Quality of Highway Safety Information Collected with an Internet-Based Survey Tool

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ABSTRACT

Identifying hazardous locations for highway agencies is a difficult task. Although crash data is utilized in various identification methods, missing crash reports, missing data in reports, randomness, and infrequency of crashes call for additional information about road hazards. The authors propose the use of an Internet-based survey tool as a means of collecting motorists’ reports about hazardous highway locations. A prototype tool was developed and responses gathered from motorists in Tippecanoe County, Indiana, in a five-month period in 2001.

The public response to the prototype tool was very positive, and the public provided a wealth of information about locations within the county. The reports were neither frivolous nor overly opinionated. Much of the information provided insight into specific problems and situations that would not be readily apparent through traditional crash analysis.

Through statistical comparison of the motorist reports and crash data, the authors found that the respondents were successful in indicating hazardous locations. In addition, the authors found that agencies responding to motorists reports have a high probability of spending their resources on investigating justified cases. Media and third-party information increases false detections of hazardous locations and their influence should be minimized, if possible. The Internet tool is well received by its users, and the information obtained from the responses to the tool is useful in detecting and remedying hazardous locations.

It was concluded that although the Internet-based method cannot substitute the existing crash-based methods, it should be used as a supplemental method to improve identification of high-crash or potential high-crash locations.

WORD COUNT: 5,676, 5 figures, 3 tables

SUBMITTED: July 29, 2002
INTRODUCTION

Identifying hazardous highway locations is a difficult task. Over many years, a variety of crash-based methods of identifying hazardous locations have been proposed and used. However, none of these methods provides a complete picture of safety at a highway location, and most are retroactive in nature; that is, crashes must occur before the locations can be identified. In addition, all of these methods are prone to the shortcomings of crash data itself, including randomness in the data and non-reporting of crashes. Thus, a better method, or a way to supplement the existing methods, of identifying hazardous locations is needed.

It is generally accepted that the driver’s perception of risk is related to the hazardousness of a location. However, the nature and scope of this relationship is not well known. Little research has been conducted to investigate the relationship between driver perception of risk and crashes at a location. If information about this relationship can be gained, it could lead to a new method of hazard identification or a great improvement in existing methods.

Currently, highway agencies collect drivers’ perceptions of highway locations in their jurisdictions with phone and mail collection systems. With these systems, the public must contact the agency during its operating hours. This causes confusion in the public over whether a local or state agency has jurisdiction at a location. In addition, the systems are not efficient in collection and storage of responses, and information may be lost through recording and transcription of the drivers’ communications. A much more efficient means of collecting this information is needed if it is to be used more vigorously in safety evaluation.

The objective of this research was to investigate the relationship between the risk perception of highway users and actual crash totals. A prototype Internet-based tool with a questionnaire focusing on driver perceptions and a database to store these responses was developed. A pilot test of the tool was conducted over five months, and the responses from the pilot study were evaluated. The information gathered from these responses was compared to crash data with the hope of determining the relationship between drivers’ risk perception and crash data.

This paper is divided into six sections. The first section discusses previous research that has been conducted with regard to identification of hazardous locations and the comparison of subjective and objective risks. The next section discusses the concept and design of the prototype Internet tool and the pilot test of the tool. The safety information gained from the pilot test is then presented and discussed. The fourth section of this paper examines the quality of the safety information against crash data, and the fifth section examines the detection power of the safety information. Finally, the paper presents conclusions from the research.

REVIEW OF THE LITERATURE

A review of the existing literature reveals that much research has been conducted on methods of identifying hazardous highway locations. A study by Chen and Wang (1) investigates the effectiveness of many such methods. The study consisted of the comparison of many existing techniques for the identification of hazardous locations and the development of a
new technique of identification. The authors compared the use of simple and more advanced techniques. The research argues that all of the traditional methods of identification are flawed in that some do not consider length and volume of section or accident severity, while the authors feel that all of these factors are important in determining whether a section is truly hazardous. The authors propose to modify accident rates by applying severity weights. A maximum acceptable value is then chosen for use as a “critical” accident rate, above which the section is considered hazardous. This research demonstrates that there is no hard and fast usable identification method, and all of the methods have their own shortcomings. In fact, any identification method using crashes can be problematic because there may be missing or inaccurate crash reporting and a considerable delay in reporting the results, depending on the highway agency. Development of other options to either assist identifying hazardous locations or replace the existing methods is well warranted.

