THE NEXT STEP IN CONTEXT SENSITIVE SOLUTIONS: PRACTICAL SOLUTIONS

Authors:
Stamatiadis N.
Professor, University of Kentucky, nstamat@engr.uky.edu

Kirk, A.
Research Engineer, University of Kentucky, akirk@engr.uky.edu

ISBN 978-88-902409-0-4

ABSTRACT

There are often conflicting elements in a design and a designer is called upon to develop a solution that will consider and address these elements by designing a roadway non conforming to the full design values used up to that point. With the need for road safety and mobility improvements growing and the availability of funds for such improvement diminishing it is important to look at road design approaches more critically. In the past, roadway designs aimed at delivering the "best" project that could be designed often resulting in an over-designed roadway. Such an approach could lead to wasteful appropriation and reduced effectiveness of the limited available funds. The underlying idea of developing contextual and practical solutions is to equally consider and address all roadway issues. The designers and planners are therefore asked to develop an appropriate solution and design that satisfies all. This may indeed necessitate the consideration of alternatives that could initially not be viewed as appropriate. Such alternatives may include the examination of an undivided facility, which may affect expected safety levels, the use of fewer lanes, which may affect expected capacity and mobility, or the use of narrower lanes, which may affect expected safety and capacity levels. The basic notion of practical solutions is the need to examine such non-typical approaches wherever they are required and determine how each of the roadway-shaping issues would be addressed in the final design. It is therefore apparent that the need for innovation and creative design is paramount in developing such practical solutions.

Keywords: Highway design, project development, project optimization.

INTRODUCTION

In recent years, an increase in travel demand coupled with the need for ongoing road preservation, safety and mobility projects has increased the number of projects to be considered. This need cannot be met while maintaining the current mode of transportation funding due to the economic conditions of states and the reduced availability of funds for such improvements. It is therefore essential to reconsider the planning and prioritization of transportation infrastructure to meet the challenge of increasing demands with limited financial resources while still delivering a reasonable system to the users.

The current project development process may consider a prioritization of projects at the planning level but then in design often focuses on how to deliver the optimum project. While some general financial bounds may be used, this design approach can often result in an over-designed roadway. As an example, a study of Kentucky's roadway system identified over 600 miles of rural four-lane roadways with an Average Daily Traffic (ADT) of less than 10,000 vehicles per day (vpd) among the 1,690 miles of rural four-lane roads. In order to avoid perpetuating this approach and inappropriate use of the limited available funds, the current roadway design approach must be reexamined with the intent, not to optimize the individual project, but instead to optimize the entire transportation system of the area. The objective of this approach is the achievement of the maximum rate of return on the individual project and not the maximum margin of return possible.

A few states have recent initiatives that would result in the design of more appropriately sized roadways. Most notably, the Missouri DOT has initiated a process that critically reviews projects resulting in more right-sized roadways. They have stated that they want fewer great roads and more good roads that make a great system (Missouri DOT, 2006). This approach will also allow for addressing more roadway needs in a shorter time period. To implement their approach, called "Practical Design", they reviewed the existing design standards and revised them in a way that addresses their concept in a new design manual.

Another state that has a similar initiative is Kentucky, where the "Practical Solutions" initiative is defined as the philosophy of building right-sized projects and without developing a specific set of standards (or design element guidelines) for designers. The basis of this approach is that the existing condition is considered the baseline design and thus any improvements delivered will generate a positive outcome beyond the existing conditions. The importance of understanding the specific needs and goals of the project is underscored by developing a customized solution that address them while considering all project issues and constraints. In this manner a disciplined planning and design approach is utilized that is not encumbered by arbitrary design guidelines allowing a project to achieve up to the maximum rate of return on investment and, consequently, freeing remaining resources to meet additional needs across the state.

This study defines the basic concepts and approach of Kentucky's Practical Solutions aiming to improve the statewide road system. This approach allows for the development of a sustainable approach for roadway planning and design by right-sizing them and meeting more transportation demands.

