Research Report
KTC-08-30/SPR369-08

KENTUCKY TRANSPORTATION CENTER

PRACTICAL SOLUTION CONCEPTS FOR PLANNING AND DESIGNING ROADWAYS IN KENTUCKY

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PRACTICAL SOLUTION CONCEPTS
FOR
PLANNING AND DESIGNING ROADWAYS IN KENTUCKY

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EXECUTIVE SUMMARY

Kentucky’s highway agency has embarked upon an initiative tagged “Practical Solutions” which sets its goal toward reducing costs throughout the project development process extended into operations and maintenance of all highway facilities. This study focuses on the planning and design stages of project development. Developing a procedure that yields up to the maximum margin of return for the investment requires an approach that takes into account specific safety issues and the commensurate design elements for each roadway. Such an approach requires that the project 1) achieves the stated goals/objectives and 2) delivers the highest rate of return for the investment.

The purpose of this study was to examine available research and develop a hypothetical example to establish the efficacy of a practical solutions approach to planning and design as well as to propose a concept and principles for application and provide a real world example of the practical design that could be achieved.

The most critical component of Practical Solutions in planning and design is the definition and clarification of the initial project concept (its specific goals and objectives), since it will be the corner stone of the project and used to significantly reduce the cost and impact of a project. A fundamental issue that must be addressed from the outset is the reexamination of how design element guidelines are viewed. In order to achieve a practical design they cannot be viewed a minimum thresholds or that always increasing their magnitude results in a better quality project.

Traditional design tends to seek as high a design speed as practical with the aim to reduce travel time. Practical design requires that levels of service should not be taken as absolutes, but rather be viewed as starting points. Each project should be viewed as 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.

System based evaluation of practical design in this study examined the safety and operational performance of various cross section alternatives, based on Highway Capacity and Highway Safety Manual procedures. The various alternative cross sections ranged from an improved two-lane section representing a practical solution approach to a four-lane divided highway.

The data 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 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.

This example indicates that for a limited budget (example used was $500 million), 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.

This study proposes the following set of five principles be applied to achieve a successful practical design:

1. Target the goals/objectives of the Purpose and Need Statement
2. Meet anticipated capacity needs
3. Evaluate safety compared to the existing conditions
4. Develop and evaluate design options and alternatives
5. Maximize design to the point of diminishing return

The study provides a practical design example: Madison Pike (KY 17) Intersection Improvement Study assesses potential intersection improvements. Its purpose was to consolidate recommendations from several independent studies and develop a plan for intersection improvements to relieve existing congestion and serve the rapidly developing communities on the corridor.

In order to develop a practical solution the purpose of the intersection improvements were determined. The original approach essentially set out to determine the feasibility of a roundabout or a traffic signal at the intersection. The designs of the two previously considered alternatives were merged to create a unique solution to the problem to address intersection delay within project parameters. This practical solution was a unique design fit to the roadway situation. As a result, the cost for the improvements was estimated at $275,000; a total cost savings of over $4.5M.

The concept of Practical Solutions has been introduced in order to encourage developing more appropriate solutions that meet specific safety and/or mobility targets. This approach encourages the designer to use creative design and move away from the “typical cross section” concept, where a standard “oversized’ template is traditionally used. The development of a new set of standards or guidelines for design element values is not advisable if Practical Solutions are to be successful in reaching their potential benefit. What is required is a procedure that assures that project goals/objectives are targeted with an acceptable solution that balances all issues and constraints and considers the points of diminishing returns for the project’s elements.

The results of the research effort identified the need for additional work on the following topics:

- Training for agency personnel and consultants
- Further validation and refinement of the practical procedure/principles
- Develop tools to resolve conflicting issues and balance competing elements

INTRODUCTION

The Kentucky Transportation Cabinet has embarked upon an initiative called “Practical Solutions” which sets a goal of reducing highway cost expenditures. . This initiative is intended to go beyond the “Practical Design” approach that has been popularized recently by several states, most notably Missouri, by encompassing the entire project development process from planning through operations and maintenance. . This change in design philosophy is driven by the desire to use scarce resources in an efficient and effective manner while maximizing the beneficial impacts to the system in its entirety. Finding the proper balance between available resources and the reasonable design criteria is a major challenge for any state but it is essential in times of budget constraints. This document provides an overview and guidance on part of this broad Kentucky initiative focusing on project planning and design.

With the need for road safety and mobility improvements growing and the relative availability of funds for such improvement diminishing it is important to look at our road design practices more critically. In the past, roadway designs aimed at delivering the “best” project within some general financial bounds and may have resulted in an over-designed facility. Such an approach could lead to added csts without significantly improving the effectiveness of the project. Some public decision makers and citizens have begun to question the use of maximum design criteria to address situations determined to be inadequate and/or unsafe. Consequently, a few states have initiatives that would match the design with the needs of the project. The basic premise of practical solutions is that it is essential to have a balance among operational efficiency, safety, project constraints and costs.

Developing a process that yields the maximum margin of return for the investment requires an approach that takes into account specific safety issues and design elements for each roadway and seeks to optimize the investment. This approach requires that the project 1) achieves the stated goals and 2) delivers the highest rate of return for the investment. The designers and planners are therefore asked to develop a design that satisfies the stated needs. This may indeed necessitate the consideration of alternatives beyond the standard or typical roadway designs. These alternatives may include the examination of an undivided facility, the use of fewer or narrower lanes, the use alternative intersection designs, or other features all of which would have differing impacts on expected safety and capacity levels. The basic notion of Practical Solutions is the need to consider and examine a range of approaches and determine which solution meets the needs with the least cost. It is apparent that the need for innovation and creative design (vs. traditional) is paramount in achieving such practical solutions.

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 (1). This will allow for a better use of funds to address 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. The Kentucky Transportation Cabinet has approached this from a slightly different perspective, where building right-sized projects is emphasized without developing a specific set of standards (or design element guidelines) for designers. In place of minimum standards, the existing condition is established as the baseline design and this creates a positive outcome when the project is improved beyond the existing conditions. This approach underscores the importance of defining the project needs and goals at the outset and developing a customized solution that addresses those issues during design.

