TRB Annual Meeting

Invited Student Paper: Bridge the Distance: Surveying a Path Forward Post the Francis Scott Key Bridge Collapse

--Manuscript Draft--

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Additional Information:	
Question	**Response**
The total word count limit is 7500 words including tables. Each table equals 250 words and must be included in your count. Papers exceeding the word limit may be rejected. My word count is:	6404
Manuscript Classifications:	Planning and Analysis; Travel Survey Methods AEP25; Survey; Traveler Behavior and Values AEP30; Behavior Analysis; Behaviors; Pattern (behavior, choices, etc.)
Manuscript Number:	TRBAM-25-03584
Article Type:	Presentation
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Word Count: 4,904 words + 6 table (250 words per table) = 6,404 words

Submitted Aug 1st, 2024

ABSTRACT

On March 26, 2024, the Francis Scott Key Bridge in Baltimore, MD, collapsed due to a collision with the container ship Dali, resulting in six fatalities and significant disruptions to over 34,000 daily trips. This research investigates the immediate impacts on local residents and travelers, focusing on changes in travel behavior, psychological effects, and potential improvements. A comprehensive survey, distributed via multiple channels, collected responses from 222 participants. Findings reveal increased congestion, higher travel costs, and significant psychological concerns, with many respondents adjusting travel times, routes, and work habits. Key suggestions for mitigating impacts from the respondents include reducing toll fees, enhancing public transportation, and promoting telework policies. This study provides valuable insights into the repercussions of major infrastructure failures and highlights the need for robust disaster response and recovery plans to support affected communities. Limitations include potential exclusion of non-internet users and a focus on short-term impacts, necessitating further research on long-term effects.

Keywords: Francis Scott Key Bridge Collapse, Travel Behavior, Survey, Traffic Impact

INTRODUCTION

On March 26, 2024, the Francis Scott Key Bridge (hereafter referred to as the Key Bridge), located in Baltimore, MD, experienced a catastrophic collapse when the container ship Dali collided with one of its piers (*1*). Six maintenance crew members working on the roadway were killed while two more were rescued from the river. Consequently, I-695 between the MD 173 and MD 157 interchanges was closed, which substantially disrupted daily traffic of around 34,000 trips, as well as the surrounding local and regional transportation network (*2*). According to the Maryland Department of Transportation (MDOT), the state plans to rebuild and replace the Key Bridge by fall of 2028 (*3*), which amounts to a reconstruction timeline exceeding four years from the collapse. Thus, it is anticipated that the collapse of the Key Bridge will have significant impact on the local and regional traffic patterns, social activities and economy in both short- and long-term.

Network disruptions resulting from bridge closures or collapses, while unusual, are not unprecedented. Notable examples in the United States include the collapse of the I-880 Cypress Street Viaduct during the Loma Prieta Earthquake in 1989 (*4*), the Hatchie River Bridge in Tennessee the same year (*5*), the I-40 bridge at Webbers Falls, Oklahoma in 2002 (*6*), the I-80 San Francisco-Oakland Bay Bridge collapse due to a tanker truck explosion in 2007 (*7*), the I-35W Mississippi River bridge collapse in Minneapolis in 2007 (*8*), and the recent I-95 overpass collapse in Philadelphia in 2023 (*9*). Internationally, the closure of the Lazienkowski Bridge in Poland due to fire damage in 2015 also provides a pertinent example (*10*). Overall, previous studies have analyzed the traffic impacts of such bridge closures and collapses from various perspectives, including traffic volume change before and after the incidents, rerouting behaviors, self-evaluation and perception of traffic impacts, and psychological impacts (*11*). Commonly used methods include the analysis of traffic data from road sensors as well as conducting surveys and interviews (*8*).

Compared to the previous bridge collapses and closures mentioned above, the Key Bridge collapse in Baltimore presents several unique characteristics and challenges due to a combination of multiple specific factors. First, the bridge accommodated a daily traffic of around 34,000 vehicle trips, which represents a substantial traffic load. Second, the extended reconstruction period for the Key Bridge may induce lasting or potentially permanent changes in local and regional travel behavior. Third, there is a lack of convenient alternative routes capable of handling the same traffic volume. The primary alternative routes in the area, the I-895 and I-95 tunnels, may not have the capacity to manage the substantial volume of traffic diverted from the Key Bridge (*12*). Consequently, traffic may be redirected through the remainder of I-695 or Baltimore City's local streets, thereby placing more pressure on local infrastructure. Fourth, the I-895 and I-95 tunnels restrict the transportation of certain hazardous materials (hazmat) (*13*). Together, these factors could potentially exacerbate traffic congestion and elevate safety risks on both regional and local roadways, resulting in significant ramifications for the daily lives of local residents.

Thus, due to the rarity of the traffic network disruptions of this magnitude in historical precedent, the traffic impact of the Key Bridge collapse on local residents and travelers—both those who frequently use the Key Bridge and those who are indirectly affected—is not well understood. Because the Key Bridge was a critical commercial and transportation artery in the Baltimore metropolitan area, its collapse itself can be treated as a natural experiment of prolonged, large-scale network disruption, offering a unique opportunity to examine traveler responses to such incidents over short, medium, and long time periods. Moreover, analyzing the traffic impact of this event can inform the development of improved guidelines and recommendations for mitigating the potential impacts of similar disruptions in the future.

