I-35W Bridge Collapse: Travel Impacts and Adjustment Strategies

Nebiyou Tilahun* David Levinson †

Abstract

On August 1^{st}, 2007, the I-35W bridge crossing the Mississippi river collapsed. In addition to the human tragedy that it caused, the bridge failure also impacted how people moved. The bridge on average carried 140,000 vehicles daily and the failure required a significant amount of traffic find new routes to reach their destinations. In its aftermath travelers had to adjust their trips, requiring them to possibly adopt changes in route, mode, departure time, or foregoing some trips. Those who had to adapt were not just the ones that previously used the bridge. With the I-35 traffic using alternate routes, those who saw or anticipated higher traffic on their regular routes also found it necessary to make adjustments. In this study we ask a sample of people that were recruited for another study if their travels had been impacted by the failure of the bridge, how they coped, and what impacts it had on their other activities.

Introduction

On August 1^{st}, 2007, the I-35W bridge crossing the Mississippi river collapsed. In addition to the human tragedy that it caused, the bridge failure also impacted how people moved. The bridge on average carried 140,000 vehicles daily and the failure required a significant amount of traffic find new routes to reach their destinations. In its aftermath travelers had to adjust their trips, requiring them to possibly adopt changes in route, mode, departure time, or foregoing some trips. Those who had to adapt were not just the ones that previously used the bridge. With the I-35 traffic using alternate routes, those who saw or anticipated higher traffic on their regular routes also found it necessary to make adjustments.

Travelers can respond in different ways to the effects of the disruption. Changing their route, changing their destination, adjusting departure time, changing their schedule, not making the trip are some of the ways in which they can cope. The trip purpose can influence which of these strategies are adopted. For instance, in the short run, a change of destination is not likely to be adopted for a work trip, whereas a change in route, adjusting departure time and/or changing schedule are very likely outcomes. On the other hand, shopping trips are likely to change their destination when travel to the previous destination takes longer than other available alternatives as a result of the disruption. Similar outcomes are likely when the trip involves social meetings as long as the other party is also mobile.

*University of Minnesota, Department of Civil Engineering, tila0006@umn.edu

†RP Braun-CTS Chair of Transportation Engineering; Director of Network, Economics, and Urban Systems Research Group; University of Minnesota, Department of Civil Engineering, 500 Pillsbury Drive SE, Minneapolis, MN 55455 USA, dlevinson@umn.edu http://nexus.umn.edu

The response is also likely to depend on the type of disruption that the network faces. In the past studies have looked at how different network disruptions that arise from earthquake damages [1, 3, 6, 7, 4] , planned reconstruction [5, 2] or special events have impacted travellers. Responses to network disruption that arise from an isolated bridge collapse are very likely to be different from one that arises out of a natural disaster such as an earth quake. Damages from earthquakes do not singularly impact a single link or the road network alone. Often activity locations are also affected. Traveler responses are thus going to be different from a singular bridge failure where almost all activity locations, and other routes to previous destinations are still functioning. A Bridge closure due to planned maintenance may have the same long term outcome as a bridge collapse. But in the short run, due to the pre-planning that takes place in developing alternate traffic routes, and in informing the public, the outcomes are likely to be much different.

The traveller response can also be affected by the supply side changes that are instituted. After the collapse of the I-35 bridge MnDOT responded by expanding Interstate 94 and converting Highway 280 into a limited access facility to cope with the additional traffic.

While differences in the type of disruption and supply improvements can lead to different responses, similarities are also bound to arise from the needs of people. In general, lower travel time, convenience, and flexibility of alternatives are bound to constrain the choices. Responses observed in the study of Giuliano and Golob [3] in the aftermath of the Northridge Earthquake suggest that once alternate routes were open, most people opted to stay loyal to their cars despite the decreased capacity on the alternative routes. In part this was because the Bus alternative had to use the same alternative routes for the most part, and did not offer many advantages. The impact of the 14 month closure of Center Street Bridge for reconstruction in Calgary [5] also shows small decline in vehicle trips, auto-users sticking to their mode, and a limited increase transit use. On the other hand, the study by Tsuchida and Wilshusen [7] shows evidence that the conversion of Route 17 to a Carpool facility after the Loma Prieta earthquake had led many people to adopt ride sharing, and a significant proportion of the adopters to continue to carpool even after the route was opened to general traffic. Other studies summarized in [3] suggest an increase in rail and ferry use followed by sharp decline after service has been reinstated.

