates far lower than those needed to cover a railroad total cost." [American Association of Railroads (1998)].

Moreover, Bitzan stressed the importance of modeling the railroad companies as multi-output firm. Previous studies have not found strong evidence of benefits resulting from mergers perhaps because of the single output nature of their analysis. Thus, an elevator asking to be served by two railroads is asking for higher railroad costs and therefore, over the long run, higher railroad rates.

The evidence that railroads face strong intermodal (truck and barge) competition comes from grain flow surveys. Tables 1 and 2 show the number of bushels and percent of the Iowa corn and soybeans that was hauled to market by mode of transport during the period September 1994-August 1995 [Baumel *et. al.* (1996)].

Each table shows two types of movements: one is direct from farms to processors and to the Mississippi River and the second is from country elevators to several markets. The movements direct from farms are necessary to completely account for all shipments because the movements from country elevators do not include grain delivered directly from farms to non-elevator markets. For the entire state, 67.6 percent of the corn and 78.9 percent of the soybeans moved to market by truck. This means that only one out of three bushels of corn moved by rail and only one of five bushels of soybeans moved to market by rail. Thirty-three and 20 percent market shares do not constitute a monopoly.

Table 1. Quantities of Iowa corn delivered to markets by rail and truck September 1994 - August 1995

Source	Millions of Bushels Truck	Rail	Total	Percent by rail
Direct from farms to*:				
Corn processors	160.9	0.0	160.9	0.0
Mississippi River	164.2	0.0	164.2	0.0
Other	144.4	0.0	144.4	0.0
From country elevators to:				
Corn processors	252.9	274.5	527.4	52.1
Mississippi River	81.7	94.2	175.9	53.6
Export ports	0.0	24.3	24.3	100.0
Livestock feeders	155.4	56.8	212.2	26.7
Other	54.9	35.9	90.8	39.8
Total	1,014.4	485.7	1,500.1	32.4

* Excludes corn that was hauled from farms to country elevators

Table 2. Quantities of Iowa soybeans delivered to markets by rail and truck, September 1994 - August 1995

Source	Millions of Bushels Truck	Rail	Total	Percent by rail
Direct from farms to*:				
Corn processors	33.6	0.0	33.6	0.0
Mississippi River	37.9	0.0	37.9	0.0
Other	40.7	0.0	40.7	0.0
From country elevators to:				
Soybean processors	241.9	75.8	317.7	23.9
Mississippi River	34.7	14.6	49.3	29.6
Export ports	0.0	5.9	5.9	100.0
Other	8.0	10.1	18.1	55.8
Total	396.8	106.4	503.2	21.1

*Excludes soybeans that moved from farms to country elevators

All of the corn and soybeans that moved directly from farms to markets was by trucks. About half of the corn and one-fourth of the soybeans that were shipped from country elevators to processors and to the Mississippi River moved by rail. All of the corn and soybeans that were shipped directly to export ports were hauled by rail. However, Table 3 shows that railroads had only about a 7 percent share of all Iowa corn and soybeans that were shipped to export ports; barges hauled about 93 percent of these shipments.

One might argue that while railroads hauled only one-third of the Iowa corn and one-fifth of the Iowa soybeans that were delivered to markets, there may be areas in the state where railroads hold a virtual monopoly. Table 4 shows the modes of transport to ship corn and soybeans from the Northwest Iowa Crop Reporting District (CRD). The Northwest CRD is the most distant Iowa CRD to most corn processor and river markets. Table 4 shows that railroads hauled only 50 percent of the combined Northwest CRD corn and soybeans to market. As with the statewide data in Tables 1 and 2, railroads hauled 100 percent of the Northwest CRD corn and soybeans to export ports and 96 percent to the Mississippi River. However, railroads hauled only 25 percent of corn shipments to feeder markets. Corn for feed was the largest market for Northwest CRD corn.

These data indicate that railroads do not have a statewide monopoly on the movement of Iowa corn and soybeans and there appears to be no isolated areas where railroads have local monopolies. Moreover, the railroad shares of Iowa corn and soybean shipments appear to be declining. The 1985 railroad shares of shipments from Iowa country elevators to non-farm markets were 56.3 percent for corn and 32.4 percent for soybeans [Baumel *et al.* (1989)]. Subtracting the direct farm-to-market shipments from the 1994-95 data in Tables

Table 3. Comparison of the quantities of Iowa corn and soybeans transported to export ports by rail and barge in millions of bushels, September 1994 - August 1995

	Thousands of Bushels			
Grain	Barge	Rail	Total	Percent by rail
Corn	340.1	24.3	364.4	6.7
Soybeans	87.2	5.9	93.1	6.3
Total	427.3	30.2	457.5	6.6

Table 4. Quantities of Northwest Iowa Crop Reporting District corn and soybeans delivered to markets by rail and truck, September 1994 - August 1995

	Thousands of Bushels			
Source	Truck	Rail	Total	Percent by rail
Direct from farms to:				
Processors	2.9	0.0	2.9	0.0
Mississippi River	0.0	0.0	0.0	--
Other	14.3	0.0	14.3	0.0
From country elevators to:				
Processors	41.6	65.6	107.2	61.2
Mississippi River	1.1	29.6	30.7	96.4
Livestock feeders	60.6	20.5	81.1	25.3
Export ports	0.0	26.3	26.3	100.0
Other	20.7	0.0	20.7	0.0
Total	141.2	142.0	283.2	50.1

1 and 2, the comparable 1994-95 railroad shares of shipments from country elevators were 47.1 and 27.1 percent respectively. Thus, the railroad share has declined since 1985.

Gervais and Baumel (1997) collected data on the number of grain hauling vehicles owned by Iowa grain producers. In 1994-95, Iowa farmers owned 6,200 semis; by the year 2000, they expect to own 12,650 semis. Their results show that Iowa farmers expect to more than double the number of semis they own between 1995 and 2000. Thus, the amount of grain that will be hauled directly from farms to markets is likely to increase sharply in the near future, further increasing inter-modal competition. In addition, the increased number of semis means that farmers will increase intramodal competition by their ability to economically haul grain to country elevators located on competing railroads. Thus, the railroad shares of Iowa corn and soybean shipments have declined in recent years and will probably continue to decline in future years.

The conclusions drawn from the Iowa survey are expected to hold for most of the corn belt states and indeed for most of the winter wheat belt states[9]. The Mississippi River provides intermodal competition to the railroads in the majority of the corn belt states. There is however an interrogation with the state of Montana because it does not have inexpensive transportation access to the Mississippi River. However, a large amount of Montana wheat is trucked to Lewiston, Idaho for barging down the Columbia-Snake River. Those trucking shipments have a legal gross weight limit of up to 105,500 lbs. Thus, trucking Montana wheat is significantly cheaper than trucking in almost all of the corn belt states where trucks are subject to a gross weight limit of 80,000 lbs. Based on those observations, there exists significant intermodal competition to rail transport in most of the grain producing states.

This is further confirmed by a recent USDA report [Eriksen, Norton and Bertels (1998)]. Railroads had an overall market share of U.S. corn shipments of 36.5 percent in 1995. This is higher than the 1994-95 railroad share of 32.4 percent of Iowa grain shipments. However, the railroad share of U.S. corn shipments direct to export ports declined from 40.5 percent in 1978 to 17.6 percent in 1994. Surprisingly, the 1995 modal share of rail to export ports jumped to 33.2 percent in 1995. This trend reversion may partially be explained by a large increase in corn exports for 1995. Corn exports have increased from 39,198 million tons in 1994 to 65,201 million tons in 1995, an increase of 66.3 percent from the 1994 year. Nearly 57 percent of this increase was carried by the railroads. Barge rates typically exceed rail rates in response to increasing export demand, resulting in a large

Table 5. Shipments of corn by mode of transport, United States, in millions of tons, 1995

Destination	Rail	Truck	Barge	Total	Percent by rail
	Millions of Tons				
Domestic	57.7	92.0	2.7	152.4	37.9
Export ports	21.7	38.1	5.4	65.2	33.2
Total	79.3	97.4	40.8	217.5	36.5

Source: Ericksen, Ken A., Jerry D. Norton and Paul J. Bestels, "Transportation of U.S. Grains: A Modal Share Analysis, 1978-1995", USDA, March 1998.

increase in the demand for railroad transport of grain.

There was an increase in the share of corn shipments by trucks over the 17 year period from 1978 to 1995. The U.S. total corn shipments in trucks increased from 27.3 percent of total corn shipments in 1978 to 44.8 percent in 1995. This positive trend in truck shipments confirms the results of the large increase in truck transport in Iowa grain flow survey.

CONCLUDING REMARKS

The recent contentious debate between railroads and railroad shippers focuses on recent service problems experienced by the Union Pacific Railroad in its purchase of the Southern Pacific Railroad. To a large extent, however, the debate rests fundamentally on the perceived degree of monopoly power of the railroad industry.

From an intramodal competition framework, railroads are indeed natural monopolies because the cost of serving a shipper by one railroad is lower than by any combination of railroad firms. Thus, in the absence of any other transportation alternative, railroads do indeed posses monopoly power. However, given intermodal competition, railroads immediately lose their monopoly status and must offer more competitive prices to maximize their profits.

We have demonstrated by economic theory that intermodal competition reduces the market power of railroads. Surveys in Iowa and in the U.S. indicate that intermodal competition is strong in the grain industry. Not only do railroads not have monopoly power, but they have continued to lose their market share of grain movements. The reasons for the erosion of market shares are increased farmer ownership of semi trucks, rapid increases in the number of local markets that are easily and economically accessed by semi trucks and the reduced share of railroad shipments to export ports. The new local markets include corn and soybean processors and local large-scale feeder markets. Given the expected growth in the number of farmer owned semis and in local processors-feeder markets, and combined growth in grain barge shipments, it is likely that railroads will continue to face even greater intermodal competition.

Grain producer and shipper groups face two basic alternatives as they lobby for increased competition in the railroad industry. The first alternative is to seek legislative measures to reregulate railroad rates, service and access. Nearly a century of experience with railroad regulation eroded the railroad market share of grain because of sticky regulated rail rates and flexible unregulated truck and barge rates. This resulted in major deterioration of railroad track and equipment and bankruptcy of a significant portion of the rail system. An alternative to reregulation to increase competition is to help grain producers and shippers to position themselves to recognize and take advantage of intramodal and intermodal transportation opportunities. They can do this by recognizing and using trucks to access the highest net bid for intramodal rail markets and by recognizing and using trucks to take advantage of intermodal opportunities at the growing number of local and regional processing and feeder markets.

REFERENCES

Association of American Railroads, "Review of Rail Access and Competition Issues", Comments presented before the Surface Transportation Board, STB Ex-Parte no. 575, 1998.

Attorney Generals States of Ohio-Illinois-Iowa-Texas, Review of Rail Access and Competition Issues, Comments presented before the Surface Transportation Board, STB Ex-Parte No. 575, 1998

Baumel, C. Phillip, Shawn R. Ferriss and Craig O'Riley, "The Iowa Grain Flow Survey: A Comparison of Iowa Corn and Soybean Movements in 1977 and 1985", Iowa State University, August 1989.

Baumel, C. Phillip, Jean-Philippe Gervais, Harold Hommes and Craig O'Riley, "The Iowa Grain Flow Survey: Where and How Iowa Grain Producers and Country Elevators Ship Corn and Soybeans", Iowa State University Extension, 1996.

Baumol, William J, John C. Panzar and Robert D. Willig, *Contestable Markets and the Theory of Industry Structure*, Harbourt Brace Jovanovich Inc., New York, 1982.

Berg, Sanford V. and John Tschirhart, *Natural Monopoly Regulation*, Cambridge University Press, Cambridge, MA, 1988.

Bitzan, John D., Railroad Cost Considerations and the Benefits/Costs of Mergers, Upper great Plains Transportation Institute, North Dakota State University, MPC Report 97-80, September 1997.

Chambers, Robert G., *Applied Production Analysis, A Dual Approach*, Cambridge University Press, New-York, 1988.

Ericksen, Ken A., Jerry D. Norton and Paul J. Bestels, "Transportation of U.S. Grains: A Modal Share Analysis, 1978-1995", USDA, March 1998.

Gervais, Jean-Philippe and C. Phillip Baumel, "The Iowa Grain Flow Survey: Where and How Iowa Grain Producers Ship Corn and Soybeans", *Journal of the Transportation Research Forum*, Vol. 37, No. 1, 1997.

Varian, Hal R., *Microeconomic Analysis*, W. W. Norton & Company, New-York, 1992.

Whiteside, Terry C., "Review of Rail Access and Competition Issues", *Statement of the Alliance for Rail Competition before the Surface Transportation Board*, Ex-Parte No. 575, 1998

Wilner, Frank N., "Legislation Shippers' Rallying Point", *Traffic World*, May 18, 1998.

ENDNOTES

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1. This modeling is almost equivalent to an oligopoly industry producing heterogeneous goods. The only difference is that the trucking industry is assumed to be perfectly competitive. In other words, there exists a sufficiently high number of trucking firms that the truck rate is assumed to be exogenous. Therefore, even when we introduce another mode of transportation in the model, because the two mode of transport are not perfect substitute, the railroad is still left with some market power to exercise.

2. An infinitely small price for rail transport will cause the demand for rail to be the same independently of the existence of truck competition, ceteris paribus.

3. We assume there is an equilibrium between the supply and demand of rail cars. This clearly may not be satisfied in the real world (e.g. grain car shortages during July 1995-March 1996 in the Upper Midwest). However, in a dynamic framework, it is easy to imagine that any disequilibrium will be corrected in the long run. Therefore, our analysis can be interpreted as a long run equilibrium model.

4. In other words, the cost structure eliminates any strategic interaction among the rail elevators at stage one of the game, *i.e.* when they choose the bid they offer grain producers. However, as we shall see, it does not eliminate strategic interaction between truck elevators.

5. It can be proven by simple comparative static analysis that the elasticity η^i is positive. The partial derivative of rail rate with respect to elevator i's bid is negative. From (5), assuming that $\partial y^{i,r}/\partial r^i \partial b^i \geq 0$, the sign of $\partial r^i/\partial b^i$ equals the sign of $\partial y^{i,r}/\partial b^i$. By performing comparative static analysis on the set of first order conditions (2) and (3), $\partial y^{i,r}/\partial b^i < 0$ and so $\partial r^i/\partial b^i < 0$. The intuition is that an increase in the elevator's grain bid must cause a decrease in the rail rate in order for the elevator to offset the loss in profit due to the increase in b^i and for the railroad to attract the same amount of grain to haul, ceteris paribus.

6. For simplicity, we abstract from the individual grain producers' transportation problem. We assume the aggregate supply

of grain $Q(\cdot)$ is located at one origin. Therefore, the quantity of grain available is a function of every net bid (cash price minus transportation cost) offered by the elevators.

7. For a formal definition of the Nash equilibrium concept, the reader is referred to Varian (1992). Roughly speaking, a Nash equilibrium is an equilibrium in actions and beliefs. In equilibrium, each player correctly foresees how likely the other player is to make various choices and the beliefs of every player are mutually consistent. In our example, the bid of elevator h is a best response to the bids actually chosen by the other $N^{t} - 1$ other truck elevators given a set of exogenous variables.

8 γ'' is positive because the railroad variable cost function is convex. $(r^{j} - \gamma')$ is positive because of the monopoly pricing practice by the railroad. By performing a comparative static analysis on the set of first order conditions (2) and (3), $\partial y^{j,r}/\partial \bar{p} > 0$.

9. The corn belt states include the states of Illinois, Iowa, Indiana, Michigan, Minnesota, Nebraska, Missouri, Ohio and South Dakota. The winter wheat belt states include the states of Kansas, Colorado, Oklahoma and Texas.

GRAIN TRANSPORTATION CAPACITY OF THE UPPER MISSISSIPPI AND ILLINOIS RIVERS: A SPATIAL ANALYSIS

by Stephen Fuller, Luis Fellin,* and Warren Grant**

ABSTRACT

A recent study projects traffic on the upper Mississippi and Illinois Rivers will nearly double by 2050. Spatial models of the corn and soybean sectors in combination with an estimated lock delay equation are used to explore the implications of increased traffic levels. Analysis shows 58 percent of the current corn movement on the upper Mississippi River would be diverted if congestion and delay associated with a doubling of traffic were experienced. It seems unlikely that the analyzed rivers would carry the projected increase in tonnage.

INTRODUCTION

The inland waterways are important transportation arteries for many commodities and products. Nearly half of the lock chambers in the inland waterway system are over 50 years of age and in need of rehabilitation or expansion. Trust fund resources are not adequate to rehabilitate or expand all locks, thus concern regarding the growing backlog of structures that require attention and the implication of this for future transportation (Bronzini, 1997). Of concern to agricultural interests in the Midwest are the upper Mississippi and Illinois Rivers which are central to the transportation of corn/soybean exports to lower Mississippi River ports (Kerkhoff, 1996). The upper Mississippi and Illinois waterways include 40 lock chambers whose average age is about 57 years. It is estimated that states bordering these Rivers (Illinois, Iowa, Minnesota, Missouri, and Wisconsin) ship over 90 percent of their export-destined corn/soybeans to the lower Mississippi River port area and about 95 percent of these shipments are transported via these two Rivers (Larson, Smith, and Baldwin, 1990; Fruin, Halbach, and Hill, 1990). Further, about one-half of U.S. corn exports and one-third of U.S. soybean exports originate on these two waterways.

A recent study commissioned by the U.S. Army Corps of Engineers, Institute for Water Resources projects traffic on the upper Mississippi and Illinois Rivers to increase about 90 and 86 percent, respectively, by 2050 (Jack Faucett Associates, 1997). Further, it estimates grain/soybean traffic as a share of all traffic to increase from 48 to 61 percent on the upper Mississippi and from 36 to 50 percent on the Illinois River. In view of the significant delay that now exists at selected locks on these waterways, agricultural interests have expressed concern regarding the projected increase in waterway traffic and its implication for congestion, delay cost and ultimately corn/soybean barge rates on these important transportation arteries. The objective of this study is to estimate the effect of the projected increase in upper Mississippi and Illinois River traffic on the cost of transporting corn/soybeans by barge and the subsequent impact on corn/soybean producer prices and revenues, and flow patterns. The analysis is accomplished with an estimated lock delay equation and spatial, intertemporal equilibrium models of the international corn and soybean sectors. The spatial models are representative of the 1990s, thus the analyses identifies the effects of projected congestion, lock delay and increased barge costs on the grain production and transportation system of the 1990s.

