Trunk Highway Trends

CHAPTER 2

In Chapter 1, we reviewed how the size of and spending on Minnesota's road system, including both the State Trunk Highway (STH) System and locally administered streets and highways, compare with other systems across the nation. This chapter focuses on the condition of Minnesota's state trunk highways and bridges, as well as the resources the Minnesota Department of Transportation (Mn/DOT) has had available to construct, preserve, and maintain them. In particular, this chapter addresses the following questions:

- **How have trunk highway revenues and expenditures, as well as Mn/DOT staffing levels, changed over time?**
- **In what condition are Minnesota's trunk highway pavements and bridges and how has this changed over the last 10 years?**
- **How have Minnesota's trunk highways been affected by growing levels of traffic?**
- **How safe are Minnesota's roads and how has this changed over time?**

RESOURCES

In this section, we examine the trends in trunk highway resources since the mid-1970s. Detailed data on revenues and expenditures are available going back to 1974. Information on Mn/DOT staffing is available back to 1970 but is only adequate for trend analysis from 1985 to the present.

Revenues

From 1974 to 1996, revenues of the Trunk Highway Fund increased from $240 million to $864 million--a growth of 260 percent. However, as Table 2.1 shows, revenue growth in inflation-adjusted dollars was only 16 percent. Revenues per capita, when adjusted for inflation, declined 3 percent.

Vehicle registration taxes, which accounted for 31 percent of Trunk Highway Fund revenues in 1996, grew the fastest. In inflation-adjusted dollars, revenues

Table 2.1: Percentage Change in Trunk Highway Fund Revenues by Source, 1974-96

	Revenues[a]	Revenues per Capita[a]
Gas Taxes	11%	(7)%
Vehicle Registration Taxes	65	39
Federal Aid	(2)	(18)
Other	(18)	(31)
Total Revenues	16%	(3)%

Source: Minnesota Department of Transportation.

[a]Adjusted for inflation using the deflator for state and local government consumption expenditures and gross investment.

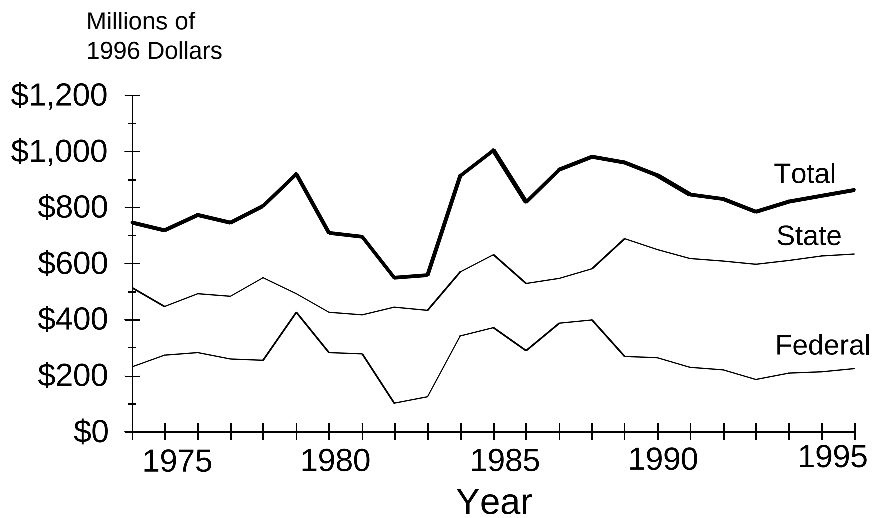
from vehicle registrations increased 65 percent. Even revenues per capita from vehicle registrations rose 39 percent. Gas tax revenues, which accounted for 35 percent of revenues, grew 11 percent between 1974 and 1996 but declined 7 percent in per capita terms. The other large source of revenues is federal aid, which accounted for 26 percent of revenues in 1996. Federal aid declined 2 percent in inflation-adjusted dollars and 18 percent relative to population.

Figure 2.1 shows that:

- **Trunk highway revenues, though relatively stable in the 1990s, have varied significantly in the past.**

Trunk highway revenues have generally kept pace with inflation but are below the peak reached in 1985.

Figure 2.1: Trunk Highway Fund Revenues by Source, 1974-96



Source: Program Evaluation Division analysis of Mn/DOT data.

Inflation-adjusted revenues grew 23 percent from 1974 to 1979 but plunged 40 percent between 1979 and 1982. By 1985, however, trunk highway revenues grew 83 percent from their 1982 low point. Revenues in 1996 were about 14 percent lower than the peak reached in 1985.

Much of the variation in revenues was due to changes in federal aid, which declined 76 percent between 1979 and 1982 and then rose 258 percent by 1985. Fluctuations in state revenue sources played a lesser role. To some extent, revenue peaks were accentuated by state revenues from bonds or motor vehicle excise taxes. The Trunk Highway Fund received revenues from these sources during only a few years, but some of those years also happened to be peak years for the receipt of federal aid. By comparison, the major state revenue sources--gas taxes and motor vehicle registration taxes--have not fluctuated much.

Spending

Highway construction prices have increased less than the general rate of inflation.

Like Trunk Highway Fund revenues, expenditures from the fund have increased since 1974. Just how much expenditures have increased since 1974 depends, however, on the index one uses to measure inflation. In analyzing revenue trends, we used an index--the national price deflator for state and local government consumption expenditures and gross investment (PGSL)--which reflects the general rate of inflation faced by state and local governments. This index shows that prices faced by state and local governments increased 209 percent between 1974 and 1996. Over the same period, according to Mn/DOT, prices for highway construction increased only 109 percent. This latter figure is based on the Minnesota Construction Cost Index, which reflects changes in highway and bridge construction prices faced by Mn/DOT.

We analyzed the trends in trunk highway expenditures in two ways. First, we used the PGSL to convert all expenditures to 1996 dollars. Table 2.2 shows that inflation-adjusted expenditures increased 6 percent from 1974 to 1996. The fastest growth was for general support and administration within Mn/DOT, which has doubled since 1974. Spending on equipment and buildings also increased significantly but, like general support and administration, accounts for a small portion of trunk highway expenditures. Also increasing faster than average were highway maintenance operations and spending by other state agencies. Expenditures on engineering services provided during the design and construction phases of projects declined 6 percent, while highway and bridge construction spending grew only 2 percent.

The second method we used to analyze spending trends was different in one respect. We used the Minnesota Construction Cost Index to convert highway construction spending to 1996 dollars. For all other types of spending, we continued to use the PGSL to make this conversion. Table 2.3 shows the impact of using this method. Instead of increasing 2 percent:

- **Inflation-adjusted spending on highway and bridge construction increased 52 percent between 1974 and 1996.**

Table 2.2: Percentage Change in Trunk Highway Fund Expenditures by Type, 1974-96

	Expenditures[a] (in Millions of 1996 Dollars)		
	1974	1996	Percentage Change
Highway Construction	$378	$385	2%
Operations[b]	141	176	24
Engineering, Research, and Investment Management	112	105	(6)
General Support and Administration[b]	13	27	110
Highway Bonds and Debt Service	39	19	(52)
Equipment and Buildings	17	18	7
Other[c]	60	78	30
Total	$761	$808	6%

Source: Minnesota Department of Transportation.

[a]Adjusted for inflation using the deflator for state and local government consumption expenditures and gross investment.

