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Impact of 4-to-3 Lane Conversions on Emergency Response

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Abstract

4-to-3 lane conversions, often called road diets, have been implemented throughout the U.S. as a means to reduce crashes. However, the reduction in lanes has led to community wide concerns across the country regarding the possible negative effect on emergency responses. This study investigates the impact of 4-to-3-lane roadway conversions on emergency response in Iowa through surveys and a retrospective analysis of EMS data. The 170 survey responses were analyzed descriptively, and a text analysis was done on two open text survey questions. Generalized linear models were constructed to examine the impact of lane conversions on emergency response times. Over half of EMS respondents believed there was no effect or a positive effect on responses, while 40% believed there was a negative effect. The negative effect was often attributed to driver confusion on how to properly yield to EMS vehicles. Despite the differing perceptions, EMS response rates from before to after the implementation of 4-to-3 lane conversions did not meaningfully differ. Overall, there was a lack of evidence of an effect of 4-to-3 lane conversions on EMS response rates in Cedar Rapids, Iowa. However, survey results showed that public guidance on how to properly respond to the presence of EMS vehicles on these roadways may be needed. This study provides evidence for addressing local concerns about road diets and emergency response to add to other known safety benefits. Results of this analysis may be applicable to other lane conversion sites when appropriately combined with local context relevant to the target area.

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1 INTRODUCTION

Reconfiguration of roadways in order to reduce the number of lanes, commonly called road diets, have been established as an effective safety countermeasure for the reduction of traffic crashes (Pawlovich, et al., 2006; Noyce et al., 2006). Reconfigurations that convert a four-lane road with two lanes of traffic in each direction into a three-lane road with one lane of traffic in each direction and a center turn lane are called 4-to-3 lane conversions (Figure 1). 4-to-3 lane conversions attempt to smooth traffic flow and reduce crashes with the addition of the dedicated center turn lane, while also providing more space for the addition of bike lanes or parking. The dedicated turn lane ensures that cars are not stopping in the driving lane, which results in fewer potential conflict points, leading to the reduction of crashes, as well as smoother traffic flow (Knapp et al., 2014).

Iowa was one of the first states to implement 4-to-3 lane conversions, starting in 1996, and by 1999, Iowa was actively promoting lane conversions throughout the state (Welch, 1999). An analysis comparing fifteen road diet sites of varying traffic volumes to fifteen non-converted sites in Iowa found the converted sites had a 25.2% reduction in crash frequency per mile (Pawlovich et al., 2006). A replication of this analysis by the Federal Highway Administration, and an additional analysis of road diets in Washington and California, demonstrated a 29% average reduction in crashes (FHWA, 2010). Similar analyses in Virginia (Lim & Fontaine, 2022), Michigan (Lyles et al., 2012), Florida (Abdel-Aty et al., 2014), and Rhode Island (Zhou et al., 2022) have found a reduction in crashes through the introduction of road diets. Due to these promising safety results, 4-to-3 lane conversions continue to be implemented widely in Iowa and across the US.

While evidence suggests that 4-to-3 lane conversions are effective at reducing crashes, throughout the nation residents and/or local officials near these proposed or implemented conversions often express concerns about potential or perceived negative impacts (e.g. Wilson, 2022). These concerns include traffic congestion, increased travel times, and longer emergency response times as a direct result of the reduction in number of lanes (FHWA, 2016; Iowa Department of Transportation, n.d). Federal guidance on lane conversions diffuses such concerns as not problematic in the majority of cases, but local evidence to support or refute such claims is largely nonexistent. The absence of local evidence in combination with public skepticism of federal claims can stall or thwart additional implementation of these safety improvement projects.

The overall objective of this project was to explore community concerns about the impact of road diets in Iowa. The specific aims of this study were to 1) survey EMS responders in Iowa about their perceptions of 4-to-3 lane conversions and 2) examine EMS response times before and after 4-to-3 lane conversions.

Several studies have used quantitative methods to examine 4-to-3 lane conversions from an economic perspective. For example, economic lane conversions studies have found that lane conversions are not expected to harm local economies (McCormick, C., 2012), and an association between lane conversions corridors and increased business sales has been identified (Yu et al., 2018), which may partially be due to increased bike accessibility (Rowe, 2013). However, there is a lack of quantitative studies that have examined the relationship between 4-to-3 lane conversions and emergency responses. Some studies have been conducted to understand the public's perceptions of 4-to-3 lane conversions (US Department of Transportation, 2010; Vergis & Niemeier, 2017; Rosales, 2007) but have not considered the perceptions or impact of these conversions on emergency responders. The U.S. Department of Transportation Federal Highway Administration conducted case studies for two New Jersey communities and found that emergency response was safer and easier after 4-to-3 lane conversions (FHWA, 2017). However, it is unclear if those conclusions were based on quantitative analyses or responder perceptions. The determinants of EMS response times have been studied (e.g. Trowbridge et al., 2009; Griffin & Mcgwin, 2013; Nehme et al. 2016), and a recent study found a relationship between traffic congestion and slowed EMS response time (Brent & Beland, 2020). Yet, to our knowledge, no studies have analyzed the effect of 4-to-3 lane conversion on EMS response times. To our knowledge, this is the first study to survey EMS responders on their perceptions of 4-to-3 lane conversions and to quantify the effect of 4-to-3 lane conversions on emergency response times.

2 AIM 1: EMERGENCY RESPONDER SURVEYS

An emergency responder survey was created to identify perceptions and experiences of emergency responders who interact with lane converted roads. This study provides important context on the person-level interactions of EMS with 4-to-3 lane conversion sites. The survey was reviewed and approved by the University of Iowa Institutional Review Board, and informed consent was obtained from all participants.

2.1 Methods

2.1.1 Survey creation—The creation of the emergency responder survey began with a literature review to better understand the questions and methods used in prior studies related to perception of lane conversions. Many past studies have used survey questions to understand the perceived impacts of lane conversions on community members (U.S. DOT, 2010; Vegis & Niemeier, 2012) including business owners (Skuratowicz et al., 2013; Bohac & Irvine, 2014; Choi et al., 2014, McCormick et al., 2012). Common themes within prior survey designs included asking respondents about their overall impression of the lane conversions effect on the community, as well as how their perception of the lane conversion changed from before to after its implementation. Within the Griffin & Mcgwin (2013) EMS and traffic congestion survey, respondents were questioned about how response times are impacted by differing road characteristics and assisting technologies, how route choice decisions are made under varying circumstances, and how road characteristics impact the ability to maneuver to emergencies.