BACKGROUND

Barge transportation on the upper Mississippi and Illinois Rivers is facilitated by canalization and a system of locks and dams which create pools with a minimum navigable depth of 9 feet. The upper Mississippi River includes 28 lock sites and 32 lock chambers while the Illinois Waterway is comprised of 8 lock sites and chambers (Figure 1). Export-destined grain and soybeans originating on the upper Mississippi and Illinois Rivers must traverse all locks below its entry point into the River. Export-destined grain/soybeans encounter no additional locks below lock and dam 27.

Nearly all locks and dams on the upper Mississippi and Illinois Rivers were constructed during the 1930's: the exceptions include lock 19, the Melvin Price, lock 27 and the T. J. O'Brien which have been constructed since the early 1950's (U.S. Army Corps of Engineers, 1992a). Lock chambers at newer facilities are 110 feet wide and

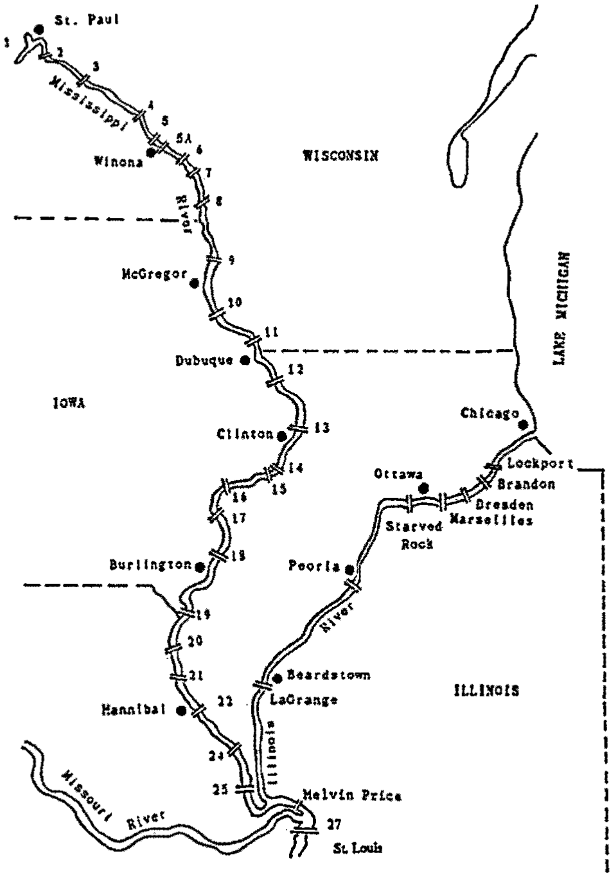

Figure 1. Upper Mississippi and Illinois Rivers

1200 feet in length and are ideal for handling tows made up of jumbo hopper barges (35' x 195') that are three barges wide and four or five barges in length. Because chambers at most remaining locks are 600 feet in length, virtually all tows must be double locked. Break-up and reassembly of the tow plus the two lockage operations require about an hour and a half whereas lockage at a 1200 foot chamber involves a single operation that is accomplished in 20 to 30 minutes. Further, as tonnage moving on the river system has increased over time, tows have experienced an increase in delay. Since operating costs of a tow boat range from $400 to $500 per hour, double lockage and delay impose a cost on operators that add to the shipper's transportation cost (U.S. Army Corps of Engineers, 1992a).

Greatest average delay is associated with those locks on the lower portion of the upper Mississippi: this is expected since these facilities handle comparatively large tonnages and their short chambers (600 foot) require double lockage of most tows. Based on annual lock performance statistics collected by the U.S. Army Corps of Engineers during 1991 through 1995, highest average delay per locked tow was at locks 22, 24, and 25, where average delay per tow ranged between three and four hours. Average delay at locks 17, 18, and 20 were comparatively high with average delay per locked tow ranging from two to three hours. Locks 14, 15, 16, and 21 had average delay per tow ranging from one to two hours as did most locks on the Illinois River (U.S. Army Corps of Engineers, 1992b, 1993, 1994a, 1994b, 1995).

PROCEDURES, MODEL AND DATA

This study is designed to measure the affects on barge costs and grain prices and revenues that result from the projected doubling of traffic on the upper Mississippi and Illinois River by 2050. The spatial models used in the analysis are representative of the 1990s, thus results identify the effects of the anticipated congestion and heightened barge costs on grain marketing and transportation in the current period.

Initially, a lock delay equation was estimated that measured lock delay as a function of utilized lock capacity. The analysis assumes future traffic on various River segments will increase proportionately through time. In which case, if a particular lock had historically operated at 40 percent of capacity (1991-1995), a 50 percent increase in traffic would have the lock operate at 60 percent of capacity. The analysis evaluates the effect of growing traffic levels by examining a 25, 50, 75, 100, 125, and a 150 percent increase in traffic over the average of the 1991-1995 traffic levels. For each lock, the lock delay equation is used to estimate the average delay per tow associated with an elevated traffic level. The estimated lock delays associated with an elevated traffic level were subsequently entered into a barge costing model to estimate the heightened barge costs associated with various routings. Finally, the heightened barge costs were included in the spatial models of the international corn and soybean sectors and the models solved to determine the effect of the elevated traffic level on flow patterns and producer prices and revenues. The effect of the elevated traffic levels and heightened barge costs are measured by contrasting spatial model solutions representative of the current lock delay patterns (base model) with solutions that reflect the increased lock delay and barge costs associated with the six elevated traffic levels.

Estimated Lock Delay Equation and Barge Costs

The most important long-run force affecting tow delay at locks is the portion of lock capacity which is utilized: further, delay appears to increase exponentially as a lock approaches capacity (U.S. Army Corps of Engineers, 1992a). To develop insight on the relationship between tow delay and utilization of lock capacity, a regression equation was estimated that was based on the 1995 annual lock performance monitoring system data for upper Mississippi locks whose chambers were 600 feet in length. The specified equation included average annual delay per locked tow as the dependent variable and portion of lock capacity utilized as the independent variable. Portion of lock capacity utilized was based on the projected traffic level and estimates of annual lock capacity (Army Corps of Engineers, 1992a). The specified equation assumed tow delay increased exponentially as lock utilization increased. The following estimated lock delay equation was obtained with ordinary least-squares: t-ratios are shown in parenthesis.

$$\text{Average Delay per Tow} = -4.348 + 3.543\,\text{Exp}(\text{Caputd})$$
$$(-12.430) \quad (14.010)$$
$$R\text{-Square} = .9034 \qquad N = 23$$

where,

Average Delay per Tow is in hours, and
Caputd is the portion of lock capacity utilized.

Barge transportation costs from selected barge loading sites on the upper Mississippi and Illinois Rivers to lower Mississippi River ports were estimated for 25, 50, 75, 100, 125, and 150 percent increases in traffic with the tow delay equation, annual lock capacity information and a barge costing model. Estimates of tow delay were obtained for each lock at the six traffic levels: these estimates were subsequently included in the barge cost model for purposes of estimating the cost of barging grain from the River's selected barge-loading sites to the lower

Mississippi River ports. To provide a benchmark, barge transportation costs that reflect recent historical traffic levels are shown: these are referred to as "base" estimates in Table 1.

Spatial Equilibrium Models

The spatial models include regional corn/soybean demands and supplies and transportation rates and costs representative of the 1992-1994 period, whereas estimated barge costs reflect the heightened congestion and delay associated with the 25, 50, 75, 100, 125, and 150 percent increase in traffic. Thus, results measure rerouted flows, and prices and revenues that would result if the anticipated congestion, delay and associated barge costs were imposed on the current production, marketing and transportation systems.

The spatial, intertemporal equilibrium models include the domestic and international corn and soybean sectors. The quadratic programming models generate interregional trade flows and prices that result from maximizing producer plus consumer surplus minus grain handling, storage, and transportation costs (Samuelson, 1952; Takayama and Judge, 1971). The models include considerable detail on regional excess demands/supplies and logistics/transportation costs in the United States and Mexico. Other trading countries are treated as an excess supply or demand regions.

The following is a mathematical representation of the developed corn and soybean models under the assumption of linear excess demand/supply relationships. Equation 1 is the objective function which is maximized subject to constraints 2 through 13. See Table 2 for definition of subscripts, parameters and variables included in the following equations:

(1) Maximize $Z = \{\sum_q$

$$- \sum_i (\alpha_{iq} + 0.5\,\beta_{iq} S_{iq}) S_{iq} - \sum_f (\alpha_{fq} + 0.5\,\beta_{fq} S_{fq}) S_f$$

$$- \sum_r (\alpha_{rq} + 0.5\,\beta_{rq} S_{rq}) S_{rq}$$

$$+ \sum_j (\alpha_{jq} - 0.5\,\beta_{jq} D_{jq}) D_{jq} + \sum_d (\alpha_{dq} - 0.5\,\beta_{dq} D_{dq}) D_{dq}$$

$$+ \sum_h (\alpha_{hq} - 0.5\,\beta_{hq} D_{hq}) D_{hq} \}$$

$$- \{ \sum_m (\sum_i (\sum_j C_{ijm} T_{ijqm} + \sum_b C_{ibm} T_{ibqm} + \sum_p C_{ipm} T_{ipqm}))$$

$$\sum_r \sum_h (C_{rhm} T_{rhqm}) + \sum_u \sum_j (C_{ujm} T_{ujqm})$$

$$+ \sum_w (\sum_i C_{iwm} T_{iwqm} + \sum_h C_{whm} T_{whqm}) \}$$

$$- \sum_b (\sum_u C_{bu} T_{buq} + \sum_p C_{bp} T_{bpq})$$

$$- \sum_d (\sum_p C_{pdq} T_{pdq} + \sum_f C_{fdq} T_{fdq})$$

$$- \sum_x (\sum_p C_{pxq} T_{pxq} + \sum_f C_{fxq} T_{fxq} + \sum_h C_{xhm} T_{xhm}) \},$$

subject to:

(2)

$$\sum_m (\sum_j T_{ijqm} + \sum_b T_{ibqm} + \sum_p T_{ipqm}) + G_{qq+1} \le S_{iq} + G_{q-1q} \text{ for all } i, q;$$

(3) $\sum_m (\sum_h T_{rhqm}) + G_{qq+1} \le S_{rq} + G_{q-1q}$ for all r, q;

(4) $\sum_p T_{bpq} + \sum_u T_{buq} \le \sum_i \sum_m T_{ibqm}$ for all b and q;

(5) $\sum_j \sum_m T_{ujqm} \le \sum_b T_{buq}$ for all u and q;

(6) $\sum_h \sum_m T_{whmq} \le \sum_i \sum_m T_{iwmq}$ for all w and q;

(7)

$$\sum_d T_{pdq} + \sum_x T_{pxq} \le \sum_m \sum_i T_{ipmq} + \sum_b T_{bpq} \text{ for all p and q;}$$

(8) $\sum_m (\sum_i T_{ijmq} + \sum_u T_{ujmq}) \ge D_{jq}$ for all j and q;

(9) $\sum_m \sum_h T_{xhmq} \le \sum_p T_{pxq} + \sum_f T_{fxq}$ for all x and q;

(10) $\sum_p T_{pdq} + \sum_f T_{fdq} \ge D_{dq}$ for all d and q;

(11) $\sum_d T_{fdq} + \sum_x T_{fxq} + R_{qq+1} \le S_{fq} + R_{qq-1}$ for all f and q;

(12)

$$\sum_m (\sum_w T_{whmq} + \sum_x T_{xhmq} + \sum_r T_{rhmq}) \ge D_{hq} \text{ for all h and q;}$$

(13)

T, S, D $\ge$ 0 for all i, j, f, q, d, b, u, p, r, h, x, and w.

Table 1. Estimated Barge Costs for Selected Routings to Lower Mississippi River Port Area with 25, 50, 75, 100, 125, and 150 Percent Increase in Traffic Levels[1]

	Barge Costs ($/Metric Ton)						
Origin	Base	25%	50%	75%	100%	125%	150%
	------------------------------$------------------------------						
St. Paul, MN	9.79	10.27	10.79	11.41	12.10	13.05	13.98
Winona, MN	9.10	9.56	10.04	10.62	11.26	11.99	12.06
McGregor, IA	8.61	9.04	9.49	10.02	10.63	11.27	12.03
Dubuque, IA	8.30	8.69	9.11	9.59	10.16	10.39	11.09
Clinton, IA	8.03	8.39	8.78	9.25	9.80	10.20	10.69
Burlington, IA	7.19	7.37	7.61	7.91	8.26	8.52	8.77
Hannibal, MO	6.60	6.68	6.83	7.02	7.25	7.49	7.87
St. Louis, MO	5.63	5.63	5.63	5.63	5.63	5.63	5.63
Ottawa, IL	7.37	7.45	7.52	7.62	7.73	7.85	7.98
Peoria, IL	6.76	6.84	6.90	6.97	7.05	7.10	7.15

[1] Represents a 25, 50, 75, 100, 125, and 150 percent increase in average 1991-1995 traffic levels.

Table 2. Subscripts, Parameters and Variables Included in Formulated Models	
Subscripts:	
q	quarter (1, 2, 3, 4)
i	U.S. excess supply regions (i = 1, 2, 3, ..., m)
r	Canada excess supply regions (r = 1, 2, 3, ..., m)
f	Foreign exporting regions (f = 1, 2, 3, 4,..., m)
j	U.S. excess demand locations (j = 1, 2, 3, ..., m)
h	Canada excess demand regions (h = 1, 2, 3,...., m)
d	Foreign importing regions (d = 1, 2, 3, ..., m)
m	Inland modes of transportation (m = 1, 2, 3)
b	Barge loading locations (b = 1, 2, 3, ..., 37)
u	Barge unloading locations (u = 1, 2, 3,..., 5)
p	U.S. ports (p = 1, 2, 3, ..., 17)
w	U.S.-Canada border crossing locations (w = 1, 2, 4)
x	Canada ports (x = 1, 2, 3,.., 5)
l	Lakers
s	St. Lawrence Ports (s = 1, 2, 3)
Parameters:	
C	Transportation and grain handling cost per metric ton for truck, railroad, barge and ship modes as appropriate
K	storage cost per metric ton
Variables:	
S_i	U.S. excess supply regions
S_r	Canada excess supply regions
S_f	Foreign excess supply regions
D_j	U.S. excess demand regions
D_h	Canada excess demand regions
D_d	Foreign excess demand regions
T	Grain flow in metric tons between nodes
G	Quantities of grain stored in the United States and Canada per quarter
Z	Quantities of grain stored in other major exporting countries per quarter

The objective function (1) maximizes net social payoff or consumer plus producer surplus minus grain handling, storage, and transportation costs. Equation 2 constrains the quantity of grain shipped from each U.S. supply region to all receiving and transhipment points in each quarter to be less than or equal to the quantity supplied or carried-over by the supply region. Similarly, Equation 3 constrains quantity of grain shipped from each Mexico supply region to all receiving locations in each quarter to be less than or equal to quantity supplied or carried over. Equation 4 constrains the quantity of grain shipped from a barge-loading location in each quarter to be less than or equal to the total quantity received from all supply regions. Equation 5 balances the inflow and outflow of grain at each barge unloading location in each quarter while equation 6 balances intercountry flows at each U.S./Mexico border crossing location. Equation 7 balances the inflow and outflow of grain at each U.S. port in each quarter. Equation 8 constrains quantity shipped by all inland transportation modes to each domestic demand region to be at least equal to or greater than the quantity demanded at each U.S. demand region in each quarter. Equation 9 constrains shipments from Mexican ports to Mexican demand regions to be less than or equal to inflows at Mexican ports. Equation 10 forces the quantity of grain received by each foreign demand region to be at least equal to or greater than the quantity demanded by each foreign demand location in each quarter. Equation 11 constrains quantity of grain shipped by each foreign excess supply region in each quarter to be less than or equal to the quantity supplied or carried over by the foreign excess supply region. Equation 12 forces quantity shipped by all inland transportation modes from Mexican ports, U.S.-Mexico border locations and Mexico supply regions to each Mexico demand region to be equal or greater than quantity demanded and equation 13 includes the non-negativity conditions.

The international corn model includes eighty-nine excess supply regions and 104 excess demand regions. The excess corn supply regions include sixty-five U.S. regions, eight Mexican regions and five foreign regions (Argentina, China, France, South Africa, and Other). Included among the excess corn demand regions are sixty U.S. regions, fourteen Mexican regions and twenty-five foreign demand regions. With the exception of Japan, South Korea, China, Canada and Taiwan, the foreign excess demand regions are an aggregation of countries. The international soybean model includes ninety-one excess supply regions and sixty-eight excess demand regions. Sixty-eight of the excess supply regions are located in the U.S., eight in Mexico, and four are foreign excess supply regions (Argentina, Brazil, Paraguay, and Other). The excess soybean demand regions include twenty-four U.S. regions, nineteen Mexican regions and twenty-five foreign regions.

Imbedded in the United States and Mexico portions of the models is an extensive transportation network that connects excess supply regions with excess demand regions and ports via truck, rail and barge modes. Excess supply regions are linked by truck and rail to thirty-seven barge-loading sites on the inland waterway system: the barge loading sites are linked to barge unloading sites on the inland waterway system and ports as appropriate. Seventeen U.S. ports receive corn and soybeans from the excess supply regions via truck, rail and barge as appropriate and then ship via maritime to a representative port in each of the twenty-five foreign excess demand regions. A representative port in each of the foreign excess supply regions is also linked by maritime to each of the foreign excess demand regions.

To reflect freezing of the Great Lakes and upper Mississippi waterways, the models disallow shipping via these arteries in the winter quarter. Grain handling and storage costs are incurred in United States, Mexico, and foreign excess supply regions; handling costs (loading/unloading) are incurred at U.S. excess supply locations, barge loading, and unloading locations, and ports while inspection fees and interlining costs are incurred at U.S.-Mexico border crossing sites. The corn and soybean models include four quarters and represent the commodity crop year (October 1 - September 30). See Appendix for more information on the spatial models.

Model Data

The spatial models were constructed with estimates of domestic and foreign excess demand and supply equations; grain handling and storage costs; railroad, truck, barge, and ship costs/rates; and applicable tariffs and quotas.