[b]Excludes equipment.

[c]Primarily includes spending by other state agencies.

In 1996 dollars, trunk highway spending has increased 27 percent since 1974.

Table 2.3: Percentage Change in Trunk Highway Fund Expenditures on Highway Construction, 1974-96

	Expenditures (in Millions of 1996 Dollars)		
	1974	1996	Percentage Change
Highway Construction[a]	$254	$385	52%
All Other[b]	383	423	11
Total	$637	$808	27%

Source: Minnesota Department of Transportation.

[a]Adjusted for inflation using the Minnesota Construction Cost Index.

[b]Adjusted for inflation using the deflator for state and local government consumption expenditures and gross investment.

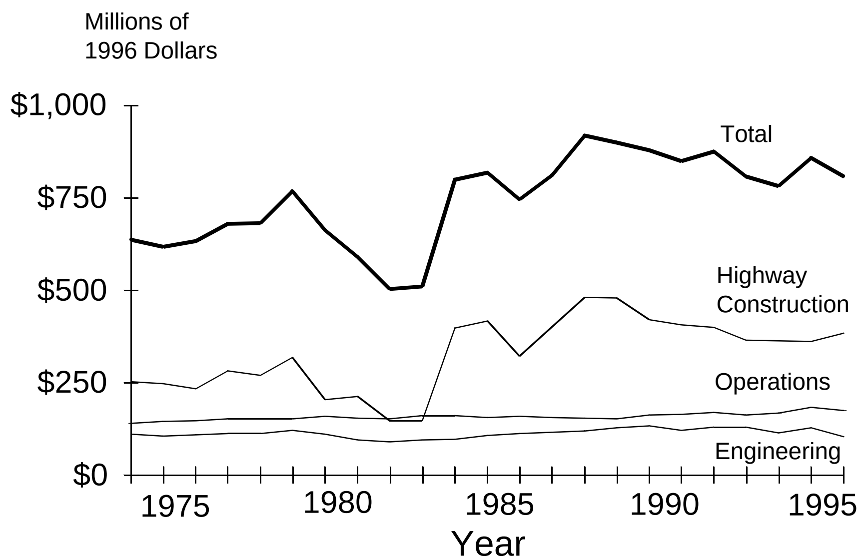
Combined with an average increase of 11 percent for other trunk highway expenditures, this substantial increase in construction spending resulted in an increase of 27 percent in overall trunk highway expenditures.

On balance, we think that this second method provides a better indication of trunk highway spending trends than the first method. It is more appropriate to apply the Minnesota Construction Cost Index to highway construction expenditures, since this cost index directly measures the changes in construction prices affecting Mn/DOT.[1]

Figure 2.2 shows the trends in Trunk Highway Fund expenditures based on the second method. As we saw earlier with revenue trends, expenditures have grown since 1974 but have fluctuated from year to year. Spending in 1996 is 27 percent greater than 1974 spending but about 12 percent below the spending peak reached in 1988. The principal source of revenue fluctuations was federal aid. Because federal aid is primarily used for highway construction, it makes sense that highway construction spending has also fluctuated over this time period.

Highway construction spending has fluctuated a lot due to changes in the level of federal aid.

Figure 2.2: Trunk Highway Fund Expenditures by Type, 1974-96



Source: Program Evaluation Division analysis of Mn/DOT data.

It is important to place the increase in trunk highway spending into perspective. The 27 percent increase in trunk highway spending exceeds the growth in the size of the trunk highway system. The number of centerline miles on the system has declined about 1 percent since 1974, while the number of lane miles has increased about 1 percent. The increase in spending is also greater than the 19 percent increase in Minnesota's population, but less than the increase in vehicle miles traveled in Minnesota, which exceeded 75 percent.

Staffing

Available data indicate that the number of staff in Mn/DOT declined significantly from 1970 until 1982. Staffing then rose until about 1990 and has declined

1 One potential drawback to the second method is that the Minnesota Construction Cost Index does not reflect changes in land prices. The highway construction category includes right-of-way purchases, as well as construction spending.

slightly since then. Due to data problems, it is not exactly clear how current staffing levels compare with levels prior to 1985. It appears, however, that the number of full-time equivalent employees has decreased since 1970.

The best available data are presented in Table 2.4. They show that the number of full-time employees in Mn/DOT increased about 16 percent between 1985 and 1990, but has declined 3 percent since then. The overall increase in full-time employees since 1985 was 12 percent. The number of part-time employees has declined during both of these periods and is down 70 percent since 1985. Although data on the number of full-time equivalent employees are not available, we can roughly estimate the number by assuming that part-time employees worked an average of 20 hours per week. Under that assumption, the number of full-time equivalent employees increased 9 percent between 1985 and 1990 but then decreased 3 percent by 1996. The overall increase in the estimated number of full-time equivalent employees between 1985 and 1996 was 6 percent.

Table 2.4: Number of Full-Time and Part-Time Employees of the Minnesota Department of Transportation, 1985-96

	June 1985	June 1990	June 1996	Percentage Change (1985-96)
FULL-TIME EMPLOYEES				
Districts and Metropolitan Division	3,245	3,765	3,563	10%
Other	1,219	1,402	1,428	17
Total	4,464	5,167	4,991	12%
PART-TIME EMPLOYEES				
Districts and Metropolitan Division	531	217	117	(78)%
Other	123	116	81	(34)
Total	654	333	198	(70)%

Source: Minnesota Department of Transportation.

The table also shows that the number of full-time employees in the field--namely, working for the outstate district offices or the Metropolitan Division--has increased slower than the number of central office employees. Also, the number of part-time employees in the field has declined more than the number of part-time staff assisting in central office functions. A rough estimate suggests that the number of full-time equivalent employees in the field increased 3 percent from 1985 to 1996, compared with a 15 percent increase for the central office.

This shift in staff resources has come during a period in which the field offices have been asked to take on greater responsibilities. Since about 1992, Mn/DOT has decentralized some of its decision-making and let the districts and the Metropolitan Division make more decisions on how to spend money allocated to them.

PAVEMENTS

In this section, we examine changes in the condition and age of Minnesota's trunk highways since 1985. We also consider whether Minnesota faces a backlog of rehabilitation work.

Background

The vast majority of Minnesota's trunk highways are in rural parts of Minnesota. As Table 2.5 shows, 87 percent of trunk highway miles are outside the 7-county Twin Cities metropolitan area, and 86 percent are in rural areas. Traffic, however, is more evenly distributed. Trunk highways in the Twin Cities metropolitan area carry about 48 percent of the traffic on the State Trunk Highway System. Urban areas throughout the state account for 49 percent of the traffic.

About 86 percent of the trunk highway mileage and half of the system's traffic are in rural areas of the state.

Table 2.5: Percentage of State Trunk Highway Miles and Traffic, 1995

	Share of Roadway Miles	Share of Vehicle Miles of Travel
Twin Cities Metro Area	13%	48%
Outstate	87	52
Urban Areas	14	49
Rural Areas	86	51
Interstate Highways	13	37
Principal Arterials	38	42
Minor Arterials	40	20
Collector and Local Highways	9	2

Source: Minnesota Department of Transportation.