Questions from prior literature were adapted for use in the current study and additional questions were created, as needed. The final survey included general questions on the perceived influence of lane conversion on emergency responses, as well as more detailed questions about their behavior in the presence of lane conversions (see Appendix A). The survey was conducted online using Qualtrics (Qualtrics, Provo, UT).

2.1.2 Site identification and selection—A series of information gathering steps were undertaken to identify sites in Iowa that had recently been converted from 4 to 3 lanes. First, the study team reviewed a 2017 report from the Iowa DOT titled "Statewide Screening for Potential Lane Reconfiguration" which included lists of already converted sites and candidate sites that might be suitable for 4-to-3 lane conversion (Iowa Department of Transportation, 2017). The Iowa DOT also provided the project team with a rough inventory of known 3-lane roads as of July 2019, a link to their 3-lane roads webpage (Iowa Department of Transportation, n.d.), and a list of known locations for future conversions or sites being considered for conversion. Local and state documents, including Iowa DOT Transportation Improvement Program reports were also searched for completed and upcoming conversion project information.

The study team also sent a web-based survey to all 18 Regional Planning Affiliations (RPAs) and 9 Metropolitan Planning Organizations (MPOs) in the State of Iowa to collect information on past and upcoming lane conversion projects. The response rate was high with 15 (83.3%) RPAs and 7 (77.8%) MPOs completing the survey.

Information for all identified sites was organized into a spreadsheet and included information such as: city name, county, street name, year project was completed, length of converted roadway. Google Street View and Google Earth were used to confirm the current (3-lane) and past (4-lane) roadway configuration and approximate the year in which the conversion occurred. This method worked well for large urban communities, but the imagery was not as reliable for less populous ones. Relevant city, county, and regional engineers or Iowa DOT staff (for state projects) were contacted to gather additional missing details for sites.

Candidate sites had to meet the following inclusion criteria: 1) 4-to-3 lane conversion site (e.g., not 5-to-3 or 2-to-3), 2) minimum converted segment length of at least 0.5 miles, 3) conversion occurred between 2015 and spring 2020. Sufficient information was gathered for 40 sites and 14 sites located in 10 different cities met all inclusion criteria.

2.1.3 Recruitment—In collaboration with personnel from the Iowa Bureau of Trauma and Emergency Services and the State Fire Marshal, survey invitations were distributed to EMS and fire personnel in the 10 communities of interest. Survey invitations were sent to EMS directors and fire chiefs of the primary EMS service providers within the service areas of the 10 communities. In total, survey invitations were sent to nine ambulance service directors, 10 fire department chiefs, and four EMS division chiefs. Chiefs and directors were asked to distribute the survey to all their personnel and follow up contact was made if an agency had low or no responses. Eligible respondents must have reported that they were an emergency responder in the included study community before the year of the road conversion and that they were aware of lane conversion at the relevant site.

2.1.4 Qualitative analysis—The EMS survey included two open-text questions which were analyzed using a qualitative text mining process to identify response themes. The open-text questions asked respondents to explain their reasoning for two questions: (1) "Before the lane conversion(s) happened on {street}, did you think that it would have a positive or negative effect on emergency responses?" and (2) "Now, after the lane conversion(s) on {street}, do you think that it has had a positive or negative effect on emergency responses? Please remember to consider any effects of the lane conversion on emergency response INDEPENDENT of any impacts related to the COVID-19 pandemic."

To prepare the data, "stop words" (e.g., *a*, *an*, *or*, *the*) were removed from survey responses, and then the remaining words were reduced to their stems (e.g., *responding* and *responded* reduced to *respond*). The frequency of each stem was counted for each of the two survey questions. Meaningful combinations of common stems, and some standalone stems, were used to identify the 18 themes outlined in Table 1. After the themes were identified, each open-ended survey question response was classified under one or more of the 18 themes. To ensure consistency in the classification process, theme coding was performed independently by two reviewers. Any differences in classifications were assessed and coded by a third reviewer. Common themes and trends in the responses were explored.

2.2 Results

2.1.1 Participation—The EMS survey received 239 responses. Of the responses, 167 were included in the final analysis. The final sample did not include those who were determined to be ineligible (n=58), and those who did not answer most of the survey questions (n=14). Respondents were deemed ineligible if they did not respond to emergencies in one of the included study areas prior to the year that the lane conversion occurred. Of the 167 responses included in the final sample, 163 (97.6%) had no missing data.

Approximately 60% of responses came from two major cities (Cedar Rapids and Des Moines; Table 2). The majority of respondents (67.7%) reported that they provide both fire and emergency services (Table 3).

2.2.2 Descriptive results—Prior to the lane conversion, 77% of respondents were aware of the planned conversion. Of the EMS respondents who were aware, 46% felt that the planned lane conversion would have a negative or slightly negative effect on emergency responses, while 19% thought that the planned lane conversion would have a positive or slightly positive effect (Table 4). After the lane conversion occurred, 41% of respondents who knew about the lane conversion prior to its development felt that the lane conversion had a negative or slightly negative effect on emergency responses, while 29% felt that the effect had been positive. Lastly, 22% of respondents believed that there had been no effect. In all, a small majority of respondents reported either no effect, or a positive effect.

Given that most respondents originated from Cedar Rapids or Des Moines, we conducted separate analyses for these two cities. An equivalent version of Table 4 for each city can be found in Appendix B. In Cedar Rapids, a majority of respondents (52%) believed there would be no effect prior to the lane conversion. After the lane conversion, respondents were split among opinions, with 28% believing the conversion to have had negative or slightly negative effect, 28% believing there to be no effect, and 36% reporting a positive or slightly positive effect. Conversely, in Des Moines, 41% expected a negative effect prior to the lane conversion. After the lane conversion, still 41% of respondents believed the effect was negative, whereas 37% thought the conversion had no effect, or a positive effect post implementation.