This research represents an initial effort to conduct a comprehensive survey aimed at understanding the immediate traffic impacts of the Key Bridge collapse on local residents, commuters, and travelers affected by the incident. Building on prior studies, the survey questionnaire addresses four key aspects of traffic impact: socio-demographics, self-evaluation of traffic impacts, rerouting behavior, and psychological impacts. Additionally, the survey solicits respondents' opinions on potential improvements to the current traffic conditions, with the aim of alleviating its negative impacts on their travel needs and lifestyle. To ensure broad outreach, the survey was disseminated through multiple channels, including paper fliers distributed to local residents, web-based geotargeted social media posts, and through local churches,

congregations, and transportation agencies. The insights gained from this research have the potential to enhance our understanding of the traffic disruptions caused by the Key Bridge collapse, establish a foundation for subsequent waves of surveys to assess longitudinal changes in travel behavior, and inform strategies for mitigating similar disruptions in the future.

METHODS

Survey Design

As discussed in the Introduction section, the survey was designed to include four parts: socio-demographics, self-evaluation of traffic impacts, rerouting behavior, and psychological impacts. In order to keep the survey salient, socio-demographic questions include only gender, ethnicity, age, number of children in the household, household income, education, and whether or not the respondents rent or own their apartments/houses, as these factors are likely to influence travel patterns. In addition, the zip codes for residential and work locations, which may link survey data with other data resources such as metropolitan planning models and thus inform route choice decisions, were explicitly asked. Self-evaluation of the general travel impact was also requested in the survey. Respondents were asked to assess how the bridge collapse affected their travel behavior and lifestyle, and to describe how they reacted (e.g did they cancel trips, avoid certain destinations, change departure time, mode, and/or route, engage in more telecommuting, etc.). Answers to these questions illustrate how travelers adapted to network changes and inform the analysis about travelers' decision-making criteria.

Rerouting behavior is one of the most common strategies to avoid unfavorable traffic conditions. In our survey, we focused on two main aspects of rerouting behavior: alternative routes and navigation tools. To understand respondents' rerouting behavior, the survey focused on three other major interstate highways in the area that can serve as substitutes for the Key Bridge (I-695, the I-895 tunnel, and the I-95 tunnel) as well as routes that make use of local roads in Baltimore city. To assess travelers' preferences and satisfaction regarding various navigation tools, respondents were asked about various smartphone applications, vehicle built-in GPS, local news and media, information provided by transportation agencies, and variable message signs (VMSs). In addition, questions related to psychological impacts were asked to see if the Key Bridge collapse affected respondents' perceptions of risk increased following the collapse or their attitudes about living and working near similar bridges in the future.

We developed the survey questionnaire online and created a customized weblink and QR code for respondents to access the questionnaire. Respondents could access the survey using either options with a smartphone or a computer. A lottery mechanism with three incentive levels—$100, $50, and $25—was employed to encourage participation. Due to the multiple layers of survey, where certain questions may or may not appear based on previous responses, it was crucial to conduct a pretest to rule out ambiguity and confusion. Such pretests also ensure the integrity of the questions in addition to the questionnaire structure (Hunt et al., 1982). We attempted a systematic pretest with students and researchers from Morgan State University (MSU), University of Maryland, College Park, and George Mason University. They were asked to systematically fill out every possible combination of choices and deliberately sabotage their responses to test the limits of the questionnaire. Researchers then probed these individuals for potential problems for the design of the questionnaire. No sign of uneasiness, confusion, or resistance was reported from our pretest. The survey plan, questionnaire, and other related materials were reviewed and approved by the Institutional Review Board (IRB) of participating universities.

Survey Distribution

Due to the diverse and extensive nature of the population affected by the key bridge collapse, it is crucial to employ a comprehensive sampling approach that targets the broadest population possible while also focusing on those directly impacted by the incident. Traditionally, methods such as telephone surveys, home interviews, and mail-in questionnaires have been employed to gather responses from specific populations or locations. However, telephone surveys and home interviews are generally expensive (*14*) and may face reluctance from individuals who are increasingly hesitant to engage with strangers (*15*). Additionally, mail-in or email questionnaires often suffer from relatively low response rates (*16; 17*).

Therefore, this study employs the following methods to maximize reach and inclusivity: 1) distributing paper survey fliers to local residents, 2) utilizing web-based geotargeted surveys, and 3) disseminating surveys through local communities and agencies, including churches, congregations, and transportation agencies.

