JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY

Synthesis Study of Best Practices for Mapping and Coordinating Detours for Maintenance of Traffic (MOT) and Risk Assessment for Duration of Traffic Control Activities

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16. Abstract

Maintenance of traffic (MOT) during construction periods is critical to the success of project delivery and the overall mission of transportation agencies. MOT plans may include full road closures and coordination of detours near construction areas. Various state DOTs have designed their own manuals for detour mapping and coordination. However, very limited information is provided to select optimal detour routes. Moreover, closures or detours should provide not only measurable consequences, such as vehicle operating costs and added travel time, but also various unforeseen qualitative impacts, such as business impacts and inconvenience to local communities. Since the qualitative aspects are not easily measurable they tend to be neglected in systematic evaluations and decision-making processes.

In this study, the current practices obtained based on an extensive literature review, a nation-wide survey, as well as a series of interviews with INDOT and other state DOTs are leveraged to (1) identify a comprehensive set of Key Performance Indicators (KPIs) for detour route mapping, (2) understand how other state DOTs address the qualitative criteria, (3) identify how the involved risks during the planning, service time, and closure of the detour routes are managed, and (4) recommend process improvements for INDOT detour mapping guidelines. As demonstrated by two sample case studies, the proposed KPIs can be taken as a basis for developing a decision-support tool that enables decision-makers to consider both qualitative and quantitative aspects for optimal detour route mapping. In addition, the current INDOT detour policy can be updated based on the proposed process improvements.

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EXECUTIVE SUMMARY

Introduction

Maintaining traffic flow during construction periods is crucial for successful project delivery and the overall mission of transportation agencies. Maintenance of Traffic (MOT) plans include partial and/or full closures of corridors, as well as mapping and coordinating detours near construction areas. In the case of closures, traffic needs to be rerouted through detour routes. Using an extensive literature review, a nationwide survey, and a series of interviews with INDOT and other state DOTs, this project explored the best practices to (1) identify a comprehensive set of Key Performance Indicators (KPIs) for detour route mapping, (2) understand how other state DOTs address qualitative criteria, (3) identify how risks associated with the planning, service time, and closure of the detour routes are managed, and (4) recommend process improvements for INDOT's detour mapping guidelines.

Findings

The best practices can be summarized in four main categories: *(1) Avoiding closures in the first place:* most DOTs reported that they avoid full closures and detours of major highways in the first place through adding road capacity, using crossovers, extra work staging and consecutive weekend closures during the construction season, and using accelerated construction methods, such as prefabrication of elements. Where detours are unavoidable, DOTs stagger their project schedules to proactively avoid creating conflicts by staging different types of work at different times. When necessary, they use creative scheduling involving local authorities, such as nighttime and weekend work scheduling, to monitor planned and ongoing work at different jurisdictions. *(2) Mapping and coordinating the detour route:* Table 4.2 presents seven key criteria (i.e., operational, technical, environmental, safety, financial, political, and social) and associated identifiers for use in detour planning, based on existing guidelines and common practices. *(3) Maintenance of traffic:* Table 2.3 presents common MOT strategies and considerations in the design of temporary traffic control plans including travel time; coordination with agencies, contractors, and nearby projects; vehicle mix; sight distance; parking; land use; and access to nearby facilities. The interviews revealed that ensuring travel efficiency and service quality is an essential part of the practice of state DOTs and can be achieved using intelligent work zone systems that perform speed monitoring, queue detection, and backup analysis and communicate travel time information as well as downstream speed notifications via portable message signs to the drivers so that they can adjust their path accordingly. *(4) Risk management:* the common risks and best practices at the three stages of a detour route's life cycle were identified. *(a) At the planning stage:* the identified best practices include providing a driving environment like the closed route; monitoring the load-carrying capacity of the pavements and bridges; and considering truck needs and emergency responders. *(b) At the implementation/operations stage:* establish an incident management plan and a committee of vital stakeholder representatives to enable transparency and quick responses. Table 2.4 and Table 2.5 present the most feasible alternatives for incident management on detour routes and enhancing work zone safety. *(c) At the closing stage:* inter-governmental agreement in sharing the liabilities and mobile push notifications help provide restoration updates to the community.

Implementation

Sections 4.3 and 4.4 of the report provide recommendations for enhancing INDOT's current detour planning practice. Sections 4.2.1 and 4.2.2 present a list of criteria, identifiers, and applicable thresholds for selecting detour routes. Section 4.2.3 presents two case studies to demonstrate how the proposed KPI table can be used to develop a decision-support tool to assist detour route mapping. In future projects, a GIS-based automated tool could be developed to automatically identify the best detour route among the possible candidates based on the criteria proposed in this study, coordinates of the work zone on the map, and project characteristic—including the duration and location (urban/rural) of the work and the traffic volume and composition. This can be useful to INDOT's Management Information Systems. The interviews revealed that the *1996 INDOT Detour Policy* is currently under revision by INDOT. Section 4.3 provides recommendations for enhancing the policy based on (a) the recommendations from INDOT experts regarding the short-comings of the current detour policy in terms of its practical use, and (b) the practices of other state DOTs that were identified from the interviews.

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LIST OF ACRONYMS AND ABBREVIATIONS

AADT: Annual Average Daily Traffic

ABC: Accelerated Bridge Construction

ADT: Average Daily Traffic

AHP: Analytic Hierarchical Process

CMV: Commercial Motor Vehicles

DOT: Department of Transportation

EVAP: Emergency Vehicle Access Plan

FHWA: Federal Highway Administration

HCM: Highway Capacity Manual

HCS: Highway Capacity Software

IHCP: Interstate Highway Congestion Policy

IMUTCD: Indiana Manual on Uniform Traffic Control Devices

ITS: Intelligent Transportation System

KPI: Key Performance Indicator

LPA: Local Public Agency

MOT: Maintenance of Traffic

QAT: Queuing Analysis Tool

PAP: Performance Assessment Plan

PIP: Public Information Plan

RUC: Road User Cost

TDM: Travel Demand Management

TMC: Traffic Management Committee

TMP: Traffic Management Plan

TOP: Traffic Operations Plan

TTBs: Temporary Traffic Barriers

TTCP: Temporary Traffic Control Plan

TTCDs: Temporary Traffic Control Devices

1. INTRODUCTION

1.1 Background and Problem Statement

Maintaining traffic flow during construction periods is critical to the success of project delivery and the overall mission of transportation agencies (Brown et al., 2016; Karim & Adeli, 2003; Miralinaghi et al., 2020). Maintenance of Traffic (MOT) plans include partial and/or full closures of corridors as well as mapping and coordination of detours near construction areas. To address critical MOT issues, transportation professionals have proposed a variety of route guidance strategies (Black, 2001; Chinitz, 2007; Liu et al., 2013; Wu & Chang, 1999; Zhang & Hobeika, 1997) and studies on "work zone road user costs" (Sadasivam & Mallela, 2015; Sudarsana et al., 2014a; 2014b). In the case of partial closures, one of the main challenges is to ensure working safety while maintaining the efficient movement of traffic and minimizing the influence on the construction work. In the case of closures, the traffic needs to be rerouted through detour routes. Traffic diversion or detour strategies are generally implemented when traffic disruptions (including traffic incidents and road repairs) cause delays exceeding half-hour or when road projects require partial lane closure (Chien & Schonfeld, 2001; Jiang & Adeli, 2003; Najafi & Soares, 2001; Schonfeld & Chien, 1999).

Various state DOTs have developed in-house design manuals to guide their project detour mapping and coordination. However, very limited information is provided to select optimal detour routes. To this end, DOTs in North Carolina, New Jersey, Oregon, New York, Florida, Ohio, Kentucky, and Wisconsin have collaborated to publish the *Alternate Route Handbook* (Dunn Engineering Associates, 2006), which provides implementation plans for alternate routes with defined criteria. However, the scope of the handbook is so broad that traffic managers have insufficient information to determine the appropriate detour mapping and coordination (FHWA, 2009; Liu et al., 2013). Moreover, these closures or detours should provide not only measurable consequences (such as increased emissions, vehicle operating costs, and travel time for drivers) but also various unforeseen qualitative impacts (such as noise, business impacts, and inconvenience to local communities) (Berger et al., 2004). In developing detour plans, agencies can quantify the measurable impacts, even in monetary terms. However, the qualitative aspects are not so easily measurable and therefore are not able to be included in systematic evaluation approaches and decision-making processes. For this reason, qualitative components tend to be neglected.

1.2 Research Needs

There is a need to identify the best practices that can help INDOT personnel facilitate optimal detour mapping and coordination plans and improve service quality management for MOT. Additionally, risk managers need to manage and evaluate the potential risks through integration of social and multidisciplinary identifiers for the detour. This entails the development of standardized practices. Therefore, the cost-effective detour plans can help in minimizing not only potential social, financial, and technical losses, but also potential risks and maintenance duration.

1.3 Scope of Work

This research documents the possible improvements on the MOT plans for INDOT based on the identified best practices for mapping and coordinating detour strategies in terms of quantitative and qualitative aspects. The main focus areas in the study report are (1) defining identifiers that have implications for technical, financial, social, and management perspectives for detour mapping plans, (2) identifying the process improvement for the current detour plan and exploring the detour coordinating plans considering the drivers, local communities, general public, and other stakeholders (e.g., county, state, federal, and office sheriff), and (3) documenting the risk management/mitigation for the duration of traffic control activities based on the best practices.

1.4 Objectives

The objectives of the synthesis study on best practices for mapping and coordinating detours for Maintenance of Traffic (MOT) can be summarized in five main points as listed below.

1. Identify current state-of-the-practice on MOT strategies.
2. Explore the promising identifiers (e.g., design, financial, social, safety, and management perspective) to be incorporated into developing detour plans.
3. Investigate best practices for mapping and coordinating detours for MOT.
4. Identify process improvement for INDOT detour planning.
5. Provide advanced risk management/mitigation strategy based on the best practices.