Risk perception of drivers may carry useful safety information about highway locations. A study conducted by Renge (2) examined the hazard and risk perception, confidence in driving, and choice of speed for a wide cross-section of drivers. The study found that more experienced drivers perceived hazards more accurately than those with less experience and thus drove at lower speeds in high-risk situations. Male drivers were found to be more confident in their abilities and evaluated the risks as less than their female counterparts. Another study of driver risk-perception was conducted by Salter, et al. (3) who focused on perceptions of risk and competition for road use. The study found that the drivers’ perceived risks correlated well with the crash frequency if they were exposed to the evaluated risk themselves.

Both of these studies show that the perceived risk of drivers may be a strong indicator of how dangerous the locations actually are. This conclusion leads to the question of whether risk perception can be used to identify hazardous locations. Such a method of identification would help improve the detection quality and overcome the time lag in crash data reporting. It would lead to a more proactive approach to remediation of hazardous locations, since the problems at such locations could be fixed before crashes occur. One study that examined this possibility for highway curves was conducted by Kanellaidis and Dimitropoulos (4), who compared the subjective risk perceived by drivers with the risk estimated based on curve design standards. The latter risk was considered objective in that study. It was found that the subjective risk ratings were systematically higher than the objective risk ratings. The authors concluded that this discrepancy was likely caused by the strictness of the design standards rather than by overestimation on the part of the drivers. Most interestingly, the highest differences corresponded with high accident locations. This study shows that there may be a relationship between perceived risk and crash frequency.

Research on risk perception must be conducted with caution to avoid bias. One of the more serious potential sources of bias involves media influence on public perception. Liu et al. (5) conducted a study regarding the change in public risk perception based on the qualitative nature of information provided through the media. The study found that public reaction to positive information about a hazard takes longer and is less intensive than negative information. This finding is relevant to the present research because locations of recent accidents covered in the media may reach a large number of public respondents and the hazard at these particular highway locations may be overestimated.
In conclusion, the current literature indicates that the crash-based methods of identifying hazardous locations may be inaccurate, which justifies examining driver risk perception to provide new insight into the problem. The literature also shows there is reason to hope that risk perception can be used as a substitute or supplement for crash data.

**PROTOTYPE INTERNET TOOL**

**System Concept**

The schematic of the Internet-based tool is shown in Figure 1. After the website user accesses the webpage, a clickable map interface appears, allowing the user to select the reported location on the map. Location coordinates and a date and time stamp are then relayed to the database, and the record is initialized in the database. The user then completes the questionnaire and submits the completed form into the database where the feedback is recorded. The agency then uses the database to create reports or print the output for analysis. If desired, the agency can add fields to the database where inspection and remediation information for the location can be registered, allowing for a complete record of activities at the location. If a common location coordinate system is used for other agency databases, this information can be linked to the response database using the location coordinates programmed into the map interface. One additional benefit of the proposed system is that a single website can be used to collect data for highway agencies at the city, county, and state levels. The motorist can report any location in the area without having to determine first which agency has.

**Prototype Design**

A prototype website was developed for Tippecanoe County, Indiana, which encompasses the Lafayette and West Lafayette metropolitan areas, as well as the Purdue University main campus. The prototype consists of three components: a map interface, a questionnaire, and a response database.

**Map Interface**

The user interface to the survey consists of a welcome page, and then a series of four interactive static maps of increasing detail. Maps at the first three detail levels are split into a four by four grid to facilitate navigation. The final level consists of an enlarged version of the map section selected at the third level. This final detail level is used by the respondent to select the location of concern. When the respondent selects a location, the selected pixel is converted to GIS coordinates. The location is then marked with a red circle and the user is given the option to change the location or fill out the questionnaire. After finishing and submitting the questionnaire, the user is given a thank-you message and the option to select another location to report. The maps load rapidly, decreasing the waiting time and reducing the possibility that the user becomes frustrated and abandons the survey. Dynamic mapping and zooming tools, which are available commercially, are another possibility for
implementation. For the purposes of this research, however, the static maps were a sufficient solution.