Distributing Paper Survey Fliers to Local Residents

The paper survey fliers were distributed by students and researchers from MSU in the vicinity of the collapsed Key Bridge, targeting a broad area including Dundalk, Edgemere, Rosedale, and Essex in Baltimore County, as well as Brooklyn Park, Glen Burnie, Ferndale, and Linthicum Heights in Anne Arundel County. The survey locations included shopping plazas, shopping malls, gas stations, bus stops, regular trucker stops, convenience stores, fast food restaurants, and various streets with high foot traffic. These locations were selected based on initial interviews with residents near the Key Bridge, with most survey responses coming from communities in Edgemere, Dundalk, and Glen Burnie. Survey fliers containing a QR code and a customized easy-to-remember weblink were distributed directly to individuals encountered by MSU students and researchers. This distribution method was employed from May 18, 2024, to July 18, 2024, resulting in a total of 1,200 paper survey fliers being disseminated.

Web-based Geotargeted Social Media Posts

The web-based geotargeted survey was implemented to reach a broader spectrum of residents and commuters likely affected by the key bridge collapse. To directly target this population, the research team utilized Commuter Choice Maryland, a statewide Maryland Department of Transportation (MDOT) program that regularly posts content related to navigating traffic in Maryland and offers guidance on dealing with the Key Bridge collapse to its followers. Specifically, three main social media platforms maintained by Commuter Choice Maryland—Facebook, LinkedIn, and Instagram—were employed for survey distribution. These social media posts remained active for a total of 26 days on each of the three platforms.

Local Churches, Congregations, and transportation agencies

The research team also distributed survey fliers through local communities and transportation agencies via established connections between MSU and these entities. Specifically, four districts and conferences of the United Methodist Church in areas most affected by the Key Bridge collapse—Annapolis, Baltimore Metro, Baltimore Suburban, and Baltimore-Washington—were targeted. A total of 146 emails were sent to the pastors and members of these districts and conferences. Additionally, the research team reached out to personnel working in various offices of the MDOT State Highway Administration (MDOT SHA) near the collapsed Key Bridge. The surveys were subsequently circulated within MDOT SHA by these personnel to facilitate wider distribution. These additional channels of recruiting potential respondents helped with reaching out to the low-income residents and other under-represented social demographic groups, which is very challenging for a survey study based on literature. These outreach efforts are particularly important because of the social demographic characteristics of residents in the affected neighborhood.

RESULTS AND DISCUSSION

A total of 301 survey responses were received by the cutoff date of July 18, 2024. The research team manually examined each response and employed the following data cleaning procedures to remove invalid entries: (1) removal of responses not giving consent to participate in the survey, (2) removal of incomplete responses, (3) removal of responses with invalid zip codes, and (4) removal of responses where the answers and entered texts indicated an extreme lack of familiarity with the Key Bridge and surrounding traffic conditions. After employing the data cleaning and processing procedure, a total of 222 usable responses were retained for subsequent analysis.

Basic characteristics of the respondents

Table 1 summarizes the basic characteristics of all respondents. Among the 222 respondents, 54.05% were female, which is slightly higher than the female percentage in the State of Maryland (51.27% according to the 5-year American Community Survey (ACS) (*18*)). In terms of ethnicity and race, all categories are represented, with White and Black or African American individuals comprising the largest proportions at 54.05% and 31.98%, respectively. These percentages are slightly above the State of

Maryland averages (52.67% for white and 29.83% for Black or African American). The age distribution across the respondents includes all age groups, with the 25-34, and 35-44 age groups having the highest proportions, which is fairly consistent with the 5-year ACS (*18*). The average number of children per household among respondents is 0.80. These variations are considered acceptable due to the relatively small discrepancies and the survey's broad target region, which includes Baltimore City and the surrounding counties affected by the Key Bridge collapse.

TABLE 1 Basic characteristics of survey respondents

		Count	Percentage
Gender	Female	120	54.05%
	Male	93	41.90%
	Non-Binary	2	0.90%
	Transgender	1	0.45%
	Prefer not to say	6	2.70%
Ethnicity	White	120	54.05%
	Black or African American	71	31.98%
	Hispanic or Latino	12	5.41%
	Native American or American Indian	2	0.90%
	Asian / Pacific Islander	9	4.05%
	Other	8	3.60%
Age	Under 25	21	9.46%
	25 – 34	62	27.93%
	35 – 44	66	29.73%
	45 – 54	33	14.86%
	55 – 64	30	13.51%
	65 – 74	9	4.05%
	75 +	1	0.45%
Number of Children in the Household	0	120	54.05%
	1	45	20.27%
	2	43	19.37%
	3	10	4.50%
	4 or more	4	1.80%
	Average	0.80	
Household Income	Less than $10,000	5	2.25%
	$10,000 - $19,999	0	0%
	$20,000 - $29,999	4	1.80%
	$30,000 - $39,999	3	1.35%
	$40,000 - $49,999	13	5.86%
	$50,000 - $59,999	23	10.36%
	$60,000 - $69,999	25	11.26%
	$70,000 - $79,999	24	10.81%
	$80,000 - $89,999	17	7.66%
	$90,000 - $99,999	20	9.01%
	$100,000 - $149,999	44	19.82%
	More than $150,000	44	19.82%
Education	Less than high school	2	0.90%
	High school graduate	19	8.56%
	Some college credit, no degree	20	9.01%
	Trade/technical/vocational Training	2	0.90%
	Associate degree	21	9.46%
	Bachelor's degree	77	34.68%

	Master's degree	65	29.28%
	Professional degree	7	3.15%
	Doctorate degree	9	4.05%
Renter or Owner	Living in a rented apartment/house	76	34.23%
	Living in my own apartment/house	142	63.96%
	Others	4	1.80%

The residential and work zip codes of the respondents are illustrated in Figure 1 and Figure 2, respectively. The geographic distribution of the respondents is well-dispersed across the State of Maryland with the Baltimore Metropolitan area being the most concentrated area, which suggests that the responses are relatively representative of the residents and travelers that are likely affected by the Key Bridge collapse.