In this paper we report on how some Twin Cities residents adjusted their travels after the I-35 bridge collapse. The sample is taken in eight Zip code areas located in the City of Minneapolis and adjoining suburbs. While the home locations of many of the respondents are not in the immediate vicinity of the failure, some worked in the Bridge's vicinity. We ask the participants if their travels had been impacted by the failure of the bridge, how they coped and what impacts the collapse had on their travels and other activities.

Data

The data for this survey came from the first phase of a two phase survey administered in the twin cities area. The survey was internet based. Recruitment was done through the mail to a set of eight Zip codes in the Twin Cities area. Postcards were sent to a pool of 5000 individuals. Reminder post cards were sent a week after initial mail was sent out. In the first phase of the survey 192 cards were returned due to wrong mailing address. All in all 269 respondents responded, of which

54 dropped out before completing the questionnaire. In this study we use the 215 respondents that completed the survey.

Demographic information on the respondents is given in table 1. The sample has significantly more women than men. It also has more respondents with education levels at the Bachelor's degree level or higher (71.6%) and household incomes lower than $30,000 (4.65%). The latter two are perhaps a result of the web based nature of the survey.

Table 1: Description of the respondents

Description	Categories	Percentages (N=215)
Sex	Male	40.9%
	Female	59.1%
age	18-34	45.1%
	35-49	34.4%
	50 and over	20.5%
Household income	Less than $50,000	25.6%
	$50,000-$99,999	50.2%
	$100,000 and over	20.5%
	Not reported	3.7%
Household Size	One	28.4%
	Two	36.3%
	Three or more	34.9%
	Not reported	0.5%
Usual mode	Car	74.0%
	Other	23.7%
	Not reported	2.3%
Home distance to 35W	0-4 Km (0-2.49 mi)	3.3%
	4-8 Km (2.49-4.97 mi)	39.5%
	8-16 Km (4.97-9.94 mi)	30.7%
	16 Km (9.94 mi) and over	24.7%
	Home location unknown	1.9%
Work distance to 35W bridge	0-4 Km (0-2.49 mi)	19.5%
	4-8 Km (2.49-4.97 mi)	10.7%
	8-16 Km (4.97-9.94 mi)	19.1%
	16 Km (9.94 mi) and over	33.0%
	Work location unknown	17.7%

In the following sections, we will discuss how the respondents found out about the bridge failure, followed by in what ways the segment of respondents whose travels were impacted differed from those that were not impacted. We fit a logit model to investigate which location and demographic variables occur more frequently among the people that reported they were impacted. We will then look at how those impacted adjusted their travels in response to the network change.

Finding out about bridge collapse

The survey asked the respondents how they found out about the bridge collapse. Among those reporting that their travels were impacted by the bridge collapse, the primary source of information were friends and family, followed by the media. On the other hand, for those who reported their travels were not affected, the primary source of information was the media and internet.

The propagation of information through personal networks utilizing communication technologies was much faster than conventional means to get information to those likely to be impacted. Those that were at a higher risk of being affected were receiving information first from friends and family at a significantly higher rate than those likely not to be affected (Table 2).

Table 2: First heard about bridge collapse

Description	All respondents	Impacted respondents
Media (TV, Radio, Internet etc.)	54.4%	33.3%
Family and Friends	39.1%	58.3%
Other	5.6%	8.3%

Modeling travel impacts of bridge failure

Impacts of the bridge failure are likely to be felt the most by people in the in the immediate vicinity of the bridge the most. In addition, those individuals who do not reside in the vicinity but have destinations such as work and leisure/social activities in the area are also likely to have their travels impacted. In this section, we will look at the location and demographic characteristics of those individuals whose travels were impacted by the bridge collapse.

Among the 215 respondents in this survey, 60 (28%) responded "yes" when asked if their travels were affected by the I-35w bridge collapse. We hypothesize that, in addition to home and work location proximity to the bridge, the respondents' household structure, the presence of kids, and the number of contacts that people have in close proximity to their residence, would be important descriptors of the likelihood their travels would be impacted by the collapse.