1.5 Report Organization

The rest of this report is organized as follows—Chapter 2 presents an overview of the current state of practice on detour planning, execution, and management of traffic. The review covers publicly available documents and DOT manuals. Chapter 3 presents the data collection methodology and data analysis, the results of which are discussed in Chapter 4. The conclusions are presented in Chapter 5.

2. LITERATURE REVIEW

2.1 Introduction

This chapter presents the findings of a comprehensive literature review on the state-of-the-art and current practices for the Maintenance of Traffic (MOT) and detour mapping. The goal of the literature review was to explore the appropriate identifiers and performance indicators (e.g., design, financial, social, safety) and other indicators that reflect the agency management perspectives currently used by state highway agencies. The literature review process consists of two main steps: (1) review of available design manuals, current MOT plans and (2) risk management strategies for detours used by INDOT and by other state DOTs. The remainder of this chapter discusses the findings of these two steps.

2.2 Current State-of-the-Art Practices for MOT Strategies in INDOT

This section provides an overview of the state-of-the-art and current practice for MOT strategies and detours mapping in INDOT. The purpose of this section is to explore the process and to identify the key factors that are considered in the *2013 INDOT Design Manual* for purposes of MOT strategies, detour mapping, and risk management. The findings of this section provide a solid basis for identifying the process improvement for the current INDOT detour mapping approach. In the following sections, a detailed review and assessment of the following INDOT manuals and the ensuing insights, are provided.

- *INDOT Detour Policy* (1996)
- Chapter 503 of the *2013 Indiana Design Manual*
- INDOT Maintenance of Traffic (MOT) plans
- *INDOT Detour Mapping Guideline*
- *Work Zone User Cost Analysis*

2.2.1 INDOT Detour Policy (1996)

At the time of writing of this report, the available *INDOT Detour Policy* was dated 1996, even though an update was in progress. The contents of this report are based on the 1996 detour policy. The intent of the policy is to provide guidance on detour route selection on the occasions that interstate route closures are required due to construction work (INDOT, 1996). A review of the manual provides an overview of the steps as well as the key factors and performance indicators suggested by this manual for detour route selection.

According to the 1996 policy, if a state highway is to be closed, official and unofficial detour routes are selected based on the six-step procedure, shown in Figure 2.1.

According to Figure 2.1, the procedure begins with the evaluation of the need for the detour. Steps 2 and 3 are dedicated to the selection of the appropriate detour route through coordination of the district with local transportation officials. Through Steps 4 to 6, official contracts for deploying the detour route and reimbursing the costs associated with the damage to the local routes are set. The following sections describe these six steps in more detail, with the aim of determining the key factors and performance indicators suggested by this manual.

2.2.1.1 STEP 1–Determining the need for a detour route. The first step is to determine whether an official and/or unofficial detour is required. In the case of full road closure, any public road can be used for the official detour. If the selected detour route is along with the state highway system and the duration of detour is expected to exceed 7 days, an auxiliary detour route (referred to as an "unofficial detour") can be selected from the local system. The intent of proposing an unofficial detour route is to identify the route most likely to be used by the traffic for convenience purposes. This provides a basis for reimbursing the local governments for the costs associated with the patronage of their routes by detouring traffic.

2.2.1.2 STEP 2–Coordination with the local officials. In the second step, the highway administrative district selects best official and unofficial detour routes, in coordination with local transportation officials. The district requests the local government to announce one proposed unofficial and/or official detour routes on the local system.

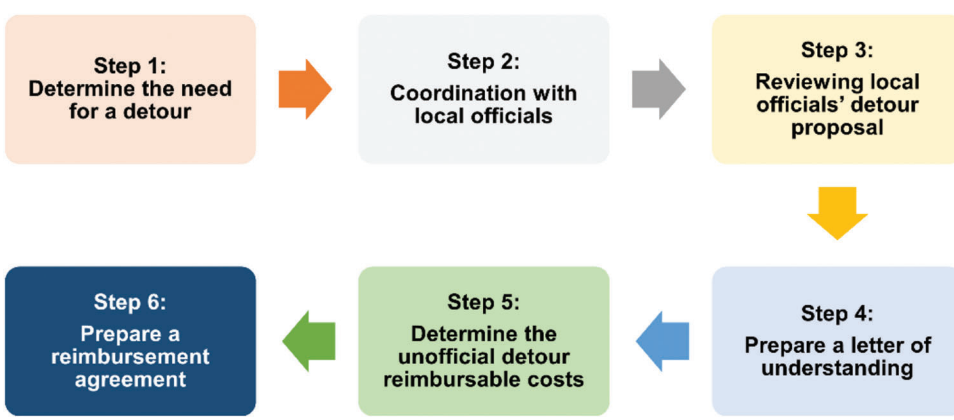


Figure 2.1 Detour route selection procedure based on the *INDOT Detour Policy* (INDOT, 1996).

2.2.1.3 STEP 3–Reviewing local official's detour proposals. At this step, INDOT reviews the local government proposal for official and/or unofficial detour routes. The possible outcomes of the review include the following.

- Traffic does not use an unofficial detour and rather uses the official detour.
- Traffic uses the proposed unofficial detour.
- Traffic uses another route.

Based on the *INDOT Detour Policy* (1996), in assessing the viability of an official detour route the following considerations should be made.

- Minimum safety standards.
- Structural capacity of the pavement and bridges to carry Indiana's legal truck loads.
- Capability of trucks to maneuver the route (adequate pavement width and turning radii).
- Volume of traffic flow.
- Needs of local traffic (emergency, school, public events, business, and so on).
- User costs due to additional distances imposed by detouring (at both the official and unofficial detour routes if applicable).
- Cost of installing official detour signage.
- Construction costs needed to upgrade the official detour route to minimum standards.
- Cost of maintaining/restoring the unofficial detour.

For unofficial detours, the proposed unofficial detour route should be compared with other routes in the local transportation system based on the following criteria.

- Travel time
- Length
- Route condition
- Capacity
- Load limits
- Community acceptance

2.2.1.4 STEP 4–Preparing a letter of understanding. When the official and/or the unofficial detour routes are selected, a "Letter of Understanding" should be sent to the local officials. The "Letter of Understanding" is a document that declares the selected road sections for the detour, the associated timelines, as well as the costs that for which INDOT would be responsible.

It is stated in the *INDOT Detour Policy* (1996) that there is no intention or obligation to improve the condition of an unofficial detour and INDOT only covers the improvement costs for official detours. The repair costs, however, are covered by INDOT for both official and unofficial detours. The amount of the repair costs is documented and paid through a "Reimbursement Agreement" as described in Step 5 and Step 6 in the sections below.

2.2.1.5 STEP 5–Determining the reimbursable costs of the unofficial detour. At this stage, INDOT and the local government representatives visit the site and document the condition of the unofficial detour prior to the announcement of the official detour route. The representatives develop a "Route Condition Inventory" and take pictures of unofficial detour route to document its condition prior to the declaration of the official detour.

It should be noted that if the local agency improves the condition of the unofficial detour, while performing the repairs the improvement costs are covered by the local agency and only the repair costs are paid by INDOT.

2.2.1.6 STEP 6–Preparing a reimbursement agreement. When the costs are documented, INDOT needs an agreement (the "Reimbursement Agreement"), to reimburse the local agency's expenses. Additional information on this step and the "Reimbursement Agreement" can be found in Appendix D of the *INDOT Detour Policy* (INDOT, 1996).

2.2.2 Discussion of Chapter 503, Indiana Design Manual *(2013)*

Chapter 503 of the *2013 Indiana Design Manual* mentions Maintenance of Traffic (MOT) as a plan for keeping the traffic flow in case the normal operation of a roadway is interrupted. The scope of a MOT plan is to maintain the continuous flow of vehicle, bicycle, and pedestrian traffic as well as access to nearby properties and utilities. MOT has two objectives: (1) efficient and safe movement of road-users through or around a work zone to ensure the safety of workers, incident responders, and equipment and (2) the efficient completion of the activities due to which normal operations are suspended (INDOT, 2013).

For all projects with "significant" public impact and when necessary, for other projects, it is intended that the TMP will include a Transportation Operations Plan (TOP), and a Public Information Plan (PIP). According to the *2013 INDOT Design Manual*, significant projects are defined as "all projects within the boundaries of a designated Traffic Management Area that occupy a location for more than 3 days with either intermittent or continuous lane closures are considered significant (INDOT, 2013)."

In addition, all projects need a TMP and all TMP's must have a Temporary Traffic Control Plan (TTCP). TMP must have a TOP and PIP for "significant" projects. INDOT's Work Zone Safety and Mobility Policy should be reviewed to determine whether a project is considered to have significant impact or non-significant impacts. The information is provided in the engineer's report for the project under consideration.

To manage the responsibilities stated above, INDOT requires that a TMP team, should be formed, and the transportation management strategy for the project should be identified. The TMP team is responsible for gathering the required data for comparing the alternative MOT strategies. The engineer's report is suggested as a starting point for the TMP team.

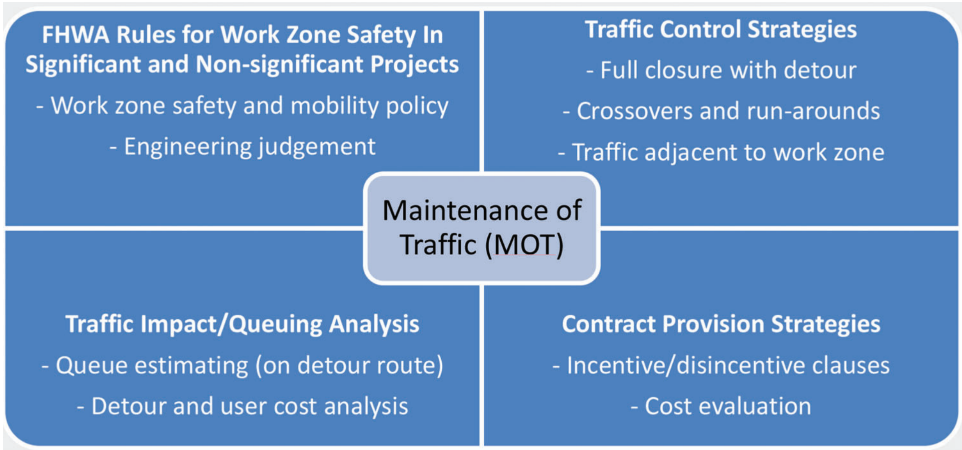


Figure 2.2 Summary of MOT features.