Questionnaire
The design objectives for the prototype questionnaire were to make it readable, short, and easily automated. In addition, the questions had to request only the desired information. To satisfy the design criteria, the survey consists of nine short, mostly multiple-choice questions. The questionnaire is shown in Figures 2 and 3. The first two questions ask the respondent for street names to serve as verification of the coordinate data from the maps. The third question focuses on how the respondent has learned that the location is hazardous. For example, the respondent may have learned the location is hazardous by observing the behavior of other drivers or by witnessing a crash. The fourth question asks the respondent about possible causes of the hazard. This question can provide the transportation agency with insight into what to look for when investigating the location. The fifth and sixth questions ask the respondents when and how frequently they pass the location. These questions prompt how knowledgeable the respondent is with the location, and what time of day the hazard occurs. The seventh question asks the respondents how much extra travel time they would accept to avoid the hazard. Travel time serves as a measure of the respondent’s level of concern. The eighth question is used to gather demographic information such as gender, age, e-mail, and zip code. The zip code can be used to determine if the respondent is from the local area. The e-mail address allows the transportation agency to contact the respondent if needed. The final question gives the respondent a chance to comment on the questionnaire and suggest improvements.

Free-response options are provided for questions three, four, and nine so as to allow the user to provide additional information not included in the given options. The rest of the survey consists of multiple-choice questions, allowing for automated recording into the database and easy sorting of the records. The survey questions are believed by the authors to satisfy the goal of a short, readable questionnaire, while making sure all desired information is gathered.

Database
The database for the Internet tool was designed with the perspective of the agency in mind. The storage of responses in a database allows for remote access to the responses throughout the agency, allowing authorized users to access and evaluate the responses at their convenience. The database can be used to generate data reports for easy viewing and evaluation purposes. The database can be programmed to screen and clean out frivolous or incomplete responses based on the criteria of the agency. Another benefit of the database is that the response data can be exported into spreadsheets or statistical programs to assist in evaluating the responses. Finally, the agency actions and response to the motorist reports can be logged into the database, creating a comprehensive record of the locations indicated by the respondents.
Pilot Test of the Prototype Tool

The prototype tool was pilot-tested from mid-July through mid-December of 2001. In order to encourage the public to use the website, the website was promoted in the local media. The promotion campaign began with an article in the Purdue Exponent student and staff newspaper on July 18 and it was followed by a television story on the local television station, WLFI, on July 23. The website was further promoted in the Lafayette Journal and Courier newspaper in advertisements from October 22-28, and in a feature article on October 28. Responses to the website continued to be collected through the first week of December.

The thorough publicizing of the website resulted in large spikes in the number of responses received, but the response rate quickly decreased after the publicity campaign ended. Over five months of data collection, the total number of complete responses was 146. In an actual implementation of the Internet tool, a lower number of responses may be expected if the website is not publicized aggressively.

SAFETY INFORMATION OBTAINED

The survey questionnaire prompted the user to provide three pieces of information that have some bearing on the safety of the location and the perceived risk of the respondent. The important information obtained from the respondent consisted of how the respondent learned the location is hazardous, the user-reported cause of the hazard, and the user-reported desirable travel time to avoid the location. Each of these pieces of information is discussed below.

Basis of High Hazard Perception

The source of knowledge of the respondent about the location’s safety is important because of the potential for media influence on perceived risk described by Liu et. al.(5). In addition, the independence of the respondent’s information may be in question if the respondent indicates they received their information through a second-hand source (media or friends/family). Therefore, a low number of respondents indicating second-hand sources is desirable. If one wants to check the value of the information not included in the crash records, the number of respondents involved or who witnessed the crash should also be low. The responses from the survey showed that approximately 10 percent of respondents indicated second-hand sources, while 20 percent indicated crash experience at a reported location. This is an encouraging result, as it indicates that the majority of respondents are providing new information unrelated to crash data, and the likelihood of media influence on the respondents is not highly significant.