The short-run excess supply equations for regions/countries were obtained with an estimated excess supply elasticity, exports or estimated surplus and price. An estimated region/country excess supply elasticity in combination with its exports or estimated region surplus and region/country price facilitated the estimation of the slope and intercept parameter of an inverse excess supply function for each region/country. In a similar manner, an inverse short-run excess demand equation was estimated for each region/country with an estimated excess demand elasticity, imports or estimated region deficit and price. The excess supply and demand elasticities for each region/country were based on the following formulations (Kreinen; Shei and Thompson, 1977; Yntema, 1932)

(1) $E_{es} = Q_d / Q_e |E_d|$
(2) $E_{ed} = Q_d / Q_i E_d$

where,
E_{es} = excess supply elasticity of region
E_{ed} = excess demand elasticity of region
Q_d = quantity demanded or consumed in region
Q_e = quantity exported from region
Q_i = quantity imported into region
E_d = own-price demand elasticity

The own-price demand elasticities (E_d) to estimate region and country excess supply/demand elasticities were taken from Sullivan, Roningen, Leetmaa, and Gray (1992). Data on production, consumption (Q_d), exports (Q_e) and imports (Q_i) of corn and soybeans for all foreign excess demand/supply countries came from the USDA's *Production,Supply and Distribution (PS&D)* database. The primary corn exporters (foreign excess supply regions) that competed with the United States in the international market were Argentina, France, Union of South Africa, and China with annual exports of 4.7, 6.4, 1.2 and 12.6 million metric tons (mmt), respectively. Leading corn importers (foreign excess demand regions) included Japan (16.8 mmt), South Korea (6.5 mmt), and Taiwan (5.7 mmt). Argentina, Brazil, and Paraguay were leading exporters in the soybean model with respective exports of 2.3, 3.9 and 1.3 mmt, while Japan (4.8 mmt), Taiwan (2.4 mmt), South Korea (1.1 mmt) and regions identified in the model as north central Europe (8.9 mmt) and southwest Europe (5.2 mmt) were leading soybean importers.

Data were not available on regional consumption (Q_d), exports (Q_e) and imports (Q_i) in the United States, thus the need to estimate these parameters for the U.S. excess supply/demand regions. Regional crop production data (crop reporting districts) for the United States came from the USDA's National Agricultural Statistical Service (www2.hqnet.usda.gov/nass/). Estimates of demand or consumption were necessary to calculate regional excess supply and demand since consumption was subtracted from production to determine whether the region was an excess supply or demand region.

In the developed corn model, the dairy, livestock and poultry sectors in the United States were responsible for 110.6 mmt (52 %) of annual corn consumption: 20 percent of total disappearance (42.7 mmt) was a result of exports with nearly 17 percent (37.3 mmt) due to food, industrial and alcohol processing. Remaining corn disappearance was attributed to seed use, shrink, handling loss and residual. Regional corn consumption by the dairy, livestock, and poultry sectors was calculated with information on regional populations and rations. Information on rations came from industry personnel, animal/poultry nutritionists at selected universities and the USDA's *Livestock-Feed Relationships, National and State.* Regional population information came from USDA publications (U.S. Department of Agriculture, 1992-1995b, 1992-1995c, 1992-1995d, 1992-1995e). A trade publication provided information on regional corn processing capacity (dry and wet-corn milling) and in combination with national estimates of processed corn output was used to estimate regional demands (Sosland Publishing Co.; U.S. Department of Agriculture, 1989-1995). Information on ethanol plants and capacities was supplied by the Department of Energy. This information in combination with national output data was used to estimate regional corn use by ethanol processors. The Department of Treasury provided data on regional corn use by breweries and distilleries.

In the U.S. portion of the international soybean model, 34.8 mmt were processed (crushed) by domestic mills, 20.9 mmt were exported and 3.5 mmt were used as seed and fed in an unprocessed form to livestock. Regional crushing demands were estimated with plant capacity estimates from the National Oilseed Processors Association and national data from USDA publications (U.S. Department of Agriculture, 1991-1994, 1995a). See Appendix for information on model data.

The slope and intercept parameters for the inverse excess demand and supply relationships were obtained with the respective excess demand (E_{ed}) and supply (E_{es}) elasticities, imports (Q_d) and exports (Q_e) and prices. Prices in U.S. regions came from the USDA's National Agricultural Statistical Service (U.S. Department of Agriculture, 1992-1995a). Prices in U.S. excess corn supply regions ranged from \$68 to \$88/metric ton while excess demand region prices ranged from \$80 to \$119/metric ton. Prices in U.S. excess soybean supply regions ranged from \$201 to \$218/ metric ton while excess demand region prices ranged from \$212 to \$236/metric ton. Information on country prices came from the USDA's *World Grain Situation and Outlook, World Oilseed Situation and Market Highlights* and *Oil Crops Yearbook.*

Regional corn and soybean production and consumption data for Mexico came from Fuller, Gutierrez, and Gillis (1994). All Mexican imports of corn (2.0 mmt) and soybeans (1.9 mmt) were supplied by the United States: about one-third of Mexican imports enter via U.S./Mexico border crossing sites. Regional prices in Mexico were imputed from U.S. Census data that related quantity and value of U.S. exports to Mexico by border crossing site and marine port and with estimated transportation/handling costs associated with moving corn and soybeans from these U.S. export locations to demand regions in Mexico. Mexican railroad and truck cost/rate parameters came from Fuller, Gutierrez, and Gillis (1994).

The truck, railroad, and barge transportation costs that linked U.S. excess supply and demand regions were estimated with computerized costing codes by Reebie Associates. The barge costing code incorporated a variety of information relating to origin and destination, commodity, tons per barge, tow type, barges per tow, and fixed and variable costs. Costs for a particular shipment were calculated by simulating barge movement over a complete cycle. An internal routing table determined links in the river network to be used by a tow. Transit time was computed for each link based on distance, speed, and delay at locks. The estimated delays at all locks with the 25, 50, 75, 100, 125, and 150 percent increases in traffic were entered into the barge cost model for purposes of estimating the affect on barge transportation cost. Barge costs reflecting historical traffic levels and congestion were compared to average actual rates over the 1991-1993 period for St. Paul, Minnesota; St. Louis, Missouri; and Peoria, Illinois. Barge rates from St. Paul, Peoria, and St. Louis to lower Mississippi River ports averaged \$9.37, \$7.30, and \$5.40 per ton, respectively, while estimated costs were \$9.79, \$6.76, and \$5.63 per ton. In all cases, the historical average rate and estimated cost differed by less than 7 percent.

Information from the public waybill sample regarding rail shipment characteristics on various routes, in combination with a railroad routing code by ALK Associates and the Reebie rail cost code were used to estimate variable and total railroad costs for each potential routing. The railroad routing code provided information on likely routings between each excess supply and demand region, railroad interchange locations, and miles traveled by each railroad. This information in combination with rail shipment characteristics were included in the Reebie cost code to estimate railroad costs. A comparison of estimated railroad costs with rates on selected corridors showed rates did not always cover the estimated total costs. For example, corn rates from the western portion of the Corn Belt (Nebraska, Iowa, Minnesota, South Dakota) to Pacific northwest ports and rates linking central Corn Belt origins (Illinois) to lower Mississippi River ports were only slightly above estimated variable costs. Thus, on these routes total railroad costs were not included in the model. Rail costs linking the western Corn Belt to Pacific northwest ports ranged from about \$23 to \$31/metric ton while costs from central Corn Belt origins to lower Mississippi River ports ranged from about \$11 to \$16/ metric ton. Rates on major corn and soybean transportation corridors were statistically compared to corn/soybean model costs to determine their similarity: the analysis of variance yielded F-ratios that failed to reject the hypothesis that mean rates equaled mean costs.

The estimated motor carrier costs were representative of five axle, 42 foot hopper trailers that were carrying 25 tons of grain. The average cost of this truck configuration was estimated to be \$1.13 per mile. Dooley, Bertram, and Wilson (1988) had estimated commercial grain trucking costs to be \$0.89 per mile in 1986. This cost parameter when compounded at 3 percent to 1993 yielded a per mile cost of nearly \$1.10 per mile or only slightly below the estimated cost of \$1.13 per mile. This comparative analysis suggested the truck cost parameter to be representative.

Ship rates linking U.S. ports with Mexican ports and foreign excess demand regions came from an estimated regression (Fellin and Fuller, 1998). The most important grain ship routes link U.S. Gulf ports to excess demand regions in west Asia and west Europe. Estimated ship rates linking the lower Mississippi River port area to Japan, South Korea, Taiwan, and west Europe were \$24.50, \$26.20, \$26.40, and \$14.20 per metric ton, respectively.

Grain handling and storage costs for U.S. country elevators, inland terminals, and port terminals were based on a national survey of grain handlers. Loading and unloading costs ranged from \$1.49 to \$3.82 per metric ton depending on transportation mode and type of grain handling facility: storage costs averaged \$0.95 per metric ton per month. Mexican grain handling and storage costs were based on communications from Boruconsa and Bodegas Rurales Conasupo which are Mexican government agencies involved in grain assembly and storage: Mexican handling and storage costs averaged about 25 percent higher than in the United States. Port discharge costs in Mexico came from Klindworth and Martinsen (1995).

Efforts were made to validate the models subsequent to their construction. In particular, efforts were made to compare historic flow patterns with flows associated with solution of the base models. Validation involved a comparison between historic export flows by U.S. port area with model-generated flows (U.S. Department of Agriculture, 1989-1995; Klindworth and Martinsen, 1995). Model-projected flows were within 5 percent of historic flows for all major U.S. port areas during the 1992-1994 period. Accordingly, the model was judged adequate for purposes of carrying out study objectives.

RESULTS

The effect of projected increases in River traffic on producer prices and revenues, and flow patterns was determined by contrasting the base solution of the corn and soybean models with model solutions that represented a 25, 50, 75, 100, 125, and 150 percent increase in traffic. The 100 percent increase in traffic approximates anticipated flows on the upper Mississippi and Illinois Rivers in 2050 while the 125 and 150 percent increases in traffic offer perspective on seasonal surges as well as periods of keen export demand.

Corn and Soybean Flow Patterns

The projected increase in traffic diverts substantial quantities of corn from the upper Mississippi River (Table 3). For example, a 50 percent increase in traffic was projected to divert 5.03 million metric tons from the upper Mississippi, a 27 percent reduction in quantity of corn transported via this transportation artery. With a 75, 100, 125, and 150 percent increase in traffic, corn flow on the upper Mississippi River was projected to decline 5.39 (30.0%), 10.78 (58.0%), 11.27 (61.0%), and 13.30 (72.0%) million metric tons, respectively, relative to historic levels (1991-1995). The anticipated increase in traffic also diverted soybeans from the upper Mississippi, however, the quantities were comparatively modest (Table 3).

Corn transportation on the Illinois River was projected to increase as a result of the growth in traffic. A 50 percent increase in freight traffic would increase corn transportation on the Illinois River by 2.7 million metric tons (Table 3). This occurs because barge transportation costs to lower Mississippi River ports increase modestly on the Illinois River relative to the upper Mississippi at increased traffic levels. For example, a 50 percent increase in traffic was estimated to increase barge costs on the upper Mississippi about 10 percent while similar increases in traffic on the Illinois River increase barge costs about 2 percent. As a result, Illinois corn supplies become increasingly attractive to excess demand regions (buyers), but, in particular, foreign buyers at lower Mississippi River ports. Thus, the increase in Illinois River corn shipments to lower Mississippi ports at the higher traffic levels. Further, corn shipments on the Ohio River were projected to decline as traffic levels and barge costs on the upper Mississippi and Illinois Rivers increase. Because of the higher barge costs on the upper Mississippi River, corn which had historically originated on this River for movement to southeast U.S. excess demand regions via the Tennessee River was replaced by rail shipments of corn from Indiana supply regions. Prior to the increase in River traffic, these Indiana supply regions had shipped via the Ohio River to lower Mississippi River ports, thus, the decline in Ohio River corn shipments.

Although important quantities of grain were diverted from the upper Mississippi and the lower Mississippi River port area at higher traffic levels and barge costs, total exports were only modestly impacted (Table 3). In particular, with a 100 percent increase in traffic, corn exports at lower Mississippi River ports were projected to decline 6.03 million metric tons; however, this decline was virtually offset by increases in exports at Great Lakes and Pacific northwest ports of 2.78 and 3.14 million metric tons, respectively (Table 3).

Corn flow patterns in Iowa, Illinois and Minnesota were more affected than other states by increased traffic levels on the upper Mississippi and Illinois Rivers. The analysis showed east Iowa corn supplies were not diverted from the upper Mississippi River at any analyzed traffic level, whereas central and west Iowa commenced diverting corn at the 100 and 50 percent levels, respectively. Diverted Iowa corn was routed to the Pacific northwest, central Illinois demand centers (processors) and the domestic market in the southwest U.S. (Texas, California). Iowa's corn shipments to central Illinois processors replaced Illinois corn which was increasingly directed to the Illinois River for export. Further, at higher River traffic levels, increasing quantities of Illinois corn moved via unit trains to lower Mississippi River ports. In addition, Iowa corn shipments to the southwest U.S. replaced Nebraska corn which was increasingly directed to Pacific northwest ports. Southeast Minnesota continued to ship to the upper Mississippi at all traffic levels while south-central and central Minnesota diverted corn shipments from the upper Mississippi at the 125 and 100 percent increase in traffic levels, respectively. Diverted Minnesota corn was routed into foreign markets via the ports in the Pacific northwest and Duluth.

Corn and Soybean Producer Revenues and Prices

As expected, corn and soybean prices and revenues in regions dependent on river

Table 3. Estimated Changes in U.S. Corn and Soybean Flows Via River Segments and Ports Resulting From a 25, 50, 75, 100, 125, and 150 Percent Increase in Traffic on Upper Mississippi and Illinois Rivers

	Corn					
	25%	50%	75%	100%	125%	150%
	----------Metric tons (millions)----------					
River Segment						
Upper Mississippi	-1.87	-5.03	-5.39	-10.78	-11.27	-13.30
Illinois	0.00	2.74	3.00	2.90	2.90	1.37
Mid and Lower Mississippi	0.00	0.00	0.00	0.00	0.00	1.54
Ohio	-1.74	-1.76	-1.70	-1.39	-1.36	-0.78
Total	-3.61	-4.05	-4.09	-9.27	-9.73	-11.17
Port Area						
Lower Mississippi	-1.66	-2.04	-2.13	-6.03	-6.49	-7.93
Other Gulf ports	0.00	0.00	0.00	-0.29	-0.29	-0.29
Atlantic	0.00	0.00	0.00	0.00	0.00	0.00
Great Lakes	0.48	0.65	0.66	2.78	2.79	4.07
Pacific Northwest	1.09	1.21	1.21	3.14	3.46	3.51
Total	-0.09	-0.18	-0.26	-0.40	-0.53	-0.64

(Continued on next page)

Table 3. Continued

	Soybeans					
	25%	50%	75%	100%	125%	150%
	---------------------------------	-----------	Metric tons (millions)	-----------	---------------------------------	
River Segment						
Upper Mississippi	-0.05	-0.06	-0.18	-0.33	-0.79	-1.98
Illinois	0.00	0.00	0.00	0.00	0.00	0.00
Mid and Lower Mississippi	0.00	0.00	0.00	0.00	0.00	0.00
Ohio	0.00	0.00	0.00	0.01	0.01	0.01
Total	-0.05	-0.06	-0.18	-0.32	-0.78	-1.97
Port Area						
Lower Mississippi	-0.01	-0.01	-0.13	-0.27	-0.72	-1.91
Other Gulf ports	0.00	0.00	0.01	0.14	0.21	0.22
Atlantic	0.00	0.00	0.00	0.00	0.00	0.01
Great Lakes	0.00	0.00	0.11	0.12	0.37	1.53
Pacific Northwest	0.00	0.00	0.00	0.00	0.13	0.13
Total	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02

Table 4. Estimated Statewide Reductions in U.S. Corn and Soybean Prices and Revenues Resulting From a 25, 50, 75, 100, 125, and 150 Percent Increase in Traffic Levels on Upper Mississippi and Illinois Rivers

	25%		50%		75%		100%		125%		150%	
State	Price ($/ton)	Revenue ($ millions)	Price ($/ton)	Revenue ($ millions)	Price ($/ton)	Revenue ($ millions)	Price ($/ton)	Revenue ($ millions)	Price ($/ton)	Revenue ($ millions)	Price ($/ton)	Revenue ($ millions)
						Corn						
Minnesota	0.27	5.5	0.71	14.4	1.12	22.8	1.54	31.40	1.83	37.3	2.27	46.2
Iowa	0.20	8.0	0.38	15.3	0.55	22.1	0.86	34.50	1.13	45.4	1.38	55.5
Nebraska	0.10	2.5	0.22	5.7	0.28	7.2	0.33	8.4	0.42	10.7	0.48	12.3
Other	0.19	2.4	0.44	5.6	0.71	9.0	1.05	13.31	1.30	16.4	1.54	19.5
Total		18.4		41.0		61.1		87.6		109.8		133.5
						Soybean						
Iowa	0.10	1.1	0.22	2.1	0.36	3.5	0.52	5.1	0.69	6.8	1.12	11.0
Minnesota	0.21	0.6	0.56	1.7	0.88	2.7	1.24	3.8	1.55	4.8	1.43	4.4
Other	0.04	0.1	0.08	0.2	0.08	0.2	0.12	0.3	0.16	0.4	0.20	0.5
Total		1.8		4.0		6.4		9.2		12.0		15.9

transportation were unfavorably affected by higher traffic levels and associated higher barge costs, whereas prices and revenues in other regions modestly increased. Traffic increases of 50 percent were projected to reduce combined annual revenues of corn and soybean producers about $45 million, while 100 and 150 percent increases in traffic were projected to reduce annual revenues approximately $97 and $150 million, respectively. Declines in corn revenues accounted for about 90 percent of the total decline in all revenues. Corn/soybean producers in Minnesota and Iowa were more unfavorably affected than producers in other states: on average, producers in these states accounted for about three-fourths of the total decline in all revenues (Table 4).

State subregions most unfavorably impacted by the increase in traffic and associated higher barge costs were located near the upper reaches of the Mississippi River. For example, in northeast and north central Iowa, and southeast, central, and south central Minnesota, corn prices were projected to decline from $1.50-$2.00 per metric ton when traffic increased 100 percent, whereas in the remaining portions of these states, prices decline $0.33 to $0.75 per metric ton.