PRACTICAL SOLUTION CONCEPTS

A clear definition of the project purpose and need is critical in achieving Practical Solutions. This will allow the project team to focus on the specific project needs and thus define an efficient customized solution without having to review designs aimed at stripping down elements of a typical design. Utilizing a focused approach, all project issues are thoroughly examined and resolved instead of simply identifying specific elements to reduce costs. As a general concept, this approach will encourage to maintain the existing cross section of a roadway if minor improvements are capable of achieving the project's goals. This practical option would be preferred over widening or total reconstruction that attempts to reduce cost by altering design elements such as pavement depth, pipe materials or any other similar individual design elements. The critical evaluation of the project's goals from the outset using a practical approach allows for selecting all individual design elements, from pavement area and drainage requirements to long term maintenance needs, in "practical" manner.

A concept that requires attention is the manner with which design element guidelines are used by transportation agencies. Some designers view the lower end of the range of current guideline values as minimum thresholds that must be exceeded by the final design. This typically creates a scenario of artificial minimum values that may lead to inappropriate designs, since the solutions developed may lead to an overdesigned project that will be not reflective of the project needs. Another issue is the implied assumption of linearity between the value used and the project "quality" relying on the assumption that bigger is better and safer: which is not always true. This approach may also contribute to an overdesigned project at higher than necessary cost.

Traditional design practices aim at providing "as high a design speed as is practical" and equating such a choice as a "surrogate for design quality" (AASHTO, 2004). The basic premise for such designs is the desire to reduce travel times and these designs are often viewed as the "best or safest possible approach" (AASHTO, 2004). The desirable level of service values suggested in the Green Book should be viewed as starting reference points and not as absolute values to be achieved at the expense of other issues (AASHTO, 2011). It is reasonable to assume that striving to achieve a certain level of service often requires more lanes than may be needed if a roadway was designed in a manner that enforces lower operating speeds. An additional benefit of lower speeds is the potential reduction in the severity level for crashes, as is frequently the case for roundabouts (FHWA, 2000; Elvik, 2003).

Significant research efforts have been undertaken in the past to identify the relationship between safety and various design elements and possibly identify standards that could be used to measure project performance. Hauer (2000) conducted a review of the safety in geometric design standards attempting to examine the belief that adherence to design standards is directly linked to safe roadways. His review indicated that while there is an inherent safety level in design guidelines little is known about the impacts of using flexibility in applying them in roadway design. Another issue that was identified by Hauer was the notion that there are two different kinds of safety. One could be called nominal safety and is measured "in reference to compliance with standards, warrants, guidelines, and sanctioned design procedures" (Hauer, 2000). Substantive safety is another kind based on the roadway's actual safety performance—i.e. crash frequency and severity. Designing nominally safe roads does not ensure substantive safe roadways, since adherence to values of each guideline does not necessarily produce a safe design.

The development of the Highway Safety Manual provides a method to determine the safety level of a roadway when design element tradeoffs are considered and provide designers with the tool needed to evaluate their choices (AASHTO, 2010). The basic approach followed for estimating safety is the use of a base model and Accdient Modification Factors (AMF). The base model is fixed for nominal conditions and the use of AMFs allow to estimate the effect of individual geometric design or traffic control features according to site characteristics. This approach provides predictive crash models for a given raodway configuration. AMFs are provided for basic geometryfor both raodway segments and intersctions.

The *Green Book* provides guidance and control values that allow flexibility for the design of new alignments or those undergoing major reconstruction (AASHTO, 2011). Even though the values provided in the *Green Book* are considered adequate for developing a safe, comfortable, and aesthetically pleasing roadway, there are cases where additional flexibility is necessary and the implications from such flexibility should be evaluated. The *Green Book* lacks background information sufficient for understanding the safety and operational implications of combinations of critical geometric features. The recently published *Guide for Achieving Flexibility in Highway Design* is a step in this direction but also lacks any quantifiable relationships for the values of various design elements (AASHTO, 2004). The Highway Safety Manual provides such a tool for designers to evaluate design element tradeoffs (AASHTO, 2010).

