Safety Consequences from Design Exceptions

Stamatiadis Nikiforos, PhD, PE
Professor – University of Kentucky

Agent, Kenneth, PE
Research Engineer– Kentucky Transportation Center

Pigman Jerry, PE
Research Engineer– Kentucky Transportation Center

SYNOPSIS

Design exceptions are used in roadway projects that require design elements that vary form typical designs. There have been concerns raised regarding the safety implications of the use of lower than typical design values. This study summarized past design exceptions in Kentucky to document their frequency and reason for their use and evaluate possible safety consequences from these exceptions. A site visit was made to the project and available crash data were obtained at these locations. There was an average of 39 design exceptions per year for the 1993 to 1998 period. The majority of the projects involved a bridge replacement with the next most frequent being roadway widening reconstruction projects and construction of turning lanes. The most common design exception was for a design speed lower than the posted speed limit followed by a reduction in sight distance, curve radius, or shoulder width. The crash analysis showed that, with a very few exceptions, use of the design exception process did not have any negative effects on highway safety. The analysis showed that the design exception projects resulted in an improvement over the prior condition although some aspect of the design may not be typical. The reasons for the design exceptions have been well documented, and there is no evidence that construction of projects with a design exception had an adverse effect on highway safety. The data here indicate that the implementation of this process does not affect negatively the safety level of the roadway. On the contrary, most sites showed a lower crash rate after the construction. However, it should be pointed out that this could be partially attributed to the fact that the constructed site has improved significantly and the use of lower design values for some geometric elements have not affected negatively the roadway safety. The study indicates that the concerns regarding potential safety issues are not supported. The design exception is a useful tool that designers should be encouraged to use, since at minimum it provides a reasonable documentation process for design choices made for a roadway project

Safety Consequences from Design Exceptions

INTRODUCTION

The basic premise of a properly designed roadway is the consideration of mobility and safety issues while addressing its natural and human environmental aspects. To achieve such a balance, trade offs among these factors are needed and are routinely performed either explicitly or implicitly. The AASHTO publication titled AA Policy on Geometric Design of Highways and Streets@ (commonly referred to as the Green Book) provides guidance to the designer by referencing a recommended range of values for critical dimensions for the design of new alignments and those undergoing major reconstruction (AASHTO, 1994). These guidelines permit sufficient flexibility to encourage independent designs for specific situations and should not be considered as standards. Considering flexibility as part of the geometric aspects of roadways is not a new concept, since it has been stated clearly in the Green Book since its first edition. However, many designers have viewed the suggested values of the Green Book as rigid standards instead of guidelines to be used in roadway design to achieve a reasonable degree of flexibility based on the roadway surroundings. Moreover, the Green Book indicates that the referenced guidelines provide a safe, comfortable, and aesthetically pleasing roadway.

An emphasis has been placed recently on the existing flexibility in design guidelines and the use of creative design in addressing the site-specific project needs has been encouraged. This philosophy was coined in the U.S. as Context Sensitive Design (CSD) and represents an approach where a balance is sought between safety and mobility needs within the community interests. Both the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) recognize the flexibility that exists in the current design guidelines, while acknowledging that the current focus on providing high levels of mobility may conflict with some interests of the community. The use of multi-disciplinary teams and public involvement at the appropriate stages of the project are also aspects that promote CSD application. There is an increasing awareness of these CSD issues within the highway community through research and workshops. There is also a desire among the highway design community to improve and enhance established highway design practices and address the community interest elements. However, the current emphasis in CSD has created concern regarding the potential decrease of safety which may result from designing various features along roadways to accommodate community interests.