In summary, the responsibilities of the TMP team are as follows.

- Create a summary of the project.
- Develop a Temporary Traffic Control Plan (TTCP), a Transportation Operations Plan (TOP) and a Public Information Plan (PIP)—minimizing the adverse impacts of traffic disruption and hazards.
- Develop Maintenance of Traffic (MOT) plan sheets—indicating the construction phases with details, detour details, and plans for modification or improvements to detour route.
- Develop a vicinity map—this map should be on a scale, large enough to indicate land use types, adjoining side streets, detours, and alternative routes.

2.2.2.1 Step 1—preliminary MOT planning. Preliminary factors and steps involved in MOT planning are presented in Figure 2.2. A brief description of each of the steps is provided. FHWA rules for work zone safety in significant and non-significant projects—FHWA's Work Zone Safety Rule has made it mandatory for a state to have a policy to systematically consider and manage the impacts of work zone on all federal-aid highway projects. On similar guidelines, INDOT has a work zone safety and mobility policy available through its webpage. These guidelines differ based on whether a project is classified as significant or non-significant. This determination is made during the project scoping stage and is included in the engineer's report for the TMP team. INDOT's work zone impact policy and/or the engineer's judgement are used as a basis to make this determination. It is mandatory to develop a temporary traffic control plan for both types; however, a traffic operation plan and a public information plan is not mandatory for projects with non-significant impacts.

2.2.2.1.1 Traffic control strategies. Various traffic control strategies such as full lane closure with detour, single lane closure, crossovers, and runaround are considered depending upon the characteristics and potential impacts of the project. INDOT mentions that in overall project planning and design, the selection of tentative strategy at the early stage of the project is essential. The following are a few traffic control strategies stated by INDOT, which fall in the scope of this study.

Complete road closure with detour. This solution involves the complete closure of either one or both directions of the roadway near the work zone and rerouting the traffic to existing alternate routes capable of accommodating excess traffic or those that can be modified to do so. Complete road closures with detour can even be used for specific time intervals during the day.

According to the current detour policy and the Indiana Code (Indiana Code Title 8. Utilities and Transportation, 2018), INDOT may be required to repair an unofficial detour in addition to the official detour on state highways system. The choice of the local route to be designated as an unofficial detour is a joint decision made by INDOT and the Local Public Agencies (LPAs). The designer should make recommendations to INDOT on not only the route selection, but also any required improvements to make the route usable depending on its condition.

As suggested by INDOT (INDOT, 2013), the factors that should be considered in assessing the detour route viability are the following.

- Work location—if travel lanes are not impacted by construction work, a complete closure is not needed.
- Duration of work—if only a few days of work are required, then there is no need for complete closure.
- The detour for an interstate project should, where possible, be another freeway. Other routes can have a combination of state system and local roads. Local road can be an "unofficial" detour; however, an agreement with the jurisdiction agency is needed as discussed earlier.
- Ability of the detour route(s) to accommodate the re-routed traffic during the peak hours. INDOT's Traffic Count Database system has data on the hourly traffic

volumes for state and other local roads. Seasonal adjustment factors are used to modify the average traffic count to estimate the peak demand. Capacity analyses are conducted on the links as well intersections to determine the throughput and identify bottlenecks. Further information on capacity can be found in the *Highway Capacity Manual* (TRB, 2010) and INDOT's *Interstate Highway Congestion Policy (IHCP) Analysis Tools* webpage (INDOT, n.d.a).
- The detour route can be modified to accommodate the displaced traffic. However, if the demand still exceeds 95% of the detour route capacity, complete closure may not be viable.
- Several factors such as geometry, condition, vertical clearance, pavement condition, bridge/structure status, and heavy vehicle volumes should be considered.
- INDOT's CARS program should be used for purposes of permitting oversized vehicles on detour routes.
- Added travel time, distance and cost for detour route users should be minimum. Engineering judgement is used to decide acceptable limits.
- Schools
- Emergency services.

FHWA Divisional Office's approval is required for full mainline interstate highway closure. To support the notion that complete closure is the best strategy, and therefore to request, the following evidence needs to be provided.

1. Safety problems that support the closure.
2. Impact of closure on construction time.
3. Submitting an INDOT worksheet which is available to assess the viability of complete closure.
4. Impact of closure on interstate commerce.

Once the decision is made, the Indiana Motor Trucking Association must be notified of complete interstate, and interstate ramp to interstate ramp closures. An INDOT member of the TMP team should notify both Indiana Motor Trucking Association and the FHWA.

Lane closure on a multi-lane highway. This strategy typically closes one or more traffic lanes. However, it may be necessary to perform a capacity and delay analysis to identify whether the lane closure will result in serious congestion. The use of shoulder or median area as a temporary lane is allowed. Care should be taken pertaining to pavement areas.

Lane closure on a two-lane road. This strategy involves using one lane for one or both directions of traffic. Use of temporary signals is suggested to coordinate traffic flow. Contractors also have the option to use flagger assistance devices. According to the *INDOT Design Manual*, flagger option might not be advisable for AADTs exceeding 10,000. If the closure extends several nights at a single location, flagging operations may not be suitable.

Other strategies. Other strategies include lane shift, median cross-over, split median cross-over, runaround with diversion of temporary bridge, and temporary road closures during the day.

2.2.2.1.2 Traffic impact/queuing analysis. INDOT mentions that the work area and traffic area should be as far separated as possible. However, regardless of this separation, the queue length and daily user cost should be estimated. The outcomes of queuing analysis are used to develop risk mitigation strategies such as restricting work to off-peak hours, temporary construction of extra lanes, etc.

When more than one viable detour route is available, an analysis may be required to identify the best detour route(s). The analysis may be as simple as calculating the additional travel time. To estimate the travel time, the *Highway Capacity Manual* and associated Highway Capacity Software (HCS) may be used.

INDOT's Queuing Analysis Tool (QAT) or QuickZone 2.0 are the preferred methods of estimating queue for exception requests to the *Interstate Highway Congestion Policy* (IHCP) (INDOT, 2013). For purposes other than IHCP exception requests, QUEWZ98 or other similar programs can be used to analyze traffic impact for freeways. For segments with stop or signal control, Synchro, Highway Capacity Software 2016, or other computer modeling software can be utilized.

2.2.2.1.3 Contract provision strategies. Cost evaluation by the project owner can help provide the contractor with an incentive or a disincentive clause in the contract. This clause is necessary to minimize the project duration by providing the contractor with additional funds for early completion of the project and assess damages for delay in construction. "A + B" bidding is a useful strategy to minimize project cost. "A" states the cost of work in the project scope and "B" states the cost considering the reduction in exposure time due to lane closure periods, i.e., the total contract days proposed by the contractor. This helps INDOT in its bid evaluation process.

2.2.2.2 Step 2—Temporary Traffic Control Plan (TTCP) development. The *INDOT Standard Drawings*, *Standard Specifications*, or *Indiana Manual on Uniform Traffic Control Devices* (IMUTCD) (INDOT, 2011) provides guidance on how to develop a well-devised work zone traffic control plan that minimizes the adverse effects of traffic disruption and hazards. The designer's responsibility is to develop such as a Temporary Traffic Control Plan (TTCP), which can include construction plan sheets, special provisions, traffic control devices, construction sequence and time, information for local businesses, residents, pedestrians, and bicyclists, routing emergency vehicles. Figure 2.3 presents the features of a TTCP. Finally, a traffic control plan checklist is available under INDOT MOT.

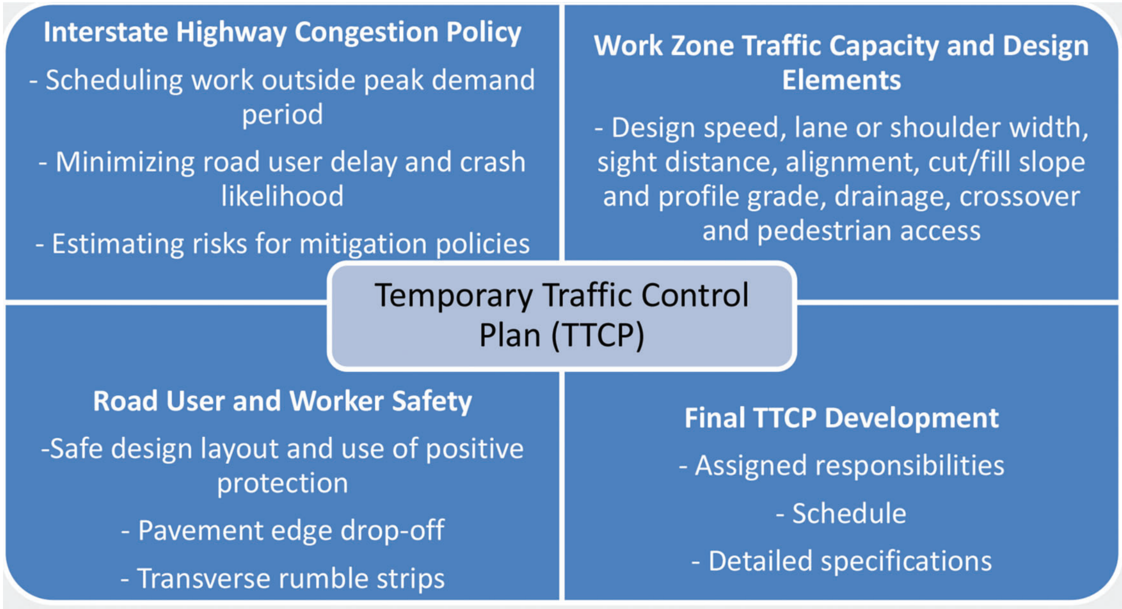


Figure 2.3 Summary of TTCP features.