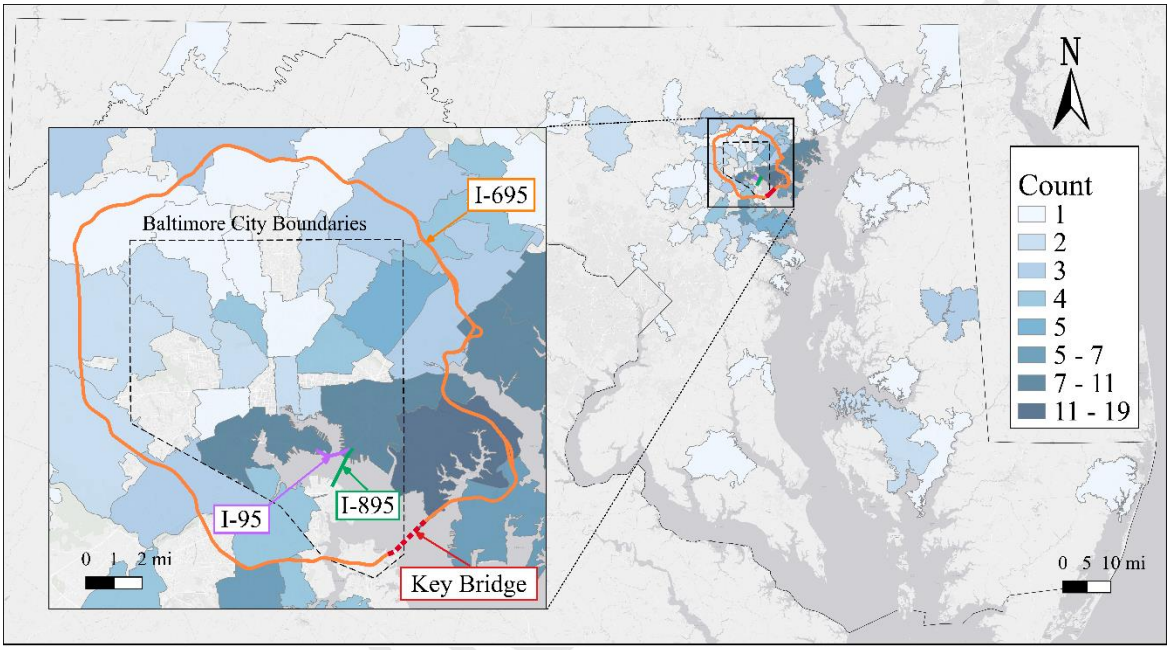

Figure 1. Summary of the zip codes reported by the respondents for residential locations

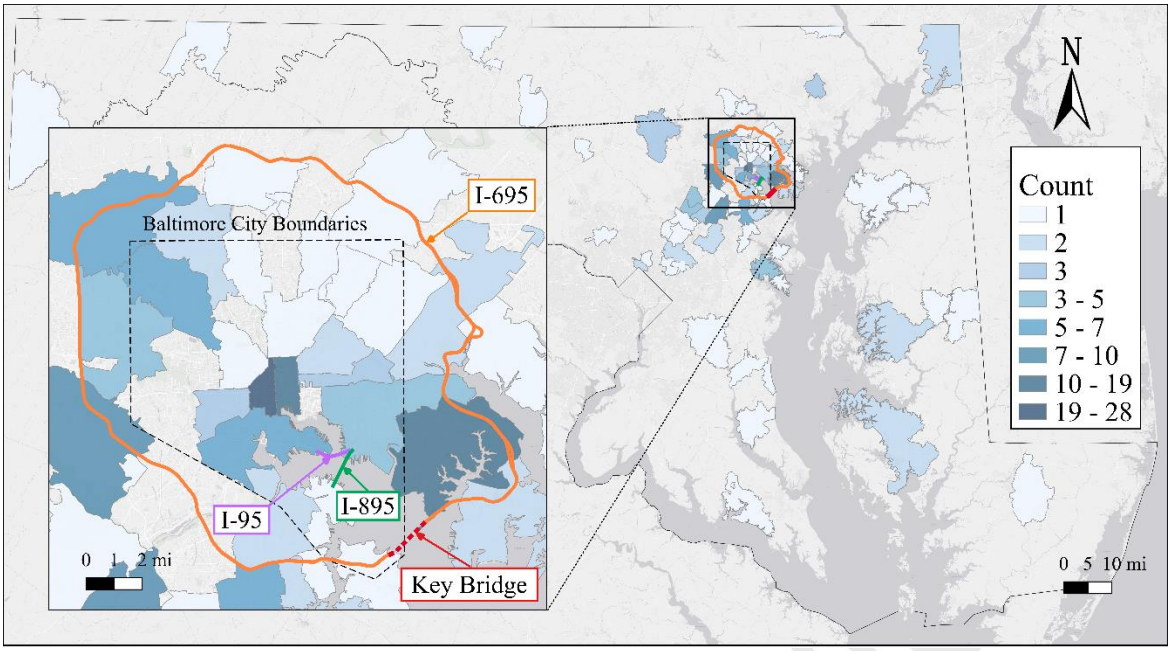

Figure 2. Summary of the zip codes reported by the respondents for work locations