SUMMARY AND CONCLUSIONS

A recent study projects traffic on the upper Mississippi and Illinois Rivers will nearly double by 2050. Inadequate trust fund resources to rehabilitate and expand locks in combination with the backlog of structures which require attention has generated concern regarding future transportation. Agricultural interests in the Midwest are particularly concerned regarding the upper Mississippi and Illinois Rivers since these arteries originate and carry about one-half of U.S. corn exports and one-third of U.S. soybean exports to lower Mississippi River ports. Spatial, intertemporal models of the international corn and soybean sectors in combination with an estimated lock delay equation and a barge cost model are used to explore the implications of a 25, 50, 75, 100, 125, and 150 percent increase in traffic levels on the upper Mississippi and Illinois Rivers. The spatial models include regional demand and supply structures and transportation rates/costs representative of the 1990s, whereas estimated barge costs reflect the heightened congestion and delay associated with the 25, 50, 75, 100, 125, and 150 percent increase in traffic. Thus, the results reflect the changes in corn and soybean producer prices and revenues, and flows that would occur if the anticipated congestion, delay, and associated barge costs were imposed on current grain production and transportation systems.

Results show increasing quantities of corn/soybeans diverted from the upper Mississippi River as traffic levels, congestion, tow delay, and ultimately barge costs increase. For example, if traffic levels were to increase 50 percent, about 30 percent of the corn would be diverted from the upper Mississippi and a doubling of traffic would divert about 58 percent of the corn. Corn supply regions at comparatively distant locations from the river would initially divert at increasing traffic levels whereas sites near the river would not be diverted at any traffic level. For example, southeast Minnesota and east Iowa corn were not diverted at any analyzed traffic level while west Iowa corn was diverted with a 50 percent increase in traffic and central Iowa and south-central Minnesota corn at a 100 percent increase in traffic. The diverted grain was typically rerouted to an alternative domestic market or port area via railroad or, in some cases, to the same port area via railroad. As expected, regional corn/ soybean prices and revenues declined as traffic levels and barge costs increased: based on 1992-1994 production levels and prices, a 50 percent increase in traffic would reduce annual producer revenues $45 million and a 100 percent increase in traffic would lower annual revenues $97 million. Producers in Minnesota and Iowa incur about three-fourths of the decline in producer revenues. The analysis shows U.S. exports to decline modestly at higher traffic levels; this was the result of the short-run excess demand and supply relationships included in the models. Finally, the analysis shows important interwaterway affects, i.e., growing congestion on one waterway system can influence commodity flows on other systems, thus the need for planners to be cognizant of these potential affects when making infrastructure decisions. In summary, the projected growth in demand for waterway transportation on the upper Mississippi and Illinois Rivers will have an important influence on tow delay and barge cost, and based on this analysis, it seems unlikely that the analyzed rivers would carry the projected increase in tonnage since economic forces would divert much of this traffic prior to reaching the projected traffic level.

The spatial models used to carry out the analysis are short-run models. The reader should be aware that in the long-run, there may be changes in relative mode costs and regional production patterns that may alter the observations made by this study.

REFERENCES

ALK Associates, Inc. (1996) *ALK's PC*Rail*. Cambridge, Mass.

Bronzini, M.S. (1997) "Inland Waterways: Still or Turbulent Waters Ahead?" *The Annals* 553, 66-74.

Brooke, A., D. Kendrick, A. Meeraus (1988) *GAMS: A Users Guide*. The Scientific Press, San Francisco, CA.

Dooley, F.J., L.M. Bertman and W.W. Wilson (1988) *Operating Costs and Characteristics of North Dakota Grain Trucking Firms*. Upper Great Plains Transportation Institute, UGPTI Publication No. 67, North Dakota State University, Fargo, North Dakota, August.

Jack Faucett Associates (1997) *Waterway Traffic Forecasts for the Upper Mississippi River Basin*. Volume I: Summary, Final Report, April.

Fellin, L. and S. Fuller (1997) "Effect of Proposed Waterway User Tax on U.S. Grain Flow Patterns and Producers." *Journal of the Transportation Research Forum* 36, 11-25.

Fellin, L. and S. Fuller (1998) "Effect of Privatizing Mexico's Railroad System on U.S./Mexico Overland Grain/Oilseed Trade." *Journal of the Transportation Research Forum* 37, 46-58.

Fruin, J., D. Halbach and L. Hill (1990) *Corn Movements in the United States: Interregional Flow Patterns and Transportation Requirements* University of Illinois Bulletin 793, September.

Fuller, S., N. Gutierrez and M. Gillis (1994) Estimated Regional Production/ Consumption of Corn, Wheat, Sorghum, and Soybeans in Mexico in 1990. TAMRC Research Report No. IM-1-94, Dept. Of Agricultural Economics, Texas A&M University, August.

Kerkhoff, S. (1996) "Old Man Rivers Not What He Used To Be." *Grain Journal*. Decatur, Illinois, September/October.

Klindworth, K.A., and A.J. Martinsen (1995) *Shipping U.S. Grain to Mexico*. U.S. Department of Agriculture, Agricultural Marketing Service, Washington, D.C., September.

Larson D., T. Smith and E. Baldwin (1990) *Soybean Movements in the United States: Interregional Flow Patterns and Transportation Requirements*. University of Illinois Bulletin 792, September.

Samuelson, P.A. (1952) "Spatial Price Equilibrium and Linear Programming." *American Economic Review* 42, 283-303.

Shei, S. and R.L. Thompson (1977) "The Impacts of Trade Restrictions on Price Stability in the World Wheat Market." *American Journal of Agricultural Economics* 59, 628-38.

Sosland Publishing Co. (1993) *1992 Milling Directory and Buyers Guide* Kansas City, MO.

Sullivan, J., V. Roningen, S. Leetmaa, and D. Gray (1992) *A 1989 Global Database for the Static World Policy Simulation Modeling Framework*. U.S. Department of Agriculture, Economic Research Service, Washington, D.C., May.

Takayama, T. and G. Judge (1971) *Spatial and Temporal Price and Allocation Models*. Amsterdam: North Holland Publishing Co.

U.S. Army Corps of Engineers (1992a) *The 1992 Inland Waterway Review*. Water Resources Support Center, Institute for Water Resources, IWR Report 92-R-7, October.

U.S. Army Corps of Engineers (1992b) *Lock Performance Monitoring System: Summary of Lock Statistics for October - December 1991 and Year to Date*. Water Resources Support Center, NDC Report 92-L-7, August.

U.S. Army Corps of Engineers (1993) *Lock Performance Monitoring System: Summary of Lock Statistics for 1992*. Water Resources Support Center, NDC Report 93-LC-1, September.

U.S. Army Corps of Engineers (1994a) *Lock Performance Monitoring System: Summary of Lock Statistics for 1993.* Water Resources Support Center, NDC Report 94-LC-4, March.

U.S. Army Corps of Engineers (1994b) *Lock Performance Monitoring System Summary by River Basin, Waterborne Commerce Statistics Center.* January-December.

U.S. Army Corps of Engineers (1995) *Lock Performance Monitoring System Summary by River Basin, Waterborne Commerce Statistics Center.* January-December.

U.S. Department of Agriculture (1988) Economic Research Service, *Livestock Feed Relationships: National and State.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1989-1995) Economic Research Service, *Feed Situation and Outlook Report.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1989-1995a) Foreign Agricultural Service, *World Grain Situation and Outlook.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1989-1995b) Foreign Agricultural Service, *World Oilseed Situation and Market Highlights.* Washington, D.C.

U.S. Department of Commerce (various issues, 1991-1994) Bureau of the Census, *Fats and Oils: Oilseed Crushings.* Economics and Statistics Administration, Washington, D.C.

U.S. Department of Treasury (various issues, 1992-1993) Bureau of Alcohol, Tobacco and Firearms, *Monthly Statistical Reports.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1992-1995a) National Agricultural Statistical Service, *Agricultural Prices.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1992-1995b) National Agricultural Statistical Service, *Cattle.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1992-1995c) National Agricultural Statistical Service. *Cattle on Feed.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1992-1995d) National Agricultural Statistical Service, *Hogs and Pigs.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1992-1995e) National Agricultural Statistical Service, *Layers and Egg Production.* Washington, D.C.

U.S. Department of Agriculture (various issues, 1992-1995f), National Agricultural Statistical Service, *Poultry Production and Value.* Washington, D.C.

U.S. Department of Agriculture (1994) Foreign Agricultural Service, *World Oilseed Situation and Market Highlights.* Washington, D.C., Cir. Series FOP 12-88.

U.S. Department of Agriculture (1995a) Economic Research Service, *Oil Crops Yearbook.* Commodity Economics Division, OCS-1995, Washington, D.C., July.

U.S. Department of Agriculture (1995b) Economic Research Service, *Production, Supply and Distribution* database. (PS&D), Washington, D.C.

Yntema, T.O. (1932) *A Mathematical Reformation of the General Theory of International Trade.* Chicago: University of Chicago Press.

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APPENDIX

Analysis was performed with linear, single-commodity, intertemporal, spatial price equilibrium models (corn and soybean models) that include excess supply/demand regions (domestic and foreign) that are linked over time and space with transportation, handling and storage costs. The models were converted into quadratic programming problems and solved with General Algebraic Modeling System (GAMS) software (Brooke, Kendrick and Meerus, 1988). The model solutions relate region exports/imports and associated interregional trade flows and region prices. In equilibrium, prices in the importing region equal prices in the exporting region plus linking transportation and storage costs and there is interregional price efficiency, i.e., flows are determined that maximize producer plus consumers surplus minus transportation and storage costs. Thus, a purely competitive market is assumed. The models used in this study are similar in structure to those used by Fellin and Fuller (1997, 1998) to evaluate the effects of inland waterway user taxes and privatization of the Mexican railroad on U.S. grain flows. However, several important changes are included in the current models. In particular, all excess demands/supplies have been updated as have most transport cost parameters. All railroad and barge cost linkages were updated and ship rates on selected routes were changed as necessary to reflect more recent time periods: research showed grain truck costs had changed little thus, this cost parameter was unchanged.

The excess supply/demand regions in the U.S. portion of the corn/soybean models were based on crop reporting districts which typically include from ten to fifteen counties. In the Mexico portion of the model, excess supplies/demands were based on states while foreign excess suppliers (exporters) were countries. Foreign excess demands (importers) represented individual countries or an aggregation of countries.

The own-price demand elasticities (E_d) to estimate excess supply/demand elasticities in the U.S. portion of the model varied by region but averaged -0.57 and -0.31 for all U.S. corn and soybean regions, respectively. For Argentina, France, and China, the other major exporters (foreign excess suppliers) of corn, the own-price elasticities were -0.48, -1.08 and -0.39, respectively. The respective own-price demand elasticities for soybeans in Argentina, Brazil and Paraguay, the other primary exporters were -0.36, -0.40 and -0.30. Japan, Taiwan and South Korea are important foreign excess demand regions (importers) in the corn and soybean models: these countries respective corn and soybean demand elasticities were -0.65, -0.33, -0.34 and -0.19, -0.15, -0.13 (Sullivan, Roningen, Leetmaa and Gray, 1992).

The most important excess corn supply regions were located in the Corn Belt states; however, located within the Corn Belt were several large excess demand regions (Iowa, Illinois, Indiana, Minnesota) that produced ethanol and wet-corn milling products. Other important excess corn demand regions were located in southeast states (North Carolina, Alabama, Georgia, Tennessee, Florida), south central states (Arkansas, Texas, Oklahoma) and California, New York, and Pennsylvania.

Domestic soybean excess supply regions were concentrated in Arkansas, Illinois, Indiana, Iowa, Minnesota, Missouri, Nebraska, and Ohio. Further, all of these states except Nebraska included at least one excess demand region: additional states including important excess demand regions were Alabama, Georgia, Kentucky, North and South Carolina, and Tennessee.

The U.S. portion of the corn/soybean models include seventeen port areas. Included were two Atlantic, five Gulf, five Pacific, and four Great Lakes ports and a port near Quebec, Canada which serves as a transhipment site for vessels which ply the Great Lakes and ocean-going vessels that do not enter the Great Lakes. The U.S. ports were linked to twenty-four foreign excess demand regions by ship rates.

INDUSTRY ISSUE PAPERS

RAILROAD SAFETY AND PUBLIC POLICY

*by Ian Savage**

ABSTRACT

This paper discusses the safety challenges faced by railroads in the United States. It discusses and evaluates public policy dealing with trespassing, grade crossing collisions, occupational injuries and operational accidents. The primary conclusion is that the government oversight body, the Federal Railroad Administration (FRA), should take on the role of teacher and risk analyst rather than that of police officer. By doing so the FRA can more effectively target safety problems and do so at reduced cost.

INTRODUCTION

Twice in recent years, the public's attention has been drawn to safety on the railroads. The first was due to a run of crashes involving passenger trains in the winter of 1996. The second was a series of crashes in the summer of 1997 involving the Union Pacific Railroad subsequent to its merger with the Southern Pacific. There were consequent calls that the government "should do something." This paper discusses whether there is cause for public concern, and assesses the adequacy of the public policy response.

To a certain extent the events described in the previous paragraph, while grabbing the public's attention, are not an accurate reflection of the true safety challenges facing the railroads. About 1,000 people are killed each year on the railroads. In 1997, 530 were trespassers[1], 460 were users of highway-rail grade crossings, 50 were employees or contractors, and six were passengers on trains (FRA, 1998). Therefore, in terms of absolute numbers, trespasser and grade-crossing user fatalities are a far greater problem than the popular image of twisted metal and burning tank cars.

Further insights can be gained by looking at recent historical trends for the three predominant casualty types. Figure 1 presents data since 1960 on employee fatalities per employee hour, trespasser fatalities per head of population, and grade-crossing fatalities per highway vehicle registered.[2] All of the casualty rates are expressed as an index with 1960 set equal to 100.

The casualty rate for crossings has recorded the most impressive improvement falling rapidly and continuously since 1967. The risk is now less than a fifth of what it was in 1960. The trespasser casualty rates also started to decline rapidly after 1967, but leveled out at about 40% below the rate in 1960. If anything, there may be a slight upward trend in recent years. Employee casualty rates increased by 30% in the 1960s. They only started to decline in 1973. The subsequent improvement has been substantial such that the fatality rate is now only half of what it was in the early 1970s.

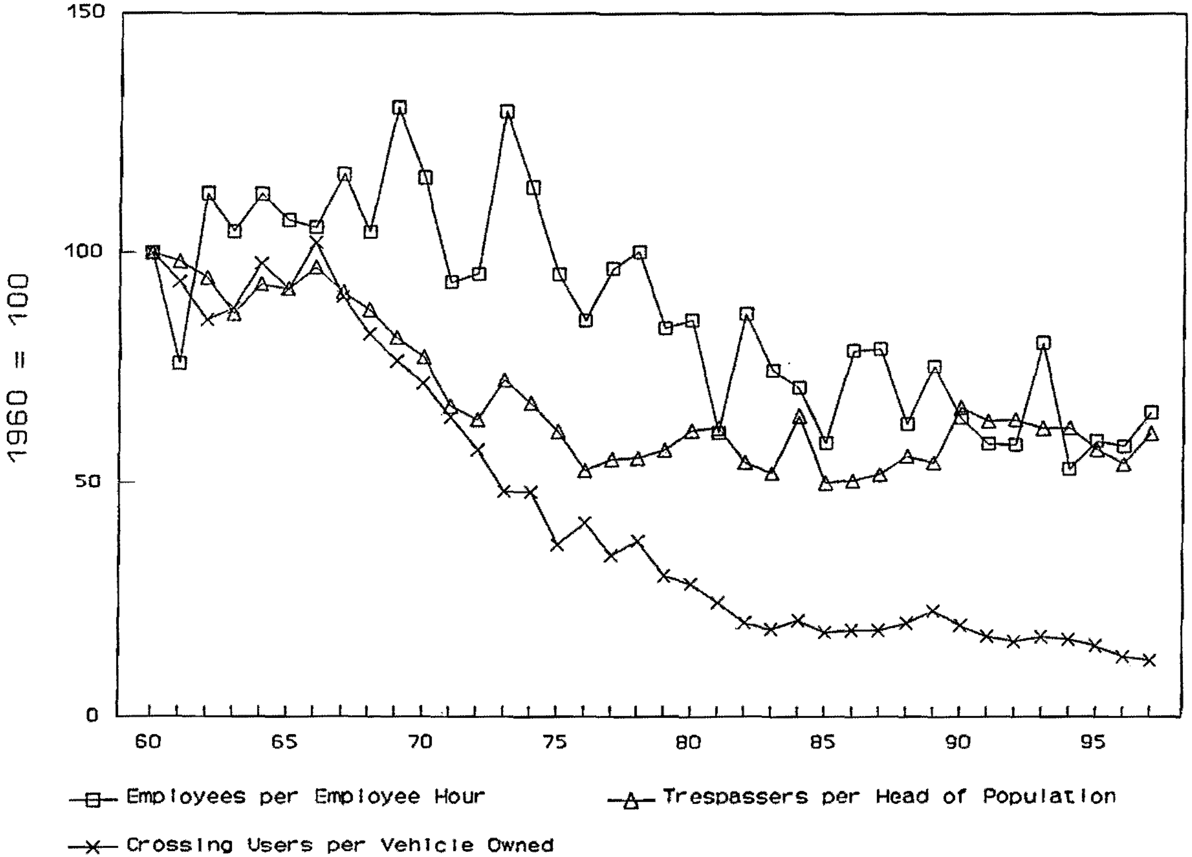
But what has contributed to these trends, and what are the prospects for changes in public policy that can contribute to further improvements? The discussion will look at the following four safety risks: trespassing, grade-crossings, employee occupational injuries, and collisions and derailments.

TRESPASSING

As is clear from Figure 1, the casualty rate for trespassers has been constant, if not increasing, in recent years. At the same time the risk at grade crossings has fallen considerably. As a consequence the number of trespassing fatalities in 1997 exceeded the number of grade-crossing fatalities for the first time since 1941. This is quite a change, for as recently as 1970 the number of crossing fatalities exceeded the number of trespasser victims by a ratio of three to one. It would not be surprising if this turnaround leads to renewed public policy interest in coming years.