The purpose of this research study is to define a practical solution design procedure to improve state roads. A balance will be achieved between the practical level of performance and expenditure that includes a targeted reduction in crashes and improved mobility. The specific project objectives of this study are to:

1. Identify potential design element improvement categories and ranges from previous research;
2. Develop a hypothetical example of appropriately limited design improvement and its safety, operational and cost impacts;
3. Propose a concept of practical solutions including key tenets to guide the application of the concept;
4. Provide a real world example demonstrating the application of such selected tenets resulting in a successful practical design; and
5. Develop a marketing package presenting practical design's rationale using a "business case" justification that demonstrates prudent results.

PRACTICAL SOLUTIONS CONCEPT

The most critical component of Practical Solutions in planning and design is the definition and clarification of the initial project purpose and need, Focusing on "what" is to be built allows for substantially greater savings rather than a design focused on "how" a project it is to be built. It is more appropriate to develop an efficient solution by focusing on the project needs rather than stripping down components of a typical design. The project should then be developed with a clear understanding of the needs, and designed to address those needs while balancing all other relevant factors. This allows for a complete examination and resolution of issues instead of simply identifying elements in piecemeal fashion for cost reduction. For the majority of roadway projects the most practical solution would be to maintain the existing cross section and provide minor modifications as appropriate. This option would be far less costly and potentially superior to a total reconstruction effort that that attempts to reduce costs by reducing pavement depth, pipe materials or similar individual design elements. By providing a practical concept from the outset, all individual design elements, from pavement area and drainage requirements to long term maintenance needs will be "practical."

A fundamental issue that must be addressed from the outset is the reexamination of how design element guidelines are viewed. There are two concepts that require attention. First, 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 results in developing solutions that are not reflective of the needs of the project and consequently a costly design that diverts scarce resources to this projects vs other needs throughout the system. Second, there is a belief that a relationship exists between the increased magnitude of these minimum values and the project "quality". This concept relies on the assumption that bigger is better and safer: which is not always true and also may result in an inappropriate project.

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" (2). 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" (2). 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 (3). 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 (4, 5).

Safety is extremely important but may not be the controlling factor in the design. Roadway design involves a dynamic interplay of several concerns as mandated by law, regulations and actual practice. Designers have always had to contend with cost restrictions which have potential effects on safety. Nevertheless, proper designs should assess all competing issues and constraints and create a solution that meets the project's mobility and safety objectives.

A recent review of the safety in geometric design standards by Hauer (6) critically examined the belief that adherence to design standards is directly linked to safe roadways. This review indicated that design guidelines have an inherent safety level, but 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" (6). 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 will provide 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 (7,8).

In order to develop Practical Solutions these concepts must be revisited while addressing project elements, such as operational performance, level of safety, roadway cross section and geometric values. Moreover, this approach allows for the development of properly sized facilities and minimizes overbuilt alternatives. This requires that the project objective for safety or capacity be <u>the target and the design element value be chosen to achieve it.</u>

Another focal point is the development of solutions that achieve the targeted goals without significant cost increases. Each project should be viewed as 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 little or no effect on increasing the return. The same is true for transportation projects. Once the target is reached, then increasing the investment (i.e. over-designing a project) will not result in the best expenditure of resources.. Moreover, the funds expended in excess of the actual project needs could have been used in other projects with a far greater return on investment. Applying practical solutions does not only improve specific projects but they allow for greater system-wide improvements.

Another critical factor that contributes to the over-design of a project is the design-year AADT. This value is frequently overestimated and may result in a project beyond the scale needed. Consideration must be given to developing more realistic projections and/or reducing the projection horizon. Customized estimates of AADT and increased attention to the factors that most influence the specific project may allow a more appropriate solution.

SYSTEM BASED EVALUATION OF PRACTICAL SOLUTIONS

The following analysis examines the safety and operational performance of various cross section alternatives, based on Highway Capacity (9) and Highway Safety Manual (7, 8) 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.

The analysis indicates that by applying a reduced cross section (practical solution) more miles of roadway can be addressed and the system-wide improvement in terms of reduction in crashes and increase in speeds will be greater than an expanded cross section (typical solution) over fewer miles of roadways. This comparison demonstrates the overall effectiveness of practical solutions and underscores the importance of considering a system-wide approach for addressing needs especially when faced with extreme budgetary constraints. Even without such a constraint, this approach has its intrinsic value.

Roadway Designs
A set of cross sections was 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

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

Mobility
The mobility for these designs is estimated based on the Highway Capacity Manual procedures (9). 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 Average Daily Traffic (ADT) of 15,000 vehicles per day, 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.

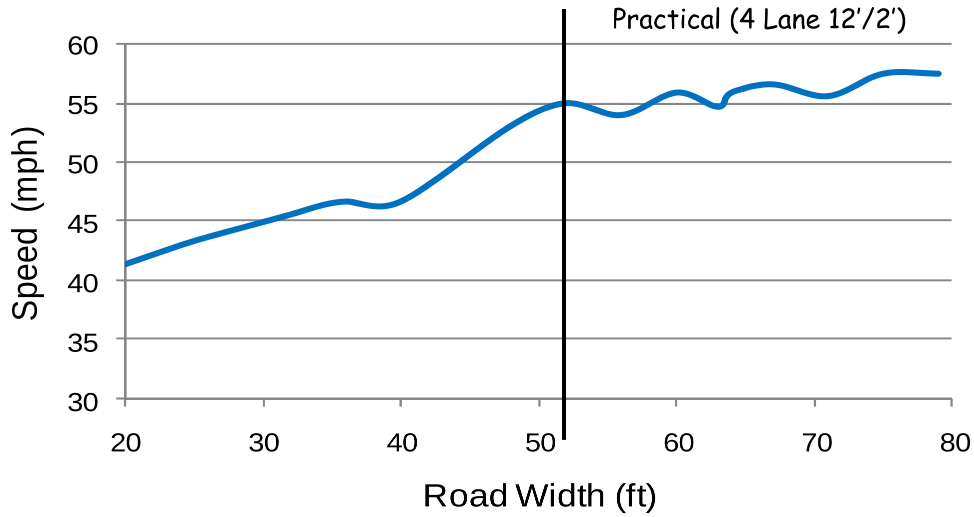

Figure 1 Mobility and road width

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 (9). 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 (10). The capacity of the two and four lane facilities is also shown to demonstrate the capacity supplied under each condition.