Self-evaluation of travel impact

Following the examination of respondents' socio-demographic information and their residential and work locations, we then examined the respondents' self-evaluation or impressions regarding the impact of the Key Bridge on their travel behaviors. As shown in Figure 3, among the 222 valid responses, 17.57% of respondents (39 respondents) reported using the bridge daily, 13.06% (29 respondents) used it 2-3 times per week, and 11.26% (25 respondents) used it once a week, totaling 41.89%, nearly half of the respondents. Conversely, 44.14% (98 respondents) indicated that they rarely used the bridge, while only 13.96% reported never having used it. This distribution suggests that the survey effectively targeted individuals who either frequently used the bridge or had used it previously. Excluding those who had never used the bridge, 87.96% of the remaining respondents identified as drivers and 12.04% as passengers. The most common reasons for using the bridge were commuting to work or school (35.60%) and visiting friends (28.80%). Additionally, 17.28% of respondents used the bridge for business purposes, while only 1.57% used it for grocery shopping.

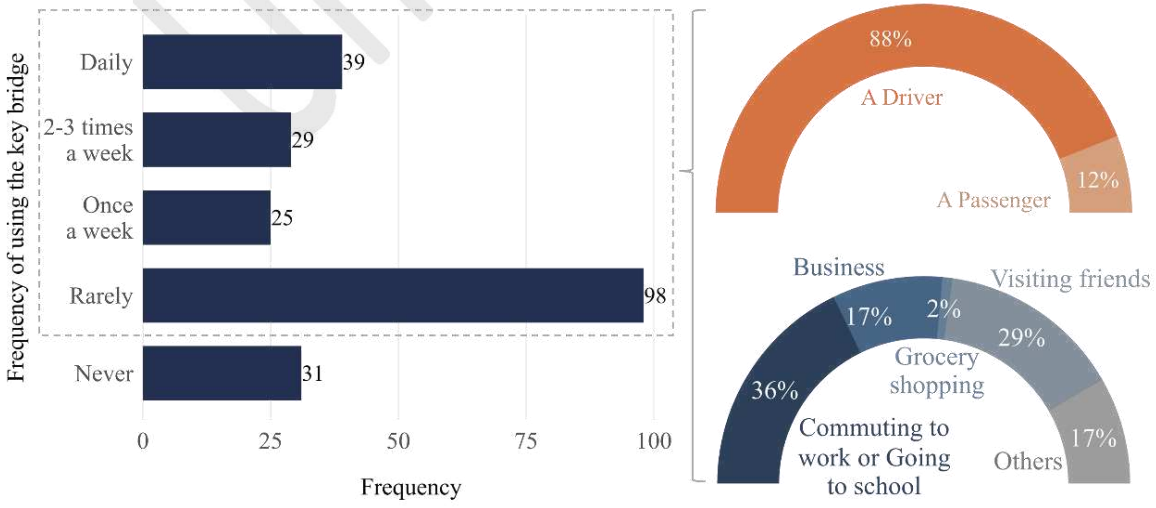

Figure 3 Summary of respondents' satisfaction with various rerouting guidance tools

To further examine the self-evaluated travel impacts, the survey also inquired about respondents' experiences with congestion, out-of-pocket travel expenses, and adjusted travel time. The results are summarized in Table 2. A substantial majority of respondents (89.19%) reported experiencing increased congestion, while only 1.80% reported experiencing reduced congestion, indicating a clear increase in road congestion. Regarding out-of-pocket travel expenses, 40.09% of respondents indicated that expenses remained about the same, whereas 21.17% reported a slight increase and 32.43% reported a significant increase. That is, a total of 53.60% of respondents have experienced higher travel costs. Only 6.30% reported a decrease in expenses. In terms of adjusting travel time, 56.11% of respondents indicated that they definitely need to adjust their travel time, and 17.19% indicated that they probably need to adjust their time of travel, collectively amounting to 73.30%. This suggests a significant need for local residents and travellers to modify their travel schedules and spend more money to mitigate the impacts of the Key Bridge collapse.