Interstate highways account for a disproportionate share of the traffic. While 13 percent of the trunk highways are on the federal interstate system, Minnesota's interstate highways carry 37 percent of the trunk highway traffic. Principal arterials account for 38 percent of the miles and 42 percent of the traffic. Other highways represent nearly half of the trunk highway miles but only 22 percent of the traffic.[2]

Overall, Minnesota's trunk highways consist primarily of bituminous materials, but interstate highways are generally concrete. As Table 2.6 shows, about 62 percent of all trunk highways are bituminous, while 18 percent are concrete and 20 percent have a concrete base overlaid with bituminous. The choice between

2 In discussing pavements, we are using *roadway miles*, rather than *centerline miles* or *lane-miles*. The State Trunk Highway System currently has about 12,000 centerline miles, 14,200 roadway miles, and 28,800 lane-miles of highways. Each mile of highway is counted only once to measure centerline miles, while each lane is counted separately to obtain lane-miles. In measuring the number of roadway miles, each centerline mile is counted twice if the highway has four or more lanes for traffic.

Table 2.6: State Trunk Highway Miles by Type of Pavement and Surface, 1996

	Interstate	Non-Interstate	All Trunk Highways
Bituminous	15%	69%	62%
Concrete	66	11	18
Bituminous over Concrete	20	20	20
Total[a]	100%	100%	100%

Source: Minnesota Department of Transportation.

[a]Some totals do not sum due to rounding.

bituminous and concrete generally depends on traffic volumes and soil conditions. Concrete tends to last longer but costs more initially. Concrete is more likely to be used on roads with high traffic volumes. As a result, two-thirds of Minnesota's interstate highways are concrete, while only 15 percent are bituminous. Concrete highways are generally overlaid with bituminous when they get older and can no longer be effectively repaired with concrete materials. About 20 percent of the interstate highways and other trunk highways consist of a bituminous surface over a concrete pavement.

Condition

Mn/DOT uses the Pavement Quality Index (PQI) to measure the overall quality of trunk highway surfaces. The PQI is a composite measure of the present serviceability rating (PSR) and the surface rating (SR).[3] The PSR measures the rideability or smoothness of the pavement, while the SR measures the degree of pavement surface defects or distresses.

In theory, the PQI can range from zero to almost 4.5. The PSR can range between zero and 5.0, while the SR ranges from zero to 4.0. Higher numbers on any of these indices represent better pavement quality.

Pavement quality has increased slightly since the mid-1980s.

Trends

Figure 2.3 shows that:

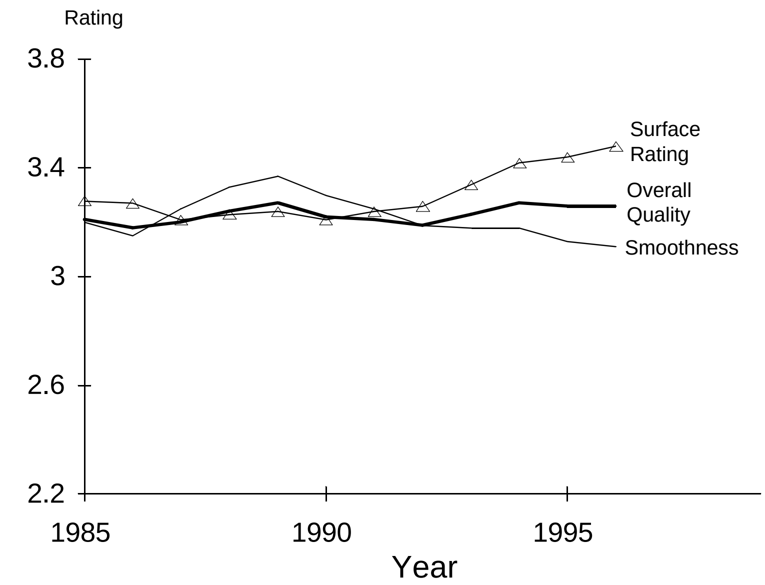
- **Overall pavement quality has increased slightly since 1985.**

Between 1985 and 1996, the PQI has varied within a narrow range from 3.18 to 3.27. The PQI increased less than 2 percent from 3.21 in 1985 to 3.26 in 1996. The figure also shows that:

- **Surface defect ratings have improved since 1985, while the smoothness of pavements has declined.**

3 Mathematically, the PQI is the square root of the product of the PSR and the SR.

Figure 2.3: Pavement Quality Ratings for State Trunk Highways, 1985-96



Source: Minnesota Department of Transportation.

The surface rating or SR has increased 6 percent from 3.28 in 1985 to 3.48 in 1996. The PSR increased from 3.20 in 1985 to 3.37 in 1989 but has declined almost every year since then. The current PSR of 3.11 is about 3 percent lower than it was in 1985.

It is not entirely clear why the rideability or smoothness of pavements has declined since 1989. In part, it may be related to the relatively small amount of grinding done on concrete pavements following a concrete pavement repair. The purpose of grinding is to improve the smoothness of the ride by leveling off the difference in height between adjacent concrete sections of the highway. This reduces the thumping noise heard by motorists and improves the ride. One of the biggest drops in the PSR rating is on concrete pavements on interstate highways.

Current Condition

Pavement quality is generally higher on more heavily traveled highways.

Table 2.7 indicates that:

- **The PQI is generally higher on interstate highways and principal arterials than on other trunk highways.**

Table 2.7 indicates that the average PQI in 1996 was 3.37 on interstate highways and 3.28 on principal arterials. Minor arterials had an average rating of 3.23, while collector and local highways had a rating of 3.15. There is also a smaller share of interstate highway miles with lower PQI ratings. Only 11 percent of interstate highway miles are rated at 2.8 or lower, while 20 percent or more of other types of trunk highways are similarly rated.

Table 2.7: Pavement Quality Index for State Trunk Highways by Type of Highway, 1996

	Average Pavement Quality Index	Percentage Rated at 2.8 or Lower
Interstate Highways	3.37	11%
Principal Arterials	3.28	20
Minor Arterials	3.23	22
Collector and Local Highways	3.15	26
All Trunk Highways	3.26	20%

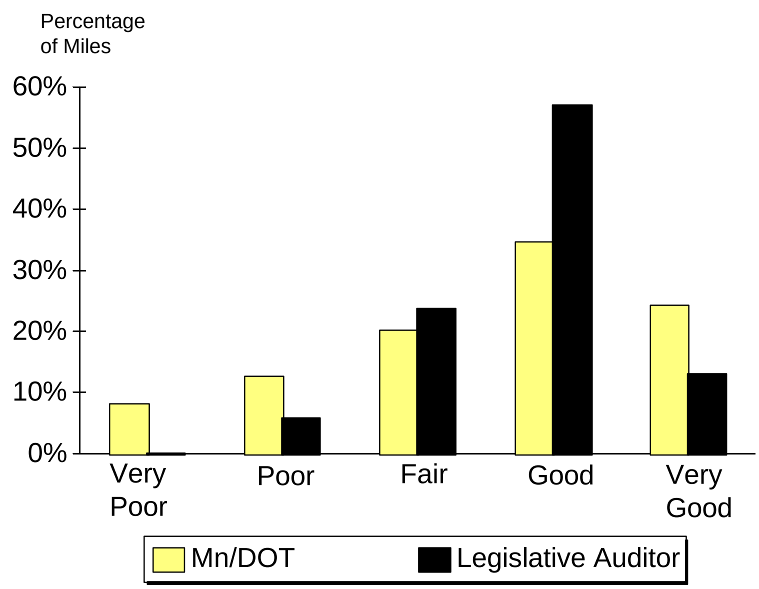
Source: Minnesota Department of Transportation.