The concept of guidelines was emphasized even more in the Flexibility in Highway Design guide (1997), a recent publication by the US Department of Transportation, and it will be further stressed in an upcoming publication from AASHTO on the same topic. These publications attempt to reinforce the concept of guidelines and eliminate the notion that the highest values of the Green Book have to be firmly applied irrespective of the project characteristics and requirements. Such an approach typically leads to roadways that put less emphasis on the impact of the design on the human and natural environment and create wide swaths of pavement cutting through communities and natural resources. This approach has been typically justified by stating that it results in a design with increased safety but this may not always be the case. A critical review of design guidelines by Hauer (2000) stated that several design guidelines are based on empirical data from several decades ago but some have not been validated through research. Also, research has demonstrated that for other guidelines values lower than those suggested in the Green Book will work well to achieve flexibility in design while balancing the concerns of safety and capacity. The CSD approach encourages the designer to use creative design and move away form the Atypical cross section@ concept, where a standard template is used. There are often conflicting elements in a design and a designer is called upon to develop a solution that will balance several of these elements by designing a roadway non conforming to the full values used up to that point. In instances where such deviations are implemented, design exceptions are applied to document and support the decision process. These documents should be viewed as an integral part of the design process, since there is a greater need today to balance the various roadway elements and deliver a product that is acceptable by the community and does not impact negatively the environment.

The design exception process allows for adjusting almost every aspect of the geometric design and may require both state and federal approval. A nationwide survey showed that 32 of 34 states responding have a design exception process in place. Like several other states, Kentucky has a formal procedure to document the request and approval of a design exception. The documentation materials include: a description of the project, the design criteria, a description of the exception requested, and the reason for requesting the exception. A critical issue for the use of design exceptions has been their impact on safety. The notion of using values lower than typical in various design elements has been viewed as a compromise to safety. Therefore, there is a need to study the relationship between safety and design exceptions and determine whether there are any safety issues. A study was initiated in Kentucky that had as objectives to: a) summarize past design exceptions by documenting their frequency and reason for their use and b) determine any safety implications stemming from adopting design policies and practices related to design exceptions.

METHODOLOGY

The Kentucky Transportation Cabinet maintains a file for each design exception. The amount of information related to any specific exception varies from only the Design Executive Summary form to fairly detailed background information. The design exception file for each case for the 1993 to 2000 period was obtained and reviewed. The data contained in the file were summarized to allow for classifying the design exception by various categories including types of project, exceptions requested, and the reasons for the exceptions requested.

An analysis of crash data was undertaken to determine the potential safety consequences of these design exceptions. Available crash data were obtained at these locations. Where possible, the dates of construction were obtained to accurately determine the before and after periods. Crash data were analyzed to determine the effect the design exception had on the crash history at the construction location. Some types of projects involved a complete reconstruction of the roadway that included more lanes. Such projects improved the safety of the roadway significantly and thus, it will be difficult to determine what the impacts of the design exception were. To address this problem, two different procedures were used in the crash analysis: 1) for roads where the number of lanes did not change, a before and after comparison was performed; and 2) for other roads, a comparison of the location crash history to the statewide average for that type of road was performed. Sites visits were completed to several locations to better understand the context and rationale for the design exception.

RESULTS

Number of Design Exceptions

The annual numbers of design exceptions from 1993 through 2000 are summarized in Table 1. The categories provided in Table 1 are according to the general type of project provided in the project description of the Design Executive Summary form. There were 319 design exceptions during the eight-year period considered. This represents an average of 40 per year with a range of from 24 in 1993 to 55 in 1998. The majority of the projects (57 percent) involved a bridge replacement. Second most common were roadway widening reconstruction projects (13 percent) followed by construction of a turning lane (9 percent).

The location of the design exception (county and route) was also examined to determine if there is any relationship between the frequency of design exceptions and functional class. This examination showed that 53 percent of the design exceptions occurred on a state route, followed by 28 percent on a non-state maintained route, 16 percent on a federal (US) route, and 4 percent on interstates. The projects which were not on a state maintained route were typically a bridge replacement. Design exceptions were used in 96 counties which represents 80 percent of Kentucky=s 120 counties. The counties with the largest number of design exceptions were Jefferson (24), Pike (12), and Scott (9). Jefferson County is predominantly urban and this may explain the large number of exceptions. On the other hand, Pike County is a rural mostly mountainous county, where design exceptions may have been used to fit a roadway through the terrain and thus require adjustment of design values. Scott County represents an area characterized by rapid economic development and numerous road construction projects which may explain the relatively high number of design exceptions.