Most of the headlines highlight unfortunate cases where children playing or people taking a well-used shortcut are struck by trains. However, victims of these types are less than a fifth of the total. The typical trespassing victim is a single adult male who is under the influence of considerable amounts of alcohol (Pelletier, 1997). The *average* blood-alcohol ratio of all victims in Pelletier's study was two to three times the legal limit for driving an automobile, and almost a third of the victims had received prior treatment for alcoholism. Many are poorly educated, but few are homeless. It would seem that the railroad right-of-way is a popular place to socialize, drink and rest. A third of the victims were sitting or lying on the tracks, which suggests the possibility that a large proportion may be committing suicide, even though they do not leave evidence for a coroner to draw this conclusion.

When one understands who the victims are, the effectiveness of an oft-discussed possible requirement to fence the tracks in urban areas can be



1960 = 100
150
100
50
0
60
65
70
75
80
85
90
95
Employees per Employee Hour
Trespassers per Head of Population
Crossing Users per Vehicle Owned

examined in a new light. While fences may deter those who become extremely inebriated off railroad property, they may have the perverse effect of making the railroad right of way even more attractive as a relatively private place to socialize. There is also the worrying fact that the annual North American rate of trespassing fatalities at two per million population is the same as in Britain where the railway is generally fenced. Trespassing is therefore a very difficult problem to tackle. The law has always placed the responsibility for taking care squarely on the trespasser, yet this does not seem to be a total deterrent. The effective response would be to change the attitudes of social trespassers by enhanced enforcement of trespassing laws, and a publicity campaign targeted at at-risk adults.

GRADE CROSSINGS

There are two basic problems. The first is that 60% of crossings with public roads are not provided with flashing lights or gates, known as active warning devices, to warn of the approach of the train. The second is that some road users do not exercise enough care when using crossings, even when gates and/or flashers are installed. The considerable reduction in the collision risk over the past twenty-five years is a testament to progress in tackling both problems.

Since 1978, over a quarter of all crossings have been closed either as a result of railroad abandonment or due to consolidation of several little-used crossings. In addition under the 1974 *Section 130* program, the federal government has spent more than $6 billion, at current prices, to upgrade the warning devices at the remaining crossings: gates have been installed where there were only flashing lights, flashing lights have been installed where there were previously only marker signs, marker signs have been installed where previously there were no signs, and little-used crossings have been consolidated with neighboring ones. On a cost-benefit basis there are many little-used crossings for which one could never justify the installation of active warning devices. Even taking this in account, I estimate in my book (Savage, 1998, Chapter 8) that based on average daily road traffic that there are still at least 8,500 and maybe as many as 20,000 crossings in need of having active warning devices substituted for passive marker signs. Unfortunately, at the current rate of progress, this will be accomplished somewhere between the years 2013 and 2036. My calculations show that the *Section 130* program demonstrates a large ratio of benefits to costs, and there are large welfare gains from continuing, and even accelerating this program (Savage, 1998, Chapter 8).

There has also been progress in advising drivers on appropriate conduct at grade crossings. The government and industry-supported *Operation Lifesaver* has attempted to make the public aware of the dangers of ignoring flashing lights or driving around closed gates. Despite these efforts, 150 highway users a year die due to ignoring properly-functioning active warning devices. The program also advises drivers on how to deal with crossings with only marker signs. Specific conduct at these crossings is rather ill-defined and was debated all the way to the Supreme Court in the 1920s and 1930s. There is no longer any legal requirement to "stop, look and listen," and the advice of *Operation Lifesaver* to "always expect a train" is clearly not a reflection of reality in many rural areas where the rational expectation is for no train to be present. There are moves to try to resuscitate the "stop, look and listen" laws by replacing the traditional "crossbucks" crossing markers with standard highway stop signs. This would clearly be advantageous to railroad lawyers attempting to deflect law suits, but it is not without its problems including the fact that slow-moving vehicles are more likely to be hit by a train than a vehicle moving quickly across a crossing. There is also an increased chance of rear-end collisions between highway vehicles at the stop sign, and the possibility that stopping for nonexistent trains may diminish the regard that drivers have for stop signs elsewhere on the highway.

OCCUPATIONAL INJURIES

Economic theory, dating back to Adam Smith, indicates that if workers are knowledgeable about job risks, market mechanisms will compensate workers for working in industries that are particularly risky. Workers with a greater tolerance of physical risk will tend to gravitate toward riskier occupations. A market failure will only exist if wages are insufficient to compensate for the risks. Railroad workers are among the highest paid workers in the nation whereas injury and fatality rates are low in comparison to peer industries that involve heavy, moving machinery and work outdoors. Construction, maritime, trucking and warehousing jobs have far higher casualty rates (Bureau of Labor Statistics, 1997a table A-2, 1997b, table 1).

Therefore the controversy surrounding occupational injuries does not concern their rate, but rather deals with the unusual method by which injured employees are compensated. The railroads are governed by the *Federal Employers' Liability Act* (FELA) which is a judicial system under which injured employees can bring suit to recover both monetary and non-monetary losses. However, awards can be reduced or eliminated if the worker was found to be partially or fully negligent. This is in contrast to the workers' compensation scheme applicable to other industries, where benefits are lower but cannot be reduced based on relative fault.

The issue of whether the railroads should change over to workers' compensation has been debated repeatedly and at length (see, most recently Transportation Research Board, 1994; General Accounting Office (GAO), 1996). However there is little prospect of any reforms in that both management and unions are firmly entrenched. Management looks to cost savings, although I regard these as quite speculative. FELA benefits are highly valued by the railroad unions, and it is unlikely that they could be removed without making some other concessions to labor.

Nonetheless my research has convinced me that the adversarial judicial nature of FELA does not foster a constructive attitude for investigating and mitigating workplace injuries. Injured employees correctly respond to FELA by not wanting to reveal details of the nature of their cases to railroad managers prior to legal proceedings. This clearly works against informal sharing of information between employees and management on ways to learn from experience in mitigating injuries. Under workers' compensation the employee is guaranteed compensation, and will therefore be able to honestly admit to the circumstances of the injury and ways in which it might be avoided in the future. FELA also works against rehabilitation and a swift return to work, because injured employees would thereby undermine the magnitude of their claims for compensation.

OPERATIONAL SAFETY

There are about 2,000 reportable operational accidents, primarily collisions and derailments, each year which result in about 20 deaths, 450 injuries and about $250 million in property damage (Savage, 1998, chapter 16).[3] Two-thirds of these occur in yards and sidings during switching operations. Derailments are primarily caused by the state of the track, while most collisions are caused by incorrect or inappropriate operating practices (FRA, 1998).

Operational safety became an issue in the 1960s when many decades of safety improvements were reversed. At that time the railroads were in considerable financial difficulties and it is widely believed that standards of maintenance were reduced. The worsening rate of collisions and derailments and employee injuries lead to the *Federal Railroad Safety Act* of 1970, the first substantial change in railroad safety regulation in sixty years. Until its passage the railroads had very little formal regulation. The 1970 Act introduced design standards for track for the first time and codified existing industry standards on the design and maintenance of freight cars. The government also appointed an inspectorate force to ensure compliance with the laws.

Despite the new regulations, collisions and derailments did not decline until the end of the 1970s. Since 1980, the rate of collisions and derailments per train mile has fallen substantially and is now only a quarter of what it was in the late 1970s (FRA, 1998). However, the cause of this reduction is subject to some controversy. The Federal Railroad Administration claims that it is a direct result of its safety regulatory efforts. The industry points to the economic deregulation of the industry in 1980. Subsequent to the *Staggers Act* of 1980, the financial health of the industry improved and railroads were able to substantially increase their expenditures on track and equipment.

In addition, there has been a change in the way that railroads handle traffic. Traffic is increasingly handled in unit trains and there is much less switching of cars. The proportion of train miles that are represented by yard and switching operations has fallen by half, from 30% to close to 13%, in the past twenty years. As most collisions and derailments occur in yards and sidings it is not surprising that the risk has fallen.

Unfortunately for the analyst, the increase in deregulation-induced expenditures parallels increases in federal safety inspections and decreases in the amount of risky switching. It is impossible to separate these effects econometrically. The inability to definitively ascribe causation for the safety improvements has led to an impasse between the industry and the government as to whether the 1970 federal safety regulations have helped or hindered the industry.

Industry Criticism of Current Safety Regulations

The industry argues that there are two major shortcomings of the present regulations: the method for setting and updating the safety standards; and strategy adopted for monitoring and ensuring compliance. The industry terms this a "command and control" strategy. To use less emotive terms, the FRA uses a quite traditional approach to regulation. Detailed minimum engineering specifications are written on how to design and maintain track and equipment, and the minimum experience and maximum hours of work for employees. An inspectorate force then conducts semi-random inspections to determine compliance, and citations are issued for violations found. In recent years the FRA has added to its arsenal a *Safety Assurance and Compliance Program* whereby teams of inspectors target individual railroads or divisions of particular railroads.

The regulations of the 1970s have drawn criticism not only from railroads but also from independent government agencies such as the General Accounting Office and the late Office of Technology Assessment in a succession of reports over the years. The regulations concerning track standards and brakes in particular have been criticized because of a lack of cost-benefit analysis in setting of the standards. It is possible that organized labor has been able to coerce Congress so as to write rules that preserve existing working practices. There is an additional concern that even when appropriate standards are written into law, the rulemaking process necessary to update these standards in the face of technical change or modern requirements is so lengthy and stifling that regulation can impede progress. The main cause of this problem is the penchant of Congress and the FRA to express standards in terms of the design of equipment rather than the performance of it. One would imagine that the FRA is really only interested in how quickly a train can stop or whether there is excessive lateral deviation in track, and not in the specific design of the braking equipment or the number of spikes per section of track.

The enforcement of the regulations has been subject to much criticism. There is considerable feeling, not only in the railroad industry, that semi-random inspections resulting in violation notices and fines are ineffective in improving safety. There is evidence that this is true in the trucking industry (Moses and Savage, 1997), and even the Occupational Safety and Health Administration (OSHA) has recognized that there must be a better way of obtaining a safe workplace. Reports by the GAO (see especially those in 1982 and 1997) suggest that the FRA does not have adequate models to determine which railroads pose the greatest safety threat and therefore cannot reasonably set priorities for targeted or special assessments of individual railroads. Resolution of violations and the payment of fines by large railroads does not normally involve senior officers of the railroads, and there is little evidence that the fines influence corporate policy.

The Necessity for Safety Regulation

To fairly evaluate the criticisms made by the industry, it is worthwhile to take a step back and evaluate why intervention in the market may be needed. Theoretical economists point to four market failures in the optimal determination of safety between firms and their customers. The first is customers cannot accurately perceive the level of safety on offer, the second is that even-fully informed customers do not react rationally to the choices they are given, the third is that uncompensated externalities are imposed on third parties, and lastly that firms are myopic in trading off the current costs of preventing accidents against accident costs in the future (Savage, 1999).

As railroads are primarily in the freight business, the problems of imperfectly informed and irrational customers are less severe than they are, say, in the airline industry. Most freight shippers are making consignments on a daily basis and are continually settling claims for minor loss or damage. In addition, because there is no threat to their own life and limb, shipping managers can quite rationally compare the prices and safety records of rival railroads or modes of transportation.

Longstanding legal requirements have also made railroads responsible for compensating bystanders for externalities caused in accidents, even in extreme cases where hazardous materials are released into the environment. The sole concern in this area is that railroads have yet to fully reflect the expected liability and clean up costs of carriage of different hazardous materials in their pricing. Too often a standard surcharge is collected on all freight movements to cover these costs. As a result too-much extremely hazardous materials are shipped and too little low or non-hazardous materials are shipped. (See Dennis, 1996, for an indication of how the magnitude of expected externalities varies markedly by commodity.)

This leaves myopia as the most threatening and most likely market failure. Two types of railroads are susceptible to such myopia. The first are the many small railroads established since the *Staggers Act*. These railroads may make myopic decisions due to inexperience rather than unscrupulous intent. The second type are those who intend to "cheat" on their customers. These railroads hope to save money in the short term by reducing expenditures on accident prevention, yet hope that their customers do not notice and react by taking their business elsewhere or demanding lower prices. There is ample evidence that this occurred in the 1960s.

Economists argue that the response to these market failures should take many complementary forms (Kolstad, Ulen and Johnson, 1990). The insurance industry can have an active role in assessing the precautions taken by a new railroad and charging an appropriate premium to reflect the probability that accident claims will result in the future. A concern about myopia by unscrupulous railroads could be mitigated if customers could readily detect the cheating. There may be a role for government in ensuring that customers are better informed not only about accidents but also about leading indicators of future safety in the form of data on inputs to safety such as maintenance activities, training and the age and condition of capital equipment.

There is also a role for direct regulation by the government to reduce the chance of myopia. The two possible causes of myopia call for two different regulatory approaches. An educational system is needed to prevent myopia by inexperienced railroads, while a delinquency system is needed to detect and punish unscrupulous myopic railroads who are trying to cheat their customers. An important question is whether the traditional forms of regulation practiced by the FRA are appropriate to these tasks, and whether new and improved regulatory strategies could be more effective and cost-efficient.

Designing an Educational System

The FRA already holds seminars, jointly with industry groups, for managers of newly-formed railroads. Press reports suggest that people attending such sessions have found them to be very useful. An open question is whether in addition new railroads should be accredited before they are allowed to operate. There is a possible model that the FRA might look to. *Railway Safety Cases* had to be completed by private operators who wished to take over the services formerly provided by the state-owned railways in Great Britain in the mid-1990s (Health and Safety Executive, 1994). In addition to requiring details of the safety management systems put in place, operators had to complete a risk-assessment exercise in which they had to identify the major safety risks they faced, appraise the probability and severity of these risks, rate the risks and provide plans for ameliorating those risks that were too high. While data on risk probability and severity may be limited and rating of risks is judgmental, the important role of the risk assessment is to require railroad managers to think deeply about the risk faced and the ways in which the railroad can reduce the risks. It is unlikely that a new railroad that has to undertake a risk-assessment exercise will be myopic due to inexperience.

Designing a Delinquency System

A delinquency system is not much different in intent from the current purpose of the FRA. The objective is to identify those railroads providing sub-standard service or those whose safety record is precipitously declining. The industry claims, and in general I am sympathetic to their claims, that the FRA's current method of semi-random inspections to find violations with design specifications leaves a lot to be desired.

There is an alternative which is frequently but somewhat misleadingly called "performance standards." To my mind the alternative entails a four-stage process. The first stage requires the FRA to adopt the role of risk analyst. The FRA would analyze data on safety performance for individual railroads to determine which railroads might be delinquent. The second stage involves inspections and evaluations of railroads that the first stage has flagged as potentially delinquent so as to confirm or disprove the FRA's suspicions. The third stage requires a delinquent railroad to prepare a remediation plan to correct its delinquent behavior. The fourth and final stage requires the FRA to monitor whether the railroad is making a good-faith effort to implement its remediation plan. Failure at this stage would trigger traditional methods of inspections, citations and fines.

Such a system is in use in the trucking industry. The Federal Highway Administration uses information on the accident rates of carriers, and other information it has, to set priorities for the work of its inspectorate. OSHA conducted an experiment in the state of Maine in 1993 whereby the largest firms where exempted from the traditional OSHA inspections if they made self-assessments of workplace risks, prepared a plan to ameliorate the risks, and made good-faith efforts to implement their plans. They intend to expand their *Cooperative Compliance Program* nationwide.

The hardest part of the proposed system is to design an information system to provide an early warning of railroads who may be cheating. An obvious component is the data that are already collected on train accidents and workplace injuries. While accidents are random events which lead to some natural variation in the number of accidents a railroad will have from year-to-year, there are well-understood statistical rules that explain the nature of this variation. Examples given in my book (Savage, 1998, chapter 20) indicate that the FRA should be able to statistically identify those railroads whose accident performance is deteriorating or is worse than peer railroads using measures which occur at least 10 times a year.

However, this is essentially an *ex-post* identification of myopic railroads. It is clearly preferable if the FRA could identify railroads who are acting myopically before their reductions in preventive efforts are reflected in increased accidents. The FRA might develop a system of warning flags for railroads whose circumstances might suggest myopic behavior, such as financial distress, declines in revenue, financial restructuring, stock offerings or being a takeover target. The FRA might also wish to develop information on safety inputs to alert them to railroads that do not appear to be spending sufficient amounts on track maintenance or who are allowing the average age of their fleets to increase, or who have inordinately high staff turnover. Such warning flags could trigger inspections or a special assessment of the railroad.

Such a statistical risk-analysis approach to analyzing data on safety inputs and outputs is only really applicable to the largest forty or so railroads. The smallest Class II and all of the Class III railroads have accidents so infrequently that any statistical inference would be impossible. It would also be impractical to collect extensive financial or safety input data on these railroads. It is likely that traditional inspections strategies will have to be retained for the smaller railroads. It may be worth investigating whether random inspections should be replaced by an annual audit of each small railroad. This would be quite manageable given that there are probably only about 300 different corporate entities involved in the railroad industry.

IN CONCLUSION

The terms of annual fatalities, the most significant safety risks are deaths of trespassers and collisions at rail-highway grade crossings. The latter risk has declined significantly over the years, and there are well-understood ways that the risk can be reduced further. Trespassing, however, is a more complex and growing problem. The victims tend to be marginalized members of society, and solutions to this problem need to be more sophisticated than just demanded that fences be erected.

Operational accidents occur much less frequently that the headlines would suggest, and the risk of these accidents has fallen significantly since the dark days of the 1960s and 1970s. There was ample evidence from the 1960s that some railroads will act myopically with regard to safety. The current challenge is investigate ways in which public policy can most effectively prevent myopic behavior. There is discussion in other branches of the Department of Transportation as well as in other parts of the federal government that new monitoring and enforcement approaches have the promise of targeting safety problems at a lower cost. From my research there is a strong suggestion that the FRA should change its outlook from that of a police officer to that of a teacher and a risk-analyst.

REFERENCES

Bureau of Labor Statistics (1997a) *Fatal Workplace Injuries in 1995: A Collection of Data and Analysis.* Report 913. U.S. Department of Labor, Washington, D.C.

Bureau of Labor Statistics (1997b) *Survey of Occupational Injuries and Illnesses in the United States by Industry.* U.S. Department of Labor, Washington, D.C.

Department of Commerce (annual) *Statistical Abstract of the United States.* U.S. Government Printing Office, Washington, D.C.

Dennis, S.M. (1996) Estimating Risk Costs per Unit of Exposure for Hazardous Materials Transported by Rail. *Logistics and Transportation Review* 32, 351-375.