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).

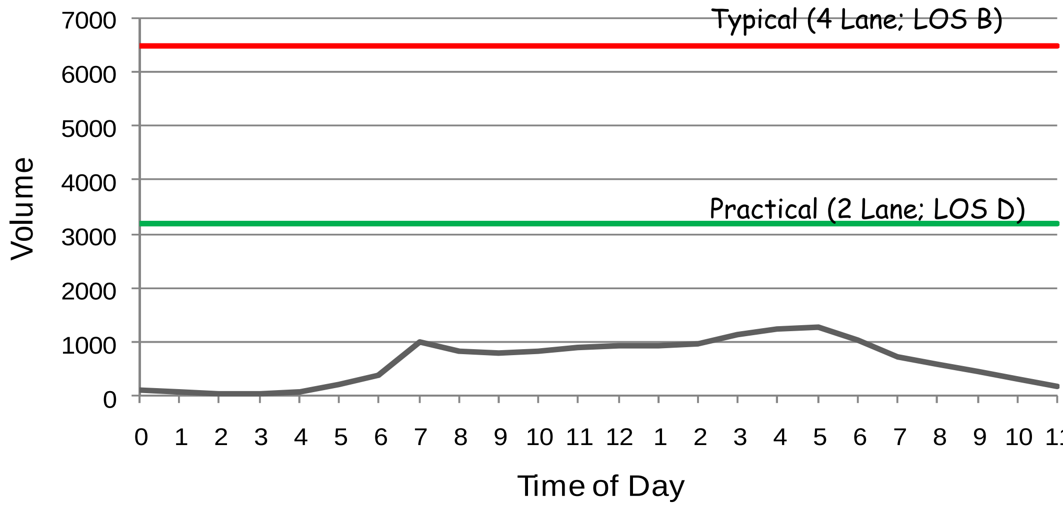

Figure 2 Capacity supply and demand

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 (7, 8). The predictions are based on models that are developed for base conditions and then adjusted with the use of Accident Modification Factors (AMF). 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.

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.

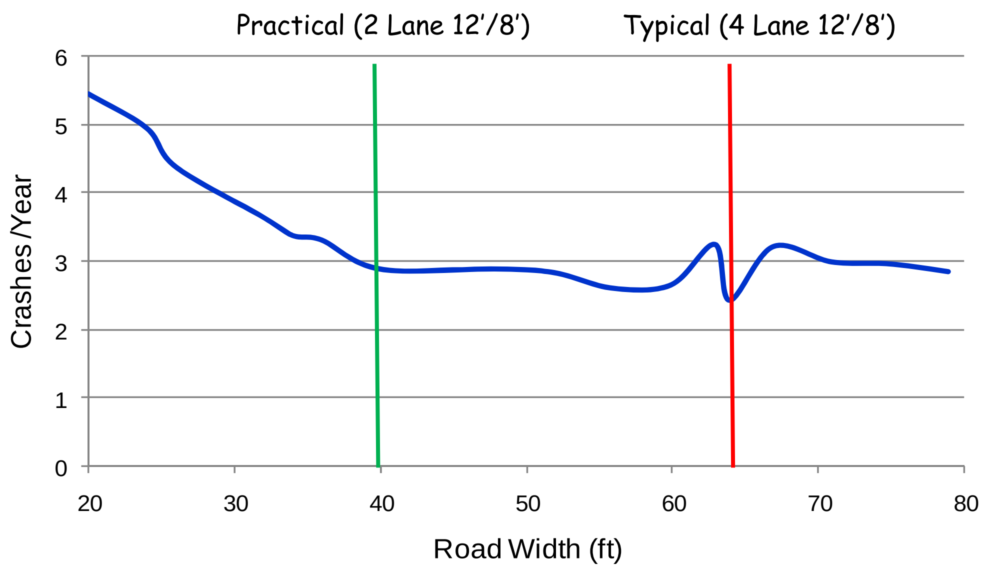

Figure 3 Safety and road width

One argument could be made 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.

PRINCIPLES OF PRACTICAL SOLUTIONS FOR PLANNING AND DESIGN

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
Every project is guided by a purpose and need statement that substantiates the transportation need in specific terms and establishes the purpose of the project. This statement must serve as the foundation of 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. Often a purpose and need statement will identify the need to "improve mobility." Alternatives are then evaluated to determine which improves mobility 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. In order to deliver a practical design, the purpose and need statement should set a specific target design, such as "improve intersection delay to less than 50 seconds per vehicle during the typical peak hour." The target of the alternatives should then be to achieve an improved delay of 50 seconds and not any other values. This will ensure that all alternatives evaluated result in similar improvements and then the most efficient at achieving the design goal can be implemented.

This targeted approach requires design discipline. The engineer must remember the intended purpose of the project and understand the trade-offs for all elements integrated in the design. If a larger roadway is proposed, then other elements such as drainage needs, right-of-way needs and environmental impact may also increase resulting in increased project costs. By targeting performance values the designs can be made more efficient and not continually escalate scope or price. It is therefore imperative that the scope of the project is clearly defined to allow the design team to develop a practical solution that does not contain any unneeded increases. The team should strive to meet the specific objectives of the purpose and need and should not attempt to exceed them just because it could be done. Design discipline calls for finding the effective and efficient combination of elements that just meet the target. Understanding the tradeoffs and the unwanted project growth effects is a critical aspect of practical solutions.