Table 1 Type of project for design exception by year

Description	Year								Total
	1993	1994	1995	1996	1997	1998	1999	2000	
Bridge Replacement	14	26	27	40	27	29	9	14	186
Widening/Reconstruction	1	7	2	8	4	6	6	8	42
Turning Lanes	5	3	3	0	6	8	2	2	29
Alignment	1	0	1	1	1	2	5	0	11
Relocation/New Construction	0	0	1	0	1	3	5	1	11
Intersection (general)	1	2	1	1	0	1	2	2	10
Pavement Rehabilitation	0	3	3	1	0	2	0	1	10
Raise Roadway Elevation	1	0	0	0	0	3	1	0	5
Sight Distance	1	0	0	1	1	1	1	0	5
Slide/Rock Fall	0	1	1	0	0	0	1	2	5
Spot Reconstruction	0	1	0	0	1	0	0	1	3
Other	0	1	0	1	0	0	0	0	2
All	24	44	39	53	41	55	32	31	319

Type of Design Exception Requested

A comparison of the elements of design exception requested indicates that there was an average of 1.8 elements for each project (Table2). The most common design element was to use a design speed lower than the posted speed limit (34 percent). The next elements were reduction in the minimum sight distance (12 percent), minimum curve radius (12 percent), or shoulder width (11 percent).

Table 2 Type of design exception requested

Exception	Year								Total
	1993	1994	1995	1996	1997	1998	1999	2000	
Design speed	9	30	31	33	30	29	14	15	191
Minimum sight distance	3	6	9	12	13	10	5	10	65
Minimum radius (curvature)	11	2	7	16	6	13	6	6	67
Shoulder width	7	12	3	5	5	16	9	6	63
Ditch width	4	4	5	6	5	8	5	6	43
Pavement/lane width	4	2	1	15	7	8	1	4	42
Bridge width	1	3	0	14	7	6	1	3	35
Number of lanes	0	0	0	5	3	3	0	5	16
Maximum grade	1	2	2	2	0	4	3	1	15
Superelevation	0	1	0	1	0	9	1	0	12
Acceleration lane	0	1	2	1	0	0	0	0	4
Clear zone/Border	0	0	0	0	0	2	1	0	3
Ohter	1	1	0	0	1	1	0	2	5
Total	41	64	60	110	77	109	46	58	562

The type of design element was related to the most common types of project. For bridge replacement projects, the most frequent design elements were: design speed (39 percent), minimum sight distance (12 percent), minimum curve radius (11 percent), bridge width (8.9 percent) and pavement width (8.1 percent). For widening/reconstruction projects, the most frequent were: design speed (36 percent), minimum sight distance (16 percent), shoulder width (12 percent), minimum curve radius (10 percent) and ditch width (9 percent). The most common types of design elements for the addition of turning lanes were for shoulder width (35 percent) and ditch width (23 percent).

These data indicate that design speed[1] is the most commonly requested type of exception for any project type. The need to use a speed lower than the posted speed limit points to the deficiency of the current approach for using design speed. The use of operating speed as a means of design may avoid this issue, since roadways designed under this approach would achieve compatibility between speed limits and operating speeds. A basic requirement placed on roadway design is meeting the drivers' expectations by creating a consistent roadway design. Driver expectancy is formed by experience and has a significant influence on the driving task, since it can increase drivers' readiness to complete a task. A consistent speed environment that conforms to driver expectations is desirable to avoid abrupt changes in operating speeds and thus create a safe operating environment. The use of operating speeds as a means of designing this environment could alleviate the need to adjust design speeds and enhance design consistency.