Mn/DOT has assigned labels to the values of the PQI. Ratings of 3.7 or higher are considered to be ‘‘very good’’ or ‘‘excellent,’’ and ratings of 3.3 to 3.6 are considered to be ‘‘good.’’ A PQI of 2.9 to 3.2 is said to be ‘‘fair,’’ while a rating of 2.5 to 2.8 is considered ‘‘poor’’ pavement quality. Pavements with a PQI of 2.4 or less are said to be in ‘‘very poor’’ condition.

According to Mn/DOT’s rating system, the average trunk highway has an overall pavement quality rating between ‘‘fair’’ and ‘‘good.’’ Figure 2.4 indicates that, according to Mn/DOT, 24 percent of the trunk highways have a ‘‘very good’’ rating and 35 percent are rated ‘‘good.’’ About 20 percent are rated ‘‘fair,’’ while 12 percent are rated ‘‘poor’’ and 8 percent are considered to be in ‘‘very poor’’ condition.

About 70 percent of trunk highway pavements are in good or very good condition.

Figure 2.4: Distribution of Overall Pavement Quality for State Trunk Highways, 1996



Source: Program Evaluation Division analysis of Mn/DOT data.

Although we have no disagreement with Mn/DOT over how ratings are calculated, we do not believe that the labels Mn/DOT has assigned to PQI ratings are appropriate. In fact, the labels are inconsistent with how Mn/DOT has calibrated the PSR portion of the PQI. The Pavement Management Unit in Mn/DOT constructed the PSR so that roads with a PSR of 4.0 or more were considered to be in ‘‘very good’’ condition and roads with a PSR of 3.0 to 3.9 were in ‘‘good’’ condition. Similarly, roads in ‘‘fair’’ condition from a smoothness standpoint were given a PSR of 2.0 to 2.9, while roads in ‘‘poor’’ condition were assigned PSR values between 1.0 and 1.9. Only roads with a PSR between 0.0 and 0.9 were considered to be in ‘‘very poor’’ condition.

An example illustrates how Mn/DOT’s PQI labels are inconsistent with how the PSR was constructed. A road with a PSR of 2.0 and an SR of 4.0 would have a PQI of 2.8 and thus, according to Mn/DOT, would be in ‘‘poor’’ condition. However, a road with a PSR of 2.0 is considered to be ‘‘fair’’ from a smoothness perspective, and a road with an SR of 4.0 is in ‘‘excellent’’ shape, since 4.0 is the maximum surface rating. It is unclear why a road with an excellent surface rating and a fair rideability or smoothness rating should be categorized as being in poor condition.

Working with Mn/DOT’s Pavement Management Unit, we derived more reasonable labels to apply to PQI ratings.[4] We think that Mn/DOT’s labels underidentify the number of miles of ‘‘good’’ pavements while overidentifying the number of miles of ‘‘poor’’ and ‘‘very poor’’ pavements. Mn/DOT’s labels also may overidentify the number of miles of ‘‘very good’’ pavements, although they underidentify the combined number of miles which are either in ‘‘good’’ or ‘‘very good’’ condition. Figure 2.4 shows that, in our view:

Only 6 percent of trunk highway pavements are in poor or very poor condition.

- **The typical trunk highway was in ‘‘good’’ condition, and only 6 percent of all pavements were in ‘‘poor’’ or ‘‘very poor’’ condition in 1996.**

We think that 13 percent of trunk highway miles were in ‘‘very good’’ condition in 1996, and 57 percent were in ‘‘good’’ condition. About 24 percent were in ‘‘fair’’ condition, while slightly fewer than 6 percent were in ‘‘poor’’ condition. Only 13 miles of the trunk highway system, or about 0.1 percent, were in ‘‘very poor’’ condition.[5]

As a result, we think that:

4 To get more accurate PQI labels, we had to make assumptions about how to label various surface ratings. For the purposes of this report, we called surface ratings of 3.6 to 4.0 very good, 3.2 to 3.5 good, 2.8 to 3.1 fair, 2.4 to 2.7 poor, and 2.3 or less very poor. Although different cutoffs could be used, they would probably not change the basic conclusion that Mn/DOT’s current PQI labels overidentify the number of miles in poor or very poor condition and understate the combined number in good or very good condition.

5 Based on Mn/DOT’s calibration of the PSR and the assumptions we used for the SR, we assigned the following labels to PQI ratings: 3.8 to 4.5 (very good), 3.1 to 3.7 (good), 2.4 to 3.0 (fair), 1.5 to 2.3 (poor), and 0.0 to 1.4 (very poor).

- **Mn/DOT does not have a backlog of pavements in "poor" condition but would have a backlog if it reduced the average amount of surface rehabilitation work done each year.**

Mn/DOT does not have a backlog of pavements in poor condition.

From 1986 to 1995, Mn/DOT did about 938 miles of resurfacing, concrete pavement repair, and reconstruction work annually. This annual amount of work represented about 6.7 percent of the roadway miles on the trunk highway system during this 10-year period. Based on information from Mn/DOT engineers, we estimate that the average expected life of surfaces on trunk highways has been about 15 years.[6] On average, Mn/DOT would have to resurface about 6.7 percent of its highways annually in order to maintain a constant average surface age and probably a constant PQI. Over the last 10 years, Mn/DOT has been able to maintain that pace of activity. In fact, the PQI has increased slightly and, as we will see, the average surface age has declined a bit. However, if Mn/DOT was unable to maintain this amount of activity, we would expect to see a decline in PQI and an increase in average surface age. While Mn/DOT has very few roads in poor condition now, the number of roads in poor condition would grow and a backlog of needed work would develop if Mn/DOT did not continue to rehabilitate at least an average of about 6.7 percent of the roads annually.

In Chapters 3 and 4, we will see that the above conclusion may need to be modified in two ways. First, we think that the amount of rehabilitation work done annually may need to be increased over time in order for Mn/DOT to maintain a constant PQI. This is due to increasing traffic loads and the declining percentage of trunk highways which consist only of their original surfaces. Second, we think that, if Mn/DOT did more preventive maintenance, it might reduce the number of miles of resurfacing work needed over the long run. Mn/DOT, however, finds it difficult to spend more on preventive maintenance because each spring it has plenty of roads which need resurfacing, and Mn/DOT does not want to develop a backlog of roads in poor condition.

Comments

By assigning more appropriate labels to the PQI, we have been able to more fairly assess the current condition of pavements on the trunk highway system. However, we have not been able to address certain issues due to a lack of adequate data.

First, it is not possible at this time to compare the condition of Minnesota's trunk highway pavements with other states. Although the Federal Highway Administration (FHWA) publishes state-by-state comparisons of pavement roughness, these comparisons are not valid. States use different equipment to measure pavement roughness. Without proper calibration of equipment, valid comparisons cannot be made. The existing FHWA data should not be used to draw any conclusions about the relative condition of Minnesota's highways.

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6 This figure is the average expected time between surface rehabilitations. Underlying pavements are expected to last considerably longer. The systemwide average of 15 years is based on an average of 15 years for bituminous surfaces, 17.5 years for concrete surfaces, and 12 years for bituminous surfaces over concrete pavements. In Chapter 3, we discuss why the average expected surface life of trunk highways may decrease in the future.