Figure 2 illustrates the shift in respondent opinions before and after the lane conversion. Each horizontal bar denotes the frequency of response types prior to the conversion, while the colors within represent the corresponding frequencies post-conversion based on the initial responses. For instance, initially, 30 respondents anticipated no effect; of these, 19 maintained this view post-conversion, while 4 changed their view to negative. Of the 37 respondents who were not aware of the lane conversion ahead of time, about one third (n = 12) believed that there was no effect, while another third reported negative (n = 9) or slightly negative (n = 3) effects after the conversion. For each “before” response category (excluding “mixed” and “Not aware”), the most common “after” response category remained the same. Of the 42 respondents who reported that prior to the lane conversion they expected it would have a negative effect on emergency responses, 23 respondents reported negative effects afterwards. Similarly, of the 16 respondents who reported expecting the lane conversion to have a positive effect on lane conversions, 11 reported positive effects after. Of the respondents who felt the lane conversion would have a mixed effect (n=13), almost half believed the lane conversion had a slightly positive (n=3) or positive effect (n=3) after the lane conversion installation.

Respondents were asked about their perception of trip time and safety from before the lane conversion to after. Of the 163 responses to this question, half (51%) thought that response times of trips requiring travel on converted lanes stayed the same. One-third (33%) thought that response times became slower and 16% thought they became faster. In terms of driving safety, of the 160 responses, 38% of respondents thought there was no change after the lane conversion, 36% thought that driving became less safe, and 26% thought that driving became safer.

Respondents who indicated that they drive during emergency responses (n = 135) were asked if they prefer or avoid driving on the lane conversion roads when able to choose the route. About half (52%) of respondents reported that they felt neutral about the lane conversion and did not prefer it or avoid it. Only 14% of driver respondents said they avoided the lane conversion, while 34% of driver respondents said they preferred it.

Lastly, respondents were asked if they were in favor of keeping the current lane configuration(s). Of the 161 responses, the results were split almost evenly. Those who favored keeping the current lane configuration accounted for 31% of responses, while 34% of respondents were not in favor of keeping the lane conversion(s), and 27% were neutral.

2.2.3 Qualitative results—

Among those who anticipated a negative impact before the lane conversion, common concerns revolved around potential congestion due to reduced lanes and driver confusion when navigating the new road layout, particularly when encountering an EMS vehicle. Of those who anticipated the lane conversion to have a positive effect on emergency responses, the most common reasons were related to the space created for EMS vehicles through wider lanes and enhanced maneuverability of EMS vehicles within the designated turn lanes.

Individuals who held a favorable perception of the lane conversion post-implementation frequently highlighted the overall improvement in safety and functionality. This sentiment was attributed, in part, to the wider lanes facilitating smoother emergency response navigation and the addition of a center turn lane providing ample space to pass other vehicles. Among respondents with a negative view of the lane conversion post implementation, prevalent concerns were around driver behavior during emergency response events. These respondents felt fewer lanes resulted in drivers blocking the center turn lane, or failing to yield to emergency vehicles, leading to the necessity of frequent maneuvers in and out of the center lane for emergency responders. Examples of qualitative responses for the question on perceptions after the conversion are displayed in Table 5.

3 AIM 2: RETROSPECTIVE EMERGENCY RESPONSE RATE ANALYSIS

The emergency response rate analysis is a quantitative analysis leveraging the use of six years of EMS data to model the change in EMS response rate from before to after the implementation of lane conversions in Cedar Rapids, Iowa. Due to ongoing concerns over the possibility of delayed EMS response rates due to lane conversions, and the lack of evidence one way or another, this analysis uses empirical data and statistical modeling to identify the relationship between lane conversions and EMS response rates in the specified region.

3.1 Methods

3.1.1 Data acquisition & lane conversion site selection—

Data from The National Fire Incident Reporting System (NFIRS) were obtained for the State of Iowa. NFIRS is a voluntary, all-incident reporting system that captures a range of incident types (e.g., fires, explosions, rescue and medical services, hazardous conditions, etc). (U.S. Fire Administration, 2021). The NFIRS format includes incident addresses, alarm and incident arrival times, and responding fire station IDs for all emergency calls. Of the 10 Iowa communities with lane conversion sites that were included in the survey study, 9 were found to not have at least one year of pre or post lane conversion data available through NFIRS, or had substantial missing data (e.g., some whole months of data missing). The remaining community was Cedar Rapids, for which four lane conversion sites had been identified for the EMS responder survey. Due to inconsistencies in the public NFIRS dataset, the final data for this study were provided by the Cedar Rapids Fire Department and includes a subset of data from the National Fire Incident Reporting Systems (NFIRS) for Cedar Rapids, Iowa, 2014–2020. Lastly, spatial data were obtained, which included city and state boundaries

(State of Iowa, 2020), Linn County fire station locations (Linn County, 2020), and The Iowa Road Network Shapefile (Iowa Department of Transportation, 2020).

Another lane conversion site in Cedar Rapids, which was previously excluded because it was 0.4 miles in length, less than the threshold of 0.5 miles for the Aim 1 survey, was added to the analysis. Subsequently, one of the original Cedar Rapids sites (1st St SW) did not have adequate observations and had to be excluded. In total, there were four road conversion sites from Cedar Rapids considered in the analysis (Figure 3).

3.1.2 Data reduction and processing—The NFIRS data were filtered to only include fires, overpressure ruptures, explosions, overheat-no fires, and rescue and EMS calls, as these incidents require a fast response where lights and sirens would be activated.

The ArcGIS Geocode Address Tool (Esri, 2021) was used to map addresses and address street corner information from the reduced NFIRS dataset. Twenty-eight geocoded addresses were removed because they were only accurate at the zip code level, street name level, or point of interest level. Next the incident data were restricted to those where the response was from personnel stationed in one of the fire districts with a lane conversion. The incident data did not include information on the route taken to the incident or the trip origin, so it was assumed that the responders took the shortest route from the corresponding fire station to the incident location, which was calculated using the ArcGIS Pro Closest Facility tool.