TABLE 2 Summary of the impressions of the traffic conditions, out-of-pocket travel expenses, and the need for adjusting the time of travel after the Key Bridge collapsed

	Count	Percentage
Impressions of the traffic condition		
More congested	198	89.19%
About the same	20	9.01%
Less congested	4	1.80%
Out-of-pocket travel expenses		
A lot more	47	21.17%
A little more	72	32.43%
About the same	89	40.09%
A little less	4	1.80%
A lot less	10	4.50%
Need to adjust the time of travel		
Definitely yes	124	56.11%
Probably yes	38	17.19%
Might or might not	25	11.31%
Probably not	14	6.33%
Definitely not	20	9.05%

Considering the travel behaviors of local residents based on our research team's familiarity with the region and taking into account reported adjusted travel behaviors from the news, we further dive into more specific questions related to how the Key Bridge collapse affected residents' travel behavior and lifestyle. The results are summarized in Table 3.

TABLE 3 Summary of more specific impact of Key Bridge collapse on travel and daily lives

	Count	**Percentage**
I have to leave home earlier for work/school because of the bridge collapse	149	40.27%
I have to change my travel mode(s) for many trips (e.g. switching from driving to taking public transit)	32	8.65%
I have to work from home more often	27	7.30%
I have to change jobs	8	2.16%
I have to find alternative locations (e.g. shopping or recreational destinations and so on) to meet my daily needs	58	15.68%

I have to travel less and cancel unnecessary trips in general	56	15.14%
Others	40	10.81%

For respondents indicating that they have to work from home more often after the Key Bridge collapse, a follow-up question was included to inquire about the number of days per week they are required to physically go into work. The histogram illustrating the differences in the number of days respondents physically attended work per week before and after the Key Bridge collapse is presented in Figure 4. The majority of respondents reported that they are able to work from home one or two additional days compared to the period before the collapse. This finding suggests that the Key Bridge collapse has had a discernible impact on the regular work schedules of some respondents.

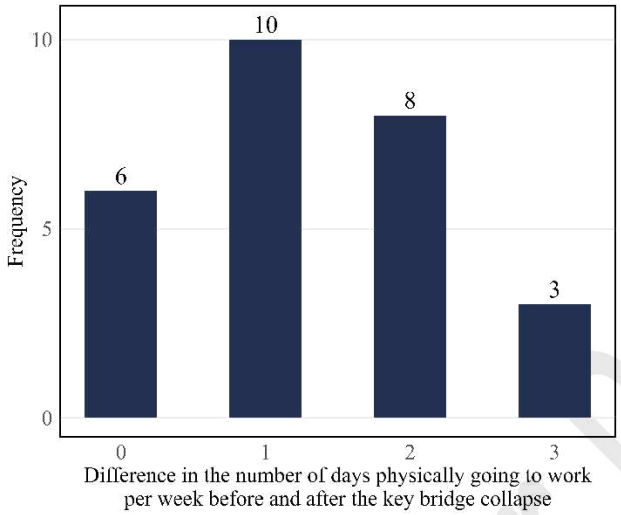

Figure 4 Histogram of the differences in the number of days physically going to work per week before and after the Key Bridge collapse

Given the extended timeframe required to rebuild the Key Bridge, respondents were also asked about the long-term impacts of the collapse. The results are summarized in Table 5. The majority of respondents expressed concern regarding the long-term effects on their commute (38.31%) and community (37.18%), while 17.18% also indicated concern about the potential impact on their income. These findings underscore the respondents' understanding of the lasting consequences of the Key Bridge collapse, highlighting the importance of monitoring these concerns longitudinally.

TABLE 4 Summary of the long-term impact of Key Bridge collapse on travel and daily lives

	Count	Percentage
I am concerned about the long-term impact on my commute	136	38.31%
I am concerned about the long-term impact on my income	61	17.18%
I am concerned about the long-term impact on my community	132	37.18%
None of the above	26	7.32%

Rerouting Behavior

The rerouting behaviors of the respondents are summarized in Table 5. Overall, major detour routes, including I-695 between Essex and Glen Burnie, the I-895 tunnel, the I-95 tunnel, and local roads through Baltimore City, exhibit substantial usage by the respondents, with the I-895 and I-95 tunnels being the most frequently used. Regarding tools used to guide rerouting, the majority of respondents relied on smartphone applications such as Google Maps, Apple Maps, and Waze, accounting for 42.22% of all

respondents. The next most commonly used tools were local news outlets, radio broadcasts, or newspapers (15.14%), Variable Message Signs (VMS) installed on highways (14.93%), and built-in vehicle GPS systems (11.30%).

TABLE 5 Summary of rerouting behavior and tools used for guiding rerouting

	Count	Percentage
Detour Routes		
I-695 between Essex and Glen Burnie	58	18.07%
I-895 (Baltimore Harbor Tunnel)	96	29.91%
I-95 (Fort McHenry Tunnel)	92	28.66%
Local roads through Baltimore City	67	20.87%
Others	8	2.49%
Tools used for rerouting		
Smartphone applications	198	42.22%
Vehicle built-in GPS navigation systems	53	11.30%
Local news outlets, radio broadcasts, or newspapers	71	15.14%
Public announcement provided by transportation agencies	35	7.46%
VMSs installed on highways	70	14.93%
My own judgement when choosing detour routes	37	7.89%
Others	5	1.07%