The location of the respondents' home and work relative to the failed bridge is shown in figures 1 and 2. The figures show a higher frequency of reported travel impacts closer to the bridge relative to other locations.

We use a logit model to investigate which respondents were impacted by the bridge failure. The model uses the self reported impact as the response variable. This is predicted as a function of proximity to the bridge, demographic and other variables. Specifically we hypothesize:

$$log[p/(1-p)] = \beta_0 + \beta_1 * H_d + \beta_2 * W_d + \beta_3 * S + \beta_4 * M + \beta_5 * C + \beta_6 * Z + \beta_7 * CH$$

where

- p: The probability of a respondents travel being impacted by bridge failure
- H_d: Distance from respondents home to bridge

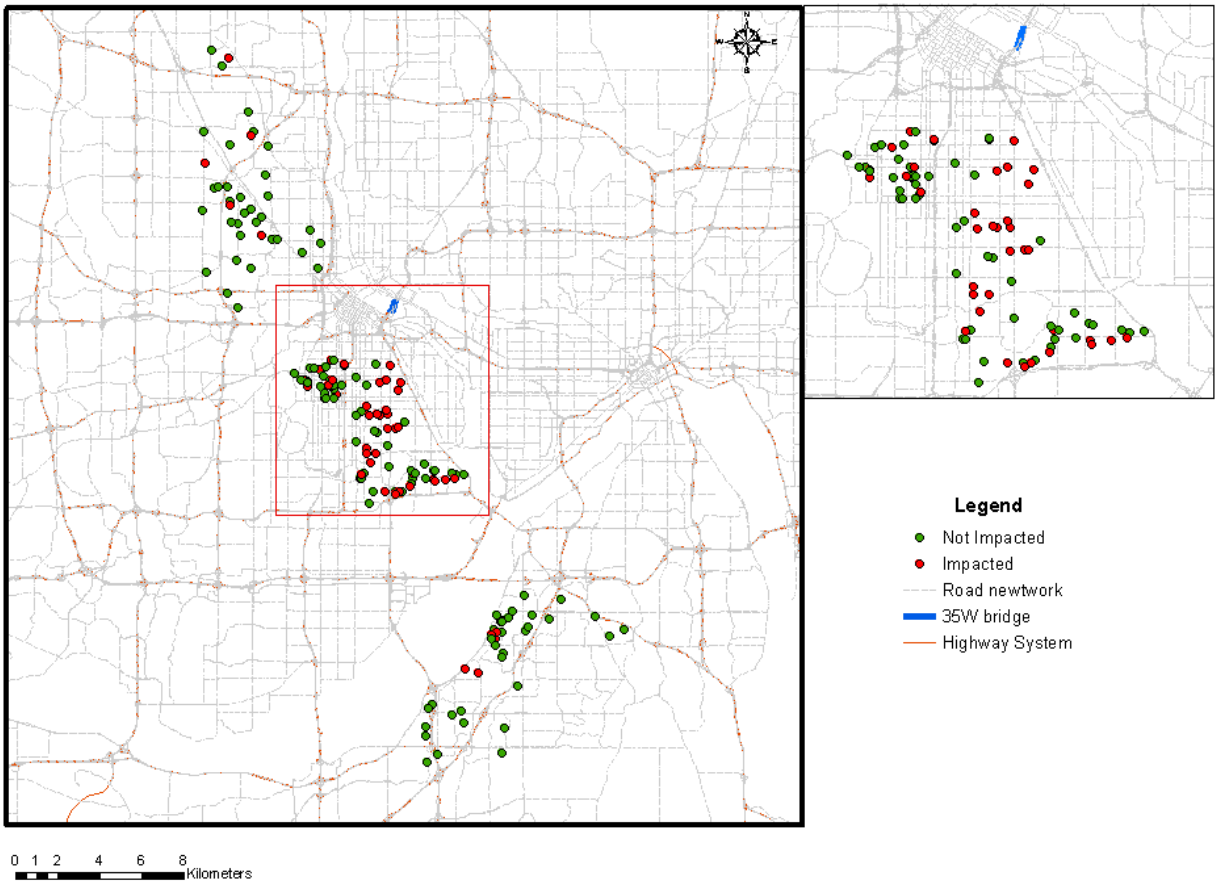

Figure 1: Respondent's home locations and reported travel impact

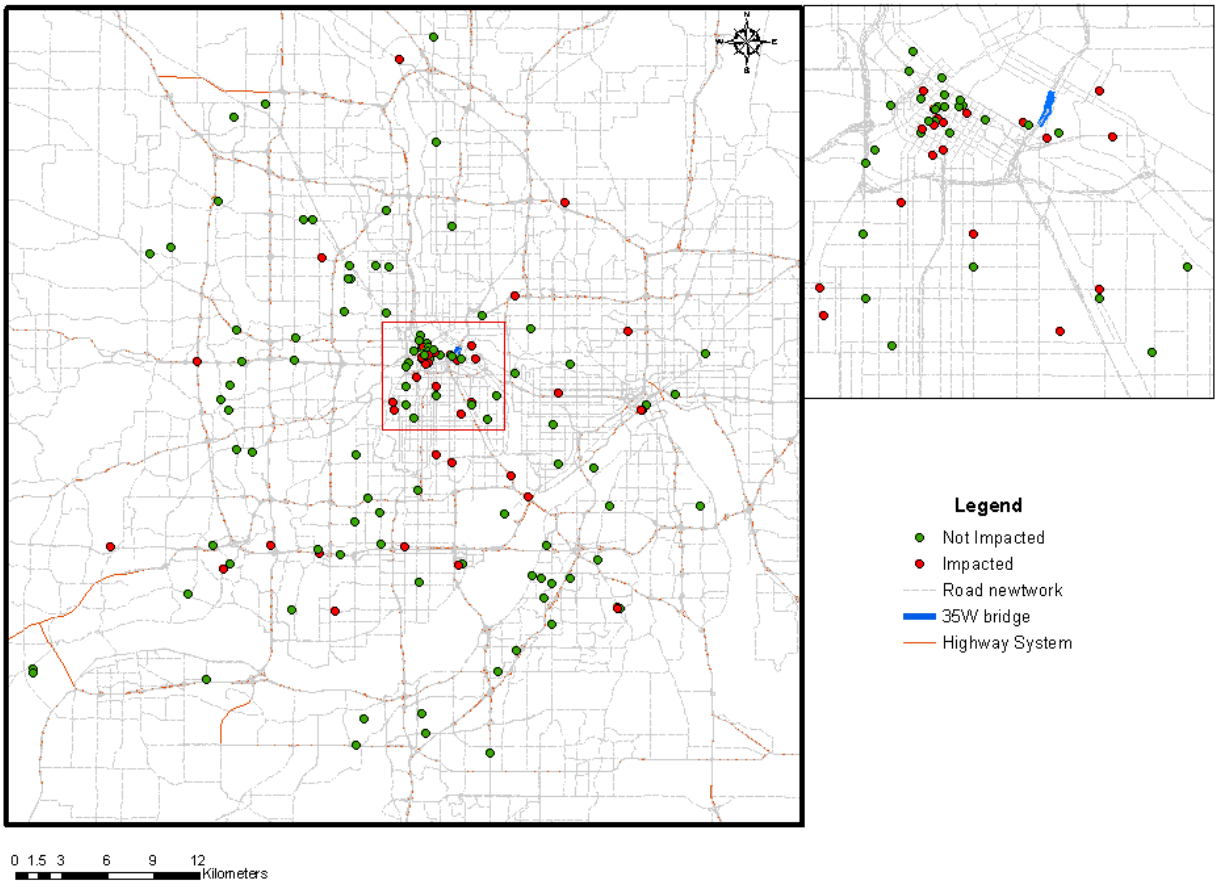

Figure 2: Respondent's work locations and reported travel impact

- W_d: Distance from respondents work to bridge
- S: Sex
- M: Usual mode to work
- C: Number of contacts with in 16 Km of home with whom the respondent communicates with at least twice a week
- Z: Household Size
- CH: Are there children 17 or under in the household?