The purpose and need statement may also serve to establish the existing conditions and constraints on the project. The statement will often state that the purpose of the project is to "improve mobility" at an intersection due to a need brought about by "failing operations at the intersection." This need should be further defined and examined to better understand the specific project situation. For example, it should be determined whether the problem is throughout the day or at a specific time, whether any approach is more prone to delays, what are the specific aspects of safety concerns (i.e. crash types, severity, and quadrant). This in-depth approach requires improved analysis and investigation at the beginning of the project development process and a revisit of the macro level data used when the project was programmed. In order to develop appropriate and practical solutions, data must be disaggregated to develop/refine the purpose and need statement thereby uncovering the specific problem area to be addressed not just the symptom. This design discipline will lead to developing a solution that addresses the specific problem, not one that enlarges the project.

2. Meet anticipated capacity needs

Another issue relative to operating and design speed 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 misconception 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.

It should also be noted that the LOS measure does not evaluate roadway capacity but they reflect some derivative of capacity often impacted by additional factors, such as traffic signal timing, roadway speed limit, number of passing zones etc. In order to truly develop an efficient solution the capacity of the provided solution should be measured to assure that the right size design is provided. The use of capacity allows for the utilization of a consistent measure of effectiveness across all alternatives. Once a design is selected, LOS can then be used to further refine the design to ensure that the chosen alternative works as efficiently as possible.

3. Evaluate safety compared to the existing conditions

It is apparent that safety in any proposed solution should be evaluated to determine the impact of the design on the safety levels. However, an issue that is often overlooked is that safety evaluations are comparing alternatives among each other and not as the incremental gains from the existing conditions. Therefore, designs are often selected because the solution is safer than any of the other alternatives. This could easily lead to over-designed and overbuilt projects, simply because of the erroneous assumption that safety improves incrementally with each design regardless of costs. This approach fails to consider that each alternative is an improvement over the existing conditions and thus misses the opportunity to evaluate the safety gains based on rate of return approach. Considering such incremental safety gains allows for creating savings on a project by increasing safety over the existing conditions (but not totally) and thus using the additional funds for other projects that may need to be improved. This approach provides a system-wide approach, where the net improvement to the system is greater (as it was shown in Table 3).

Central to this principle is the need for reestablishing the understanding of safety improvements. The use of safety models for predicting safety performance of a roadway is essential in developing these comparisons and allowing for developing these incremental gains over existing conditions. An understanding of the level of safety for the existing conditions is also central to this approach, since without it there will be no benchmark to compare the proposed alternatives. Therefore, this approach will allow for developing projects that would always consider the existing conditions and thus result in improved safety. Current practices under the KYTC roadway section and spot improvement HSIP program take a similar approach to impact safety with minimal cost.

4. Develop and evaluate design options and alternatives

Often typical solutions are put in place because they have proven that they work well. However, the use of typical solutions or designs only addresses problems by simply replacing the problem area (and everything else). In order to achieve an efficient solution, a design customized to 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 will therefore require a unique solution to address it as practically as possible.

In order to achieve this type of design the underlying problem in a project area must be clearly defined and understood as discussed above with the purpose and need statement. The design(s) should then attempt to address these problem areas, as simply as possible. As problem areas and types may change throughout a project area, then so too will the design change to meet these needs. This approach will result in varying design elements and cross sections throughout a project based on the specific needs and context of the project areas.

In order to tailor a design to the project constraints all 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

Each project should consider its issues and constraints and develop a design with a combination of elements that address these. This is a key component of implementing Practical Solutions and achieving improvements. These constraints could be varied and include topographical, environmental, historical, existing infrastructure, and budgetary issues. 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.

Operational considerations should also be viewed in terms of diminishing returns. For instance, projects are typically designed to accommodate 20 year traffic forecasts. The practice of estimating traffic volumes 20 years into the future is 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. As roadway capacity can only be added in large increments by adding additional lanes, widening to add another lane will always lead to a diminished return unless that lane is 100 percent utilized. In instances when a 20 year forecast requires significant improvement such as from a 2 to 4 lanes or a 4 to 6 lanes cross section, it may be appropriate to develop intermediate forecasts, such as 10 to 15 years, to determine if widening or other improvements are still warranted. This approach will eliminate significant construction costs that may only be used 15-20 years out and then only during peak periods. However, other improvements can be made that will be beneficial beginning immediately. Also half-steps can be taken such as the purchase of ROW to accommodate the longer term forecast, but for now building and maintaining substantially less roadway.

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. This concept was clearly demonstrated in the previous section (Figures 1 and 3 for speed and safety, respectively) where there are points where any additional roadway will incur very little additional benefits. An aspect that is critical here is that the designer needs to consider all these elements and their associated points of diminishing returns to determine the most appropriate solution. These elements may often lead to conflicting scenarios and procedures for resolving them should be developed.

PRACTICAL SOLUTIONS EXAMPLE

Background

The Madison Pike (KY 17) Intersection Improvement Study was conducted by the Northern Kentucky Area Planning Commission (NKAPC) in conjunction with the Kentucky Transportation Cabinet (KYTC) to assess potential improvements along KY 17 at the following three intersections: 1) Holds Branch Road / Pioneer Park, 2) Old Madison Pike, and 3) Transit Authority of Northern Kentucky (TANK) Facility Entrance / Lakeview Drive. The purpose of the study was to consolidate recommendations from several independent studies conducted on the corridor and develop a comprehensive plan for intersection improvements to relieve existing congestion and serve the rapidly developing communities on the corridor. This discussion focuses on the practical solution developed for the intersection of KY 17 at Old Madison Pike.