Response time was calculated using alarm time and arrival time and ranged from two to 21 minutes. After consulting with the Cedar Rapids Fire Department, it was confirmed that this time range is typical for trips that start at the fire station, whereas any trip under two minutes would typically occur when emergency responders were already in the field, and any trip above 21 minutes would likely be an error.

Because exact travel time on the road (from dispatch of emergency vehicle to arrival at site) was not available from the data, response time was defined as time from the initial alarm to arrival at the incident site. The Cedar Rapids Fire Department confirmed that the time from alarm to dispatch is consistent enough to reasonably assume a negligible impact on the study results. Therefore, the relationship between emergency response rate and the variables of interest can still be indirectly observed.

The selected lane conversion sites were imported to the map. The ArcGIS Pro Intersect tool was used to locate trips which traversed on the lane conversion sites, as well as to indicate how much of the trip took place on the sites. Trips that did not traverse the sites, including those that only crossed over the sites were removed.

Trips were exported and an indicator variable was added to specify the lane conversion(s) driven on, as well as the length and the percentage of the trip on the lane conversion. For those trips which included multiple lane conversions, the length and percentage of trip were summed across conversions. An indicator was added to specify whether the trip took place before or after the lane conversion. Trips that occurred during the calendar year of the lane conversion were excluded. Lastly, all trip files were combined and merged with roadway characteristics and other relevant trip characteristics.

Relevant trip characteristics included weighted number of lanes, weighted average annual daily traffic (AADT), weighted speed limit, weighted number of traffic signals, season, and time of day. Season was a binary variable differentiating winter (i.e., December, January, and February) from non-winter. Peak traffic was a binary variable differentiating peak (i.e., 7:30–8:30 am and 11:30 am-6:30 pm) from off-peak trips. Peaks were identified by analyzing the daily crash frequency data in Cedar Rapids, IA.

Weighted number of lanes, weighted speed limit, and weighted AADT were created from non-weighted versions of the variables which were provided in the Iowa Road Network Shapefile. The Iowa Road Network Shapefile was split into 10-meter increments and spatially joined to the trips. 10-meter road segments that appeared no more than twice within a given trip were removed as they were assumed to be side streets which were not associated with the trip. The relevant trip characteristics were averaged across all 10-meter segments for each trip and the weighted variables were merged into the full dataset by trip ID.

3.1.3 Statistical analysis—

A generalized linear model was constructed to characterize the effect of lane conversion status on emergency response rates. The outcome variable was defined as the emergency response time (in minutes). A Poisson distribution was specified for the distribution of the count outcome, and a log link function was employed to relate the mean outcome to the explanatory factors. The model featured the log of the emergency response distance (in kilometers) as an offset variable. Thus, the outcome could effectively be conceptualized as an emergency response rate, quantified as minutes per kilometer traveled. A lower value corresponds to a faster response rate.

In pursuit of the best fitting model specification for emergency response rate and lane conversion status while controlling for the potential confounders, variable selection was performed. The initial stage of model selection employed a stepwise backward elimination algorithm using the Akaike Information Criterion (AIC). Lane conversion status was explicitly retained throughout this process as the primary exposure variable of interest. Additionally, a substantial correlation was observed between the covariates weighted AADT and weighted speed limit. Upon further examination, weighted speed limit was found to have greater explanatory power than weighted AADT: when entered in separate models, the former yielded a lower value of AIC and was associated with a higher partial test statistic. Hence, weighted speed limit was retained and weighted AADT was excluded.

As an alternative to the Poisson distribution, comparable generalized linear models were considered based on the negative binomial distribution, which would account for possible overdispersion in the response times. However, modeling results based on the two distributions were remarkably similar. The estimate of the negative binomial dispersion parameter was close to zero, and AIC favored the simpler Poisson models.

3.2 Results

3.2.1 Characteristics of emergency response trips—

Of the 3,872 emergency response trips used in the analysis, 61% were associated with Wiley Blvd, 18% with Johnson Avenue, 13% with 42nd Street, and 7% with Mt Vernon Rd (Table 6). Wiley Blvd was the most frequently traveled because a fire station is located on this road segment.

There are more after conversion observed trips for most lane conversion sites. However, the Mt. Vernon Rd. conversion site has fewer after conversion trips. It is also important to note that 42nd St. had far less before conversion trips. The proportional distribution across categorical variables is comparable for trips occurring before and after lane conversions. However, the dataset shows a larger proportion of trips in the winter for trips occurring after the lane conversion. All quantitative variables in the dataset (e.g. traffic signals, number of lanes), including response rate, are comparable between observations occurring before and after lane conversions.

3.2.2 Association between lane conversions and emergency response rate—

Two final standard fixed effects generalized linear models were considered: a best-fitting model where all fixed effects were additive, and a comparable model with a two-way interaction between road segment and lane conversion status. The model with the interaction terms provided adjusted estimates of emergency response rates before and after the lane conversion, while accounting for other individual differences between the segment locations, which provided meaningful local context. However, based on AIC, the inclusion of the interaction did not substantially improve the model fit, and therefore, the model without the interaction terms was used for the reporting of the results displayed in Table 7.

Comparison of emergency response rates before and after the lane conversion, produced by the two-way interaction model, show similar results for each road segment (Figure 4). For three of the four segments, there were negligible differences in response rate before and after the lane conversion. There is a distinctly large decrease in the response rate (i.e. faster response) for trips on 42nd St. after the lane conversion compared to before. This, and the stark difference in the size of the error bars, may be due to the relatively small number of observations for 42nd St. prior to lane conversion. The small number of observations leads to a larger standard error for the estimate of the associated interaction term, and results in a point estimate which is governed by only 14 recorded observations. However, outlier and influence diagnostics were investigated to verify that no single observation had undue influence on the estimate.

The final fixed effects model is presented in Table 7. The rate ratio is obtained by applying the exponential function to the Poisson output parameter. It can be interpreted as a factor change in the response rate given a one-unit increase, or with the inclusion of, an independent variable, while holding all other variables constant. For example, before the lane conversion, the response rate (minutes per kilometer) is expected to be 1.024 times greater than after, when holding all other variables constant. If the Wald confidence interval passes through one, then the coefficient can be considered not statistically significant. The Wald 95% confidence interval for lane conversion status spans from 0.922 to 1.056 and is not statistically significant.