After the preliminary field check, the checklist should be updated and completed to ensure that TTCP addresses all applicable work zone traffic-control elements.

The overall process flow of the development of a traffic control plan is as follows.

1. Engineer's report—an initial strategy for work zone traffic control is recommended.
2. The designer is now responsible to obtain feedback from the concerned highway district regarding proposed MOT.
3. Preliminary field check—the recommended traffic control strategy is reviewed against actual and anticipated field conditions.
4. Hearing—at this stage, the plan, profile, cross-sections, the construction schedule, and phasing, in addition to environmental impact reports should be completed. The permit process and the special provisions should be prepared.
5. Final field check—revisit any shortcomings identified in the hearing stage and should be coordinated with the district's communication office.
6. District construction review—if needed, the proposed TTCP is revised by the designer until both the district construction and traffic offices concur.
7. Final tracings submission—preparation of final contract documents. Unofficial detours should not be demonstrated in the plans or special provisions.

2.2.2.3 Step 3—Other considerations. Figure 2.4 presents the important steps in the entire MOT strategy and planning process and gives an insight into the other conditions considered by INDOT as a final step of their detour planning.

INDOT states that for projects on interstate routes where the AADT exceeds 50,000, an Incident Management Plan (IMP), which is separate from the TOP, may be required. A few incident management strategies suggested by INDOT (INDOT, 2013) include the following.

- Intelligent Transportation System (ITS)
- Courtesy patrol
- Emergency responder's coordination
- Surveillance, i.e., closed circuit cameras and loop detectors
- Enhanced mile-post markers
- Media coordination
- Designated local detour routes
- Contract support for incident management
- Incident/emergency management coordinator
- Incident/emergency response plan
- Dedicated breakdown area
- Contingency plans
- Stand-by equipment
- Stand-by personnel

The next section addresses the detour mapping guideline currently used by INDOT.

2.2.3 INDOT Detour Mapping Guideline

The current state of practice for planning detours with INDOT involves primarily the use of a detailed framework (INDOT Editable Interstate Detour Figure) that can be used to generate a detour route (INDOT, n.d.a). The INDOT Editable Interstate Detour Figure is an unpublished spreadsheet used internally by INDOT for detour planning. Although active, the framework places much more emphasis on technical criteria and leaves out several other important considerations such as social and environmental. Table 2.1 presents a summary of this framework.

In its entirety, the current INDOT worksheet provides planners with a way to decide between multiple viable detour route options by providing them with a

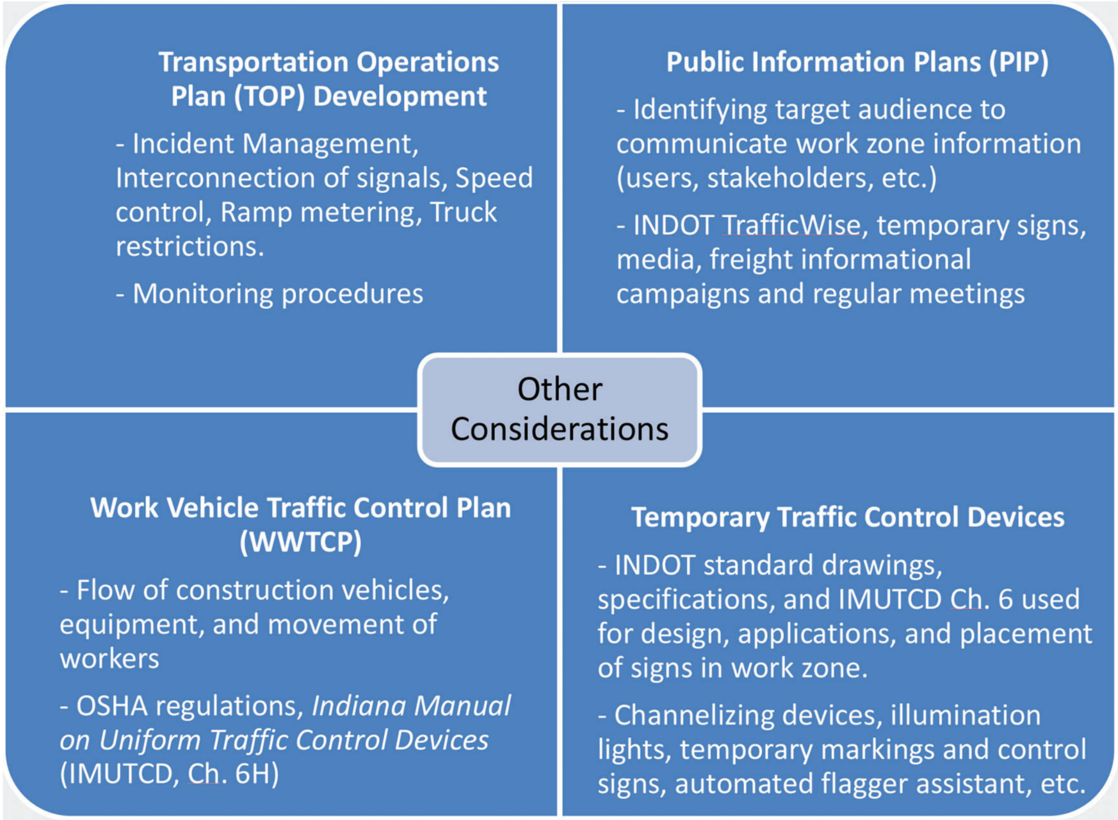


Figure 2.4 Additional considerations for MOT.

TABLE 2.1
Current INDOT detour mapping framework (adapted from INDOT Editable Interstate Detour Figure (INDOT, n.d.b))

Summary of Findings
1. Duration of work
2. Travel distance along detour
3. Detour legs restricted by construction or special events
4. Detour legs engaged as part of a detour for another project
5. Pavement condition on detour
6. Bridge ratings on detour
7. Structure ratings/condition on detour
8. Vertical clearance on detour
9. Traffic volume to capacity
10. Other concerns
Is interstate detour route viable?

way to evaluate and determine the best possible candidate among competing choices. As shown in Table 2.1 ten different criteria are considered when evaluating the alternatives, all the way from the duration of the work on the project to considerations of traffic volumes on each of the detour routes. The process of selecting a detour route begins with proposing viable detour options, two or more, if available. In its current state, the worksheet specifies that all proposed detours of interstates are preferred to be on another interstate or freeway with full access. If none is available, the worksheet recommends a cross-over or runaround.

If viable detours on interstate or freeway are present, they are each evaluated according to the criteria presented in Table 2.1. In general, the worksheet recommends deploying a detour if the duration of work is at least 3 days, otherwise, a detour may not be necessary. Works that may take less than 3 days in duration include sign structure installation, signal modernization, concrete polymeric bridge deck overlays, high friction surface treatment, mowing, RPM maintenance, and lighting maintenance.

Having established the duration of the project, and if a closure is warranted and thus the deployment of a detour, the available alternatives are compared for added distance. The best candidate should be similar in length to the original route. Thus, the detours that add a significant distance to the total route are less favorable as detours. The detour options are then checked for potential conflicts with other planned events. Since detouring traffic to a given route inevitably increases that routes total traffic volume, it is imperative that planners assess each leg of the proposed detour for special events such as sports or parades that may impact traffic flow. If such events are possible or planned, planners assess their duration and significance before deciding the viability of that leg as a detour. This is considered in Criterion #3 in Table 2.1.

In the same way that special events can increase the traffic volume on a given leg of the detour, having more than one interstate detour traffic to the same route can also increase that route's traffic beyond its capacity. Thus, the current worksheet requires planners to verify that the current alternatives being considered are not being engaged as detours for other projects. If not, the routes are considered as viable detours, and if yes, the planners are encouraged to review the traffic volumes on the routes to ensure that the added traffic volumes do not exceed recommended levels to cause congestion. This is represented by Criterion #4 in the summary in Table 2.1. Since each of the legs on the detour route must cope with traffic volumes that would otherwise have been on the road, it is essential that the pavement condition for each section of the legs has a pavement surface evaluation of at least "fair or better." Thus, the worksheet requires planners to evaluate and assess the pavement condition as indicated in Criterion #5 of Table 2.1. If the pavement condition is determined to be "at least fair," the leg is considered a viable detour option. Otherwise, planners may assess whether the sections can be improved as part of the project MOT. If the planners determine that this is in the best interest of the project and required MOT, the repairs are initiated, and the leg is considered a viable detour. Otherwise, the leg is not a viable detour option. The worksheet recommends determining pavement condition using the INDOT Road Analyzer tool (INDOT, n.d.b).

Bridges are also supposed to be checked in the same way as pavements are checked. The bridges are checked for their load rating and only those that are rated "fair or better" can be considered as viable detour options. The worksheet suggests checking the bridge design and load sufficiency rating using the FHWA bridge database (FHWA, 2021). Similarly, other structures on the detour routes such as culverts must be checked for the structural rating and only routes whose structures are rated fair or better may be considered as viable detour options. For those that are not, options are presented to assess whether improvements can be made as part of the detour MOT plan.

Criterion #9 in Table 2.1 is concerned with the vertical clearance on the detour route. According to the worksheet, clearances of less than 14 ft may be an issue. This is because traffic on the road may often include high vehicles and trucks and detouring them to a route with low clearances may pose challenges that may result in damage to the vehicles and the infrastructure such as overpasses and bridges. Thus, detour alternatives are checked for minimum vertical clearances and only those that meet the criteria may be considered as viable options.