Madison Pike is a major north-south arterial in Fort Wright, KY. The roadway is heavily traveled as it serves as a primary route providing access to the cities of Covington, KY and Cincinnati, OH. The intersection of KY 17 and Old Madison Pike (Figure 3) was a stop-controlled intersection with control only for eastbound traffic from Old Madison Pike. Northbound and southbound KY 17 have two through lanes with a northbound left turn lane for access to Old Madison Pike. Old Madison Pike is a two-lane road approaching from the west. A large vacant parcel of property exists to the east of KY 17 which currently had no access to the property east of the intersection. The intersection is constrained by topography of the area with a major rock cut on the northwest quadrant of the intersection, a steep downgrade to the east and a large bridge structure approximately 150 feet to the south. Under the existing conditions, the intersection operated at a LOS F during the AM and PM peak periods, with anticipated increasing delays in the future.

The project was originally undertaken with a traditional design approach analyzing two alternatives for the intersection. The first was a traditional signal upgrade and the second the introduction of a modern roundabout (Figure 4). These two alternatives were considered for all intersections on the corridor without regard to the specific constraints of each location. The design for these alternatives yielded project estimates between $5M and $5.8M because both alternatives caused major impacts to the existing bridge structure and rock cuts near the intersection. In order to address the high cost associated with these alternatives, a practical design approach was undertaken to develop a more feasible alternative for the intersection.

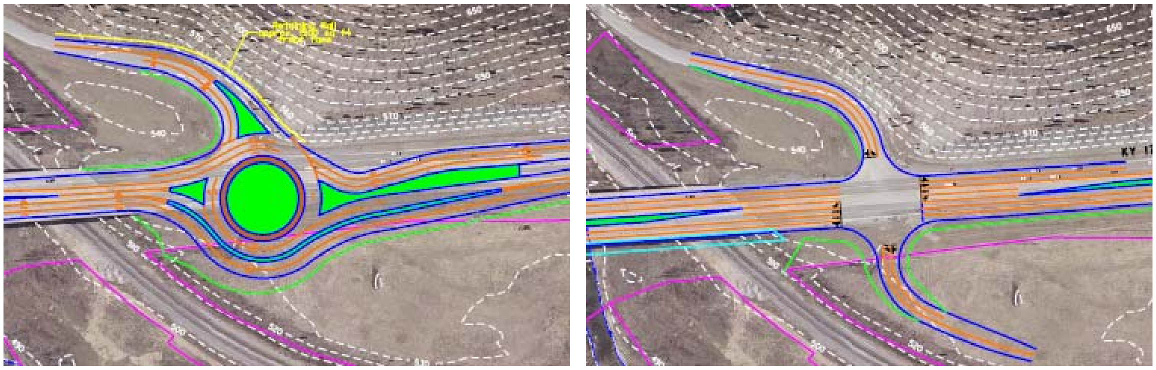
Figure 4 Roundabout (L) and traditional signal (R) alternatives

Practical Design Approach
In order to develop a practical solution the purpose of the intersection improvements were determined. The original approach essentially set out to determine the feasibility of a roundabout or a traffic signal at the intersection. The new approach set out to clearly decrease delays from the stop controlled approach on Old Madison Pike. No safety concerns were identified other than those resulting from increased congestion at the intersection. In order to meet the operational needs, a desired level of service was established by the project team of achieving a LOS D or E. Additionally, the project aimed to decrease delays without substantially widening KY 17 as no plan for widening the roadway to a six lane section were under consideration. Therefore, the final alternative would be best to operate a total of four through lanes (two in each direction). This understanding of the project environment guided the design approach. Furthermore, it was understood that the problem was purely associated with the stop controlled approach and no existing problems were present on KY 17. Therefore disturbances to KY 17 should be minimized.

After the constraints of the project were determined it was important to define the specific demands placed on the project. Traffic volumes for each intersection were based on the future land uses in the corridor and surrounding areas. However, as KTYC has no plans for a future corridor improvement (i.e., lane additions), the peak hour projected traffic flow was adjusted to allow a maximum of 1700 vehicles per lane per hour (vplph) for all traffic flows. This constrained forecast provided a reasonable estimate of the traffic that would be expected in light of both planned residential and commercial development, as well as planned roadway improvements.

After the intent of the project and its operating parameters were established additional constraints of the project were identified. The previous signal and roundabout alternatives clearly showed the impacts of disturbances to both the rock cut and the bridge. In order to provide a minimal cost improvement, it was imperative to stay within or near the existing cross section and not cause significant disturbances to these two major physical constraints.

The designs of the two previously considered alternatives were merged to create a unique solution to the problem to address intersection delay within these parameters. First, the concept of a northbound bypass lane, as used on the roundabout was chosen to minimize delay associated with this heavy movement. Access to the eastern parcel was provided by an easement with the parcel to the north. Signal control was used as it represented the smaller footprint of the two options. This resulted in a signalized inside left turn from Old Madison Pike which would merge into the northbound KY 17 traffic. The existing cross section on KY 17 would also be able to be maintained with minimal widening on the shoulder to accommodate a small channelizing median for the left turn. This alternative is shown in Figure 5.

Figure 5 Selected alternative (Practical Solution)

This practical solution project was a unique design fit to the roadway with its specific issues and constraints. As a result, the cost for the improvements was estimated at $275,000; a total cost savings of over $4.5M for a single intersection. Delay at intersection was estimated at LOS B, which actually exceeded the target value LOS D/E.

CONCLUSIONS AND RECOMMENDATIONS

Roadway projects that address mobility, safety, community and environmental issues are required and are considered by DOTs on a daily basis. Budgetary constrains however create a reality that designers have to deal with and use innovative approaches and think “outside the box.” The concept of Practical Solutions has been introduced in order to encourage the development of more appropriate solutions without compromising safety or mobility. This approach requires the designer to use creative design and move away from the “typical cross sections” concept, where a standard “oversized’ template is traditionally used. 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 if Practical Solutions are to be successful in reaching their potential benefit. What is required is a procedure that assures 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.