In the final fixed effects model, there was insufficient evidence to conclude that lane conversion status (before vs after) had an impact on emergency response rates. Season, weighted number of lanes, weighted speed limit, percentage of trip on converted segment, number of traffic signals, peak traffic, and an indicator variable for conversion site all were retained in the model as potential confounders and improved model fit.

4 DISCUSSION

Results of the quantitative analysis on emergency response rates indicated negligible differences in emergency response rates from before to after the implementation of the 4-to-3 lane conversions in the study area, after adjusting for possible confounding factors. Thus far, studies on 4-to-3 lane conversions have been focused on business impacts, public perceptions, and overall traffic flow. To our knowledge, this is the first study to use a quantitative method to analyze the impact of 4-to-3 lane conversions on emergency responses. The quantitative results presented here were also consistent with response time perceptions from EMS responders, as over half of respondents believed that the lane conversion had no effect, or a positive effect, on emergency response times.

Perceptions of the effect of the lane conversions on emergency responses were polarized and varied by city. Overall, more than half of respondents believed that the lane conversion had no effect, or a positive effect on emergency responses. Also, 58% of respondents were either in favor of or felt neutral about keeping the lane conversion. However, a negative perception of the lane conversion was common throughout the survey, both before and after the lane conversion, accounting for approximately 40% of responses. Interestingly, opinions about the lane conversion from before to after tended to be consistent. Most respondents who felt negatively or positively towards the effect of lane conversions on emergency responses prior to its implementation had the same perception afterwards.

In general, new infrastructure is often met with some level of community resistance (Swann et al., 2019), and opinions of the projects can be difficult to sway. In fact, a group of researchers coined the term ‘bikelash’ in describing the common phenomenon of community resistance to new bike lanes (Wild et al., 2016). Local concerns over infrastructure plans can block safety interventions from being developed. Inferring from these results, it may be beneficial to have public discourse on the benefits of road diets prior to their implementation to properly influence post-implementation perception. This may involve educating citizens on the impacts and benefits of road diets and receiving their feedback.

Although opinions regarding the overall effect of the lane conversions on emergency responses were somewhat polarized, this had little influence on the actual usage of these roads for emergency responses. Only a small number of respondents (14%) reported avoiding the lane conversion sites during emergency response trips, and 34% of respondents preferred to use the converted roads.

Emergency responders who perceived the lane conversion negatively seemed to be most concerned with the lack of appropriate driver behavior on 3-lane roads during emergency response trips. These results suggest that educating drivers on the appropriate ways to yield on 3-lane roads in the presence of emergency response vehicles may be beneficial. More specifically, this provides an opportunity to educate drivers that the middle lane is not an appropriate place to stop. This issue is not just specific to lane conversions and has been revealed through other studies. In fact, in an emergency responder survey not specific to lane conversions, 95.3% of emergency responders agreed public education on how to react to emergency response vehicles would decrease response time (Griffin & McGwin, 2013).

This analysis found no difference in emergency response rates resulting from 4-to-3 lane conversions on four segments in Cedar Rapids, Iowa. Survey analyses indicated that over half of respondents felt that the lane conversions have had no effect or a positive effect on emergency response trips. However, around 40% of respondents felt that the lane conversions have had a negative or slightly negative effect on emergency response trips. Additional analyses suggested that these negative perceptions of lane conversions may come from prior misconceptions of lane conversions or poor driver behavior due to lack of education on how to yield to emergency responders on 3-lane roads. These issues can be avoided through public education on 4-to-3 lane conversions. Planners and community stakeholders should be proactive in sharing relevant information on road diets and responding to concerns prior to implementation.

4.1 Limitations

While the results of this study provide insight for the state of Iowa and a sound methodology for future lane conversion (or other roadway modification) analyses, results of this analysis were limited. The survey was retrospective, so recall bias may lead to inaccurate information on how respondents felt about the lane conversion prior to its implementation. Also, the survey was voluntary, so those with stronger feelings towards the lane conversion may have been more likely to answer the survey. Further, some of the communities surveyed had a low response rate and volunteer EMS providers were not well represented in the survey. The emergency response rate analysis was limited to one city and the analysis did not compare emergency response rates on non-converted segments. Lastly, we lacked access to additional roadway characteristics data that could have benefited our model (i.e. changes over time in probe travel data, granular traffic volume data, and land use). However, our familiarity with local context, and conversations with local officials led us to believe that these factors likely would not significantly influence our results. Due to these limitations, caution should be taken in generalization of our results beyond the area of analysis.

5 CONCLUSIONS

The findings from this study provide local evidence to refute claims on changes in emergency response rates after the implementation of 4-to-3 lane conversions in Cedar Rapids, Iowa. The results of this study also provide important context for Iowa communities regarding EMS perceptions of 4-to-3 lane conversions and illuminate the need for community education on 4-to-3 lane conversions (e.g., how to properly yield to emergency vehicles, pre-implementation communication of safety benefits), which can lead to safer EMS transfers and general acceptance of roadway conversions from the community.

However, public concerns regarding lane conversions go beyond Iowa borders. In fact, road diets have been rolled back across the country due to local concerns and pushback for a variety of cited reasons, mostly pertaining to the effects of traffic congestion and its repercussions. Due to the differences in traffic patterns and the built environment throughout the U.S., future work should be done either locally in other regions or on a nation-wide scale to investigate the impacts of road diets on traffic congestion and its consequential effects, such as delays in emergency response times. Road diets provide a promising solution to mitigate crashes, which would likely benefit numerous communities. Yet, to fully harness the potential of road diets, it's crucial to demonstrate evidence-based impacts – whether positive, negative, or neutral – as demonstrated in our study, especially as local communities persistently push back.

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Appendix A

Which community do you provide emergency response for most of the time? (drop down options)

What types of services do you personally provide in {city}? Check all that apply.

- Fire
- Ems
- Other

Near which of the segments shown in the map do you respond to calls most often?