The satisfaction levels with various rerouting tools are summarized in Figure 5. Overall, most respondents express satisfaction with smartphone applications, with 11.90% being extremely satisfied and 39.52% somewhat satisfied. However, 22.39% of respondents still report being somewhat dissatisfied or extremely dissatisfied with these apps. Regarding recommendations provided by the media and transportation agencies, most respondents feel neither satisfied nor dissatisfied, while 34.24% are inclined towards satisfaction and 24.33% lean towards dissatisfaction. In terms of rerouting recommendations provided by Variable Message Signs (VMSs), 60% of respondents are either extremely satisfied or somewhat satisfied, whereas only 14.28% report dissatisfaction. Despite the lower percentages of dissatisfaction for each tool compared to neutral or satisfied responses, a significant minority of the public remains dissatisfied with available navigation tools. This finding suggests that relying on a single rerouting tool may be insufficient. Instead, it may be advisable to use multiple tools simultaneously to effectively guide the rerouting behavior of local residents.

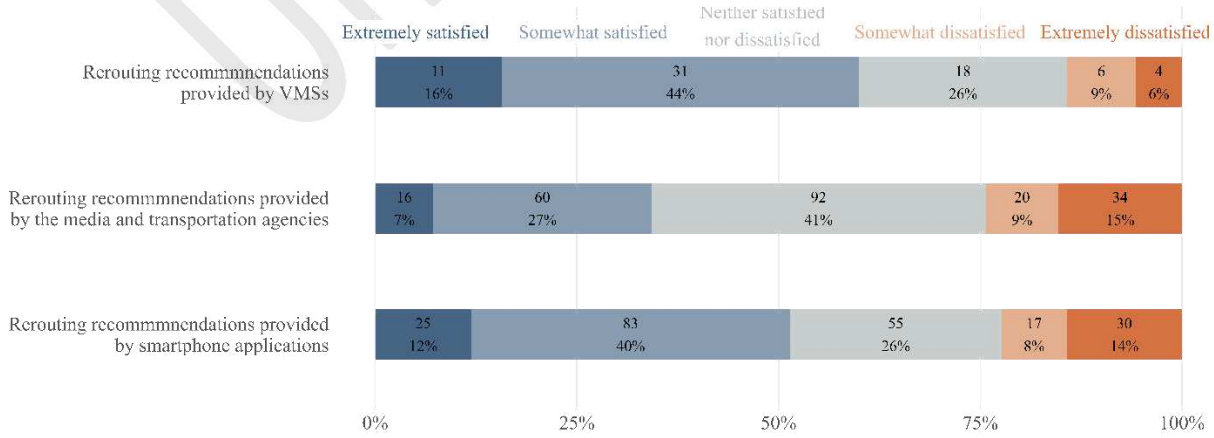

Figure 5 Summary of satisfaction with various rerouting guidance tools

Psychological Impact

Figure 6 illustrates the psychological shifts in attitude towards relocating for work and residential purposes, as well as concerns among local residents regarding increases in perceived risk due to traffic rerouting. Using a consistent Likert scale, we can see that individuals currently renting their residences show notable inclination towards relocation, with 10.53% indicating a definite intention to move and 13.16% leaning towards probable relocation. In contrast, among homeowners, only 2.11% express definite relocation plans, while 4.93% are inclined towards probable relocation. This disparity suggests that renters are predisposed to consider relocation, possibly due to greater flexibility in housing options.

Regarding future residential or occupational proximity to bridges, 14.86% and 17.12% of respondents indicated a definite or probable avoidance to living or working near a bridge, collectively representing nearly 32% of the sample. This suggests a shift in perceptions regarding the safety and resilience of bridges as transportation infrastructure, with approximately one-third of individuals expressing reluctance to reside or work near such structures. Furthermore, 25.68% and 36.94% of respondents reported being definitely or probably concerned about potential increases in traffic safety risks due to significant traffic rerouting through their neighborhoods, aggregating to a total of 62.62%. Conversely, only 9% of respondents expressed no concern regarding these safety risks. These findings reflect a heightened psychological concern and distress related to the negative traffic impacts associated with the Key Bridge collapse, which has also been observed following bridge closure and collapse events in the past (*11*).