Another concept that has direct impact on practical solutions is that of the rate of return for a project. Each project is an investment and as such requires an understanding of the returns to be realized. As in any financial situation, there is always a point of diminishing returns, i.e. greater investment will have no or little effect on increasing the return. The same is true for transportation projects. Once the desired target is reached, increasing the investment (i.e. over-designing a project) will accrue little or no additional benefits. This concept is even more important nowadays due to economic issues that states face, since funds expended inappropriately in overdesigned projects could have been used in other projects generating a greater return on the investment. The use of practical solutions allows for distribution of the limited funds among more projects for improvement, thus resulting in a greater system wide improvement and return of investment.

Practical Solutions Principles

The following set of five principles can be applied to achieve a successful practical design:

1. Target the goals/objectives of the Purpose and Need Statement

The purpose and need statement of every project is the document that substantiates the transportation need in specific terms and establishes the purpose of the project. This document then becomes the litmus test for the project against which all improvements and solutions will be evaluated. In order to deliver a truly “practical” design, the purpose and need statement should serve as the target, not the lowest threshold of acceptable performance. Alternatives developed for a project are often evaluated to determine which improves the project objective the most. This approach can easily lead to overbuilt projects as alternatives are increased and improved to the point of achieving high, and often unneeded, levels or performance as they are “better.” On the other hand, if the project objective is viewed as a target, then each alternative would be evaluated based on its proximity of achieving the target; not necessarily exceeding it. In order to deliver a practical design, the purpose and need statement should instead set a specific target design, such as “improve travel delays to less than 100 seconds per vehicle during the typical peak hour.” The target of the alternatives should then be to achieve an improved delay of 100 seconds and not any other values. This approach will force that all alternatives evaluated result in similar improvements and then the most efficient at achieving the design goal can be implemented. Designs developed in this manner will result in properly sized projects which will be difficult if design goals are continually exceeded. It is therefore imperative that the scope of the project is clearly defined in order for the design team to develop a practical solution. The team should strive to meet the goals of the purpose and need and should not attempt to exceed them just because it can be done.

2. Meet anticipated capacity needs

Another issue relative to project development and final design is the underlying concept of mobility and how is measured. The concept of Level of Service (LOS), as established in 1950 with the first edition of the Highway Capacity Manual, measures roadway user acceptance of roadway performance on a grade scale (A through F representing free flow travel to congested conditions, respectively). LOS is effective in that it provides a simple way of relating complex issues readily to the public in terms everyone can understand. However, due to the ingrained sense of grading, it is obvious that a higher grade is always better than a lower one and especially when LOS of F is considered. Based on this a priori concept, roadways that are designed to operate at LOS D for example are often viewed as inappropriate by the public and local representatives. This preconception remains even when such designs provide adequate capacity and low delays and may actually serve the community needs better than a high speed roadway designed to LOS A.

The fact that LOS is measured differently for each roadway facility type creates an additional concern when alternatives are evaluated. In fact, eight different LOS definitions are provided in the Highway Capacity Manual for various facility types. This does not allow for comparisons to be made using a similar scale and creates inconsistencies when evaluating alternatives. For example, the LOS for four-lane roadways is measured on vehicle density while that of two-lane roads is measured on percent time spent following another vehicle. This difference in the criteria does not allow for a consistent comparison between these alternatives. While LOS is a good measure for understanding the operation level of a given design, it is poor in directing the evaluation of alternatives.

The choice of the desired and acceptable level of service becomes important, since it will have a significant influence on the final dimensions of the facility. It is therefore imperative to reconsider the recommended values in the *Green Book* and select a level of service that is more appropriate for the roadway context and addresses the purpose and need statement. The level of service for the off peak periods should be also considered to determine whether the facility is overdesigned. This will allow for determining the appropriate level of service for the facility throughout the day and not only for a very short period.