Using the criteria included in this worksheet, candidate routes can be evaluated, and the most viable route can be selected. This is similar in concept to our framework in this study, with the exception that our proposal expands this framework to include several other important aspects including political considerations, social aspects, and environmental concerns in addition to the technical aspects.

2.2.4 Work Zone User Cost Analysis

Chapter 503 of the *2013 Indiana Design Manual* provides guidelines to determine the daily detour user costs. Detour user costs consist of user delay cost and vehicle operating costs. To estimate user delay cost, increased travel time per vehicle, and the user's value of time should be determined. The US Department of Transportation estimated value of time varies from $9 to $30 per hour based on type of trips (Ayala, 2014). A value of $16 per hour per vehicle may be used as suggested by INDOT (INDOT, 2013). The lost time is determined in the *Indiana Design Manual* by estimating the extra time traveled per vehicle in detour route compared to the work-zone area. To estimate vehicle operation costs, the extra distance traveled per vehicle along with the vehicle operating cost should be estimated. The manual estimates the vehicle operation costs include fuel, maintenance, and depreciation costs, which IRS Standard Mileage Rate estimated at $0.575 per mile in 2020. In addition to user costs, the cost of improvements regarding the detour route such as repaving or widening the pavement, and signal improvements must be included. To determine the daily detour user costs, the following equations are proposed by Chapter 503 of *INDOT Design Manual* (INDOT, 2013).

1. Detour User Cost = ((Cost in Lost Time) + (Cost in Extra Distance Traveled))
2. Cost of Lost Time = (No. of Vehicles Detoured) × (Increase in Travel Time per Vehicle) × (Value of Motorist Time)
3. Increase in Travel Time = (Length of Detour / Average Detour Travel Speed) – (Length of Work Zone / Average Travel Speed through Work Zone)
4. Cost in Extra Travel Distance = (No. of Vehicles Detoured) × (Net Increase in Length of Travel) × (Vehicle Operating Expense)

where, the net increase in length of travel distance is the difference between the detour and non-detour distances.

2.2.5 Summary of INDOT's MOT Practices

Chapter 2.2 of this report reviewed the current state of-the-art and state of practice within INDOT concerning detour mapping and Maintenance of Traffic (MOT) during traffic incidences and construction works on corridors. The documents reviewed include the *INDOT 1996 Detour Policy* (INDOT, 1996), Chapter 503 of the *Indiana Design Manual* (INDOT, 2013) as well as the *INDOT Detour Mapping Guideline*. The reviewed documents showed that although INDOT does not currently have an active framework for detour mapping, there exists a procedure (set up in the detour policy) by which a detour route can be selected. The procedure is summarized in six steps, as shown in Figure 2.1. These include assessing the need for a detour, coordinating with local officials to determine the best detour if one is needed, reviewing proposals from local authorities about potential detours, signing a memorandum of understanding and finally deploying the detour and disbursing any reimbursements.

The above process, as outlined in the policy ensures that the agency deploys an unofficial detour in addition to the official designated route. The official route is determined using a similar process, as outlined in Table 2.1 and includes several criteria such as duration of work, added distance on detour route, geometric and structural integrity of detour route, etc.

During the operations of the detour, a Maintenance of Traffic (MOT) plan, is provided for the efficient and safe movement of road-users through or around a work zone as well as the efficient completion of the activities that have suspended the normal operation of the roadway. The *Indiana Design Manual* (2013) outlines several procedures for successful MOT strategies. These include Transportation Operations Plan (TOP), and a Public Information Plan (PIP) for projects that have "significant" impacts to the public and when necessary, for other projects. significant projects are defined as "all projects within the boundaries of a designated Traffic Management Area that occupy a location for more than 3 days with either intermittent or continuous lane closures are considered significant (INDOT, 2013)." All projects need a TMP and all TMP's need to have a Temporary Traffic Control Plan (TTCP). The Work Zone Safety and Mobility Policy should be reviewed to determine whether a project is considered to have significant impact or non-significant impacts. These procedures are summarized in Figure 2.2, Figure 2.3, and Figure 2.4.

2.3 Summary of the Review of State-of-the-Art Practices for MOT in Other State DOTs

A detailed review of the state-of-the-art and practices for MOT in other state DOTs is documented in Appendix A of this report and is summarized here. Agencies regularly conduct maintenance and rehabilitation works on their roads. During these construction periods, detours are often necessary when the scope of the work is large or when the anticipated disruptions to traffic are significant. Other times, unexpected events such as traffic collisions and other incidences can cause disruptions to traffic to a significant extent that a detour may be necessary. Consequently, all agencies have incident management plans which they use to address highway incidents. These traffic incident management plans come in a variety of ways, including simple guidelines outlining what agencies should be involved in resolving the incidents—police, local transportation authorities, emergency services, etc. Other management plans exist in the form of pre-planned routes for traffic detouring on certain important links within the jurisdiction. Whether an agency relies on a stipulated guideline or on a pre-planned map, they all follow certain given criteria that helps them evaluate the suitability of a given route for detour purposes. This section summarizes some of the criteria outlined in some of the incident management plans of given DOTs as presented in Table 2.2.

Across the DOTs considered, the criteria most considered for traffic incident management plans are the technical, operational, and financial. Of the three, the technical criteria were the most emphasized. Under each criterion, agencies have various identifiers. For example, technical criteria may include identifiers such as lane widths, vertical clearance, horizontal and vertical curvature. Each of these criteria and identifiers play an important role in determining the viability of a route for detour use. The technical aspects for example ensure that the structural integrity and geometric standards of the chosen route are consistent with the required standards. This includes requirements of lane widths not less than a specified limit to allow for large vehicles and allow for normal travel without significant reduction in speed or level of service.

When a road serves truck traffic, it is important that the chosen detour route can handle the detouring truck

TABLE 2.2
Criteria and identifiers commonly considered by DOTs

		DOT				
Criteria	**Identifier**	**WV**	**NJ**	**DC**	**IN**	**MI**
Technical	Lane width	Yes	Yes	Yes	Yes	Yes
	Truck traffic	Yes	Yes	Yes	Yes	Yes
	Pavement structural rating	Yes	–	–	Yes	Yes
	Vertical clearance	Yes	Yes	Yes	Yes	Yes
	Horizontal curves	Yes	Yes	Yes	Yes	Yes
	Vertical grade	Yes	–	–	–	–
Operational	Fuel/rest stations	Yes	Yes	Yes	–	–
	Nearby projects		Yes	–	Yes	Yes
	Duration of work	–	–	–	Yes	Yes
Financial	Travel time	–	–	–	Yes	–
	User cost	–	–	–	Yes	–
	Additional distance	–	–	–	Yes	Yes

traffic. Because truck traffic is typically heavy load in nature, the chosen detour must have sufficient structural rating to withstand the loading imposed on it by the trucks. Additionally, trucks typically require higher and wider clearances compared to passenger cars. It is therefore necessary that the chosen detour route at least meets the required minimum vertical clearance to avoid collision of vehicles with highway infrastructure such as overhead bridges. Across all the agency plans examined, all considered lane widths, truck traffic, vertical clearance and horizontal curves as shown in Table 2.2. However, only the West Virginia DOT explicitly considers vertical grade as an identifier. According the West Virginial traffic incident management plan, vertical grade on detour routes must be no greater than 8%. The rest of the DOTs did not indicate specifications on vertical grade, nor did they directly include it as an identifier in their incident management plans.

As far as operational criteria are concerned, most DOTs considered the presence of fuel stations or rest areas on the route as well as whether other projects nearby could potentially be using the same route as a detour. Checking for the presence of rest and fuel stations on the route is particularly helpful for long-haul drivers who take frequent breaks to reduce and prevent accidents. In addition, while it is an important factor for consideration, some DOTs indicated that they do not explicitly include this identifier in the management plans, perhaps because it may be considered implicit. Nonetheless, West Virginia, Washington DC, and New Jersey indicated that they include it explicitly in their traffic incident management plans. Considerations of other projects in the vicinity of the route serves the purpose of avoiding congestion that may arise from multiple road closures redirecting traffic through the same detour route. Like the rest areas and fuel stations criteria, not every DOT stated that this is an explicit consideration. Only three out of the six traffic incident management plans of DOTs indicated that they consider this criterion: Indiana, New Jersey, and Michigan.

Finally, the third criteria considered was the economic aspect. This was explicitly considered by only the Indiana DOT who considers the costs and financial implications of the detour routes on both the agency and user. The user might incur costs due to delays faced on the detour due to increased congestion or lower speed limits. They may also incur costs due to increased fuel consumption which may result from the stop-and-go driving that may occur on the detour route. Finally, vehicle operating costs may as well be higher because of less-than-ideal driving conditions. All these are quite difficult to quantify directly but can be estimated by considering other factors such added travel distance and time delays.