- Mormon Trek Blvd
- S 1st St.
- Neither of these areas

Near which of the segments shown in the map do you provide emergency response most often?

- Johnson Ave NW and Wiley Blvd SW
- 1st St SW
- 42nd St NE
- N Center Point Rd. in Hiawatha
- None of these areas

Were you an emergency responder (regardless of agency) in {city} prior to {year of conversion}?

- Yes
- No

Lane conversions are the reconfiguration of a roadway, often from 4 lanes to 3 lanes, as shown in the graphic. They are also sometimes called “road diets.”

Are you aware of the lane conversion(s) on {street}?

- Yes
- No

Before the lane conversion(s) happened on {street}, did you think that it would have a positive or negative effect on emergency responses?

- Positive
- Slightly positive
- No effect
- Slightly negative
- Negative
- Mixed (both positive and negative)
- I was not aware of the planned lane conversion before it happened

Please explain your answer to the previous question: (written response)

Now, after the lane conversion(s) on {street}, do you think that it has had a positive or negative effect on emergency responses? Please remember to consider any effects of the lane conversion on emergency response INDEPENDENT of any impacts related to the COVID-19 pandemic

- Positive
- Slightly positive
- No effect
- Slightly negative
- Negative
- Mixed (both positive and negative)

Please explain your answer to the previous question: (written response)

Compared to before the lane conversion(s), and independent of any impacts related to the COVID-19 pandemic, do you think the response time of calls that require travel on {street} are...

- Faster
- Slightly faster
- The same

- Slightly slower
- Slower

Why do you think response times have become faster on trips that require travel on {street}? Check all that apply.

- Decreased traffic congestion
- Drivers are better at yielding to emergency vehicles with the new roadway configuration
- Ability to pass/travel in the center turn lane with lights and sirens
- Other road user behavior (please explain)
- Other reasons (please list)

Why do you think response times have become slower on trips that require travel on {street}? Check all that apply.

- Increased traffic congestion
- Drivers do not properly yield to emergency vehicles with the new roadway configuration
- Other road user behavior (please explain)
- Other reasons (please list)

How often are you the driver during emergency response trips? (scale from 0–100%)

Compared to before the lane conversion, and independent of any impacts related to the COVID-19 pandemic, do you think driving on {street} during an emergency response is more or less safe now?

- More safe
- Slightly more safe
- No change
- Slightly less safe
- Less safe

Please explain you answer to the previous question: (written response)

When you have a choice in route as the driver, do you prefer or avoid traveling on {street} during emergency response?

- Prefer
- Slightly prefer
- Neutral
- Slightly avoid

- Avoid

Considering the impacts to your emergency response travel, are you in favor of keeping the current lane configuration(s) on {street}?

- I strongly agree with keeping the current lane configuration
- I somewhat agree with keeping the current lane configuration
- I am neutral or have no opinion about keeping the current lane configuration
- I somewhat disagree with keeping the current lane configuration
- I strongly disagree with keeping the current lane configuration
- Other (written response)

Are you a paid or volunteer responder? (If you are sometimes paid and sometimes volunteer, select the option that reflects your status most of the time in {city}.

- Paid, career
- Paid, per call
- Volunteer

Compared to before the lane conversion(s), and independent of any impacts related to the COVID-19 pandemic, do you think your response time when traveling in your personal vehicle on {street} either to the station or directly to the scene (if applicable) is now:

- Faster
- The same
- Slower
- I don’t know
- Not applicable- I don’t use my personal vehicle to respond to calls

Please share any other thoughts you have about the conversion of streets from 4 to 3 lanes: (written response)

Appendix B

Table B1.

Survey responses to lane conversion impact questions in Cedar Rapids (N=38)

Response	Before the lane conversion(s) happened on [Street], did you think that it would have a positive or negative effect on emergency responses?	Now, after the lane conversion(s) on [Street], do you think that it has had a positive or negative effect on emergency responses?
Negative	16%	20%
Slightly negative	8%	8%
No effect	52%	28%

Response	Before the lane conversion(s) happened on [Street], did you think that it would have a positive or negative effect on emergency responses?	Now, after the lane conversion(s) on [Street], do you think that it has had a positive or negative effect on emergency responses?
Mixed (both positive and negative)	12%	8%
Slightly positive	8%	24%
Positive	4%	12%

Table B2.

Survey responses to lane conversion impact questions in Des Moines (N=58)

Response	Before the lane conversion(s) happened on [Street], did you think that it would have a positive or negative effect on emergency responses?	Now, after the lane conversion(s) on [Street], do you think that it has had a positive or negative effect on emergency responses?
Negative	41%	41%
Slightly negative	13%	15%
No effect	15%	15%
Mixed (both positive and negative)	11%	7%
Slightly positive	9%	9%
Positive	11%	13%

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Figure 1.
4-to-3 lane conversion example[1]