3. Evaluate safety compared to the existing conditions

Safety of any proposed solution should be evaluated to determine the impact of the design on the safety levels. Similar to the problem in principle 1, safety evaluations are often conducted by comparing alternatives among each other and not consider their incremental gains from the existing conditions. Therefore, designs are often selected because the solution is safer than any of the other alternatives. This approach could easily lead to over-designed and overbuilt projects, simply because of the erroneous basis of comparisons since it fails to consider that each alternative is an improvement over the existing conditions. The comparison to the existing conditions will also allow for evaluating safety gains based on a rate of return approach, since incremental safety gains allow for creating savings on a project by increasing safety (but not totally) and thus using the additional funds for other projects that may need to be improved.

The use of safety models for predicting safety performance of a roadway is essential in developing estimates for each alternative and allow for estimating these incremental gains over existing conditions. Apparently, the user needs to also determine the level of safety for the existing conditions in order to establish the benchmark for comparisons. Therefore, this approach will allow for developing projects that would always consider the existing conditions and thus result in improved safety.

4. Develop and evaluate design options and alternatives

Typical solutions are often selected because they have proven that they work well. However, the use of typical solutions frequently addresses problems by simply replacing the problem area and, with it, everything else. Customized designs to address the specific problems and needs should be developed instead of simply replacing the existing conditions with something that may have worked at other locations. The unique problems and constraints in a project mandate a unique solution to address it as practically as possible within the context of the project.

A clear understanding of the underlying problem for a project is essential and should be developed in the purpose and need statement. The design(s) should then attempt to address these problem areas efficiently. Moreover, the design should be flexible to address the changes that may occur on the problem areas and types throughout a project area and allow for varying design elements and cross sections throughout a project based on the specific needs and context of the project areas. To achieve this, all available design options and alternatives should be available to the designer. This includes all types of intersection designs, access/turn movement control and prohibition, and cross-sectional and geometric elements. Having a full range of options and alternatives available to the design team will allow for them to be chosen and applied as necessary to obtain the best value of the project.

5. Maximize design to the point of diminishing return

The existing issues and constraints for each project should steer the development of a design to a combination of elements that address them. This is a key component of implementing Practical Solutions. Project constraints are typically varied in nature including topographical, environmental, historical, existing infrastructure, and budgetary. To meet such constraints designers are encouraged to use innovative designs. By designing projects around these elements, through innovative designs or adjusted operational/safety definitions, it is possible to significantly decrease project costs while providing benefits to the roadway system. An issue of concern is the traffic forecasts used for design, which is typically a 20 year traffic forecast. Such forecasts are a difficult task and subject to many factors that may influence the prediction. Recent traffic monitoring has shown a trend in volumes that indicate a decrease in vehicle miles traveled. If this pattern continues, it could significantly affect the need for projects based on the need to increase capacity. While the practice of forecasting 20 years into the future insures that facilities are not under-built, it also tends to assure that facilities are overbuilt. The design life issue may need to be revisited in order to provide the most practical solution.

Projects are financial investments that accrue a variety of benefits. However, there is always a point where the return remains virtually unchanged with increasing investment. This is the point of diminishing returns and when this occurs it is not reasonable to continue investing. An aspect that is critical here is that the designer needs to consider all possible alternatives and establish their associated points of diminishing returns. However, each project decision regarding the various goals (e.g. safety, mobility, costs) may result in conflicting scenarios and procedures for resolving them should be developed.

PRACTICAL SOLUTIONS APPROACH EXAMPLE

The application of Practical; Solutions is demonstrated through the use of an example by examining the safety and operational performance of various cross section alternatives, based on Highway Capacity (TRB, 2000) and Highway Safety Manual (AASHTO, 2010) procedures. The various alternative cross sections range from an improved two-lane section representing a practical solution approach to a four-lane divided highway. The alternatives are then evaluated on both an individual project basis as well as a system-wide evaluation assuming budgetary constraints. This demonstration underscores the balancing of tradeoffs required for the application of Practical Solutions and describes the potential benefits of the approach.

Roadway Designs

A set of possible cross sections are developed to be used in this example representing possible design options for roadways in Kentucky. These cross sections and their total required right of way are summarized in Table 1.