Results of the model fitting are given in table 3. Respondents that lived within a 4 Km radius of the bridge were much more likely to have their travels impacted by the bridge failure rather than those outside. The estimated coefficients to the successive categories are positive and decreasing with 4-8 Km radius higher than that for 8-16 Km, which is higher than greater than 16 Km radius. The same is true of where people worked. Those within 0-4 Km of the bridge reported their travels were impacted, similarly those in the 4-8 Km radius were also impacted but to a lesser magnitude. While there wasn't a significantly different rate of impact among those in the 8-16 Km radius as compared to those over 16 Km out, the trend is still positive. In both work proximity and home proximity we find a decreasing impact as the home and work locations go farther out from the center.

Table 3: Modeling bridge failure impacts, location and demography

		Estimate	Std. Error	z value	Pr(>|z|)
	(Intercept)	−3.8440	0.9999	−3.84	0.0001 ***
Home to bridge distance	8-16 Km	0.4583	0.5792	0.79	0.4288
	4-8 Km	0.8870	0.5484	1.62	0.1058
	0-4 Km	3.3130	1.3347	2.48	0.0131 *
Work to bridge distance	8-16 Km	0.3467	0.5386	0.64	0.5198
	4-8 Km	1.0410	0.6025	1.73	0.0840 ·
	0-4 Km	1.2939	0.5889	2.20	0.0280 *
Sex	Male	−0.4756	0.4106	−1.16	0.2467
Mode	Car	0.9350	0.5535	1.69	0.0912 ·
Contacts in 16 Km	1-4	0.6287	0.6785	0.93	0.3541
of home (base=0)	5-9	0.0485	0.7584	0.06	0.9490
	10 or more	1.0209	0.6573	1.55	0.1204
Household	two	1.1423	0.5314	2.15	0.0316 *
size (base=1)	three	1.4209	0.6830	2.08	0.0375 *
Children in household	(Yes=1)	−1.1701	0.6505	−1.80	0.0721·
Null deviance:	201.69 on 168 degrees of freedom				
Residual deviance:	169.14 on 156 degrees of freedom				
psuedo-R^2	0.161				

Car users tend to identify them selves as impacted relative to other mode users. This may be because car users had the flexibility to choose their destinations including those destinations across the bridge at all times that they have their car with them. In contrast, those who take transit or

walk may have a limited set of destinations, as the set may be constrained by the availability of transit services, the time it takes, or by the distance of the destination from considering destinations that were connected by the bridge from where they lived or worked.

We anticipated that those with larger number of contacts within 16 Km of their homes could be impacted by the bridge collapse. The impacts would depend on those contacts are located and if access to those contacts (or where they were usually met) was reduced due to the bridge collapse. Hence the number of contacts serves as a proxy for the increased likelihood that contacts in the impact region were present. We categorized the number of self reported contacts for the respondents into four categories - those that had no close contacts in a 16 Km radius of their homes, those with 1-4, 5-9, or '10 or more' close contacts in 16 Km of their home, respectively. A "close contact" in this case is defined as those contacts that the respondent communicates with at least twice a month either face to face or through other communication technologies and don't reside in the same household as the respondent.

The trend from the model weakly suggests that those with 10 contacts or higher were more impacted as compared to those with less contacts ($p - value = 0.12$). However, none of the categories were statistically significantly different from those with no contacts in a 16 Km radius. This is likely due to the set of circumstances discussed in the previous paragraph that would be necessary for the travel impacts to be felt.

Households that had multiple members reported being impacted as compared to single households. The trend is increasing with household size. However, households with children were less impacted as compared to their counterparts. A possible reason for this outcome is that all adult households do not have child care constraints on their time-use, and as a result maybe more mobile than their counter parts.

Travel Impacts and Strategies

The survey asked those impacted to describe their frequency of use of the bridge, and how they have adjusted their travels after the collapse. In addition the entire sample was asked if the loss of the bridge resulted in changes on how frequently they visited friends, how often they went shopping, and its impact on their online shopping frequency.

Among the sixty people that identified them selves as being impacted by the bridge collapse, ten reported that they used the bridge at least a few times a week or more for their work commutes, seven people reported using it a few times a month for work commutes and the remaining forty three used it rarely or never on their work trips. On non work trips, there were sixteen people that used the bridge at least once a week, forty nine that used it a few times a months, and ten that rarely or never used it for this purpose (Table 4). Over all use of the bridge in the sample is weighed towards non-work trips. The responses also indicate that the I-35W bridge was not the sole alternative the majority of our respondents used. Even among those impacted, only six (10%) reported using it daily.