User-Reported Causes of the Hazard

Another important piece of information gained from respondents is the user-reported causes of hazards at the locations. This information may provide a highway agency with potential insights helping to focus their safety investigation properly. In addition, many respondents gave expanded answers using the open-ended option. The expanded responses provided details about the user-perceived safety problems at the locations. A summary of the different
response options and the number of respondents indicating each one is shown in Figure 4. From this figure, it is apparent that the primary causes of concern for respondents in this study were driver speed and traffic control at the location of concern. In the Other category, motorists mentioned various additional causes for concern: maintenance, turning vehicles, driver behavior, lane markings, high traffic, enforcement, buses, and trains.

Acceptable Bypass Travel Time
The acceptable bypass travel time serves as a proxy for perceived risk level at the location. Drivers are asked to determine how much extra time they are willing to spent to avoid the hazard. Because drivers are believed to make route choice decisions primarily based on travel time, the extra time they specify provides a convenient measure of the amount of perceived risk. Because the geographic area of the study was relatively small, a maximum time of 10 or more minutes was chosen as the highest travel time level. From the results of the survey, it was discovered that most drivers perceived a low level of risk at their locations of concern (between 0-4 minutes). About 30 percent of drivers, however, were willing to spend four or more minutes to avoid the location, and this indicates a significant perceived risk on their part. The travel times reported by the respondents will be further investigated in the following section of the paper.

QUALITY OF THE SAFETY INFORMATION
With the responses from the motorists in hand, the quality of the safety information must be evaluated. In this case, the information is considered to be of good quality if there is a positive correlation between the number of responses for each location and the number of crashes at each location. If this correlation exists, then it can be said that locations indicated by respondents are more hazardous than locations not indicated by respondents.

In order to evaluate the information, a number of selected state-maintained intersections were examined. A sample of 360 locations was obtained using an integrated database developed by Weiss (6), which combines the Indiana state road inventory and the Indiana State Police crash databases. The crash statistics were not considered in this selection. The original number of locations was narrowed to 260 by removing locations that had recently undergone safety improvements or that could not be uniquely identified using the information contained in the ISP crash reports. The finished sample contains locations that are believed unchanged in safety within the period between 1997 and 2001. Out of the pre-selected 260 state-maintained intersections, motorists reported 31 as hazardous.

Number of Responses
In order to investigate the correlation between responses and crashes, the state-maintained location sample was separated into six groups according to the number of responses per location. Table 1 shows the characteristics for these six groups. Based on the average number of crashes per location, it appears that there is a positive correlation between increased perceived risk and number of crashes, as the average number of crashes per location decreases from Group B through Group F. The only exception is that Groups A and
B do not appear to follow this trend, and this anomaly is likely due to randomness in the crash data, as the number of locations in Groups A and B are small.

In order to test the statistical significance of this result, a binomial test of the difference between each pair of groups has been conducted (for example, between A and B, A and C, C and E, etc.). In this case, the null hypothesis is that the first group is not more hazardous than the second group. Using this assumption and binomial distribution, the probabilities were calculated that a crash count in the second group is at least equal to the observed crash count in that group. This likelihood is the significance value for the test. If the significance value is small enough, then the null hypothesis may be rejected, and the group of locations with the higher number of responses per location may be assumed to be more hazardous. The matrix of significance values resulting from the binomial test is shown in the second part of Table 1. The significance values shown in the table confirm the trend indicated by the average number of crashes per location in Table 1, with the exception being between Groups A and B, which was anticipated earlier. The results of the binomial testing thus show that the locations indicated by respondents are significantly more hazardous than those locations not indicated by respondents, and that the level of hazard increases as the number of responses increase.

Acceptable Bypass Travel Time

Because the bypass travel time has been used as a proxy for the perceived risk level, it is desirable to investigate whether the bypass travel time provides better information about location hazardousness than the number of responses. This time, the overall measure of hazard is the total bypass travel time reported for a location by all respondents reporting this location. In this way, the time-based measure is supposed to reflect not only the number of responses but also the level of concern. In order to test the quality of this hazard measure, the state-maintained location sample was separated into groups based on the total bypass travel time. Five groups of sites with 0-4, 5-9, 10-14, 15-19, and 20+ minutes of total bypass time were considered. The difference in hazard between groups has been compared in a similar manner as the groups of locations sorted by number of responses. It was found that while the desirable trend still exists (travel time increase with increased hazard), this trend seems to be weaker than in the case of number of reports. Thus, it can be concluded that the number of responses at a location is a better measure of hazardousness than the total travel time reported for the location.