Table 1 Cross section examples

4 Lane Undivided			4 Lane Divided (15ft median)			2 Lane		
Width (ft)			Width (ft)			Width (ft)		
Lane	Shoulder	Road	Lane	Shoulder	Road	Lane	Shoulder	Road
11	2	48	11	2	63	10	0	20
11	6	56	11	6	71	10	6	32
11	8	60	11	8	75	10	2	24
12	2	52	12	2	67	11	2	26
12	6	60	12	6	75	11	6	34
12	8	64	12	8	79	12	0	24
						12	6	36
						12	8	40

Mobility

The mobility for these designs is estimated based on the Highway Capacity Manual (HCM) procedures (TRB, 2000). The procedures for rural roads are used and the metric of mobility used is the average speed of passenger cars. The roads are assumed to carry an ADT of 15,000 vpd, with 10% trucks, 10 access points per mile, and on rolling terrain. The speed estimates are summarized in Figure 1. The data indicate that in general wider roads produce higher operating speeds. One can also observe that at some point there are limited returns on increased speed for the investment to be made. This point is at a road width of 52 feet, where a speed of 55 mph can be achieved. Providing a wider roadway will only marginally increase the speed, while there are roadway widths where there will be a reduction in speeds. Therefore, it can be concluded that the optimal speed for the 15,000 ADT roadway while considering the optimum return on investment could be achieved with a roadway width of 52 feet or a four-lane undivided roadway with 12 foot lanes and 2 foot shoulders. This will be the practical solution for addressing mobility issues for this roadway. It should be emphasized here that the data in Figure 1 is based on the calcualtion procedures set forth in the HCM and assumptions noted above and changes to these assumptions will reult in a diffrent trend and practical solution.

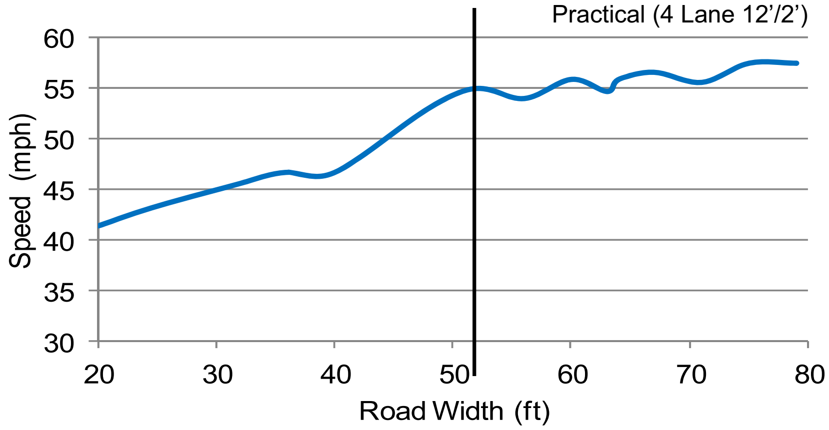

Figure 1 Mobility and road width (15,000 ADT)

Capacity

The capacity of a four and two-lane roadway designs for a similar facility (15,000 ADT, 10% trucks, 10 access points per mile and rolling terrain) were estimated based on the Highway Capacity Manual procedures (TRB, 2000). The capacity for a two-lane rural facility with 12-foot lanes and 8-foot shoulders is 3,200 vehicles per hour. The capacity for a four-lane undivided road with 12-foot lanes and 8-foot shoulders is 6,500 vehicles per hour, and the capacity for a four-lane divided with the same cross section is 6,700 vehicles per hour. The hourly traffic distribution for the 15,000 ADT is shown in Figure 2. These were based on typical distribution for rural arterials as were obtained from prior research (KYTC, 2004). The capacity of the two and four lane facilities is also shown to demonstrate the capacity supplied under each condition.