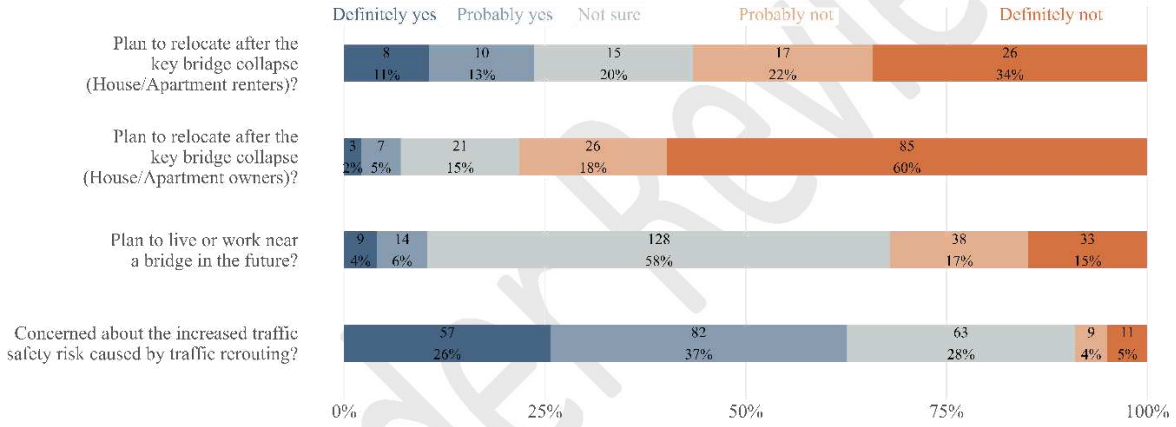

Figure 6 Summary of the plan to relocate after the Key Bridge collapse

Suggestions for Potential Improvements

To prepare for the ongoing and future impacts of the Key Bridge collapse, respondents were asked to provide suggestions for potential future improvements, with the results summarized in Table 6. All proposed suggestions received some level of support, with the most frequently endorsed measures being the reduction of toll fees for nearby tunnels (25.31%) and the implementation of telework or flexible work hour policies (22.22%). Additionally, promoting transit fare discounts, increasing bus services, and installing more detour road signs were relatively popular, with endorsements of 15.74%, 14.35%, and 11.88%, respectively. Some respondents also suggested promoting and facilitating rideshare arrangements (8.18%). These findings highlight that, as we continue to adapt to the aftermath of the Key Bridge collapse, there are various measures that could be implemented to better assist local residents and travelers in adjusting to the situation.

TABLE 6 Summary of suggestions for potential future improvement

	Count	Percentage
Reduce toll fees for using the nearby tunnels	164	25.31%
Increase bus services to the affected areas	93	14.35%

Install detour signs along the roads and suggest alternate routes in the affected areas	77	11.88%
Promote transit fare discount for affected areas	102	15.74%
Facilitate rideshare arrangements (e.g. Uber or lyft and so on) via media or smartphone applications	53	8.18%
Implement telework or flexible work hour policies for daily commuters in the impacted areas	144	22.22%
Others	15	2.31%

CONCLUSIONS

The collapse of the Francis Scott Key Bridge has had profound and multifaceted impacts on the local community, affecting daily travel, economic activities, and psychological well-being. This research has provided a detailed assessment of these impacts through a comprehensive survey that highlights significant changes in travel behavior, increased congestion, higher travel expenses, and notable psychological concerns among the residents. The analysis revealed that a substantial majority of respondents experienced increased congestion and travel costs, with many having to adjust their travel times and routes. The collapse also led to a discernible shift in work habits, with a certain portion of respondents working from home more frequently.

The psychological impact of the bridge collapse is also significant, with many respondents expressing concerns about long-term safety and the desirability of living or working near bridges in the future. This heightened anxiety is likely to persist as the impacted area undergoes a prolonged period of adjustment due to the relatively long rebuilding time. It is worth noting that the psychological impacts on the community emphasize the importance of addressing mental health and safety concerns in disaster response and recovery plans. Ensuring transparent communication and providing adequate support to affected residents can help alleviate anxiety and improve resilience.

Additionally, the survey identified several key areas where residents feel improvements could mitigate the ongoing negative impacts, such as reducing toll fees for nearby tunnels, increasing bus services, promoting telework policies, and enhancing detour signage and transit fare discounts. These findings suggest that flexible work arrangements, improved public transportation, and reduced tolls can play a crucial role in mitigating the adverse effects of major infrastructure failures, indicating a need for policies that encourage and facilitate such measures.

While this research provides valuable insights into the impacts of the Key Bridge collapse, several limitations should be acknowledged. First, the survey's reliance on online and paper distribution methods might have excluded individuals without internet access or those less likely to participate in surveys. Second, the study's focus on short-term impacts may not capture the long-term behavioral and psychological changes that could emerge over the extended reconstruction period. Last, while efforts were made to include diverse demographics, the study may not fully account for the varied experiences and needs of all affected subgroups, such as non-English speakers or individuals with disabilities. More research is needed in the future to properly address these limitations.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Award No. 2427232. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The research received Morgan State University IRB approval with IRB No.: #24/04-0129. The authors would like to thank Dr. Gang-Len Chang, along with the staff and personnel at Office of Traffic and Safety and Office of Transportation Mobility and Operations of Maryland Department of Transportation, for their valuable input and suggestions in improving the survey questionnaire. The authors would also like to thank Christol Medley and the team at Commuter Choice Maryland for their valuable assistance in distributing the survey fliers. The authors also acknowledge that a large language model, ChatGPT, was used and only used in improving the language when preparing the manuscript. The authors acknowledge the limitations of

language models, and the accuracy, validity, and appropriateness of written language have been rigorously verified by the authors.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: D. Yang, S. Zhu, M. Jeihani, X. Yang; data collection: D. Yang, M. Jeihani, B. Baylor; analysis and interpretation of results: D. Yang, T. Shen, M. Jeihani, X. Yang; draft manuscript preparation: D. Yang, T. Shen, M. Jeihani, X. Yang, S. Zhu. All authors reviewed the results and approved the final version of the manuscript.

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