Crash and Media Influences Excluded

Due to the media’s influence on risk perception described by Liu et al. (5), it is desirable to minimize the influence of the media in this analysis as much as possible. In addition, it is desirable to try to isolate independent responses from each individual, as well as focus on information not typically obtainable through crash data. Thus, a third binomial evaluation was conducted on a sample with removed reports with indicated crash experience or media as a source of information. This removal resulted in a reduction in the number of indicated locations from 31 to 21. The state-maintained location sample was again separated into groups based on the number of responses for each location, and this grouping of locations is
shown in Table 2. Examining the table reveals that there is a disparity between Groups C and D, but otherwise the results appear to be consistent. These results are reinforced by the significance matrix also shown in Table 2. The results are not quite as convincing as for the testing conducted including all responses, but there is an indication of promise in the results, since the number of locations is low. A larger analysis group could provide results that are more definitive.

DETECTION POWER OF THE METHOD

Now that the quality of the information has been checked and confirmed, it is important to examine the detection power of the method in identifying hazardous locations. This is accomplished through evaluating the method performance in detecting hazardous locations among the 261 state-maintained locations. The evaluation criteria are detection rate and false detection rate. The detection rate in this case is the number of hazardous locations reported divided by the total number of hazardous locations in the sample. Similarly, the false detection rate is the number of non-hazardous locations reported as hazardous divided by the total number of non-hazardous locations in the sample. Before calculating these rates, a hazardous location has to be defined to allow classification of locations as hazardous or non-hazardous. A location is considered hazardous if the number of crashes recorded at the location exceeds a threshold number of crashes during three consecutive years. Instead of assuming a single threshold value and trying to define it, we checked the detection performance of the method for various threshold values.

The detection rates were computed for threshold values widely ranging within 5 and 30 crashes for three years. For locations reported at least once, the detection rate fell in a range between 35 and 45 percent, and the false detection rate was within the range of 3 to 7 percent depending on the threshold value. It can be concluded that the detection rate is not high enough for the method to serve as a substitute for crash-based methods. The relatively low detection rate and the positive results of the binomial test indicate that the investigated method can provide supplemental information to crash-based methods and improve their performance.

Another measure of the investigated method of performance, of particular interest to highway agencies, is the efficiency rate. The efficiency rate is the ratio of correctly reported hazardous locations to all the reported locations. From the agency perspective, the efficiency rate expresses the likelihood that the agency responding to a motorist report will use resources efficiently by investigating orremedying a location that deserves attention (is hazardous). The higher the efficiency rate, the more valuable the responses are to the agency. Similarly to the detection rates, the efficiency rates were computed for a range of crash thresholds. The efficiency rate curves are shown in Figure 5. As indicated in the figure, the efficiency rate increases dramatically as the number of motorist reports warranting agency action increases. Responding to the first report about a location, the agency has a 55 percent chance that the location turns out to be dangerous (threshold crash count is 15). This chance increases to 86 percent for two reports and to 96 percent for three reports. The highway agency may be quite confident in the hazardousness of a location if it is reported by motorists multiple times.
The efficiency rates calculated for all obtained reports and for reports without crash and media impacts were compared. The comparison showed that both rates are similar, but the efficiency rate for the reports without the crash and media impacts was generally higher. This indicates that the impacts of crash experience and media have introduced additional false detections, which concurs with the way media influences people as concluded by Liu et al. (5). It is clear that the personal and uninfluenced hazard perception carries valuable and useful information about road safety and it needs to be investigated further.

CONCLUSIONS

The Internet-based tool performed well in collecting the perceived risks experienced by highway users in Tippecanoe County, Indiana. The tool collected a variety of safety information useful to a highway agency, including perceived causes of the safety problems at the location and the amount of perceived risk.

The locations indicated by respondents were significantly more hazardous than other locations and this trend generally held true when crash experience and media influence were eliminated from the analysis.

The number of responses at a location was found to be a better indicator of hazardousness than total travel time at a location, and the respondents were found to detect hazardous locations at a significantly better rate than would be selected at random.

Finally, although the detection rate was not high enough to recommend the method as a sole way of detecting hazardous locations, the false detection rate was sufficiently low and the efficiency rates high enough to indicate that the investigated method should supplement the existing crash-based detection for their benefit.