Second, the PQI does not measure the adequacy of the underlying pavement relative to the traffic and loads it carries. The PQI measures smoothness and surface defects but does not directly indicate a pavement's structural adequacy. A pavement can have a shorter life if the loads it carries exceed its design capacity or are too high during the crucial thawing period in spring. Mn/DOT does not have a statewide system of collecting data on the structural condition of all trunk highways. Some districts, however, collect these data on all or a portion of their highways. District 2 in Bemidji reported to us that the number of miles at risk due to loads has increased from 218 miles in 1989 to 362 miles in 1995. This increase is due in part to increasing truck traffic. In addition, Minnesota increased the general weight limit on trunk highways in 1986 and reduced the load restrictions on principal arterials and key market routes during spring. The lessening of load restrictions may have placed more roads at risk of premature failure.

Finally, the pavement quality trends we examined do not include any possible worsening of pavement conditions during recent winter months. PQI data reflect conditions during 1996 prior to the winter of 1996-97.[7] According to some accounts, this winter has taken an unusually harsh toll on Minnesota's roads, including its trunk highways. Not only have state and local governments incurred larger than average snow removal costs, but roads have also experienced more potholes than usual. Any effect of the 1996-97 winter on the pavement quality of Minnesota's trunk highways will not begin to show up in PQI measurements until data are collected later this year. In addition, the magnitude of the effect is unclear at this point because Mn/DOT will probably repair most of the potholes before PQI measurements are taken.

Age

The average age of trunk highway surfaces has declined, although pavement age has continued to increase.

An examination of pavement and surface ages provides both encouraging and discouraging signs for Minnesota's trunk highways. On the one hand, as Table 2.8 indicates:

- **The average age of the surfaces on Minnesota's trunk highways declined from 11.5 years in 1985 to 10.9 years in 1995.**

Table 2.8: Average Surface and Pavement Ages, 1985 and 1995

	Average Age in Years	
	Surface	Pavement
1985	11.5	32.5
1995	10.9	39.8

Source: Minnesota Department of Transportation.

7 More precisely, the 1996 PQI data reflect conditions in both 1995 and 1996. Data needed to calculate the PQI are collected on about half of the trunk highways each year. As a result, the 1996 PQI data consist of 1996 measurements for half of the trunk highways and 1995 measurements for the other half.

This is encouraging news, because it indicates that construction and rehabilitation work on the State Trunk Highway System have been sufficient over the last decade to reduce the average age of the surfaces on trunk highways. A highway is considered to have a new surface if it has just been constructed, reconstructed, resurfaced, or had a concrete pavement repair.[8]

On the other hand, the average pavement age on trunk highways has increased steadily from 32.5 years in 1985 to 39.8 years in 1995. Pavement age indicates the age of the underlying pavement, which may have been resurfaced one or more times since the road was initially built. Although this is not a favorable trend, the significance of this trend is unclear. It is not known how long pavements can last if properly maintained. One point of view suggests that pavements may last indefinitely as long as they are properly maintained and are resurfaced before they deteriorate too much. Another point of view suggests that, while pavements may be able to have indefinite lives, each successive overlay or new surface applied to a pavement may last a shorter time than the previous surface.

One way of illustrating the aging of Minnesota's trunk highway pavements is provided by Table 2.9. Between 1985 and 1995, the share of trunk highway miles which have their original bituminous surface has declined from 14 percent to 8 percent. In contrast, the share which have been resurfaced at least once has increased from 47 percent to 53 percent of all trunk highway miles. Also, the share of concrete pavements declined from 24 percent to 19 percent, while the share of bituminous-over-concrete pavements increased accordingly. Based only on the changes in the shares of concrete and bituminous-over-concrete pavements, we estimate that the average expected life of trunk highway surfaces may have

Fewer trunk highways have their original surface.

Table 2.9: Change in Pavement and Surface Composition of State Trunk Highways, 1985-95

	1985	1995
Original Bituminous	14%	8%
Bituminous over Bituminous	47	53
Concrete	24	19
Bituminous over Concrete	15	19
Total[a]	100%	100%

Source: Minnesota Department of Transportation.

[a]Some totals do not sum due to rounding.

8 The average surface age of 10.9 years is high relative to an average expected life of 15 years and might indicate that Mn/DOT has a backlog of old pavements needing work. One would generally expect the average age to be about 8 years, given a 15-year life. However, we do not think that average surface life indicates a backlog problem for two reasons. First, the median surface age is 9 years and might be closer to 8 years if Mn/DOT had more accurate data on the last time some roads were resurfaced. According to Mn/DOT's Pavement Management Unit, some roads may have been resurfaced but the resurfacing was not reported to the Unit. Second, some old trunk highways have performed well despite their age. Good original materials and low levels of truck traffic may explain why some roads still have a good PQI even though they have not been resurfaced in 20 or more years.

declined by as much as 0.25 years between 1985 and 1995. This estimate does not reflect any deterioration in the average expected surface life due to the shift from original bituminous to bituminous-over-bituminous highways.

BRIDGES

In this section, we review the condition and age of trunk highway bridges. Trend data are available for at least the last 8 years and, in some cases, for the last 10 years. We also consider whether Mn/DOT has a backlog of bridges needing work.

Background

In 1995, there were 2,911 bridges and 1,703 culverts on Minnesota's trunk highway system.[9] The total number of trunk highway structures has increased 2 percent from 4,530 in 1988 to 4,614 in 1995. The total area of these structures, as measured by the sum of the total deck area of bridges and the roadway area of culverts, is perhaps a better indicator of the size of the system and its funding needs over the long run. The total area of trunk highway structures has increased 9 percent since 1988, growing from 40.5 million square feet to 44.1 million square feet. In 1995, bridges accounted for 92 percent of the total area. Culverts accounted for only 8 percent of the area, while accounting for 37 percent of the total number of trunk highway structures.

About 60 percent of the deck area on Minnesota's bridges is on the trunk highway system.

The State Trunk Highway System has a majority of the structure area in the state, although it only has about one-fourth of the bridges and culverts in the state. In 1995, the trunk highway system accounted for 23 percent of Minnesota's bridges and culverts and 60 percent of the total structure area. Most of the long bridges in the state are on the trunk highway system.

Condition

There are several indicators which can be used to assess the current condition of trunk highway bridges and culverts and track changes in condition over time. Below, we examine sufficiency ratings, condition ratings, and various measures of the extent of bridge deficiencies.

Sufficiency Ratings

Sufficiency ratings are used for federal funding purposes and are calculated using a complicated formula. In general, the sufficiency rating considers three factors: structural adequacy and safety, serviceability and functional obsolescence, and

9 A culvert is a drainage opening beneath an embankment.

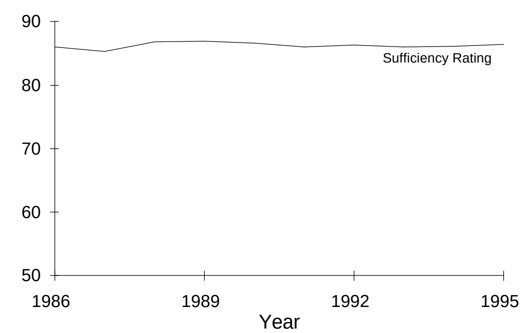
essentiality for public use.[10] These three factors account for 55 percent, 30 percent, and 15 percent respectively of the sufficiency rating. The maximum sufficiency rating is 100. A sufficiency rating less than 80 is used by the federal government to indicate that a bridge qualifies for rehabilitation funding. A sufficiency rating less than 50 qualifies a bridge for replacement funding.