Respondents were asked what changes they made to their work travel after the bridge collapse. Twenty seven of the respondents said they now use different routes, while the remaining have not chosen route change as their new strategy. Nine of the ten people that used the bridge at least once

Table 4: Use frequency of I-35W bridge among those affected

Frequency	Work trips	Non work trips
At least once a week	10	16
At least once a month	7	33
Rarely/Never	43	10

a week for their work commute are part of this number. In addition, five individuals that used the bridge a few times a week as well as 13 people who used it rarely or never on their commutes have also changed their routes to work. What this implies is that in the weeks after the bridge collapse, even those whose route did not include the bridge link had to adapt to the traffic change.

A few individuals (N=5 of the 60) have also adopted a strategy of changing their departure time. Four out of these have also changed their route adopting a mixed strategy. Other strategies such as changing mode and changing work schedule have not been adopted by anyone who participated in this survey (table 5). People stayed loyal to their mode, and to their work schedule, only choosing to adjust their route for the most part, and only in a few cases, decided to adjust their departure times to make their previous schedule work.

Table 5: Strategies adopted for work commute

Strategy	Yes	No
Route change	27	33
Changed departure time	5	55
Schedule change	0	60
Mode change	0	60

When asked if their travel time to work has changed after the collapse, the majority of those who said their travels have been impacted reported they have maintained their previous travel time. Only 12 of the 60 individuals reported changes (9 reported increased travel time, 2 reported a decreased in travel time, 1 unknown). The large number of people (80%) who report that their travel time has not changed is presumably the reason why change of mode or change of schedule were not adopted as strategies. The simplest strategy (changing a route) seems to have sufficed even though the impacted set included those that didn't use the bridge on a daily basis. Where travel times has increased, it was mostly 10 minutes or less, with only person reporting having to travel an additional 15 minutes over what was their previous travel time.

Table 6: Number of routes tried after bridge failure

	Number of routes
One route	2
Two routes	12
Three routes	7
More than three routes	4

As table 6 shows, those that changed their routes experimented with several routes. In many cases people responded that they have tried two, three or more routes since the bridge failure.

One could argue the loss of the bridge would lead to a either a change in route, a change in destination, or people foregoing some trips. Both among the entire survey sample and among those who reported their travels having been impacted, the level of foregoing trips is small. When asked about what the impact of the bridge collapse had on visiting friends, shopping, or online shopping, a majority responded that the frequency was not affected. 8.3% and 11.7% of the 60 impacted by the collapse indicated a reduction in frequency of visiting friends and going shopping respectively. The responses are shown in table 7.

Table 7: Reported effect of bridge failure on different activities

Description	Impact	All respondents	Impacted respondents
Effect on Visiting friends	Increased it	1.4%	1.7%
	Not affected	94.4%	90.0%
	Decreased it	3.3%	8.3%
Effect on Shopping	Increased it	0%	0%
	Not affected	91.6%	85.0%
	Decreased it	5.6%	11.7%
Effect on Internet Shopping	Increased it	0%	0%
	Not affected	99.1%	96.7%
	Decreased it	0.50%	1.7%

Conclusions

This study looked at the travel impacts of the I-35W bridge collapse on a sample of respondents in the Twin Cities area. The respondent pool did not reside in the immediate vicinity of the collapse, allowing us to look at some of the distributed impacts. We find that closer individuals either due to work location, or home location were significantly impacted than farther ones. In addition, the respondent's usual mode, and household structure were found to be significant explanatory variables.

In this sample, the bridge was used more frequently for non-work trips than work trips. Those impacted by the collapse adopted changing routes as their method of coping with the changes in their work commute for the most part. This happened even in cases when the respondent didn't previously use the bridge for work commutes suggesting new strategies were used by other travelers not directly affected by the collapse.

Those adopting new routes also looked at two or more routes rather than settling with the first route they tried. With only two of 35 respondents reporting using one other route, the majority of respondents tested different alternatives before settling. The only other type of change adopted by a minority of the affected respondents was adjusting their departure time, often in addition to a change in route.

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