Federal Highway Administration (annual) *Highway Statistics.* U.S. Department of Transportation, Washington, D.C.

Federal Railroad Administration (1998) *Railroad Safety Statistics: Annual Report 1997.* U.S. Department of Transportation, Washington, D.C. The predecessor editions of this annual report were entitled *Accident/Incident Bulletin* until 1997.

General Accounting Office (1982) *The Federal Approach to Rail Safety Inspection and Enforcement: Time for Change.* Report CED-82-51. U.S. Government Printing Office, Washington, D.C.

General Accounting Office (1996) *Federal Employers' Liability Act: Issues Associated with Changing How Railroad Work-Related Injuries are Compensated.* Report GAO/RCED-96-199. U.S. Government Printing Office, Washington, D.C.

General Accounting Office (1997) *Rail Transportation: Federal Railroad Administration's New Approach to Railroad Safety.* Report GAO/RCED-97-142. U.S. Government Printing Office, Washington, D.C.

Health and Safety Executive (1994) *Railway Safety Cases: Guidance on Regulations.* HSE Books, Sudbury, UK.

Kolstad, C.D., Ulen, T.S. and Johnson, G.V. (1990) *Ex-post* Liability for Harm vs. *Ex-ante* Safety Regulation: Substitute or Complements? *American Economic Review* 80, 888-901.

Moses, L.N., and Savage I. (1997) A Cost-Benefit Analysis of United States Motor Carrier Safety Programs. *Journal of Transport Economics and Policy* 31, 51-67.

Pelletier, A. (1997) Deaths among Railroad Trespassers: The Role of Alcohol in Fatal Injuries. *Journal of the American Medical Association* 277, 1064-1066.

Savage, I. (1998) *The Economics of Railroad Safety.* Kluwer Academic Publishers, Norwell, Mass.

Savage, I. (1999). The Economics of Commercial Transportation Safety. In *Transportation Economics, Policy and Management: A Survey in Honor of John R. Meyer*, ed J. Gómez-Ibáñez, W.B. Tye and C. Winston. Brookings Institution, Washington, D.C.

Transportation Research Board (1994) *Compensating Injured Railroad Workers Under the Federal Employers' Liability Act.* Special Report 241. National Academy Press, Washington, D.C.

ENDNOTES

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This paper is a summary of the author's recently competed book *The Economics of Railroad Safety*, published by Kluwer Academic Publishers in July 1998.

1. For the purposes of this paper, trespassers are defined as those people trespassing at places other than at rail-highway grade crossings. People with known suicidal intent are excluded from the data.

2. Sources of data are FRA (1998), Department of Commerce (annual), and Federal Highway Administration (annual).

3; A train accident is defined as "a safety-related event involving on-track equipment (both standing and moving), causing monetary damage to the rail equipment and track above a prescribed amount." That amount changes with inflation and was $6,500 in 1997 (FRA, 1998).

COMPETITIVE EFFECTS OF RAILROAD MERGERS

by Curtis M. Grimm and Joseph J. Plaistow**

ABSTRACT

In the post-Staggers era, the U.S. railroad industry has experienced a significant number of mergers and a sharp reduction in the number of Class I rail carriers. This paper provides analysis of the competitive effects of these rail mergers, with a focus on Union Pacific-Southern Pacific, Burlington Northern-Santa Fe, and Southern Pacific-Santa Fe. Specifically, a methodology to quantify horizontal competitive effects of rail mergers is developed and applied to these mergers.

INTRODUCTION

In the post-Staggers era, the U.S. railroad industry has experienced a significant number of mergers and a sharp reduction in the number of Class I rail carriers. This has given rise to increasing concern by shippers as to the effect of these mergers on rail competition. It is therefore important to carefully analyze the competitive impacts of rail mergers since 1980. Much of the debate regarding competitive effects contains misconceptions regarding the degree to which mergers have reduced competition in specific markets. Shippers have argued that there is an important cumulative effect on competition given the continuous reduction in the number of Class I carriers since 1980. Others have pointed to declines in rail rates since 1980 concurrent with merger activity as evidence that newly proposed parallel mergers will not reduce competition. Furthermore, many observers have been unaware of important differences with regard to competitive impacts of the recent mega-mergers. In this paper, we examine competitive effects more carefully, using a qualitative method for mergers prior to the mid 90's, and a quantitative method developed by the authors for the SP-SF, BN-SF, UP-SP and Conrail consolidations. Finally, the paper will explore policy implications.

THE END-TO-END MERGER WAVE: ICC RAIL POLICY 1980-1995

The 4-R and Staggers Acts, along with ICC administrative actions, encouraged end-to-end consolidations and set off a railroad merger wave. However, it was a conscious, explicit policy of the ICC to encourage end-to-end mergers but to discourage parallel mergers. Indeed the only major parallel merger proposed to the ICC between 1980 and 1995, the Southern Pacific-Santa Fe, was turned down by the ICC:

> [A]s the Commission warned over five years ago in its Merger Policy Statement, parallel mergers are not favored where there are no other competing railroads. See *Merger Policy Statement*, 363 I.C.C. 784, 791 (1981). The burden of demonstrating that such a merger is in the public interest is a heavy one, and must be borne on the shoulders of substantial evidence. *SFSP*, 2 I.C.C 2d at 833 (1986)

As a result of this policy, the U.S. railroad system went through a major restructuring in the early 1980's, leaving three large systems dominant in the East and four major roads dominant in the West, without significant horizontal anticompetitive effects. The major consolidations restructuring the U.S. system in the early 80's as well as subsequent consolidations up to the mid-90's, as listed in Table 1, were primarily end-to-end. This can be documented most readily by simple inspection of maps of the merging carriers, which are available by request from the authors. Thus, it is incorrect to offer predictions about effects of recent parallel mergers based on experience regarding the end-to-end consolidations between 1980 and 1995.[1]

RECENT MERGERS: PARALLEL EFFECTS

Recent U.S. rail mergers have raised more serious issues regarding horizontal competitive effects. In this section of the paper, we will describe the methodology we have developed to quantify these effects. Then we will present our analysis of 2-1 horizontal effects for the SP-SF, BN-SF, UP-SP, and NS-CSX-CR mergers.

Table I			
Class I Unification 1980-1998			
Effective Date of Unification	Type of Unification	Applicant Railroads	Controlling Railroad/ Company
6/2/80	Control	DT&I	GTW
12/1/80	Merger	SLSF	BN
9/23/80	Control	C&O/SCL	CSX
6/3/81	Control	Maine Central	Guilford
1/1/82	Merger	BN/C&S/FW&D	BN
6/1/82	Consolidation	SOU and N&W	NS
12/22/82	Merger	UP/MP/WP	UP
1/1/83	Consolidation	Family Lines/L&N	Seaboard System
7/1/83	Control	Boston & Maine	Guilford
1/5/84	Control	D&H	Guilford
2/19/85	Control	SOO/CMSP&P	SOO
3/26/87	Control	CR-government	CR-private
8/12/88	Merger	UP/MKT	UP
10/13/88	Control	SP/SSW/DRGW	DRGW
4/27/95	Purchase	UPC&NW	UP
9/22/95	Merger	BN/ATSF	BNSF
9/11/96	Merger	UP/SP	UP
6/20/98	Control	NS/CSX/CR	NS and CS

Source: Railroad Mergers by Frank N. Wilner and AAR *Railroad Ten-Year Trends*

Methodology to Quantify Horizontal Competitive Effects of Rail Mergers

The starting point in conducting a rigorous evaluation of the consequences of railroad mergers is the definition of the relevant markets. The Department of Justice and Federal Trade Commission's horizontal merger guidelines for defining relevant markets provide a clear and powerful market definition tool. Accordingly, boundaries for markets can be established as follows:

> Specifically, the Agency(DOJ or FTC) will begin with each product (narrowly defined) produced or sold by each merging firm and ask what would happen if a hypothetical monopolist of that product imposed at least a 'small but significant and non-transitory' increase in price, but the terms of sale of all other products remained constant. If, in response to the price increase, the reduction in sales of the product would be large enough that a hypothetical monopolist would not find it profitable to impose such an increase in price, then the Agency will add to the product group the product that is the next-best substitute for the merging firm's product.

Department of Justice and Federal Trade Commission Horizontal Merger Guidelines, April 2. 1992, Section 1.11.

To apply these standards to railroad mergers, it must first be understood that a railroad's "products" consist of the transportation of commodities between specific origin-destination pairs. A railroad is truly a multi-product firm, in that each origin-destination and type of commodity shipped can properly be regarded as a unique product. If we begin with such a correctly-defined product of the merging firm -- we must then ask, in the words of the merger guidelines, whether in response to a hypothetical price increase, "the reduction in sales would be large enough that hypothetical monopolist would not find it profitable to impose such an increase in price." As to numerous commodities and shippers, there is clear evidence that a hypothetical rail monopolist could profitably increase prices.

While some shippers in a broader market could shift to other competitors in response to such a price increase, this does not help in rendering a price increase by a monopoly railroad unprofitable. The key is that a monopoly railroad can selectively raise prices to specific shippers in accordance with the availability to the particular shipper, for particular movements, of source, product or intermodal competition.

Another market definition issue is the scope of the geographic market. A key point here is that shippers captive to one railroad with another nearby benefit from indirect competition in many ways.

With reference to Figure 1, Industrial Site #1 is a shipper served by only Railroad B, but with Railroad A located in the vicinity. There are many ways a shipper in the position of Industrial Site #1 could gain value from the presence of an independent Railroad A. This shipper benefits from Railroad A/B competition in at least the following ways:

Industrial Site #1 can transload by truck to Railroad A, or threaten (tacitly or explicitly) to do so and use this threat to gain a reduced contract rate.

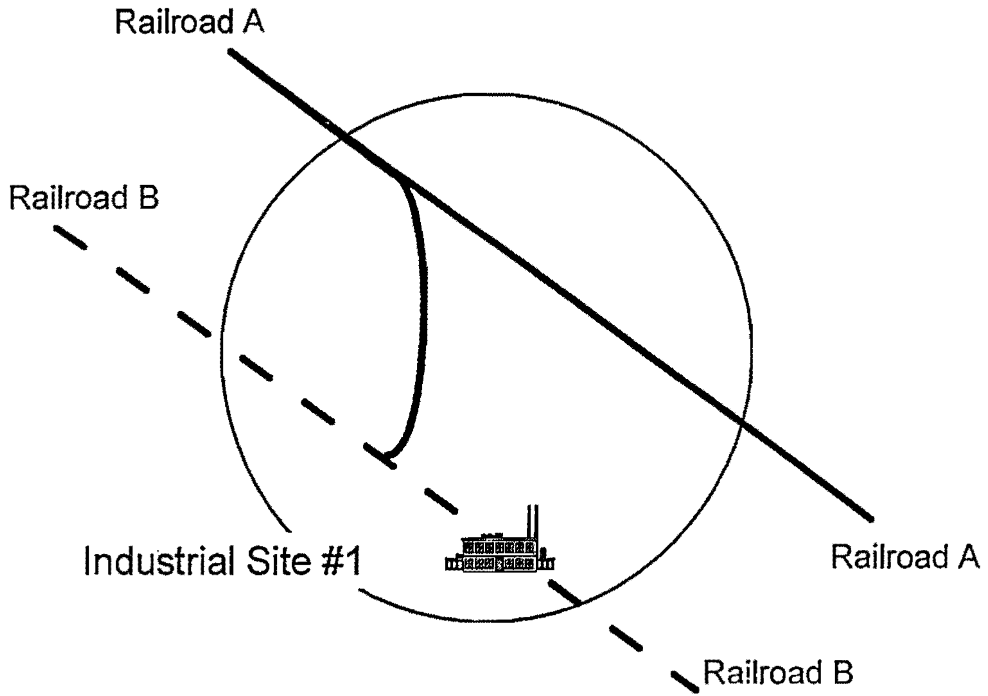
Industrial Site #1 can shorthaul Railroad B, or threaten to do so and use this threat to gain a reduced contract rate. This may involve STB action to limit the rate charged by Railroad B in such an instance.

Industrial Site #1 can build out a spur line to connect with Railroad A, or threaten (tacitly or explicitly) to do so and use this threat to gain a reduced contract rate. A variant of this occurs when plant expansions are required to handle increasing volumes.

Industrial Site #1 can relocate plant/facility to Railroad A's line upon receiving a more favorable contract rate, or threaten to do so, and use this threat to gain a reduced contract rate.

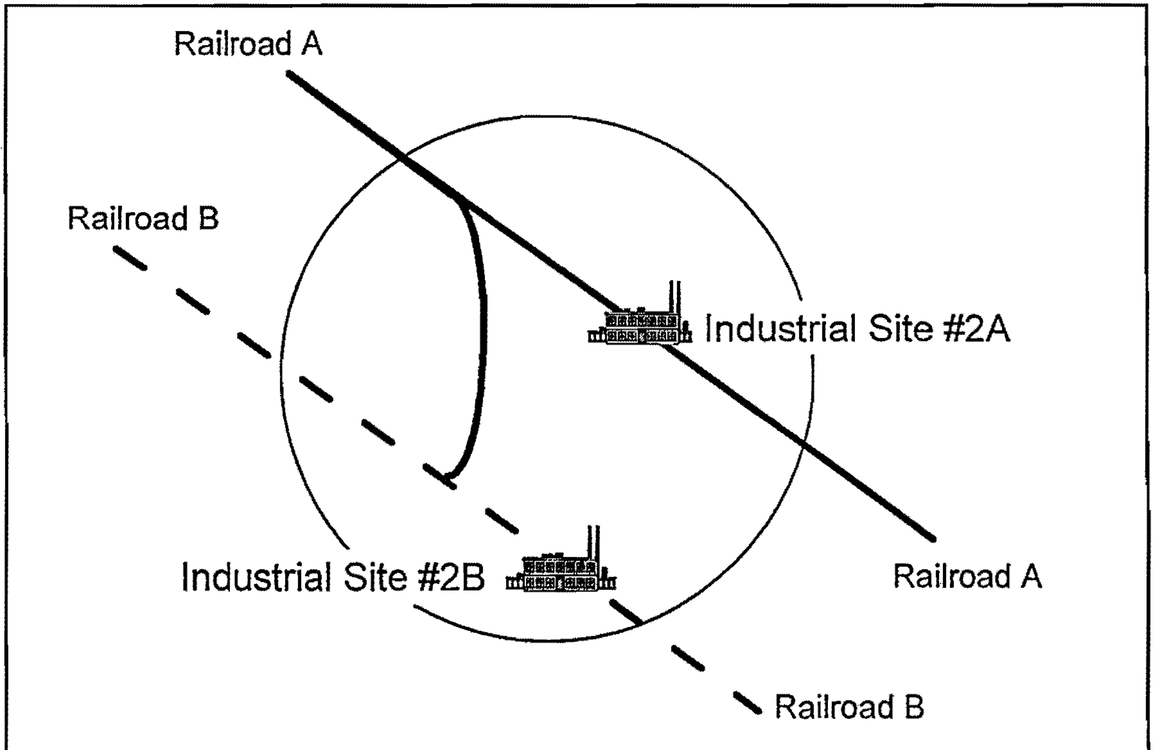
Referring to Figure 2, the shipper has "captive" plants located on both railroads (Industrial Site #2B is captive to Railroad B and Industrial Site #2A is captive to Railroad A) but relative production levels across the two plants are determined in part by rail rates to each plant. Thus, Railroad B and

Figure 1



Shipper has physical access to only one applicant but is in proximity to the other.

Figure 2



Shipper has captive plants on both Railroads A and B lines.

Railroad A will compete with regard to this shipper's traffic.

Industrial Site #3 competes in the product market with Industrial Site #4, as depicted in Figure 3. This product market competition will result in "upstream" competition between Railroad B and Railroad A.

Following a Railroad A/B merger, a shipper faces a choice between Industrial Site #5 and Industrial Site #6, as depicted in Figure 4. Prior to the merger, the shipper would have received the benefits from Railroad B and Railroad A ex ante site location competition; the choice of a site would not be finalized until a long-term contract with one of the railroads was locked in.

The examination of types of shippers impacted by a loss of competition, as discussed above, supports a definition of rail markets as narrowly defined origin-destination pairs using BEA's. A BEA-BEA market definition also follows that of the Justice Department in the SP/SF and UP/SP cases, in particular that of Witness Pitman in his testimony and academic writings related to the SP/SF case,[2] defining markets as flows between origin and destination BEA's. In the SF/SP case, the ICC supported this definition of markets, but the STB found it too broad in the UP/SP case.

A final issue in defining rail markets is the complexity that many long-haul movements entail coordination by more than one carrier. It is common for connecting carriers to submit a single competitive bid for the entire movement. Therefore, competition is greatly enhanced when the alternative, fully-independent routings are available. If one firm participates on all routings, competition can be greatly hampered. The Commission has clearly stated that independence of routings is critical:

> Competition between railroads generally requires the presence of two or more independent routes, that is, routes having no carriers in common. When a single carrier is a necessary participant in all available routes, *i.e.*, a bottleneck carrier, it can usually control the overall rate sufficiently to preclude effective competition.

Consolidated Papers, Inc., et al v. Chicago and North Western Transportation Co., et al, 7 I.C.C. 2d 330, 338 (1991).

Accordingly, we focus our primary attention on instances where the number of independent railroad routings is reduced, especially from 2-to-1. The ICC's and STB's notion of independent routes set forth can be illustrated in the table below.