Figure 2.5 shows that:

- **The average sufficiency rating on trunk highway bridges has been relatively constant between 1986 and 1995.**

During this period, the average rating has varied within a narrow range from 85.3 to 86.9. Between 1986 and 1995, the average rating has increased less than 1 percent.

Figure 2.5: Average Sufficiency Rating for Trunk Highway Bridges, 1986-95



Source: Minnesota Department of Transportation.

Condition Ratings

The typical trunk highway bridge is in good to fair condition.

Condition ratings focus exclusively on the structural adequacy of bridges. Unlike sufficiency ratings, condition ratings do not consider the serviceability of bridges and whether they meet various width and other geometric criteria. Condition ratings also do not explicitly measure the relative importance of bridges like sufficiency ratings do, but condition ratings can be compared for bridges on different types of trunk highways.

A condition rating can range from zero to 9, with a 9 indicating a new bridge and a zero indicating a bridge that is unusable. Generally, bridges with ratings of 7 to 9 are considered to be in good to excellent condition. Ratings of 5 or 6 indicate that a bridge has some deficiencies but is in fair or satisfactory condition. Ratings of 4 or less indicate that a bridge is in poor to critical condition.[11]

Table 2.10 shows that:

- **The typical trunk highway bridge is in good to fair condition.**

10 Serviceability primarily measures the extent to which a bridge meets various geometric criteria including such factors as the bridge's roadway width and alignment, vertical and horizontal clearances, and underclearances. Essentiality for public use refers to the importance of the bridge in terms of the type of highway it serves, the traffic it carries, and the length of the detour which would be necessary if the bridge could not be used.

11 United States Department of Transportation, *The Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* (Washington, D.C., 1993), 123.

Table 2.10: Average Condition Ratings for Trunk Highway Bridges and Culverts, 1995

	Superstructure	Deck	Substructure	Culverts
Interstate Highways	7.25	6.99	7.05	6.87
Other Federal Aid Highways	7.11	6.93	7.01	6.75
Other Trunk Highways	6.89	6.64	6.74	6.59
All Trunk Highways	7.09	6.84	6.92	6.64

Source: Minnesota Department of Transportation.

Bridge sufficiency ratings have increased slightly since the mid-1980s, while condition ratings have declined a bit.

The table provides average condition ratings for bridge superstructures, decks, and substructures, as well as for culverts.[12] In 1995, the typical bridge had ratings in the low 7s or high 6s, indicating that the average bridge was in good to fair condition. Culverts had a slightly lower rating but still a satisfactory one.

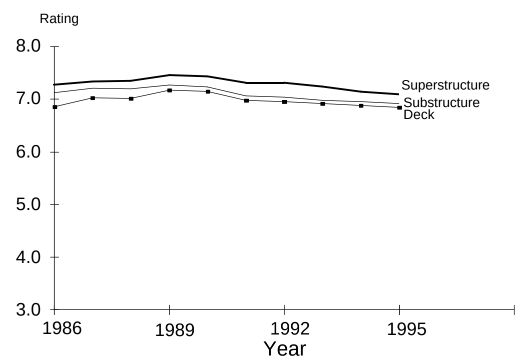
Condition ratings are generally somewhat higher for bridges on interstate and other federal aid highways than for bridges on other trunk highways. For example, the average condition rating for superstructures was 7.25 on interstate highway bridges in 1995 and 7.11 on other federal aid highway bridges. In contrast, bridge superstructures on other trunk highways had an average rating of 6.89.

Figure 2.6 displays the trends in condition ratings from 1986 to 1995. Condition ratings of all components increased between 1986 and 1989 and have declined since 1989. In general:

- **Bridge and culvert condition ratings in 1995 were slightly lower than ratings in 1986.**

The average superstructure rating decreased 2 percent, while the average substructure rating decreased 3 percent and the average culvert rating declined 6 percent. The average deck condition rating decreased less than 1 percent.

Figure 2.6: Average Condition Ratings for Trunk Highway Bridges, 1986-95



Source: Minnesota Department of Transportation.

12 The superstructure of a bridge includes the entire portion of a bridge structure which receives and supports traffic loads and in turn transfers the resulting reactions to the bridge substructure. The superstructure includes the deck, which comes in direct contact with vehicle loads, as well as the floor system, supporting members, and bracing. The substructure includes the abutments, piers, grillage, or other construction built to support the superstructure and transfer loads from the superstructure to the ground. Culverts do not have a definite distinction between superstructure and substructure and have no deck.

Slight declines in condition ratings were generally experienced on each of the three types of trunk highways we discussed above. For example, average superstructure condition ratings declined from 7.44 to 7.25 on interstate bridges from 1986 to 1995. On other federal aid highways, the average bridge superstructure rating decreased from 7.26 to 7.11. Bridges on other trunk highways experienced a decrease from 7.13 to 6.89.

Deficient Structures

Mn/DOT routinely tracks the number of structures that are deficient. There are two types of deficient bridges and culverts--structurally deficient and functionally obsolete. A structurally deficient bridge or culvert generally has one or more of its major components in poor structural condition. A functionally obsolete bridge does not meet the criteria established for width, clearance, roadway alignment, or load carrying capacity.[13] Any structure classified as structurally deficient is excluded from the functionally obsolete category so that it is not double counted.

There are three different categories that Mn/DOT uses to track deficient bridges. One category includes only those deficient bridges which have a sufficiency rating below 50. These bridges are eligible for federal replacement or rehabilitation funding. A second category includes deficient bridges with a sufficiency rating below 80. Bridges with sufficiency ratings between 50 and 80 are eligible for federal rehabilitation funding. The third category includes all deficient bridges including those with sufficiency ratings of 80 or more.

Data on deficient bridges are presented in Table 2.11. The extent of the deficiencies can be measured in three ways: 1) the number and percentage of bridges which are deficient, 2) the deck area on deficient bridges and the percentage of all deck area which is on deficient bridges, and 3) the estimated cost to eliminate bridge deficiencies through replacement or remodeling.

Table 2.11: Deficient Trunk Highway Bridges, 1990 and 1995

	Year	Number of Deficient Bridges	Percentage of Bridges	Deck Area (in Millions of Square Feet)	Percentage of Area	Estimated Improvement Cost (in Millions)
Sufficiency Ratings Less than 50	1990	269	5.8%	2.01	4.8%	$285.1
	1995	234	5.1	1.65	3.7	184.7
Sufficiency Ratings Less than 80	1990	592	12.8	4.07	9.8	463.5
	1995	541	11.7	4.15	9.2	321.8
All Sufficiency Ratings	1990	699	15.1	4.91	11.8	529.8
	1995	626	13.6	5.32	11.8	386.3

Source: Minnesota Department of Transportation.

13 Technically speaking, a bridge or culvert is structurally deficient if it has a condition rating of 4 or less for deck condition, superstructure, substructure, or culverts, or an appraisal rating of 2 or less for structure evaluation or waterway adequacy. A structure is functionally obsolete if it has an appraisal rating of 3 or less for deck geometry, underclearance, or approach roadway, or an appraisal rating of 3 for structure evaluation or waterway adequacy.