The underlying idea of Practical Solutions is to equally consider and address all issues including safety, environment, community, capacity, mobility, and budget. Designers will be asked to develop an appropriate solution and design that efficiently balances all factors. This implies that they should consider typical and non-typical designs and elements in their development and evaluation of alternatives. Such approaches may require the use of fewer and narrower lanes, unique intersection solutions instead of traffic signals, and narrower shoulders. Identifying all possible design options and properly evaluating them through objective measures of effectiveness is imperative for delivering an appropriate and practical project with a reasonable cost. This may indeed necessitate the consideration of alternatives that could initially not be viewed as appropriate. The basic notion of Practical Solutions is the need to examine non-typical approaches wherever they are required and determine how each of the roadway-shaping issues would be addressed in the final design.

During the project planning phase alternatives should be developed on a conceptual scale and include all reasonable solutions that address the project issues and objectives. Identification of conceptual solutions or alternatives should begin with specifying the goals/objectives to be addressed based on the purpose and need statement. Depending on the complexity of the problem, it may be necessary to present and evaluate a number of alternatives. The number and range of alternatives selected should be appropriate to the identified needs.

After alternative strategies have been developed, it is necessary to move to a more detailed examination of both the constraints of the study area and the ultimate design of the project. This is achieved by a high level of interaction between the design elements and the project constraints. As such the ultimate design should be responsive to all issues. In order to find the most appropriate solution to project elements, it is a necessity to examine a wide range of design choices that consider all relative issues to address the specifics of the project. Therefore, the choices identified should be reflective of the goals and objectives identified in the purpose and need statement.

A number of concepts regarding mobility and safety were presented and discussed within the application of Practical Solutions. Each of these concepts has an impact on the final solution to be selected and requires special attention. The choice of the desired and acceptable level of service becomes important, since it will have a significant influence on the size 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 issues and constraints and specifically addresses the goals/objectives in the purpose and need statement. 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.

The *Green Book* provides guidance and control values that allow flexibility for the design of new alignments or those undergoing major reconstruction (3). 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* 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* provides some information on these areas, but also lacks any quantifiable relationships for the values of various design elements (2). The Highway Safety Manual should also provide a tool for designers to evaluate such design element tradeoffs (7, 8).

Practical Solutions should not be confused with or viewed as Value Engineering. The latter concept 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 aims to develop appropriate and contextual solutions for projects considering the entire spectrum of options and balancing the various project requirements. Moreover, Practical Solutions is a system sensitive approach where reasonable solutions are sought to address more problem areas within constrained financial resources. This can be achieved by applying the concept of diminishing returns and viewing the project as an investment. At some point in the design process, larger cross sections and wider right of way may not “return” significant improvements for the investment to be made. The current budgetary constraints and limitations necessitate such an approach for addressing more problem areas with limited resources. This approach calls for just meeting specific project goals and objectives, not significantly exceeding them.

The results of the research effort identified the need for additional work on the following topics:

- Training should be developed for the agency personnel and consultants. The basic premise and concepts of Practical Solutions as well as the role of the various elements identified above should be presented through a training venue (workshop or presentations).
- Further validation and refinement is needed for Practical Solutions principles presented above. The report presented the hypothetical justification and also discussed potential application of the principles in a case study. However, it is desirable to use these principles in other cases to determine their applicability and identify potential refinements to make them meaningful for designers as they face a variety of situations. The use of similar principles and procedures in other states should be monitored and assessed for best practice adoption.
- Tools that consider the conflicting interests of the various project constraints and developing means to resolve these conflicts for selecting the most appropriate practical solution are needed with particular attention given to safety and mobility. This will enhance and facilitate the widespread use of Practical Solutions, while providing sound means for systematically evaluating alternatives and options.

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APPENDIX A

Practical Solutions Presentation

PRACTICAL SOLUTIONS FOR PLANNING AND DESIGNING ROADS

Good roads creating a great system

Realities

- Limited budget
- Need for roadway improvements
  - Safety
  - Mobility
- Unfunded short term needs
- More projects than funds

Objective

- Use available funds more efficiently
  - Address more needs faster
  - Complete more projects
  - Opportunities for balancing priorities system-wide

The Approach

To deliver an improved system with limited resources, KYTC must find ways to extract more value from our expenditures

KYTC will derive this value from "**Practical Solutions**"

What are Practical Solutions?

prac•ti•cal so•lu•tions (prăk´tĭ-kəl səlóosh'ns) n.

1. A process by which the value of a project is maximized
2. Ensuring that a project is the correct solution for it's surroundings: RIGHT SIZING
3. An approach to transportation in which an improvement is considered on the basis of its contribution to the entire system instead of its individual perfection

The "Basics" of a Roadway Project

- Project costs
- Mobility increased
- Safety improved

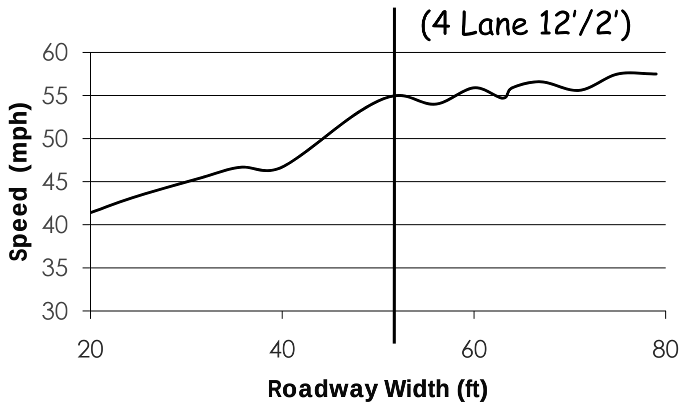
Basic Road Costs

- 2 lane
  - $5.7-8.7 million/mile
- 4 lane
  - $18.9-23.9 million/mile

Basic Needs-Mobility

- Estimates of mobility
  - Delay
  - Speed
  - Time
  - Level of Service (rating of congestion)