In addition to the considerations and factors that affect detour route mapping, several fundamental aspects, and considerations about the design of TTCPs were pointed out in the reviewed manuals. Table 2.3 presents these fundamental criteria. As evident in the table, almost all these criteria are commonly considered

TABLE 2.3
Fundamental considerations in TTCP design

Criteria	Sub-Criteria	State DOT WV	NJ	DC	IN	MI
Technical	Road type	Yes	Yes	Yes	Yes	Yes
	Geometrics	Yes	Yes	Yes	Yes	Yes
	Sight distance	Yes	Yes	Yes	–	Yes
	Road user volumes	Yes	Yes	Yes	Yes	Yes
	Road user speeds	Yes	Yes	Yes	Yes	Yes
	Vehicle mix (buses, trucks, and cars)	Yes	Yes	Yes	Yes	Yes
	Work zone length	Yes	Yes	Yes	Yes	Yes
	Duration of construction	Yes	Yes	Yes	Yes	Yes
Operational	Timing, scope, and characteristics of the construction project (full- or part-time, night-time work, work staging)	Yes	Yes	Yes	–	Yes
	Travel time and expected delay	–	Yes	–	Yes	Yes
	Emergency response	Yes	Yes	Yes	Yes	Yes
	Inspection and maintenance needs	Yes	Yes	Yes	Yes	Yes
	Queue length	Yes	Yes	Yes	Yes	Yes
	Transit services	Yes	Yes	Yes	Yes	Yes
	Coordination with agencies, contractors, and nearby projects	Yes	Yes	Yes	Yes	Yes
	Parking	Yes	Yes	Yes	Yes	Yes
Safety	Please refer to Table 2.5	Yes	Yes	Yes	Yes	Yes
Political	Legal authority	Yes	–	Yes	–	Yes
	Political sensitivity	–	Yes	–	–	–
Social	Human factors (drivers' familiarity with TTC signals and signs)	Yes	–	–	Yes	Yes
	Residential or commercial land use	Yes	Yes	Yes	Yes	Yes
	Access to businesses, neighborhoods, major activity centers	Yes	Yes	Yes	–	Yes

TABLE 2.4
Considerations in incident management

Incident Management Strategies	State DOT			
	WV	NJ	DC	MI
Closing one direction, making a U-turn, and diverting the traffic	Yes	–	–	Yes
Adjusting traffic patterns	Yes	Yes	–	Yes
Using police push buttons	Yes	–	–	–
Onsite towing vehicles	–	Yes	Yes	–
Speed zoning	–	Yes	Yes	–
Applying parking limitation along temporary detours, particularly in downtown areas	Yes	–	Yes	Yes
Using law enforcement control at intersections	Yes	Yes	Yes	–
Suspending work activities along long-term detours or under extreme weather conditions	Yes	–	Yes	Yes
Identifying detection, response, and clearance strategies	–	–	–	Yes
Maintaining good public relations through news media	–	–	Yes	–
Training the decision-makers and responders	–	–	–	Yes

TABLE 2.5
Considerations in work zone safety

Work Zone Safety Enhancement Strategies	State DOT			
	WV	NJ	DC	MI
Crash reduction strategies for rear end and side swap crashes	Yes	–	Yes	Yes
Coordination with neighboring construction sites	Yes	Yes	Yes	Yes
Road safety audits	Yes	–	Yes	Yes
Temporary rumble strips	Yes	Yes	Yes	Yes
Safety award/incentives	–	Yes	–	Yes
Separate truck lane(s)	Yes	Yes	Yes	Yes
Real-time work zone monitoring surveillance systems	Yes	Yes	Yes	Yes
Moveable traffic barrier systems	Yes	Yes	Yes	Yes
Parking restrictions, ramp closures and reversible lanes	–	–	–	Yes
Vehicular dimension restrictions and road geometry restrictions	Yes	–	Yes	Yes
Temporary traffic signals and improve signal coordination	Yes	Yes	Yes	Yes
Emergency maintenance repairs	–	–	–	Yes

by the state DOTs considered in this study. The only exceptions that are not common are legal and political considerations, as well as social factors such as familiarity of the drivers with the posted signs and signals.

It should be noted that the purpose of this table is to provide a list of criteria considered during TTCP design based on the manuals reviewed. The table does not seek to evaluate the quality, or the effectiveness of the approach pursued by state DOTs in applying these criteria.

Also, in addition to the key factor and MOT strategies, a variety of topics are covered in the manuals, to improve the safety and efficiency of the most feasible alternatives for detour route incident management and work zone enhancement (Table 2.4 and Table 2.5).

3. DATA COLLECTION AND ANALYSIS

3.1 Introduction

After the review of publicly-available manuals and documents, the research team undertook initiatives to collect more data in order to ascertain the best practices. This was necessary because not all documents are publicly available or accessible, and some information is proprietary. To achieve this, the research team designed a survey questionnaire, and distributed it to various transportation agencies across the country.

Based on the information received from the survey, the team conducted follow-up telephone interviews with INDOT personnel as well as the survey respondents from other state DOTs, as described in the following sections. Through the survey and interviews, the research team was able acquire more in-depth information regarding the practices used at several organizations for detour planning and Maintenance of Traffic. Section 3.2 discusses the survey questionnaire design, structure, distribution, and results. Section 3.4 presents the structure, design, and the results obtained from interviews with INDOT personnel and other state DOT experts. This is followed by a summary of the findings.

3.2 Initial Survey Questionnaire

3.2.1 Questionnaire Design

Part of the study objectives was to understand the state of the detour mapping and coordinating for MOT practice used by agencies. The survey mainly poses questions on (1) the current state-of-the-practice on MOT strategies, (2) the promising identifiers, and (3) advanced risk management/mitigation strategy based on the best practices.

3.2.2 Survey Structure

The survey was intended to collect additional information from transportation agencies and departments of transportation across the country on their detour mapping practice. This effort was to complement the research goals of ascertaining the best practices for detour mapping. Basic information on these practices is publicly available on agency websites and published manuals, as outlined in earlier sections. For agencies that may have proprietary methods or otherwise rely on information that they have not made public and are willing to share that information, the survey was intended to help the research team obtain such information. Therefore, the survey structure was designed such that agencies and state DOTs got a specific set of questions depending on whether they have an active framework. A schematic demonstration of this structure is shown in Figure 3.1.

The first question of the survey asks the respondent whether their agency has an active framework for detour route selection. If the respondent answers "Yes" they are presented with one set of questions intended to ascertain more information about their framework. Similarly, if their answer is "No" they are presented with a different set of questions intended to learn more about their detour mapping practices. The research team understands that some of the respondents may not be familiar with the concept of an active framework, and even so, others may be unsure whether their agency has one. In this case, respondents are presented with a "Not Sure" option, and the questions are presented accordingly.

The common questions mainly seek to ascertain more information about the relative importance of different criteria that were identified based on the literature review, how the agency considers qualitative criteria in detour mapping, as well as the public outreach strategy of the agency in the face of unforeseen conditions on detour routes. A copy of the survey questionnaire can be found in Appendix B at the end of this report.

3.2.3 Questionnaire Administration

The survey questionnaire was distributed among participants of diverse roles and levels at INDOT and other state DOTs as well as among FHWA and AASHTO. Before distributing the survey, the research team appropriately went through Purdue's Institutional Review Board process to ensure compliance with the institution regulations about research topics on human subjects and the data collection and analysis. After the successful completion of the IRB process and subsequent approval, the team contacted the SAC members to help distribute the survey questionnaire among the above participants. As the SAC members were themselves in leadership positions in INDOT, there was ample opportunity to reach a large pool of participants. The SAC members sent out an invitation email to request members from INDOT and other state DOTs, FHWA, and AASHTO experts to participate in the survey. The email also requested the participants to further distribute the survey questionnaire among their colleagues. A copy of the invitation email is provided in Appendix C.

Qualtrics software was used to create, store, and analyze the responses of the survey questionnaire. Qualtrics software stores the responses in chronological order and does not reveal the answers that make the participant identifiable. The following section is dedicated to the discussion and analysis of the responses to the survey questionnaire.

3.2.4 Survey Questionnaire: Analysis and Results

This section presents and analyzes the collected data from the survey. The survey was administered from June to October 2020, and 76 responses from experts from 19 state DOTs, including INDOT, were collected. Almost 30% of the received respondents partially answered to the questions and thus were excluded from

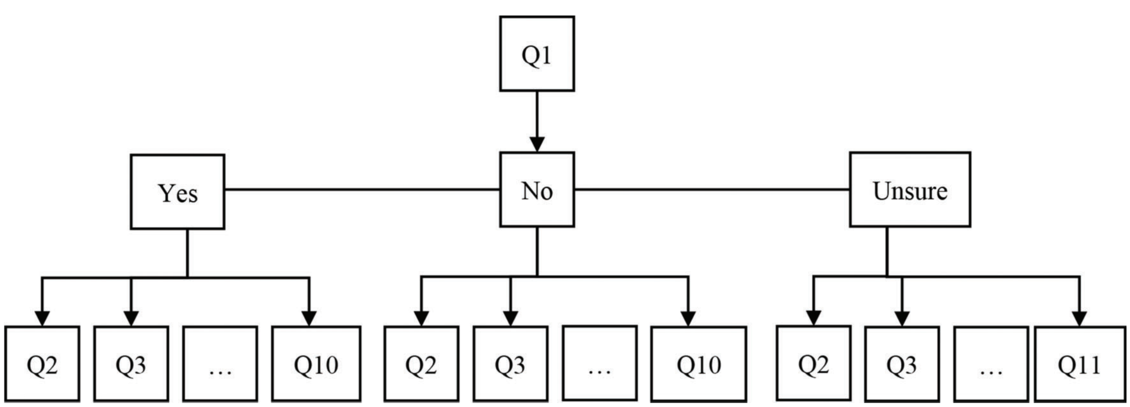


Figure 3.1 Survey questionnaire structure.

the final analysis. The remaining 70% of the responses were considered in the analysis.

This section is organized on a question-by-question basis. First, each question and the rationale behind its design is reviewed in detail, and next, the responses are analyzed, and the ensuing observations and implications are provided.

Q1. Having an active detour mapping framework. The first question of the surveys asked the respondents whether their agencies had an active detour framework. An active detour framework is defined as an outlined set of instructions, procedures, or guidelines that can be used to generate a detour map on demand. This is distinguished from a pre-planned incident management plan or pre-drawn detour map that can be deployed when needed. An active framework lists or spells out procedures and guidelines that can be used to narrow down and pick a detour route from a list of potential candidates. Responses to this question are summarized in Figure 3.2. The responses from INDOT are presented in a separate chart because the research team received multiple responses from INDOT, and therefore, categorized them separately to avoid skewing the results.