[1]Used with permission © Iowa Department of Transportation

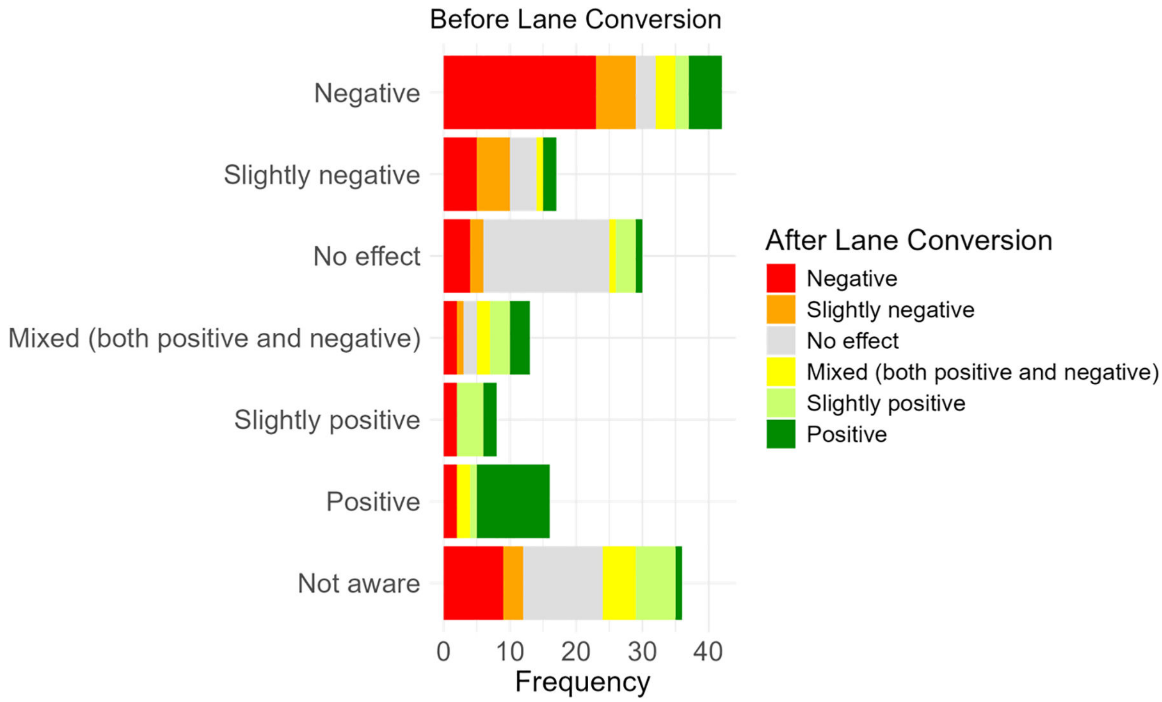

Figure 2.

Change in overall opinion for survey responders from before to after lane conversion

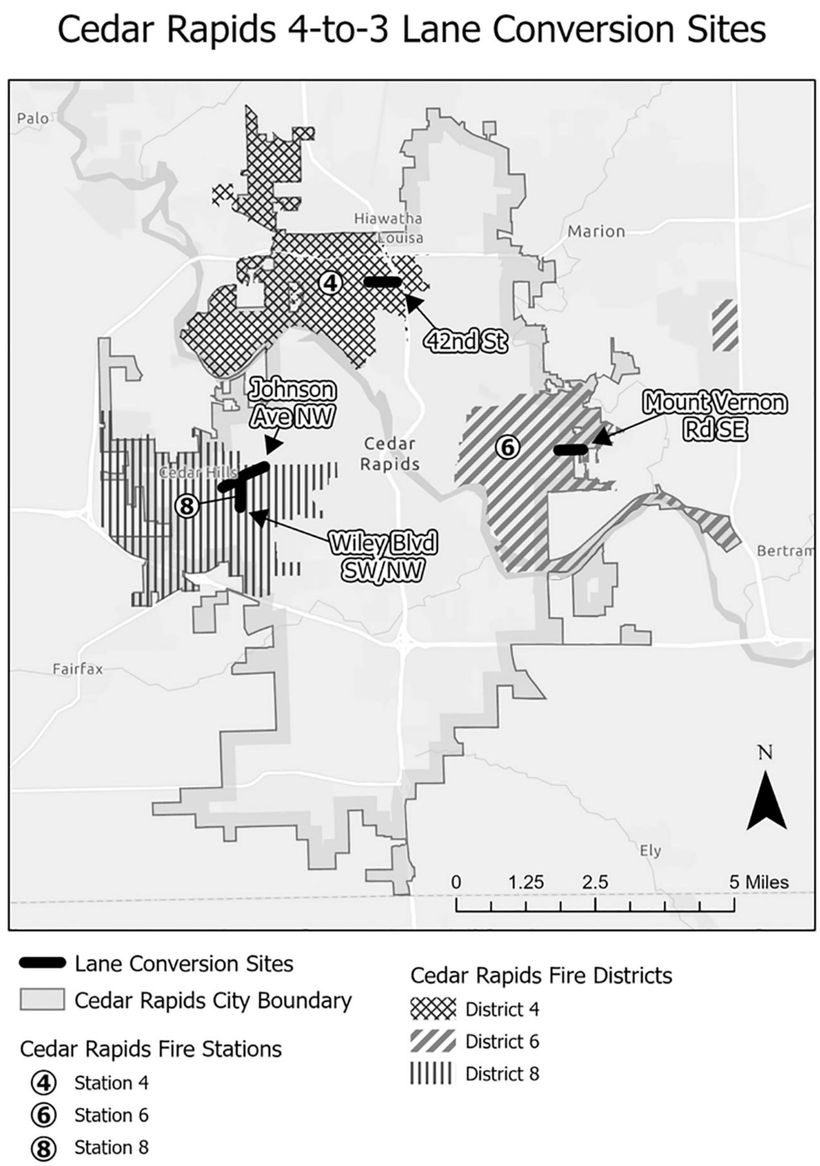

Figure 3.

Map of 4-to-3 lane conversions, fire stations, and fire districts in Cedar Rapids that were included in the analysis

Figure 4.
Emergency response travel rate (min/km) before vs. after road conversion by road segment

Table 1.

Themes used for classification of open response questions

Driver confusion	Parking
Blocked turn lane	Slower traffic
Fail to yield or move	Slower EMS response
Bike	Safer/better
Roundabout[2]	Desire more lanes
Limited/less space	More dangerous
Peak traffic congestion	Dislike, not otherwise classified
Oncoming traffic	Approval, not otherwise classified
Construction	Neutral, not otherwise classified

[2]A roundabout theme was included because a roundabout was added to Johnson Ave NW at the same time as the lane conversion, which respondents occasionally referenced in their responses

Table 2.

Survey respondents by lane conversion site[3]

Community	Site	Site Frequency	Total (N=167)	% of Total
Ames	S 3rd St	15	15	9.0%
Cedar Rapids	Johnson Ave NW and Wiley Blvd SW	8	38	22.8%
	42nd St NE	8		
	1st St SW	22		
Des Moines	University Ave	58	58	34.7%
Fort Dodge	S 29th St; S 25th St	6	6	3.5%
Hiawatha	N Center Point Rd	9	9	5.4%
Iowa City	S 1st Ave	4	10	6.0%
	Mormon Trek Blvd	6		
Mason City	N Federal Ave/US 65	20	20	12.0%
Sioux City	W 7th St	7	7	4.2%
Waukon	Rossville Rd	2	2	1.2%
Waverly	Bremer Ave/IA 3	2	2	1.2%

[3]Johnson Ave and Wiley Blvd lane conversion sites were combined in Table 2 because the two streets intersect, and the fire station is on Wiley Blvd, so it is common to drive on both

Table 3.