MEMPHIS TO SAN ANTONIO	
Current Rail Routes	**Market Share for That**
SP DIRECT	17%
UP DIRECT	31%
BN-UP	4%
CSXT-UP	26%
NS-UP	22%

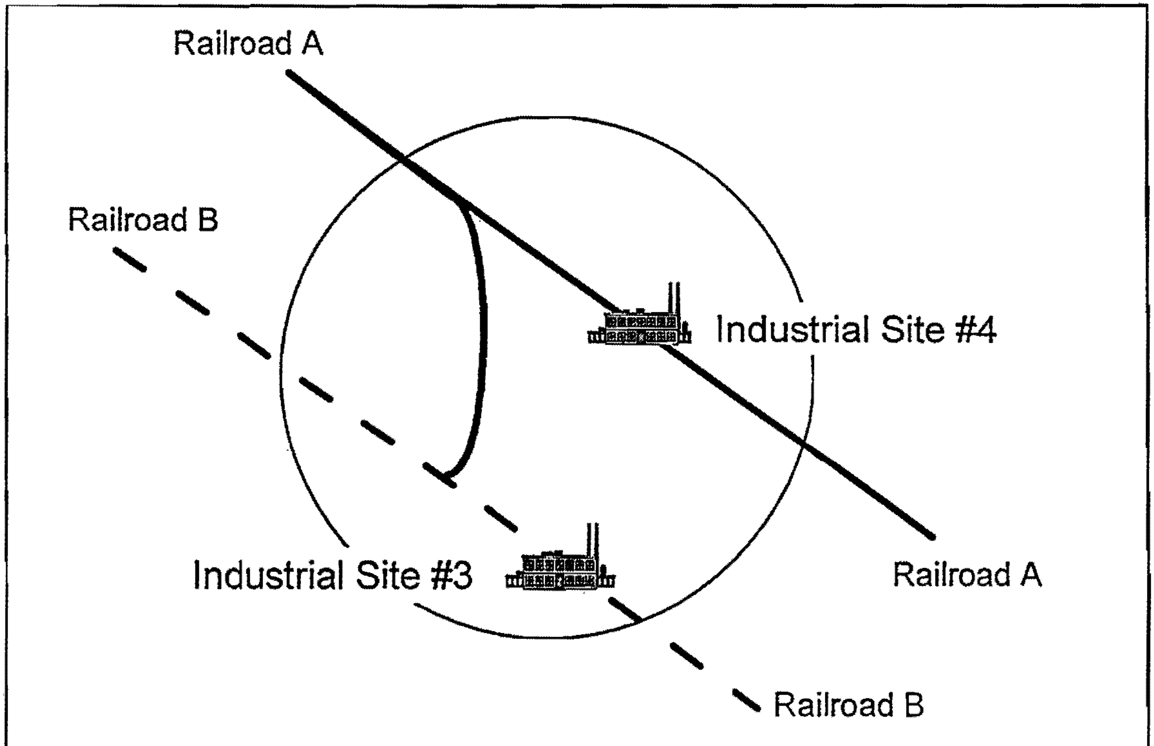
Prior to the UP/SP merger, there were five rail routings in the Memphis to San Antonio market, but only two independent routes. Either UP or SP becomes a bottleneck carrier for each of the five routes, leaving two independent competing routes pre-merger. After the UP/SP merger only one independent route remains, as UP/SP participates in each of the routes. Thus this BEA pair constitutes a 2-to-1 market with regard to the UP/SP merger.

2-1 Horizontal Effects: The Evidence

Figure 5 provides a comparison of 2-to-1 competitive impacts across three mergers;[3] SP/SF, BN/SF, and UP/SP. The comparison shows clearly that the competitive harms of the UP/SP merger dwarf those of the primarily end-to-end BN/SF consolidation, as well as the largely parallel SF/SP proposed consideration, which the ICC denied as anticompetitive. Other methodology is used to estimate 2-1's., as shown in Figure 6, also corroborate the substantial and unprecedented horizontal competitive effects of the VP-SP merger. Figure 6 shows the results of four alternative methodologies that were all included as testimony in the UP/SP merger case.

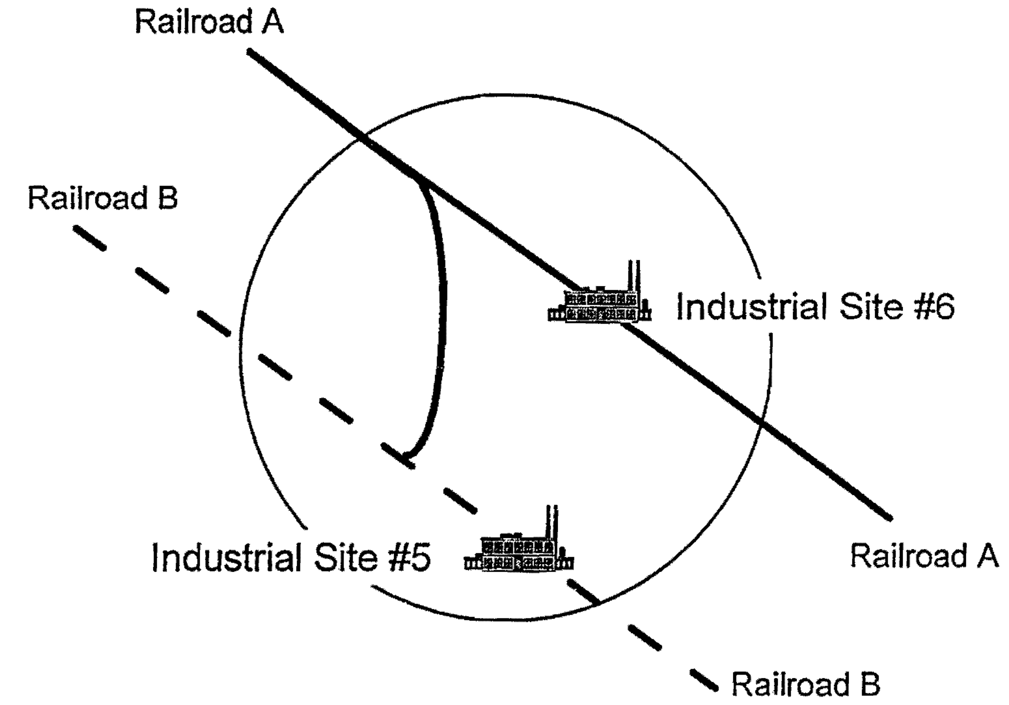
In comparison, the joint acquisition of Conrail by NS and CSX was pro-competitive in that 1-2 strongly outweighed 2-1 effects. On a BEA-BEA basis, it was estimated that $706 million of revenue

Figure 3



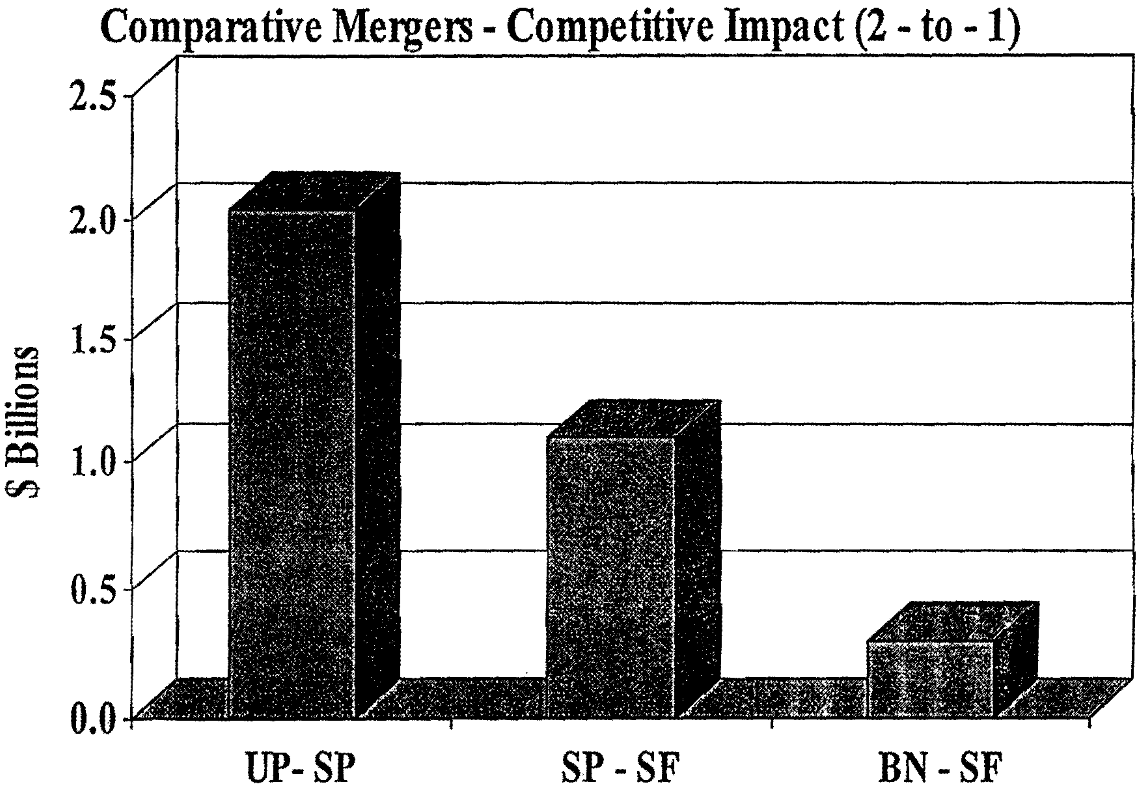
Shippers served by different railroads competing in same product market.

Figure 4



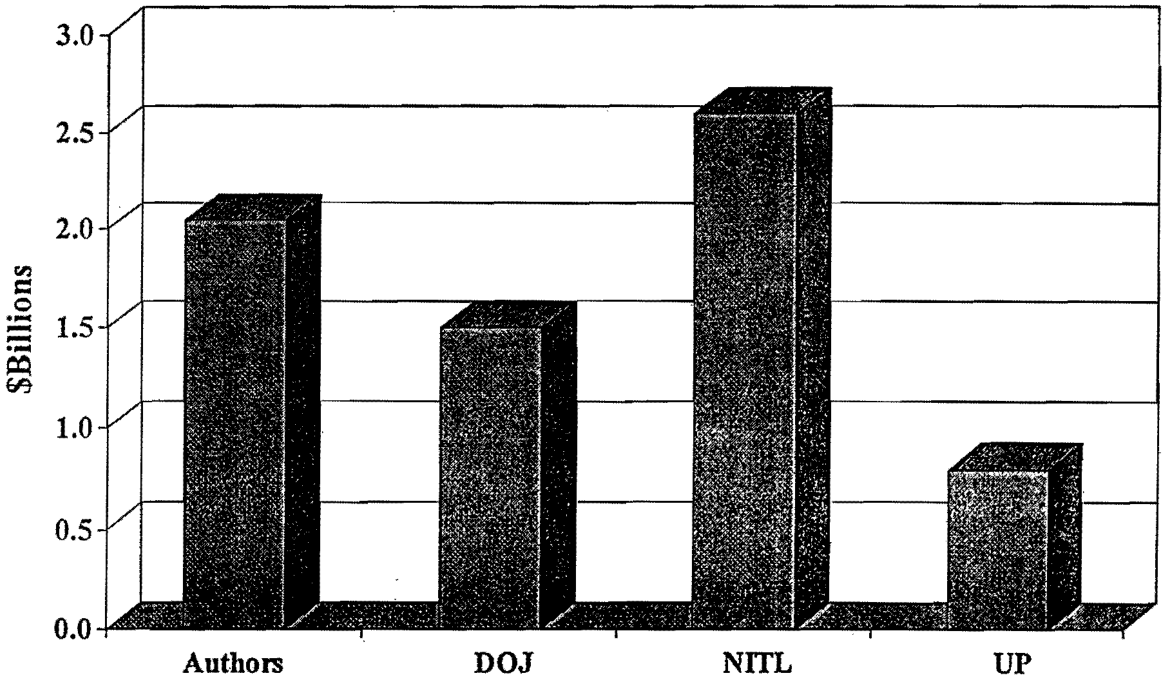
Shipper benefits from ex ante site location competition.

Figure 5



Comparative Mergers - Competitive Impact (2 - to - 1)
$ Billions
2.5
2.0
1.5
1.0
0.5
0.0
UP- SP
SP - SF
BN - SF

Figure 6
UP-SP Merger - Competitive Impact (2 - to- 1) Estimates by Parties of Record



from Conrail-only traffic would be served by both Norfolk Southern and CSX after the merger.[4]

IMPLICATIONS

One of the essential premises underlying the deregulation of transportation, communications and other industries is that in the absence of price and entry regulation, these industries would be sufficiently competitive to generate improvements in allocative, technical and dynamic efficiency in each industry. However, competition must be preserved and promoted for this premise to be realized.

Recently shipper support has intensified for legislation to provide the needed competition for rail shippers. The Canadian model provides one such example of what this might entail.[5] However, to the extent that support for competitive access legislation is premised on counterbalancing or undoing anticompetitive effects of rail mergers, our analysis suggests that attention should be focused on only the Union Pacific-Southern Pacific merger, which had unprecedented parallel effects and resulted in elimination of rail competition in many Western markets.

Under this approach, regulators would first identify the sites requiring added access because of problems flowing out of recent mergers and second, work to find a reasonable remedy for restoring competition. This tailored approach would provide competitive relief to shippers most aggrieved and build on the Staggers deregulatory foundation.

Union Pacific's service meltdown focused attention on Houston as one potential site for application of the tailored approach to restore rail competition. Shippers have testified that reduction in rail competition from the UP/SP merger left them with insufficient rail options. In the UP/SP merger, BNSF was granted access to 2-to-1 shippers in the Houston area, but questions remain as to the viability of a tenant's competition over the landlord's long-distance trackage rights.[6]

REFERENCES

Harris, Barry C. (1997) Verified Statement, STB Finance Docket No. 33388, CSX/NS June 19, 1997.

Pittman, R.W. (1990) Railroads and Competition: The Santa Fe/Southern Pacific Merger Proposal, *The Journal of Industrial Economics*.

ENDNOTES

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1. The UP/MKT merger did contain parallel elements, but the parallel elements involved low traffic volume, and resulted in three or four competing railroads after the merger. However, most affected markets had three or four competing railroads after the merger. The Wisconsin Central merger also had parallel elements within Wisconsin.

2. Pittman, R.W. (1990) Railroads and Competition: The Santa Fe/Southern Pacific Merger Proposal, *The Journal of Industrial Economics*.

3. The 2-1 competitive impacts of the BN/SF merger were calculated using precisely the same methodology as for the UP/SP and *SFSP*, based on the same 1994 data. It could be argued that the 2-1 impact of the BN/SF and UP/SP mergers were partially ameliorated by various settlements and conditions. The results provided in Figure 5 do not attempt to estimate the impacts of such conditions. Of course, the extent to which the UP/SP settlement with BN/SF actually ameliorates the 2-1 competitive harm of the UP/SP merger was a sharply contested issue in that case and continues to be debated.

4. Harris, Barry C. (1997) Verified Statement, STB Finance Docket No. 33388, CSX/NS June 19, 1997.

5. Canada's 1987 National Transportation Act included several provisions to increase rail intramodal competition, in particular for shippers captive to a single railroad. Most importantly, the Canadian interswitching legislation promotes such competitive access in a more vigorous manner than U.S. reciprocal switching legislation. Such access is provided to shippers primarily within an urban area through rates set by government fiat. Dating back to 1908, interswitching was required within distances of four miles. In

ther words, assume a coal mine has physical access to only one railroad (Railroad A), but is located within four miles of a second railroad (Railroad B). The coal mine can arrange to ship its coal with Railroad B, with Railroad A required to move the coal from the mine to the junction with Railroad B at prescribed rates. The 1987 legislation extended this to 30 kilometers and also provided the National Transportation Agency to set compensatory rates for such interswitching, to be adjusted annually. Shippers outside this limit who compete with shippers within the 30 kilometers limit can apply to be deemed within the limit. According to the National Transport Agency of Canada (1992), Canadian National and Canadian Pacific currently interswitch between 130,000 and 140,000 cars annually, with half that volume outside the previous four mile limit. According to the National Transportation Act Review Commission (1992), the percentage of shippers having access to two or more railroads has increased from 54 to 80 percent because of the extension of the interswitching limit.

6. Our testimony on October 16, 1998 in the oversight portion of the UP/SP merger proceeding showed that BNSF had gained only a 9% market share using their trackage rights. UP had a 91% market share.

BOOK REVIEWS

Divided Highways: Building the Interstate Highways, Transforming American Life

Tom Lewis

New York: Viking Penguin, 1997; ISBN-0-670-86627-X

The song writer of 1917 summed it up, "How ya gonna keep em down on the farm, After they've seen Paree". This could well be the theme of the national highway program. Despite difficulties that arise, members of the great public of all classes once they get behind the wheel in a car and see the paved road, there is no turning back to the long hike, the street car and bus, or the horse. The "love affair of Americans with the automobile" is not an emotional binge; it is a transforming, revolutionary social force. As we shall see, Tom Lewis, author of *Divided Highways*, gets pretty close to seeing this , but at the end can't quite bring himself to face it. Otherwise it is a very good book, perhaps the best that has ever been written on the highway program.

Tom Lewis is a professor of American history at Skidmore College, Saratoga Springs, New York, a famous women's college with high academic standing. His book covers the history of the Federal aid highway program, its culmination in 1955 with the authorization of the Interstate highway construction, and the actual construction and completion of the system; in other words, the period from 1919 to near the present. As a professional historian he has done a thorough job with sources and documents, and the interview of leading persons with knowledge of the highway program. His historical discussions are well structured, interestingly told, and connected to significant human interest events.

Lewis makes clear that the great social transformation of society in the period did not happen all by itself. In the case of highway transportation there were two outstanding national leaders, Thomas Harris MacDonald, who took care of the roads, and Alfred P. Sloan, who had a formative influence in the manufacture of automobiles. Sloan is well known, but not many, even transportation scholars, know about MacDonald. Lewis writes the best appreciation of MacDonald the man and administrator that has ever been done.

From 1919 to 1953 MacDonald was the Federal aid highway program. The Interstate System, his creation, was constructed in the post-MacDonald period. That is the main root of some of the problems. No leaders of the post-MacDonald period rose to the status of the Chief: all with one particular exception were like MacDonald, technically very competent, quite honest and honorable, energetic, and program interested. One, Lowell Bridwell, was not an engineer, but he compensated in program interest and experience. The position was renamed Administrator and now required Senate confirmation, but that seemed to generate turnover rather than new light. MacDonald got by with the limited salary of a simple bureau chief, hoped that the party chiefs and Presidents would leave him alone.

In the movies of the period, Henry VIII did not know whether the chicken or the egg had precedence, but he did know that "that little hen didn't do it all by herself." And so with the social revolution involving highways; there were other forces: higher incomes and urban dispersal. The new suburban homes were not Paree, but they were not the Depression nor the war. A lot of the highway problems that emerged involved these parallel forces. And none of them--urban planning, tax policy, legal reform, transportation policy, to name some, had the same quality of leadership and creativity displayed by MacDonald and Sloan in highways and vehicles.