More research should be conducted to expand upon and add to the promising results presented here. It is an area not well explored.

ACKNOWLEDGEMENT

The authors are grateful to the Joint Transportation Research Program (JTRP) of Purdue University and the Indiana Department of Transportation for the financial support of the research.

The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration and the Indiana Department of Transportation. The paper does not constitute a standard, specification, or regulation.
REFERENCES


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FIGURE 1 Schematic of Proposed System.
Tell Us Your Roadway Safety Concerns

Help us find Dangerous Locations on the Highways in Tippecanoe County

Instructions:
The map below is divided into sections. Click on the section that contains the location of concern.

FIGURE 2 Screen Capture of the Web Page with the Tippecanoe County Map
1. Where is the danger located?
   a. At/Near Intersection  b. Between Intersections

2. If possible, please give the street names at this location.
   Road with Unsafe Location:   Nearest Crossing Road:

3. How did you learn that this location is unsafe? (Mark all that apply)
   a. Witnessed Near-Crash  e. Involved in Collision  g. Learned About it from
   b. Involved in Near-Crash  f. Other Drivers Act  h. Learned About it from
   c. Witnessed Collision  g. Existing Stoplights/Signs  i. Other (please specify):
   d. Involved in Collision  h. No Stoplights/Signs

4. What makes this location unsafe? (Mark all that apply)
   a. Sight Obstructions  e. High Traffic  i. Weather
   b. Speed  f. Pedestrians  j. Other (please specify):
   c. Trucks  g. Existing Stoplights/Signs
   d. Construction Work  h. No Stoplights/Signs

5. How often do you pass this location?
   a. Less than once per week  c. 3-5 times per week  e. Twice per day
   b. 1-3 times per week  d. Once per day  f. More than twice per day

6. At what time of day do you usually pass this location? (Mark all that apply)
   a. 12 am – 3 am  d. 9 am – 11 am  g. 4 pm – 6 pm
   b. 3 am – 6 am  e. 11 am – 1 pm  h. 6 pm – 9 pm
   c. 6 am – 9 am  f. 1 pm – 4 pm  i. 9 pm – 12 am

7. If possible, how much extra time would you be willing to spend to bypass this location?
   a. Less than 2 minutes  d. 6 to 8 minutes
   b. 2 to 4 minutes  e. 8 to 10 minutes
   c. 4 to 6 minutes  f. More than 10 minutes

8. Please fill out the following information. (The information is for study purposes only and will be kept confidential)
   Age:  a. 16-25  Gender:  a. Male
   b. 26-35  b. Female
   c. 36-45  c. 46-55  d. Home Zip Code:
   d. 46-55  e. 56-65  f. 65+
   E-mail address:

9. Feedback to improve the survey.
   A. Is the clickable map convenient?
      a. Yes  b. Indifferent  c. No
   B. Is the site user-friendly?
      a. Yes  b. Indifferent  c. No
   C. Is the survey readable?
      a. Yes  b. Indifferent  c. No
   D. Are the question types sufficient?
      a. Yes  b. Indifferent  c. No
   E. Are the response options adequate?
      a. Yes  b. Indifferent  c. No

Please clarify any responses from previous questions that you wish and make any other comments below:

FIGURE 3 Sample Survey Questionnaire.
FIGURE 4 User-Reported Causes of Hazard.
FIGURE 5 Efficiency Rate Curves.
### TABLE 1 Binomial Test Results Based on Number of Responses

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<thead>
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<th>Group</th>
<th>Number of Responses Per Location</th>
<th>Number of Locations</th>
<th>Total Crashes</th>
<th>Avg. Number of Crashes</th>
<th>Signif. Compared to Group B</th>
<th>Signif. Compared to Group C</th>
<th>Signif. Compared to Group D</th>
<th>Signif. Compared to Group E</th>
<th>Signif. Compared to Group F</th>
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### TABLE 2 Binomial Test Results Based on Number of Responses (Media and Crash Exclusions)

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<th>Number of Locations</th>
<th>Total Crashes</th>
<th>Avg. Number of Crashes Per Location</th>
<th>Signif. Compared to Group B</th>
<th>Signif. Compared to Group C</th>
<th>Signif. Compared to Group D</th>
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