Emergency response survey responder personnel type distribution

Types of Personnel	N	%
Fire Only	27	16.2%
EMS Only	10	6.0%
Fire and EMS	113	67.7%
Fire, EMS, and Other	16	9.6%
Fire and Other	1	0.6%
Total	167	100%

Table 4.

Survey responses to lane conversion impact questions

Response	Before the lane conversion(s) happened on [Street], did you think that it would have a positive or negative effect on emergency responses?	Now, after the lane conversion(s) on [Street], do you think that it has had a positive or negative effect on emergency responses?
Negative	33%	30%
Slightly negative	13%	11%
No effect	24%	22%
Mixed (both positive and negative)	10%	7%
Slightly positive	6%	10%
Positive	13%	19%

Table 5.

Example quotes for each theme[4]

Theme	Example Quote[5]	Response type of example quote
Driver confusion	“Drivers are confused when we are approaching with lights and sirens, somtimes going to the middle lane or dart to the other side even when we are in the middle lane.”	Negative
Blocked turn lane	“Vehicles stay in the center turn lane more often than pulling to the curb”	Slightly negative
Fail to yield or move over	“Ppl still don’t get out of the way.”	Mixed (both positive and negative)
Bike	“It seems as though the vehicles are now using the bike lane to pull over to the side of the road and there usually isnt any traffic in those lanes so it gives them a place to move over safely to”	Positive
Roundabout	“the round a bout slows us down considerably”	Slightly negative
Limited/less space	“Less room for people to pull over when traveling the same direction”	Negative
Peak traffic congestion	“Traffic is congested & forces drivers to weave in & out of traffic. Creating more opportunities for accidents.”	Negative
Oncoming traffic	“Now may have to go into oncoming traffic if someone is turning or the turning car is the opposing traffic flow”	Negative
Construction	“in the short term while construction was under way it significantly slowed our response through the area.”	Slightly positive
Parking	“ …bicycles and parked cars still have a priority…”	Negative
Slower traffic	“Traffic flow has slowed due to complacent drivers traveling at below normal speeds holding back traffic flow. Previously with multiple lanes, this could be mitigated by having an extra lane to pass.”	No Response Selected
Slower EMS response	“increase in response time due to more stopping/starting”	Slightly negative
Safer/better	“Ability to pass in the turning lane or the ability to strattle both lanes if needed”	Slightly positive
Desire more lanes	“Reduction in lanes leads to more difficulty maneuvering fire engines and ambulances”	Negative
More dangerous	“The reality is that there is always someone occupying space within the east bound, west bound and turning lanes making it more dangerous”	Mixed (both positive and negative)
Dislike, not otherwise classified	“Still trying to guess what drivers are going to do.”	Slightly negative
Neutral, not otherwise classified	“I don’t think it’s had any effect.”	No effect
Approval, not otherwise classified	“Traffic seems to be unaffected and flows well. There is still plenty of room for vehicle to move out of the way.”	Positive

[4]Some example responses we’re coded under multiple themes

[5]Responses are shown as typed.

Table 6.

Characteristics of emergency response trips

	Before Conversion		After Conversion	
	N	**%**	**N**	**%**
Total (N=3867)	**1202**	**100%**	**2665**	**100%**
Lane Conversion Site				
42nd St.	14	1.16	493	18.50
Johnson Ave	238	19.80	490	18.39
Mt Vernon Rd.	175	14.56	94	3.53
Wiley Blvd	775	64.48	1588	59.59
Peak Traffic				
Off-Peak	650	54.08	1450	54.41
Peak	552	45.92	1215	45.59
Season				
Not Winter	1035	86.11	2034	76.32
Winter (Dec, Jan, Feb)	167	13.89	631	23.68
Weekend				
Not Weekend	872	72.55	1934	72.57
Weekend	330	27.45	731	27.43
	Mean (Median)	**SD (IQR)**	**Mean (Median)**	**SD (IQR)**
Traffic Signals	2.42 (3.00)	1.71 (3.00)	2.38 (3.00)	1.74 (3.00)
% of trip on converted site	20.77 (15.21)	17.40 (18.70)	19.99 (15.57)	16.13 (16.53)
Number of Lanes (weighted)	3.43 (3.63)	0.83 (1.51)	3.25 (3.29)	0.79 (1.52)
Speed Limit (weighted)	33.46 (34.14)	5.15 (6.32)	33.18 (32.36)	5.83 (6.61)
AADT (weighted)	9648.79 (10361.71)	4401.10 (7416.73)	8621.63 (9134.82)	3732.89 (5645.61)
Trip Distance (km)	2.01 (1.88)	1.10 (1.44)	2.16 (2.08)	1.21 (1.61)
Response Rate (min/km)	5.35 (5.00)	1.73 (2.00)	5.43 (5.00)	1.93 (2.00)

Table 7.

Generalized linear modeling results for lane conversion and emergency response travel rate

Parameter	Rate Ratio	Wald 95% Confidence Interval
Lane Conversion Status		
Before	1.024	(0.992, 1.056)
After (Reference)		
Season		
Not Winter	0.969	(0.937, 1.002)
Winter (Reference)		
Number of Lanes (weighted)	*1.027*	*(0.999, 1.055)*
Speed Limit (weighted)	*0.981*	*(0.978, 0.984)*
Percentage of trip on converted segment	*1.009*	*(1.008, 1.010)*
Traffic Signals (number)	*0.836*	*(0.826, 0.847)*
Traffic		
Off-Peak	*1.037*	*(1.009, 1.066)*
Peak (Reference)		
Lane Conversion Site		
42nd St.	*0.760*	*(0.722, 0.800)*
Johnson Ave	*0.744*	*(0.708, 0.781)*
Mt Vernon Rd.	*0.889*	*(0.838, 0.942)*
Wiley Blvd (Reference)		