The share of trunk highway bridges which are deficient depends on which sufficiency rating categories we examine. In 1995, about 5 percent of trunk highway bridges had sufficiency ratings below 50. These bridges represented less than 4 percent of the total area on trunk highway bridges and culverts. Mn/DOT estimates that it would take about $185 million to correct the deficiencies on these bridges.

The estimates of deficient bridges, areas, and improvement costs are greater if bridges with higher sufficiency ratings are included. For example, about 541 or 12 percent of trunk highway bridges and culverts had sufficiency ratings less than 80 in 1995. These bridges represented 9 percent of the total area and would cost an estimated $322 million to improve.

The trunk highway system has a backlog of structurally deficient bridges.

Table 2.12 shows that most of these 541 bridges had a deficiency related to their condition or structural adequacy.[14] Deficient bridge conditions accounted for 356 of these bridges, and it would require $195 million to correct the deficient conditions. Structural conditions are the only deficient factor for 240 bridges and would require an estimated $100 million in improvement projects. This latter figure is more than twice the average annual amount Mn/DOT spent on bridge replacement, preservation, and safety between 1991 and 1995.[15] These data suggest that:

- **There is a backlog of bridges which are structurally deficient and need to be improved or replaced.**

We are less convinced of the need to improve or replace those bridges which are labeled deficient only because of their failure to meet width, clearance, or other

Table 2.12: Type of Deficiency for Trunk Highway Bridges, 1995

	Number of Deficient Bridges[a]	Deck Area of Deficient Bridges (in Millions of Square Feet)	Estimated Improvement Cost (in Millions)
Condition Only	240	1.71	$100.2
Condition and Other Factors	116	0.87	95.3
Load But Not Condition	2	0.03	24.2
Other Factors	183	1.54	102.1
Total	541	4.15	$321.8

Source: Minnesota Department of Transportation.

[a]Based on sufficiency ratings less than 80.

14 Of the 541 bridges, Mn/DOT considers 333 to be structurally deficient. Another 147 bridges are considered to be functionally obsolete based on substandard width, clearance, or other geometric factors. The remaining 61 bridges are deficient railroad bridges over trunk highways.

15 In the 5-year period (1991-95), Mn/DOT spent an annual average of $45.8 million for bridge replacement, preservation, and safety work. Mn/DOT also spent an annual average of $16.9 million for expansion purposes--namely, new bridges which did not previously exist.

geometric criteria. The decision on whether to improve those bridges should be based primarily on an assessment of the benefits and costs. Widening or replacing a bridge may or may not make sense depending on the cost of the improvement and the extent to which the project is expected to reduce accidents and congestion.

It is somewhat difficult to interpret the long run trends in the number of deficient bridges and the estimated cost to improve them. On several occasions, the criteria used to determine whether a bridge is deficient have changed and caused more bridges to be labeled deficient. In particular, there were some major changes in 1988 and 1990 as new federal criteria were implemented. As a result, it is probably best to examine the trends which have occurred since the last significant change in 1990.[16]

Even the trends since 1990 are not easy to interpret. Some of the data in Table 2.11 show that Mn/DOT has been able to reduce the backlog of deficient bridges since 1990. The number of deficient bridges has declined 9 to 13 percent, depending on what sufficiency ratings are included. In addition, the estimated cost to improve bridges declined roughly 30 to 35 percent. However, while the deck surface area of deficient bridges declined 18 percent for deficient bridges with sufficiency ratings less than 50, it increased for the other categories. Mn/DOT also believes that its data may understate estimated improvement costs, particularly for bridge deck rehabilitations. This would affect 1995 more than 1990, since there is a higher percentage of deck rehabilitations in the 1995 data, and would suggest that estimated improvement costs for deficient bridges did not decline as much as shown in Table 2.11.

Mn/DOT has reduced the backlog of deficient bridges since 1990 but a significant backlog remains.

We estimate, however, that the cost of improving deficient bridges decreased between 1990 and 1995 even allowing for the potential understatement of deck rehabilitation costs.[17] As a result, we think that:

- **Spending over the 1990-95 period was sufficient to modestly reduce, but not eliminate, the magnitude of the deficient bridge backlog.**

Although Mn/DOT has a backlog of deficient bridges, other states may face bigger backlogs. Available data suggest that a substantially smaller percentage of Minnesota's bridges are deficient than the national average. Minnesota has a smaller percentage of structurally deficient bridges and a much lower percentage of functionally obsolete bridges than the national average.[18]

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16 Effective in 1990, states were required to apply a uniform set of federal criteria for determining whether a bridge's width was adequate. As a result, more bridges in Minnesota were identified as having deficient widths.

17 Even if the understatement of deck rehabilitation costs would have applied only to 1995 and to all deficient bridges, which it does not, it would not account for the entire decrease in estimated improvement costs between 1990 and 1995.

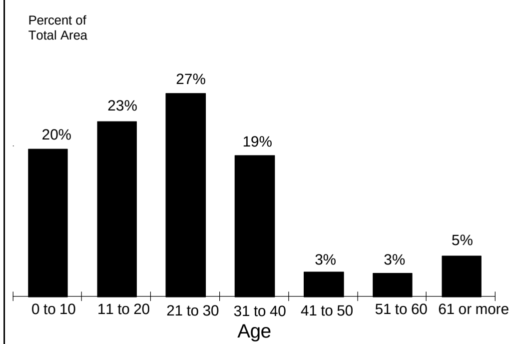
18 Minnesota has a smaller than average percentage of deficient bridges on both its state and local highway systems.

Age

Data presented in Table 2.13 and Figure 2.7 show that:

- **Trunk highway bridges are aging, but Minnesota will benefit from a favorable age distribution for the next 15 to 20 years.**

Figure 2.7: Age of Bridges and Culverts by Year Built, 1995



Source: Minnesota Department of Transportation.

While trunk highway bridges are aging, only a small share of them are nearing the end of their expected lives.

The average age of trunk highway bridges and culverts has increased modestly over the last 10 years. From 1986 to 1995, the average age of trunk highway structures increased from 31 to 34 years. In 1995, it had been about 28 years since the average structure had been either built or remodeled.

Table 2.13: Average Age of Trunk Highway Bridges

	Based on Year Built	Based on Year Last Remodeled
1986	31.3	NA
1988	NA	26.8
1995	34.2	28.4

NA = Not available.

Source: Minnesota Department of Transportation.

Despite the aging of trunk highway bridges and culverts, Minnesota is currently benefiting from the fact that most of its structures are relatively new and are not expected to need replacement for some time. Figure 2.7 shows that 70 percent of the structures were 30 years old or less in 1995 and almost 89 percent were 40 years old or less.[19]

Given an average expected life of 60 years, this age distribution suggests that Minnesota may benefit for the next 15 to 20 years by being able to replace a relatively small share of its bridges. However, starting in about the year 2015, Mn/DOT will likely face an increasing need to replace bridges.

19 The data in Figure 2.7 are based on the year that a structure was built. Based on year last remodeled, 83 percent of Minnesota's structures are 30 years old or less and 94 percent are 40 years old or less.