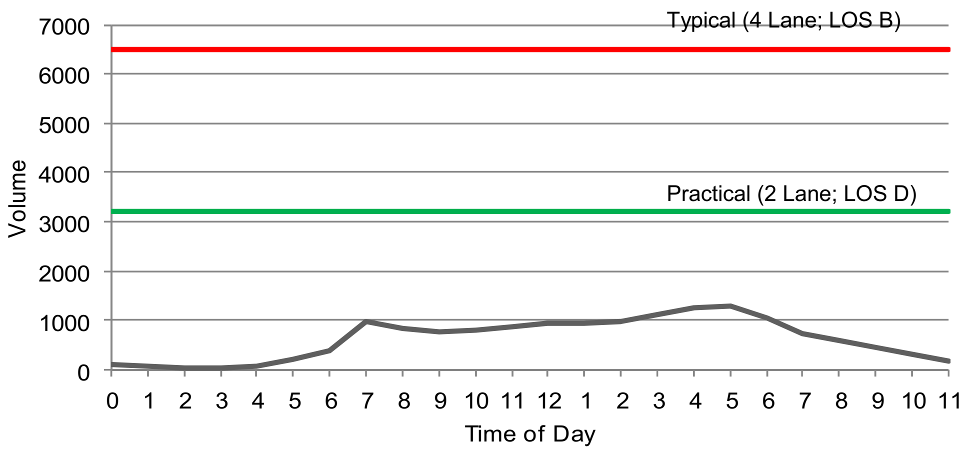

Figure 2 Capacity supply and demand

The data in Figure 2 allows for a comparison of the capacity supplied and the actual traffic demand. It is apparent that both designs will offer adequate capacity and the capacity will never be exceeded (unless volumes increase) for both designs. However, the four-lane facility will experience more time that it will be underutilized indicating that the funds were not used efficiently by constructing a facility that even at peak hours can accommodate a significantly larger traffic volume (for this case approximately 2,000 vehicles per hour more).

An additional aspect that should be noted here is the level of service under which each facility will operate. In the four-lane design, the facility will operate at level of service B at peak period and A for most of the day while in the two-lane design it will operate at level of service D at peak and C the remainder of the day. The two-lane solution is more appropriate for this case where the level of service is more balanced throughout the day while still maintaining a level of service that is reasonable (but it may be considered non-desirable).

Safety

The safety performance for each of the facility types noted in Table 1 can be estimated based on prediction models developed for the Highway Safety Manual (HSM) (AASHTO, 2010). The predictions are based on models that are developed for base conditions and then adjusted with the use of AMFs. The base conditions reflect a typical cross section for each scenario. For example, the base conditions for four-lane divided roadways are 12-foot lanes, 8-foot shoulders, and 30-foot median. The expected number of crashes per year is developed for these conditions and then this estimate is adjusted to reflect the deviation of the design element from these conditions. For cases where more than one element is changed, the combined effect is estimated by the product of the individual AMF. Figure 3 presents the expected safety performance for each of the designs considered here. It should be emphasized here that the data in Figure 1 is based on the HSM calcualtion procedures and assumptions noted above and changes to these assumptions will reult in a diffrent trend and practical solution.

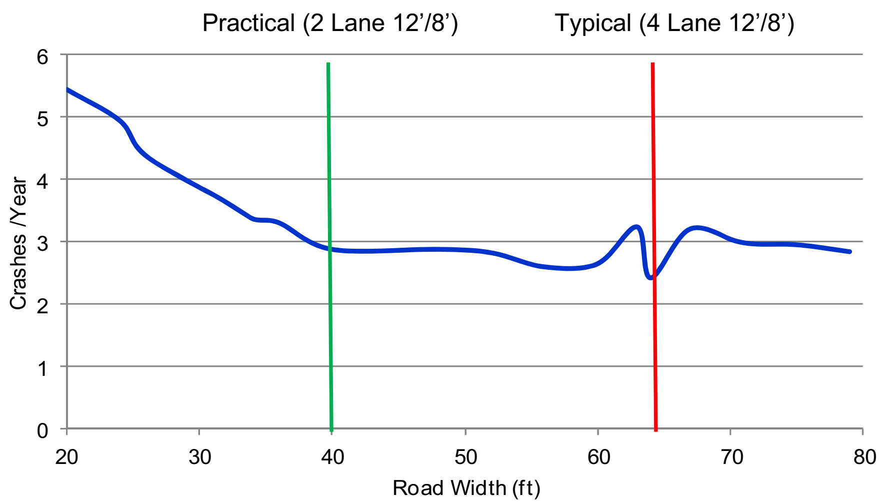

Figure 3 Safety and road width (15,000 ADT)