Reason for Design Exception

The reasons for the design exception were also examined to determine any possible trends (Table 3). There was an average of 1.7 reasons per design exception provided for justification. The most common reason referred to were the existing conditions on the road (66 percent). In many cases, this was further explained by a comment indicating that a design speed lower than the posted speed limit was requested to match existing roadway conditions. Another explanation of the existing conditions was problems with the existing horizontal and vertical alignment noting that it would not allow speeds higher than the requested design speed. This reason was followed by the right-of-way issue (33 percent) and project cost (25 percent). The usual comment made concerning right of way was that the exception would limit the amount of right of way needed for the project. The reason related to cost was that the cost to meet typical criteria would be excessive. These two reasons could be considered as one, since right of way costs are part of the project cost. Therefore, these reasons combined were very close to the first reason (58 percent) and may be indicative of the practical issues designers face when dealing with roadway projects. It should be noted here that the percentages were estimated based on the number of design exceptions and not on the reasons provided.

Table 3 Reason for design exception

Reason	Number	Reason	Number
Existing conditions	207	Stop condition	18
Right-of-way issue	103	Utility	17
Cost	78	Defer construction	4
Length (scope)	35	Railroad issue	2
Environmental	27	Lighting	1
Adjacent property issue	25	Congestion	1

The crash history of the project was noted in 21 projects (6.7 percent). The actual crash history was specified in only a very few instances. The reference was usually a comment that there had been several crashes at the project site in the past several years with no specific data provided. There was a general reference to safety concerns noted for 12 other projects. However, a review of the crash history at these locations did not typically find any problem prior to construction of the project.

[1] Design speed is a selected speed that controls the values of the various geometric elements to be used during the roadway design; posted speed is the roadway speed limit and typically is based on the 85th percentile operating speeds; operating speed is the desired speed at which most motorists feel safe and comfortable.

Historic or environmental features were also noted in 17 projects including a variety of features. The most common reference noted impacts to a stream or wetland with other features including a historic register property and a stone masonry wall.

Crash Analysis

It was determined that site visits would provide additional information regarding the safety consequences of the design exception and allow for better understanding of the conditions for the exception. The locations were selected to provide a range of types of projects, design exceptions and adequate statewide coverage. Projects where crash history was a reason for the design exception as well as cases with historical or environmental concerns were given higher priority. Finally, projects completed within the time frame that would allow for collecting crash data and available before construction data were sought. Following this process, 86 sites were identified and site visits were conducted. When possible, the crash history at the locations was summarized using the available data. As noted earlier, the objective was to determine possible safety consequences from the design exceptions. In order to conduct a before and after type of analysis, the start and end dates of the construction are desirable and the construction must have occurred during a time period for which before and after crash data were available. Since crash data could typically be obtained for the years of 1995 through 2000, the construction period had to be within these years to allow a before and after comparison. Moreover, sufficient time should have passed after the construction to allow for significant crash history to develop. An alternative to the before and after analysis for the older projects, where before data is not readily available or where the exact date of construction is not known, would be to calculate the crash rate at the location after the project and compare that rate with statewide crash rates for similar types of roads. This approach would allow for determining whether the design exception had any effect as compared to similar roads, which are presumably constructed without any exceptions.

The analysis was conducted for 65 of the 86 sites due to available crash history. Locations off the state maintained system are not included, since crash data are not available at those locations. In many cases, the construction date was recent and this did not allow for adequate after data to be collected and thus, would not allow for any detailed before and after type of analysis. The crash history was obtained at some locations where the construction has not been completed and compared to statewide averages to determine if there had been a crash problem.