In 1919 when the Chief got started there were virtually no paved roads outside the corporate limits of towns and cities. In MacDonald's 34 year tenure, there were created over one million miles of hard surfaced highways, 250,000 of them the "State roads" of the Federal aid highway program. Other entities, State and Federal, were moved to pave farm roads, village streets, work relief projects, park and forest roads, and other road types. New technologies involving asphaltic surfacing, construction equipment, signage, highway patrols, traffic engineering, contract administration., and others were introduced and progressively improved over time.

In 1919 there was very little State government; the States were a huge hiatus between strong local entities and Federal agencies. MacDonald and his associates created the first major State program in more than a century. Before MacDonald, Federal-State relations were limited to a few low budget items in the Department of Agriculture. After MacDonald, Federal-State joint programs were modeled on the highway precedent in such fields as education, welfare, health, resource, conservation, safety administration, law enforcement, etc. Though by now far overshadowing highways in volume of expenditures, none so far have accepted State control of designating national standards, system eligibility, and funding sources, as did MacDonald with the American Association of State Highway Officials. Before long, the States came to exceed the Federal government in funds available for highways;

before the Interstate program, Federal funds were barely one third of total available funds. A good part of even Federal-aid systems came to be financed by States alone. Few Federal-State programs outside highways have repeated this experience; Federal funds still dominate the process.

MacDonald was an average looking guy, a rather ordinary executive office on the sixth floor of his building was all he needed, and his personal life was that of most of the great middle-middle class. After the death of his wife in 1935 he dwelt in a modest room in the Cosmos Club, only a half dozen blocks from his office. He was not a participative manager. His staff in the Bureau rarely saw him, he only talked to highway executives, Committee chairmen, and leaders of the highway industry. He faced down such national demagogues as Huey Long and Herman Talmadge of Georgia, cutting them off without a cent. He directed his fury at the Budget Bureau, and when he rarely attended a budget meeting there was always a tongue lashing directed at some insistent Budget person. In his lifetime the highway program escaped most budget review.

Macdonald's one imperious act was in his use of the common elevator, which carried him up and down non-stop; a perquisite of Cabinet Secretaries, Congressional leaders, Presidents, etc. When his resolute secretary--Miss (Carolyn) Fuller--was granted the same privilege, there was a muted tongue wagging among the staff. This echoed mildly for years, but when he left office in 1953, sure enough he married her and moved to Texas. This is mentioned only to show how well Tom Lewis has found the full human scale of the highway program and the redoubtable Chief. It is a mark of authenticity.

All five chapters of Part 3 of the book are devoted to the Post-MacDonald era and Interstate construction. The author dwells with the problems that emerged. Here he goes beyond the sphere of the historian and indicates his own and some others' anti-highway sentiments. While his history of this period is good, his policy opinions at this late date are not defensible. The most contentious of the problems that emerged had to do with the taking of homes in urban areas to build the Interstate expressways. Earlier, the Federal aid program was achieved through stage construction on existing road right-of-ways, so that any land taken for relocation--as in the case of straightening out bad curves--was minimal, but even here a few good properties were disturbed with bad local protests. The Interstate system, however, was built on entirely new locations. In urban areas large swaths of property had to be taken, and of course the protests multiplied. Stories got in the newspapers; some of them, like the noted programs of David Brinkley, contained assertions which bordered on falsehoods. Others in the intellectual community, following the lead of Lewis Mumford, became stylishly anti-highway and talked about life in the great city, transit as a way of life, and the need for comprehensive planning.

Several other issues got mixed into the broth of the 1960's:

1. Fiscal conservatives pointed with alarm to the great growth in highway expenditures. The fact that the Federal government paid 90 percent of Interstate cost led to a panicky literature on State and local corruption in highway expenditures. This generated speeches and hearings in Congress and the hiring of extra auditors. Very little irregularity in the expenditure of highway funds has ever been found.

2. Deficits in the highway trust fund occurred in the late 1950's when Congress, in a panic over a supposed recession, relaxed the safeguards against the use of the trust and ordered acceleration of highway construction, leaving a fiscal mess which took several years to correct.

3. The planning establishment, despite Lewis Mumford's blind faith, had no way to develop Metro area plans on a scope required to match the highway program. Neither funding nor technical capacity was available to meet comprehensive planning requirements. In some States, such as California, only the Highway Department had the technical capacity to do modern comprehensive planning.

4. The transit establishment, despite new Federal funds including infusions of highway money has not developed new transit concepts equal to modern urban growth, leaving by default use of automobiles for urban transportation needs.

5. Similarly, general transportation policy has not developed concepts for integrating highways into a balanced transportation system.

6. Civil rights and race relations got into the mix, many alleging that urban highways tended to be placed in minority neighborhoods, which was in part true because minorities tended to live in parts of the city where congestion was a problem and access to other city residents was difficult.

All the difficulties of modern society, in the minds of some, came to be connected with the Interstate program. None of this stopped the completion of the system or the public's acceptance of it. What would we have done if it had not been built? We need not answer this question; we should ask, what will we do in the post-Interstate era now upon us. So far there are no MacDonalds or Sloans to help with this one

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Computer Simulation in Logistics

Roy L. Nersesian and G. Boyd Swartz
Westport, Connecticut: Quorum Books, 1996; ISBN #0-89930-985-2

The authors point out in the introduction that the study of logistics may defy mathematical precision. For example, the authors suggest that the school of hard knocks is the basic training ground for logistics. That is, because of the pressures of the real world and the complexity of a logistics problem, it may be impossible to quantify all aspects of a logistics decision. There are, however, a number of options available for the effective teaching of logistics. One is the case method, which can be rather artful in that it combines both quantitative and qualitative facts about a problem and attempts to solve it. Another way to teach logistics is to use simulation, which provides a more quantitative response to typical problems faced by logistics managers. This book is about simulation. The general caution for the reader is that, while simulation can be very flexible and applied to a variety of situations, each simulation needs to be tailor-made for each firm. Thus, there are risks with applying simulations as generic solutions to all firms.

This is a cross between a textbook and a how-to manual. It is organized with each chapter devoted to a particular simulation designed to solve logistics problems. No rationale is given for the selection of simulations which are contained in the book and not all of them seem to have direct relevance to the field, e.g., the selection of aircraft and siting an ambulance station. The major questions, according to the authors, were whether to include the simulations in each chapter, as opposed to placing them in the appendix, and what programming language to use. For the former question, discussion of each simulation is incorporated into each chapter while the specific code is in an appendix which accompanies each chapter. In regard to the second issue, basic is the language of choice. Actually the authors present each simulation in both Gwbasic and visual basic (VB). The rationale is that basic has been around since the 1960's and "is well known by a wide range of people in the field of simulation." Visual basic is a more modern version of that language and has an advantage in that it can be easily integrated with Excel spreadsheets. While it is true that basic has been around for approximately 40 years, it is not the case that it is necessarily the language of logistics managers. Nor is it necessarily taught in colleges and universities in favor of other programming languages. From that standpoint, the choice of language may pose difficulties in using this as a text. That is, it may require learning yet another language for both faculty and students. This may be less of a problem for practitioners who may use the book primarily as a how-to manual.

The book is organized by different simulations as individual chapters. Each simulation is discussed in terms of the methodology, the nature of the problem, the logic of the model (normally presented in Gwbasic), how to evaluate the results, how firms may make similar decisions in the real world, and any enhancements which may be made to the simulation by using visual basic. The authors have attempted to keep the simulations simple to encourage users to modify them for their own application. The discussion in each chapter is rather detailed both in terms of the basic code as well as the application to either Lotus or Excel spreadsheets. The result is that the reading can be quite tedious and the reader needs to be careful in following the literal instructions.

My primary criticisms of the book are the choice of simulation language and the selection of simulations which are supposed to be related to logistics. While most are rather logical, some appear odd. For example, the chapter headings are as follows:

The Normality of Things
When to Reorder and How Much?
Determining Warehouse Capacity
How Many Warehouse Docks?
How Many Trucks Should be Owned?
Tankers Serving a Pipeline
Selecting Aircraft
Just-In-Case Inventory for Delivery
Push Manufacturing
Pull Manufacturing
Combining Warehouses
Factory Inventory
The Economic Run Length
Siting an Ambulance Station

Chapter 1 discusses the normal distribution and its importance in simulation exercises. This chapter sets the tone of the book in presenting a detailed discussion of how to simulate the normal distribution as well as instructions on how to enter simulation code into spreadsheets. This chapter represents a building block for many of the subsequent chapters.

"When to Reorder and How Much" is very useful. The traditional way of dealing with this problem is by calculating the Economic Order Quantity (EOQ) which balances ordering and holding costs. The difficulty is that the model makes assumptions which may not hold true in actual practice, e.g., the variability of lead times. The solution for the authors is a trial and error simulation which specifies reorder points while minimizing stock-out costs and related holding and ordering costs.

"Determining Warehouse Capacity" is also useful in that it can have wide application. The simulation assumes multiple products and dedicated warehouse space for each product. For example, each product has its own storage bin and products cannot be mixed in the same bin. However, if a bin is empty it can be used by any product. The question is, given some level of demand and its variability, how many storage bins does the warehouse needs? The next chapter, "How Many Warehouse Docks?", is normally solved with queuing theory. However, when assumptions regarding arrival patterns are not valid, such problems need to be simulated. My concern here is that this is not particularly new and would it be the province of the logistics manager or the industrial engineers to make such decisions?

"How Many Trucks Should be Owned" and "Tankers Serving a Pipeline" address similar problems. The authors differentiate the problems by suggesting that the tanker decision is driven more by operating efficiency while decisions as to how many trucks may also be driven by policy issues such as customer service. Both problems deal with the scheduling of different vehicles of various capacity to maximize capacity.

"Selecting Aircraft" takes the perspective of an airline, with a variety of planes, and asks how they should be routed given a fixed network, variation in demand and different vehicle capacities. Conceptually this chapter is similar to the questions of trucks and tankers above. While somewhat interesting, these may not be mainline decisions for a logistics manager. As in the case of determining the number of warehouse docks, these problems can be solved by alternative methods, e.g., linear programming and various routing algorithms.

There are a series of chapters dealing with "Just in Case Inventory for Delivery," as well as "Push Manufacturing," "Pull Manufacturing," and "Factory Inventory." When taken together, the value of these chapters is twofold. First, they suggest a hierarchy of inventory positions, e.g., a factory dealing with a distributor who in turn deals with a retailer, etc. Thus, there is an implied supply chain context to this discussion. In addition, there is value in the demonstration that inventory costs can be reduced by being reactive to actual movement of the product rather than anticipating product sales based on forecasts. Such a change in philosophy is at the core of current supply chain management strategies. The drawback to these chapters is that they assume the reduction of transit times, in order to minimize inventory, but don't consider increased transport costs.

"Combining Warehouses" deals with the question of warehouse consolidation. This topic is receiving substantial focus in the logistics literature through the application of the so-called "square root rule." Simulation offers a solution to some of the assumptions made by the square root rule including what happens to demand characteristics at the consolidated facility as well as transit time and transit time variability. Simulations are developed which cover a variety of situations ranging from a proactive and reactive ordering systems.

"Economic Run Length" deals with the classic problem of balancing production line set up costs and variable production costs. The authors enrich the problem by including various quality tolerances and variable demand for a variety of products. The simulation also allows orders to be filled directly from the production line as well as from inventory.

"Siting and Ambulance Station" is actually a poor choice of how to frame this type of location problem. This is actually a simulation of a center of gravity methodology which is helpful in siting plants and warehouses. It is a relatively straightforward method which finds the location by minimizing total ton-miles. Simulation allows the manager to make the analysis with greater precision rather than relying on restrictive assumptions.

In general the authors have taken great care to present this material in a useable format. Its value is clearly a function of the nature of the problems the reader wishes to solve and the reader's skill in basic. The volume would be enhanced further with a more extensive bibliography relating not so much to logistics but toward basic or other programming languages.

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Modeling Economic Inefficiency Caused by Public Transit Subsidies

K. Obeng, A.H.M. Golam Azam, and R. Sakano
Westport, CT: Praeger Publishers, 1997: ISBN 0-275-95851-5

Public transit in the United States is highly subsidized. As economists have shown us, subsidies can cause distortions in the market; if the market were otherwise perfect, the subsidies would create inefficiencies which prevent the economy reaching an optimal level. The authors of this book use statistical methods to determine the nature and extent of the inefficiencies in public bus agencies.

The authors start with an overview of transit subsidies and how subsidies cause inefficiencies. They discuss the history of subsidies from early in the century when transit firms made profits and didn't need subsidies through the growth and subsequent decline of Federal subsidies. They also discuss the varied objectives of transit subsidies, for example, trying to extend fixed route bus into low density areas where it is ill-suited or trying to maintain low fares to keep transit affordable to the poor. The difference in objectives is of interest later in the book when it becomes clear that evaluating the effectiveness of a subsidy must take into consideration its purpose.

They describe both technical and allocative inefficiencies. A technical inefficiency exists when the output of a firm is less than the maximum possible given the amount of resources (labor, fuel, or buses) used. Allocative inefficiency , as they use the term, is the use of input resources in less than optimum proportions, given the price of the resources. The nature of the distortions that subsidies might produce include having an excessive number of buses, increasing the wage rate of labor, or providing too much service among others.

The second chapter goes into greater detail about the trends in subsidies using Section 15 data (i.e., information collected by the Federal Transit Administration) from 1983 to 1992 for bus only transit agencies. The data clearly show that as Federal subsidies dropped for operating and capital expenses, the states picked up more of the operating costs and the local governments picked up more of the capital. The chapter is marred by poorly labeled tables; it is frequently not clear whether numbers are in dollars or percentages, or, if dollars, whether constant or current.

The next chapter presents the theory linking subsidies to inefficiency, and the fourth chapter develops the model forms for testing the impact of subsidies on the cost of bus transit. The next three chapters quantitatively estimate the inefficiencies resulting from the subsidies using three different statistical methods: an iterative non-linear three stage least squares approach, data envelopment analysis, and a stochastic frontier model. They use these approaches to look at the proportion of fuel, labor, and capital used.

The concluding chapter summarizes the results and draws some policy recommendations from them. The analysis shows that the nature of the inefficiencies varied by type of transit agency, that is whether the firm was public or private, purchased service, and was a small, medium, or large firm. The different statistical approaches seem to produce different results, a not uncommon finding. However, in almost every case the firms appear to use excess labor given their capital.

I had looked forward to the authors' policy recommendations, but did not find those useful. Some are too obvious to be meaningful; for instance, "The nature of the distortions differs by type of firm so that policies to reduce them should differ among firms. This policy recommendation must be applied to an individual transit firm only after all efficiencies and their sources are fully examined." Others do not seem to recognize the environment in which transit agencies exist; for instance " The federal subsidy formulae must take into account local and state funds and must reflect the marginal subsidy rates of inputs to each firm to determine the overall amount and type of subsidy to be offered." But if the Federal government bases its subsidy on how much the sate and local governments are providing, the state and local governments will surely reflect that in their decisions. And some do not recognize the political pressures on transit managers; "To ensure Pareto optimality, fare subsidies should be based upon the inverse of elasticity of average cost, or the inverse demand elasticity rule commonly used in establishing prices for various submarkets."

While in many ways the book is interesting, it is also frustrating. The organization seems as if each chapter had originally stood on its own (which it very likely had as a journal article); thus, discussions of the effect of subsidies and types of grants available seem to keep reappearing, rather than being completely covered in one place. The impact of politics on subsidy and fare decisions is incorporated in one of the models, which includes a variable representing the presence of a congressman from the transit agency's state on a committee that influenced transit subsidies; however, for the most part the political and other pressures on the local managers is left out.

The preface states that the book is aimed at "students of public transit economics," but would be useful to people in transportation and urban planning. I suspect that while it would be of interest to the former, the latter would find it heavy going and a great deal more than they want to know about the topic.

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APPENDICES

STATEMENT OF PURPOSE

The Transportation Research Forum is an independent organization of transportation professionals. Its purpose is to provide an impartial meeting ground for carriers, shippers, government officials, consultants, university researchers, suppliers, and others seeking an exchange of information and ideas related to both passenger and freight transportation. The Forum provides pertinent and timely information to those who conduct research and those who use and benefit from research.

The exchange of information and ideas is accomplished through international, national, and local TRF meetings, and by publication of professional papers related to numerous transportation topics.

The TRF encompasses all modes of transport and the entire range of disciplines relevant to transportation, including:

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HISTORY AND ORGANIZATION OF THE TRF

A small group of transportation researchers in New York started the Transportation Research Forum of New York in March 1958. Monthly luncheon meetings were established at that time and still continue. The first organizing meeting of the American Transportation Research Forum was held in St. Louis, Missouri, in December 1960. The Transportation Research Forum of New York sponsored the meeting and became the founding chapter of the ATRF. The Lake Erie, Washington D.C. and Chicago chapters were organized soon after and have been joined by chapters in Philadelphia, Northern California, Pacific Northwest, and New England. The TRF currently has over 500 members.

With the expansion of the organization into Canada, the name was shortened to Transportation Research Forum. The Canadian Transportation Forum now has approximately 300 members.

TRF organizations have also been established in Australia and Israel. In addition, an International Chapter was organized for TRF members interested particularly in international transportation and transportation in countries other than the U.S. and Canada.

Interest in specific transportation-related areas has recently encouraged some members of TRF to form other special interest chapters, which do not have geographical boundaries -- Agricultural and Rural Transportation, Personal Computer Users, High-Speed Ground Transportation, Aviation, and Cost Analysis. TRF members may belong to as many geographical and special interest chapters as they wish.

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In addition to monthly meetings of the local chapters, national meetings have been held every year since TRF's first meeting in 1960. Annual meetings generally last three days with 25 to 35 sessions. They are held in various locations in the United States and Canada, usually in October or early November. The Canadian TRF also holds an annual meeting, usually in the spring.

Each year at its annual meeting the TRF presents an award for the best graduate and undergraduate student papers. Recognition is also given by TRF annually to an individual for Distinguished Transportation Research.

Annual TRF meetings generally include the following features:

- Members are addressed by prominent speakers from government, industry, and academia.
- Speakers typically summarize (not read) their papers, then discuss the principal points with the members.
- Members are encouraged to participate actively in any session; sufficient time is allotted for discussion of each paper.
- Some sessions are organized as debates or panel discussions.
- The *Journal of the Transportation Research Forum* is a volume of approximately 100

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