The data presented in Figure 3 shows that there is a limit of returns based on the road width. Safety improvements are achieved continuously when a two-lane road with 10-foot lanes and no shoulders is upgraded to wider two-lane road cross sections. In this case (road with 15,000 ADT), the number of crashes per year is anticipated to be reduced from 5.45 to 2.86 with a two-lane facility with 12-foot lanes and 8-foot shoulders. From this point forward, wider roadways will have marginal safety improvements with the maximum been achieved with a four-lane undivided roadway with 12-foot lanes and 8-foot shoulders. Even in this case, the expected number of crashes is 2.41 per year offering a 15 percent reduction but at a significantly higher cost. The data shown here supports the notion that even though wider roadways will have a safety improvement, it may not be practical to develop such solutions due to the low effectiveness and small gains in safety. Therefore, the practical solution in this case will be the design of a two-lane road.

An issue that could be argued here is that even small gains in safety improvements are justifiable, since this is a major obligation to the travelling public. However, the safety issue should be viewed in a systems approach where it provides the ability to address more problem areas effectively and allow for system-wide improvements (note: similar system-wide decisions are routinely made regarding the placement of barriers and guardrails). According to the Kentucky Transportation Cabinet, the costs to upgrade a two-lane facility with another two-lane road is between $5.7 to $8.7 million per mile while for an upgrade to a four-lane road the cost is $18.9 to $23.9 million per mile. Assuming a budget of $500 million and average costs for a two-lane upgrade of $7.2 million per mile and a four-lane upgrade of $21.5 million per mile, the number of miles of two-lane rural roads with 10-foot lanes and no shoulders can be estimated. In this case, the total miles that can upgraded to a two-lane facility with 12-foot lanes and 8-foot shoulders is 69.4 while for the same amount of funds the total number that can be upgraded to undivided four lane facilities is 23.3 miles. The total safety and operational improvements for this scenario are summarized in Table 2.

Table 2 Summary of improvements for $500 million budget

			Improvement			Total Improvement[1]	
Cross Section	Crashes per Year	Travel Speed (mph)	Miles	Crashes per Year	Speed (mph)	Crashes[2]	Speed[2]
2 Lane, 10 ft L, 2 ft S	5.4	41.4	--	--	--		
2 Lane, 12 ft L, 8 ft S	2.9	46.7	69.4	-2.5	+5.3	-173.5	367.8
4 Lane, 12 ft L, 8 ft S	2.4	55.9	23.3	-3.0	+14.5	-69.9	337.9

[1] The total improvement is the product of miles to improve and metric (crashes or speed)

[2] Units are crash-miles per year and mph-miles

This example indicates that the use of the two-lane cross section would potentially result in a system-wide reduction of 173.5 crashes per year, whereas, the four lane cross section would only have a reduction of 69.9 crashes per year. Even though the four lane cross section provides a "safer" solution on a project basis, it does result in addressing fewer miles and thus limits the potential for greater safety gains. Likewise, the two-lane improvement provides a greater reduction in delay by increasing travel speed over a greater length of total projects. The consideration of system-wide performance is therefore critical in determining the overall benefit of the project, especially under significant budgetary constraints.

CONCLUSIONS AND RECOMMENDATIONS

Recently, reduced budgets for transportation agencies have created a reality that designers have to deal with and use innovative approaches to deliver roadway projects. The concept of Practical Solutions has been introduced in order to encourage developing more appropriate solutions without unduly compromising safety or mobility. Using creative design and moving away from the "typical cross section" concept, where a standard "oversized' template is traditionally used, are focal points in this approach. Designers are frequently called upon to develop a solution that will consider and address conflicting elements by designing a roadway that balances these elements and constraints. The development of a new set of standards or guidelines for design element values is not advisable, since they would only create another set to be applied. On the contrary, Practical Solutions establish a philosophy that emphasizes that project goals/objectives are targeted with an accepted solution that balances all issues and constraints and considers the points of diminishing returns for the project's elements.