The analysis showed that, with a very few exceptions (6 of the case study sites), use of the design exception process did not affect the safety level of the project. This resulted in the construction of projects with crash rates lower than either average rates for the type of location where the project occurred or the crash rate at the site before the construction occurred. Therefore, it could be concluded that constructing roadways with lower than typical design values for some geometric elements does not affect negatively the safety of the projects. It should also be noted that even though these lower values were utilized, these were within the acceptable values suggested by the Green Book.

As mentioned earlier, there were 21 projects (6.7 percent) where a direct reference to a prior crash problem was noted in the background information. Moreover, there were another 12 locations (3.8 percent) with a general reference to safety concerns. It could then be assumed then that the introduction of design elements with lower values may have an adverse effect on the safety level of these sites. However, the improvements made to these roadways had a positive impact on the safety level of these sites, since the construction improved overall the site. This is also true for most of the sites, since when comparing the existing geometric conditions before construction, the improvement projects resulted in improved roadway geometrics at all sites.

CONCLUSIONS

The effect of design exceptions on roadway safety has been an issue that has limited the frequency of their application. The idea behind this is the use of lower than typical values will result in lower safety levels and it may also increase liability. This study aimed to first summarize past design exceptions by documenting their frequency and reason for their use and then determine the possible safety implications due to using such design policies and practices in Kentucky.

The most common design exception has involved a reduced design speed at a bridge replacement project. The typical reason for the exception was that the design conformed to the existing conditions on the roadway adjacent to the project and thus, there is no need to construct a bridge that would conflict with the context of the roadway. Roadway widening and shoulder addition were the next types of projects most frequently requested. For these projects the use of a reduced design speed was most frequently noted. These data indicate that there may be a need to revise the method by which design speeds are determined and used in roadway design. Moreover, these data may be indicative of the need for using a different type of speed that would reflect the operating conditions of the roadway rather than an abstract design speed.

The crash analysis shows that use of the design exception process has not resulted in construction of projects with higher crash rates than before. The basic analysis was conducted by comparisons of the current rates to the statewide averages or to before conditions. Based on the available data there is no apparent safety consequences from the applied design exceptions. An issue that could be of significance here is the magnitude of the changes applied in most of these design exceptions. The flexibility in several of these cases was often a minor deviation from the originally intended or typically applied values. Such minor changes were not capable of producing significant safety consequences. These design exceptions tended to be representative of the conservative and safe approach taken by designers when considering values that vary from traditional design. Therefore, the absence of safety impacts resulting from flexible design applications is obviously a positive finding as well as a reassuring assessment of the designer's judgment. An additional issue that could result in no safety consequences form these design exceptions is most of these projects resulted in an improvement over the prior condition although some aspect of the design may not be typical. The reasons for the design exceptions have been well documented, and there is no evidence that construction of projects with a design exception had an adverse effect on highway safety.

Given this analysis, it is recommended that the current design exception process continues in Kentucky. The data here indicate that the implementation of this process does not affect negatively the safety level of the roadway. On the contrary, most sites showed a lower crash rate after the construction. However, it should be pointed out that this could be partially attributed to the fact that the constructed site has improved significantly and the use of lower design values for some geometric elements have not affected negatively the roadway safety. It is desirable to continue monitoring these sites and determine their safety level in the future by comparing them with other similar sites throughout the state.

The study indicates that the concerns regarding potential safety issues are not supported. The design exception is a useful tool that designers should be encouraged to use, since at minimum it provides a reasonable documentation process for design choices made for a roadway project. The basic idea of documentation is central to the decision process and could limit potential liability concerns. This tool allows designers to complete a design that is sensitive to the context of the roadway without compromising any safety.

REFERENCES

American Association of State Highway Transportation Officials (1994). *A Policy in Geometric Design of Highways and Streets*, Washington, DC

Federal Highway Administration. (1997) *Flexibility in Highway Design, FHWA-PD-97-062*, Washington, DC (1997)

Hauer, E. (2000) *Safety in Geometric Design Standards I and II, in Conference Proceedings of 2nd International Symposium on Highway Geometric Design,* Mainz, Germany