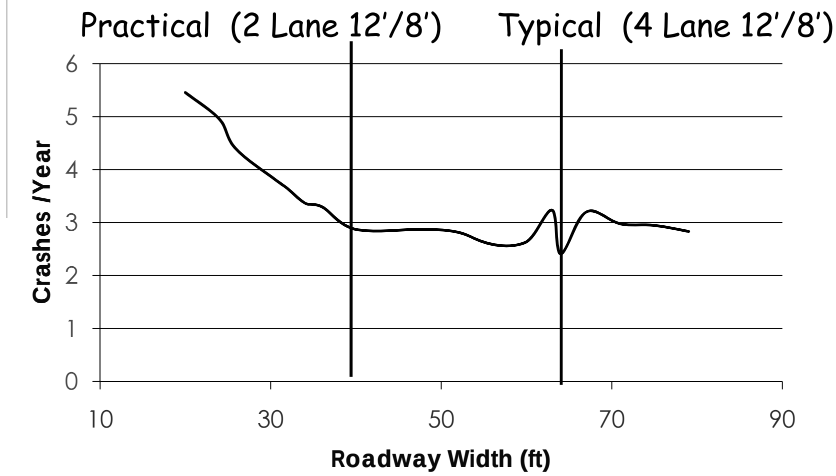
Speed and Road Width

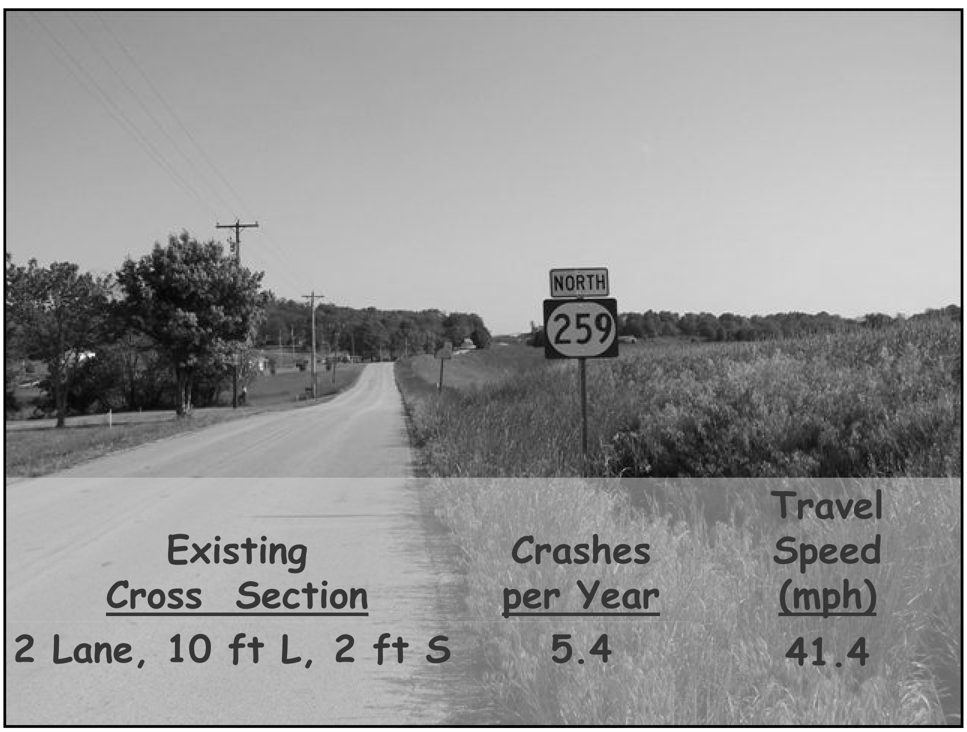


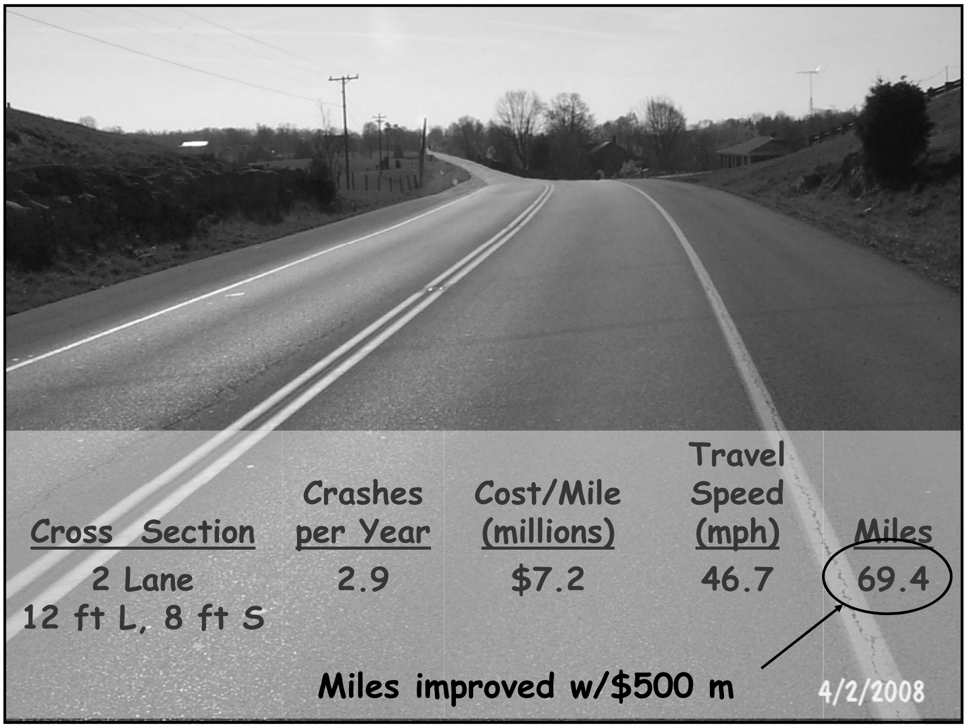
Basic Needs-Safety

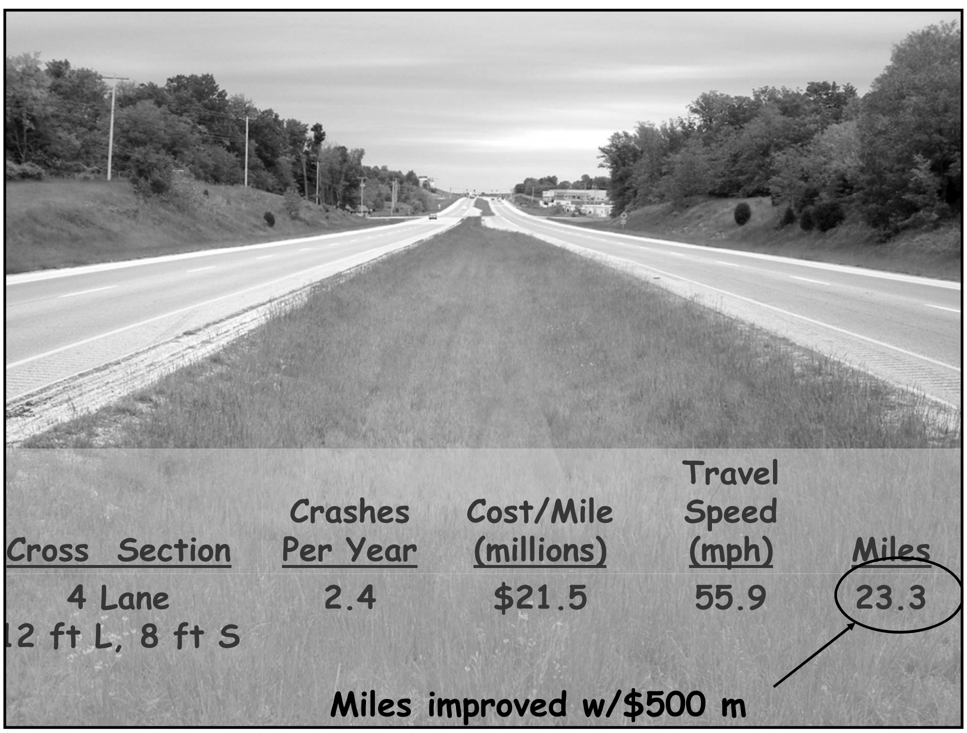
- Crashes happen with every roadway design
- Goal: Safety improvement

Safety Tradeoffs






Cross Section
Crashes per Year
Cost/Mile (millions)
Travel Speed (mph)
Miles
2 Lane
12 ft L, 8 ft S
2.9
$7.2
46.7
69.4
Miles improved w/$500 m
4/2/2008


Cross Section
Crashes Per Year
Cost/Mile (millions)
Travel Speed (mph)
Miles
4 Lane
12 ft L, 8 ft S
2.4
$21.5
55.9
23.3
Miles improved w/$500 m

Road Improvement Example (1/2)

Available budget $500 m to improve 2 lane roads

Cross Section	Crashes per Year	Cost (millions)	Speed (mph)	Miles
2 Lane, 10 ft L, 2 ft S	5.4	--	41.4	--
2 Lane, 12 ft L, 8 ft S	2.9	$7.2	46.7	69.4
4 Lane, 12 ft L, 8 ft S	2.4	$21.5	55.9	23.3

Miles to improve w/$500 m

Road Improvement Example (2/2)

Design	Miles Improved w/$500 m	Crashes per Year Reduction	Travel Speed Increase	Total Reductions	
				Crashes	Travel Time
Practical	69.4	2.5	5.3	173.5	367.8
Typical	23.3	3.0	14.5	69.9	337.9

More miles, fewer crashes and fewer delays for same budget!

Principles

- Target the goals/objectives of the Purpose and Need Statement