This expected trend is somewhat complicated by the recent discovery by Mn/DOT that some of its bridges may not last as long as previously expected. Mn/DOT has found problems with some of the steel bridges built between 1950 and 1980. Steel bridges that are subject to high volumes of heavy truck traffic are thought to have fatigue-prone steel elements and may need major rehabilitation or replacement earlier than would otherwise be expected. Mn/DOT has estimated that 87 bridges carry traffic loads which may put them at risk. The costs of repairing or replacing these bridges may be as high as $270 million, with about 85 percent of the estimated costs applying to bridges in the Twin Cities metropolitan area.

CONGESTION

The total amount of travel on Minnesota's streets and highways increased 76 percent between 1974 and 1994, including a 36 percent increase over the last 10 years. Travel on the State Trunk Highway System increased more, because most of the largest increases have occurred on interstate highways and principal arterials which are part of the system. For example, from 1985 to 1995, travel on trunk highways increased 46 percent. The largest increase was on urban interstate highways (87 percent) and rural interstate highways (62 percent). Travel also increased 55 percent on other urban principal arterials. Travel on collector and local highways on the system actually declined 24 percent.

Congestion has grown on Minnesota's highways.

This increase in travel has resulted in a significant increase in congestion on some interstate highways and principal arterials. One way to measure congestion is to compare the traffic volume on a highway to its capacity or peak service flow. In Table 2.14, we examine how the percentage of Minnesota highways which had significant congestion changed over a recent 10-year period. A highway is

Table 2.14: Percentage of Streets and Highways with Significant Congestion, 1984 and 1994

	Percentage of Miles with Volume-to-Service Flow Ratios Exceeding 0.95	
	1984	1994
URBAN		
Interstate	36.3%	45.5%
Other Freeways	13.3	39.4
Other Principal Arterials	19.1	18.4
Minor Arterials	13.6	8.4
Collectors	0.6	1.5
RURAL		
Interstate	0.0%	11.7%
Other Principal Arterials	0.6	2.9
Minor Arterials	0.7	0.9
Major Collectors	0.1	0.0

Source: Federal Highway Administration.

considered to be congested if its traffic volume exceeds 95 percent of its capacity. According to this definition:

- **The miles of congested highways in Minnesota increased from 449 miles in 1984 to 694 miles in 1994, with urban interstate highways and freeways being the most congested.**

Nearly 46 percent of urban interstate highways and 39 percent of other urban freeways were congested in 1994. In addition, 18 percent of other urban principal arterials and 12 percent of rural interstate highways experienced congestion.

Most, but not all, of the congestion is in the Twin Cities metropolitan area. In the last several years, Mn/DOT has addressed congestion in the metropolitan area by focusing on installing meters on freeway ramps, building some high-occupancy vehicle lanes, and permitting buses to use highway shoulders. Data from Mn/DOT indicate that the percentage of metropolitan area freeway miles which are congested has declined slightly in recent years. Mn/DOT, however, believes that the biggest gains from the ramp metering system have already been realized and that freeway congestion will probably grow in the future.[20]

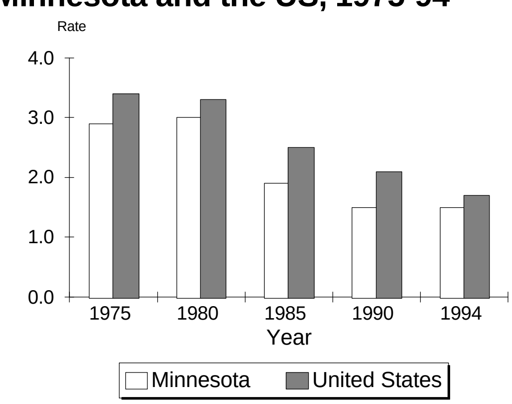
SAFETY

The fatality rate on all of Minnesota's roads has declined by nearly 50 percent since the mid-1970s. In 1994, there were 644 fatalities on Minnesota's roads, or 1.5 fatalities for each 100 million vehicle miles driven. This rate was significantly lower than the rate of 2.9 experienced in 1975, when there were 754 fatalities on Minnesota's roads.

Highway fatality rates have been declining in Minnesota and many other states.

As Figure 2.8 shows, much of the decrease came during the 1980s. In addition, the trend in Minnesota reflected the national trend. The fatality rate on roads throughout the nation also declined by about 50 percent between 1975 and 1994. The reasons for this trend are not entirely clear. The aging of the baby boom generation, greater seat belt usage, and more severe penalties for driving while intoxicated each may have played a role in reducing fatality rates.

Figure 2.8: Fatality Rate per 100 Million Vehicle Miles Traveled, Minnesota and the US, 1975-94



Source: National Highway Traffic Safety Administration.

20 Minnesota Department of Transportation, *Performance Report* (St. Paul, 1996), 88-90.

Minnesota's fatality rate per 100 million vehicle miles of travel has generally been below the national average. In 1994, Minnesota's rate was about 14 percent lower than the national rate. In addition, data from the Federal Highway Administration suggest the injury rate in Minnesota is also lower than the national average. While Minnesota's road standards may play a role in our lower fatality and injury rates, it is unclear how significant road standards are in reducing fatality and accident rates. It is possible that the driving habits of Minnesotans relative to drivers elsewhere may explain a significant portion of the difference in rates.[21]

Minnesota's trunk highways are generally safer than other roads in the state. Trunk highways carry about 60 percent of the state's traffic but account for a lower share of the state's crashes. In 1995, 47 percent of the fatalities and 40 percent of the injuries on Minnesota's roads occurred on trunk highways. In addition, 40 percent of the property damage crashes were on trunk highways.

SUMMARY

Funding for the State Trunk Highway System is higher today than it was during the mid-1970s. However, funding has declined from the peaks reached during the mid- to late 1980s. The decline is mostly due to lower levels of federal aid. State funding has also declined since the late 1980s, when the state gasoline tax was last increased and vehicle excise taxes were last transferred to the Trunk Highway Fund.

Stable construction prices have helped maintain the purchasing power of the Trunk Highway Fund.

The purchasing power of the Trunk Highway Fund has been helped, however, by stable construction prices. Prices for highway construction in Minnesota have increased significantly less than the general rate of inflation. As a result, overall spending from the Trunk Highway Fund in 1996 was only 12 percent below the peak reached in 1988.

There is a backlog of trunk highway bridges needing repairs or replacement, although some modest improvement appears to have been made in recent years in reducing the backlog. There does not appear to be a similar backlog for trunk highway pavements, although Mn/DOT would develop a backlog if it reduced the amount of pavement rehabilitation work done each year.

Trunk highway pavement and bridge conditions have been relatively unchanged over the last decade. Pavement conditions have improved slightly, while bridge conditions have declined slightly. Both pavements and bridges on the State Trunk Highway System are aging. However, Mn/DOT has been able to keep pavements in good condition by resurfacing them. Over the last decade, the average age of the surfaces covering trunk highway pavements has declined modestly. Based on age alone, a relatively small percentage of the bridges may need replacement over the next 15 years. About 89 percent of bridges and culverts are 40 years old or less, and they are generally expected to last 60 years. Problems with steel fatigue

21 Minnesota also has a lower fatality rate on interstate highways, where differences in road standards are less likely to be a factor.

on certain bridges subject to high volumes of heavy truck traffic may require the replacement of some bridges earlier than would otherwise be expected.

Congestion has been growing on trunk highways over the last several decades. Mn/DOT has been able to constrain the growth in congestion somewhat through the installation of freeway ramps and other projects. However, future growth in congestion is expected.