Every project typically has a number of issues including safety, environment, community, capacity, mobility, and budget. Practical Solutions aims to equally consider and address all these issues by developing an appropriate design solution that efficiently balances all. This implies that a designer should consider typical and non-typical designs and elements in their development and evaluation of alternatives including consideration of alternatives that could initially not be viewed as appropriate. The basic notion of Practical Solutions is the need to examine such non-typical approaches wherever they are required and determine how each of the roadway-shaping issues would be addressed in the final design.

Concepts regarding mobility and safety issues were presented and discussed within the application of Practical Solutions. Each of these concepts impacts the final solution and requires special attention. The choice of the desired and acceptable level of service is important, since it significantly influences the size of the facility. It is therefore imperative to establish this in relation to the project-specific goals and needs and not simply based on the recommended values in the *Green Book.* The level of service for the off peak periods should be also considered to determine whether the facility is over-designed. This will allow for determining the appropriate level of service for the facility throughout the day and not just for a short peak period.

Adequate flexibility for the design of new or reconstructed facilities is provided in the *Green Book* (AASHTO, 2011). For most control values, the *Green Book* indicates that the recommended ranges provide a safe, comfortable, and aesthetically pleasing roadway. However, there are cases where additional flexibility is necessary and therefore, the implications from such flexibility should be evaluated. The *Green Book* does not provide information sufficient for understanding the safety and operational implications of combinations of critical geometric features. The Highway Safety Manual addresses the implications of such combinations more successfully and should become a tool for designers to evaluate such design element tradeoffs, once it becomes available.

Practical Solutions aims to develop appropriate and contextual solutions for projects considering the entire spectrum of options and balancing the various project requirements. As such, it should not be confused with or viewed as Value Engineering, which is typically applied as a cost-cutting approach to a project that has been designed aiming to reduce the cost of the accepted design.

Practical Solutions is a system sensitive approach where reasonable solutions are sought to address more problem areas within constrained financial resources. Applying the concept of diminishing returns and viewing the project as an investment allows for a system wide evaluation and prioritization of needs. The driving concept behind Practical Solutions is that at some point in the design process, larger cross sections and wider right of way does not "return" significant improvements for the investment to be made. At that point, the design should not increase the roadway footprint any further and use this as the selected alternative. The current budgetary constraints and limitations necessitate such an approach in order to address more problem areas with the limited available resources. This approach calls for just meeting specific project goals and objectives, not significantly exceeding them.

REFERENCES

American Association of State Highway Transportation Officials (2011). "*A Guide for Achieving Flexibility in Highway Design*." Washington, D.C.

American Association of State Highway Transportation Officials (2004). "*A Policy on Geometric Design of Highways and Streets*," Washington, DC.

American Association of State Highway Transportation Officials (2010). "*Highway Safety Manual*", Washington, DC.

Elvik, R. (2003) "Effects of Roadway Safety of Converting Intersections to Roundabouts: Review of Evidence from Non-U.S. Studies," *Transportation Research Record 1847.* Transportation Research Board, Washington, D.C. pp. 1-10.

Federal Highway Administration. (2000) "*Roundabouts: An Informational Guide,"* FHWA-RD-00-67, Washington, D.C.

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

Kentucky Transportation Cabinet (2004) "*Traffic Forecasting Report 2004*", Division of Multimodal Programs, Kentucky Transportation Cabinet, Frankfort, KY.

Missouri Department of Transportation (2006) "*Practical Design Implementation Manual,"* Missouri DOT, Jefferson City, MO.

Transportation Research Board (2000) "*Highway Capacity Manual*," Transportation Research Board, Washington, D.C.