As Figure 3.2 shows the responses from INDOT were inconsistent, as almost half of the INDOT personnel were unsure about having in place, an active detour mapping framework. Only one-fifth of INDOT members indicated that they have an active framework for detour mapping. The diversity of the responses received from INDOT may imply that although there are documents about detour route selection, they are not yet organized to form a uniform document or guideline to be recognized as an active detour mapping framework.

According to Figure 3.2 which presents the responses received from other state DOTs, 37% of other state DOTs have an active detour mapping framework. This means that only 9 out of 18 state DOTs reported having an active framework for detour route selection. 47% of the respondents from other DOTs indicated that their DOT does not have an active detour framework, and 16% were unsure about this question. The overall results show that almost only one-third of state DOTs rely on guidelines or frameworks for detour mapping.

It should be highlighted that the number of participants form different state DOTs is different and this might have affected the outcomes. For example, the number of responses received from other state DOTs is limited to a single response in most of the cases. However, several responses have been collected from INDOT personnel. Therefore, the results cannot be generalized unless more responses are collected from each individual state DOT.

Q2. Individuals involved in detour planning. Survey respondents were asked to identify specific positions in their DOTs is involved in the detour planning process. The question included suggestions for common personnel titles, and respondents were asked to select as many as are applicable. The options presented to the respondents were the following.

- Traffic Management Committee (e.g., TMC input)
- Transportation Management Plan (TMP) team/committee/stakeholders
- Maintenance Director/Foreman
- Work Zone Safety Engineer
- Construction Engineer (e.g., area engineer)
- Pavement Engineer (for health assessment of alternate detour options)
- Environmental Engineer (to evaluate possible environmental/social/historical concerns)
- Project Manager
- Detour Route Selection Committee
- District Traffic Engineer (DTE)

Figure 3.3 presents the responses to this question. The responses are categorized in a way to differentiate the DOTs with and without an active framework. This allows for the assessment of the changes in the combination of the team involved in the detour mapping

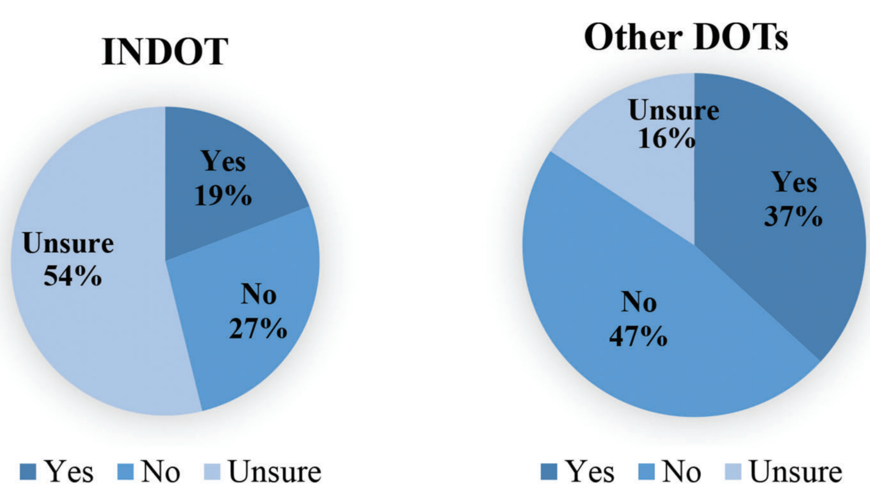
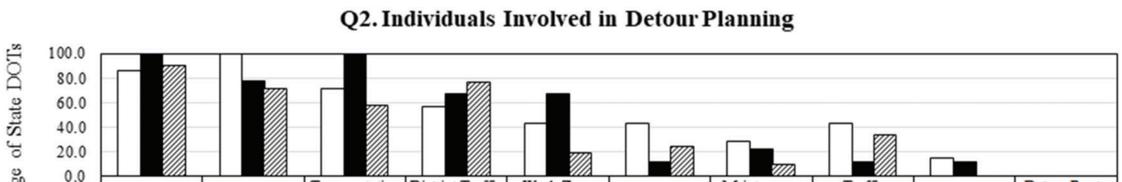


Figure 3.2 Responses of INDOT and other DOTs about having an active framework.



	Construction Engineer	Project Manager	Transportation Management Plan Team	District Traffic Engineer (DTE)	Work Zone Safety Engineer	Pavement Engineer	Maintenance Director/ Foreman	Traffic Management Committee	Environmental Engineer	Detour Route Selection Committee
□No	85.70	100.00	71.4	57.10	42.90	42.90	28.60	42.90	14.30	0.00
■Yes	100.00	77.80	100	66.70	66.70	11.10	22.20	11.10	11.10	0.00
▨INDOT	90.50	71.40	57.1	76.20	19.00	23.80	9.50	33.30	0.00	0.00

Figure 3.3 Personnel involved in detour planning.

process between the DOTs with and without active detour mapping frameworks. The vertical axis shows the percentage of respondents that have selected each of the suggested roles that are involved in the selection of appropriate detour routes. Because respondents could select more than one option, the totals in the graph may exceed 100%.

Several observations can be made from the figure. Firstly, the overall configuration of the team that decides about the detour route differs significantly for agencies with and without an active framework. Despite this difference, however, five key roles are common between the received responses from other state DOTs. These include the construction engineer, project manager, transportation management plan team, the district traffic engineers, and the work zone safety engineer. The responses received from INDOT show a similar combination except for the fact that the role of a work zone safety engineer is less pronounced.

A significant difference in the roles of pavement engineer and traffic management committee in making the final decision was observed between DOTs with and without active frameworks. This difference, specifically the presence of the pavement engineer, can be attributed to guidelines and requirements set by state DOTs with an active detour mapping framework.

Another observation is that no respondent indicated the contribution of a detour selection committee. This observation suggests that DOTs currently do not have an independent team, titled as "detour selection committee," responsible for detour selection.

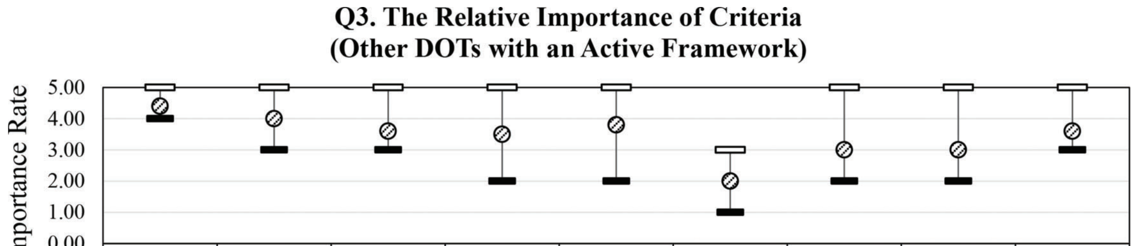
Finally, the responses show that the role, titled as "Environmental Engineer," seems to be less involved in the selection of the detour route process among all state DOTs. However, this conclusion cannot be generalized due to two main reasons. First, several titles other than the one included in the survey questionnaire might be involved in detour mapping. Secondly, individual responders may not be fully aware of the organizational chart.

Q3. The relative importance of criteria. In selecting a detour route, several alternative routes may be considered at any one time, and several criteria must be considered to determine which route best meets the current needs. These criteria were compiled based on the documents and manuals that were reviewed during the literature review process. The respondents were presented with a list of some of the most common considerations for detour mapping and asked to rate their relative importance. The choices included considerations such as safety, route suitability for Commercial Motor Vehicles (CMVs), accessibility, ease of operation and monitoring, financial and social costs, environmental and political considerations. Different agencies may rate the relative importance of each of these criteria differently, and these ratings may vary according to the prevailing situation. Consequently, survey respondents were asked to rank the relative importance of each of the listed criteria.

To determine the possible impact of the availability and application of a detour mapping framework on the relative importance of the proposed criteria, the responses of state DOTs with and without an active framework were summarized in separate figures. Figure 3.4 and Figure 3.5 present a summary of the responses received from the state DOTs with and without an active framework, respectively. In the figures, three values are reported for each of the criteria. These three values are the minimum, average, and maximum rates, on a scale of 0 to 5, assigned to each of the criteria. Although the average of the responses provides valuable insights, the ranges of the received responses can convey useful information about possible uncertainties and lack of a unified methodology that incorporates the relevant criteria.

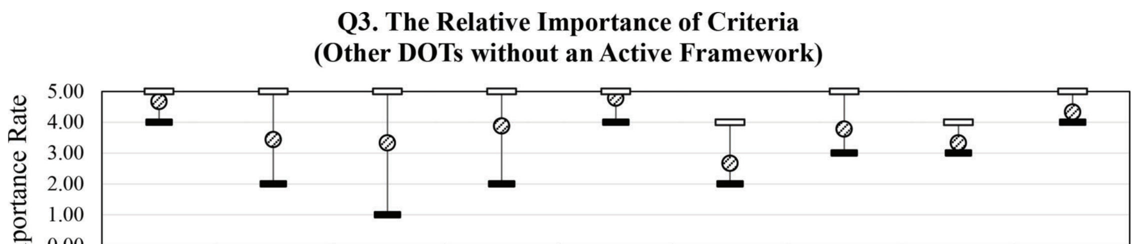
Before evaluating the results of the collected data, an inherent limitation of survey questionnaires and its potential impact on the interpretation of the results should be noted and elaborated. The limitation is related to the perception of the respondents about the definition of each of the criteria included in the question, which adds an inevitable level of subjectivity to the participant responses. Therefore, specific care should be exercised when interpreting the results and making general conclusions. Considering this limitation, the following key observations can be made from the comparison of Figure 3.4 and Figure 3.5.