- Meet anticipated capacity needs
- Evaluate safety compared to the existing conditions
- Develop and evaluate design options and alternatives
- Maximize design to the point of diminishing return

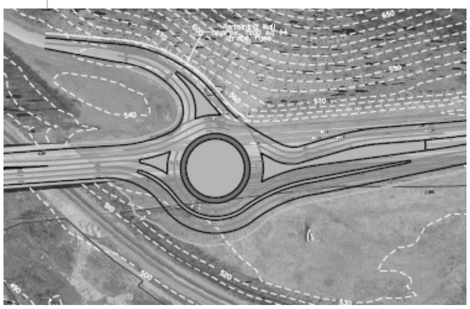
Case Study

(1/3)

- Madison Pike (KY 17) Intersection Improvement Study
- Comprehensive plan for improvements at intersections
- Current LOS F

Case Study

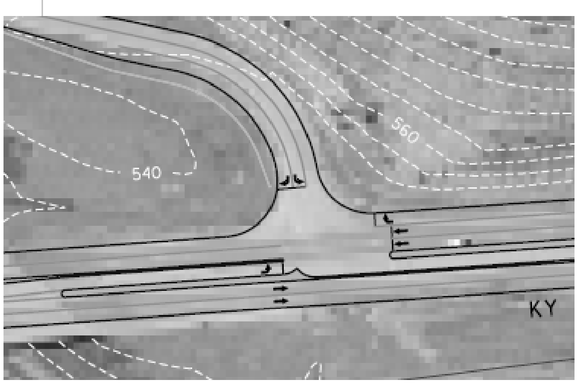
(2/3)



Traditional designs $5-$5.8 m

Case Study

(3/3)



Practical Design

Real issues:
Delay from side street;
no need for widening

Cost: $275,000

How it Works

- Balance needs
  - Cost
  - Safety
  - Mobility
- Evaluate options
- Document and justify decisions

Ground Rules

Practical Solutions is NOT

- **Cutting corners**
  - We must deliver the system as promised
- **Compromising safety**
  - Every project gets safer
- **A magic bullet**
  - It will not solve all our problems

Summary

- More projects with same funds
  - Decreased traffic delays
  - Improved safety
- Potential for setting system-wide approach and priorities
- Appropriate and contextual design

For more information or a complete publication list, contact us at:

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