- Starting from the technical criterion, it can be concluded that regardless of the presence or absence of an active framework for detour mapping, states DOTs put a great



	Technical	Operational	Financial	Accessibility	Safety	Environmental	Social	Political/ Jurisdictional	Route Suitability for CMVs
Ave	4.40	4.00	3.60	3.50	3.80	2.00	3.00	3.00	3.60
Min	4.00	3.00	3.00	2.00	2.00	1.00	2.00	2.00	3.00
Max	5.00	5.00	5.00	5.00	5.00	3.00	5.00	5.00	5.00

Figure 3.4 The relative importance of the criteria considered by the state DOTs *with* an active detour route mapping framework.



	Technical	Operational	Financial	Accessibility	Safety	Environmental	Social	Political/ Jurisdictional	Route Suitability for CMVs
Ave	4.67	3.44	3.33	3.88	4.78	2.67	3.78	3.33	4.33
Min	4.00	2.00	1.00	2.00	4.00	2.00	3.00	3.00	4.00
Max	5.00	5.00	5.00	5.00	5.00	4.00	5.00	4.00	5.00

Figure 3.5 The relative importance of the criteria considered by the state DOTs *without* an active detour route mapping framework.

emphasis on technical aspects when selecting the appropriate detour route.

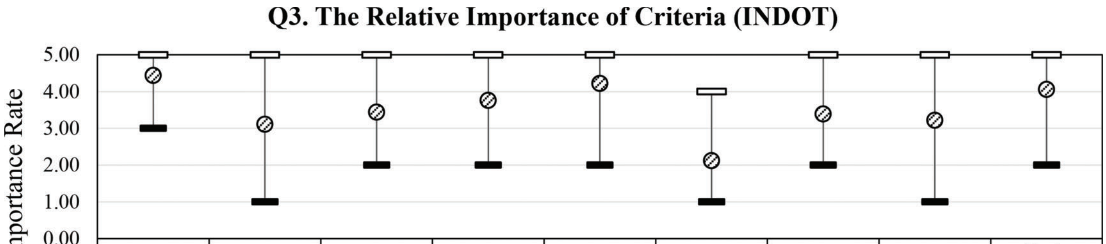
- When it comes to the operational, financial, and accessibility considerations, although the average values for the DOTs with and without an active framework are not significantly different, the range of the received responses are considerably larger for state DOTs that do not have an active framework. On the one hand, this implies that DOTs with an active framework may benefit from guidelines and requirements to consider the operational, financial, and accessibility impacts of deploying a detour route. On the other hand, this shows that there might be diverse approaches for addressing these three criteria due to the lack of a solid framework to consider all the key factors in the deployment of a detour route.
- Regardless of the existence an active framework for detour mapping, environmental issues were assigned the lowest score among all the criteria provided in the question. Furthermore, environmental issues are rated to have a higher level of importance in the detour route selection process of the DOTs without an active framework.
- Overall, technical, safety, and route suitability for CMVs, are the three most important criteria for detour mapping among the state DOTs without an active framework. On the other hand, for the state DOTs with an active framework, although the technical aspect has the highest level of importance, the weight assigned to other criteria are close to each other. This indicates a more balanced approach for considering all aspects other than technical requirements such as operational, safety, social, political, as well as the suitability of the selected route for CMVs in detour mapping.

As the next step, the responses received from INDOT personnel to this question are evaluated. Figure 3.6 shows the minimum, average, and maximum rates for the criteria based on the opinion of INDOT members.

The following observations can be made from the comparison of the responses received from INDOT with other state DOTs.

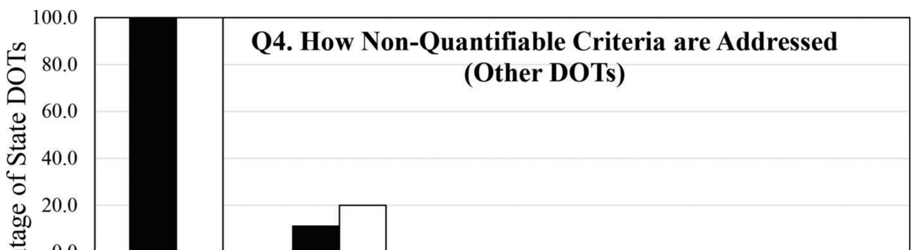
- As evident in the figure, the ranges for the received response are quite diverse. This shows that there might be a lack of solid guidelines for balancing the level of emphasis associated with each of these criteria.
- Technical, safety and route suitability for CMVs have the greatest level of importance in selecting the best detour route, which is similar to the state DOTs without an active framework, as compared to those with an active framework.
- Similar to other state DOTs, environmental issues do not seem to play a significant role in detour mapping.

Q4. Non-quantifiable criteria. In examining the criteria explored in the previous section, some criteria, such as safety and financial considerations, may have clearly quantifiable margins and thresholds upon which



	Technical	Operational	Financial	Accessibility	Safety	Environmental	Social	Political/ Jurisdictional	Route Suitability for CMVs
Ave	4.44	3.11	3.44	3.76	4.22	2.12	3.39	3.22	4.06
Min	3.00	1.00	2.00	2.00	2.00	1.00	2.00	1.00	2.00
Max	5.00	5.00	5.00	5.00	5.00	4.00	5.00	5.00	5.00

Figure 3.6 The relative importance of the criteria considered by INDOT.



	We use professional/ expertise judgement	We have adopted a guideline provided by the state	We have our own manual, but it's not publicly available	Development of manual for detour decision is currently in progress	We have future plans to develop a manual
No	100.0	11.1	0.0	0.0	0.0
Yes	100.0	20.0	0.0	0.0	0.0

Figure 3.7 The approach used by other state DOTs to address and consider non-quantifiable criteria.

decisions may be based. Other criteria, however, such as social considerations, may be difficult or even impossible to quantify. Therefore, subjective judgment may need to be used where applicable and standard guidelines need to be pursued. Survey respondents were asked to briefly state how their agencies address non-quantifiable criteria. Options presented to the respondents are listed below. In addition, they were also provided with space for additional comments and answers.

- We have adopted a guideline provided by the state.
- We have our own manual, but it's not publicly available.
- We use professional/expertise judgment.
- The development of a manual for detour decision is currently in progress.
- We have future plans to develop a manual.

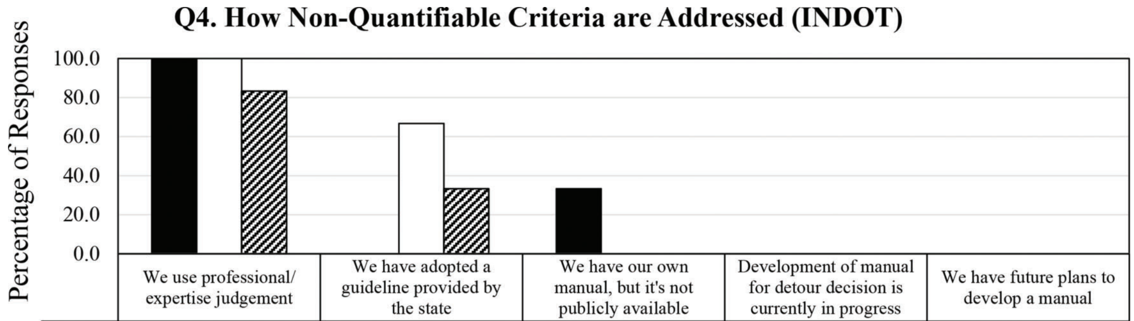
Figure 3.7 demonstrates the options selected by respondents to this survey question.

According to the results, all respondents relied on professional/expert judgments to address and consider qualitative criteria. DOTs with an active framework rely more on the guidelines provided by their state DOT as compared to DOTs without an active framework.

It can be seen in Figure 3.8 that according to the respondents from INDOT just like other DOTs, all responded that were sure about the existence of an active framework in their DOT, rely on professional/ expertise judgment. Respondents, who stated that INDOT has an active framework, relied more on the guidelines provided by INDOT compared to others. Also, respondents from INDOT mentioned that they are planning to develop a manual for detour mapping that also considers the qualitative criteria.

Q5. Dealing with unforeseen circumstances on detour route. According to the detour mapping practices, during the deployment and operation of the detour route, measures must be put in place to ensure the continued flow of traffic. In case of unforeseen conditions arising on the detour route, agencies may need to respond accordingly to address the situation. Survey respondents were asked to rank the following immediate public outreach strategies in the order they might follow them. They were asked to assign a rank of 1 for the immediate response and rank of 4 for the last response step.

- Installing emergency signboards at the start of the route.
- Deploying a team on-site to divert the flow of traffic.
- Have developed a mobile application wherein users can be sent push notifications immediately.
- Depend on the use of local news/radio stations to spread the information.



	We use professional/ expertise judgement	We have adopted a guideline provided by the state	We have our own manual, but it's not publicly available	Development of manual for detour decision is currently in progress	We have future plans to develop a manual
■ No	100.0	0.0	33.3	0.0	0.0
□ Yes	100.0	66.7	0.0	0.0	0.0
▨ Unsure	83.3	33.3	0.0	0.0	0.0

Figure 3.8 The approach used by INDOT to address and consider non-quantifiable criteria.

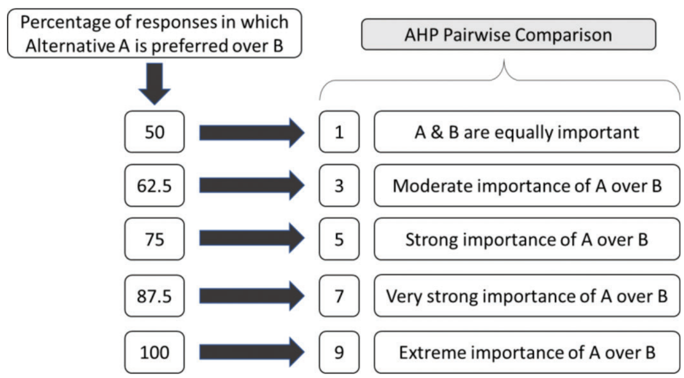


Figure 3.9 Using AHP pairwise comparison to determine the relative importance of immediate response strategies.

Initially, the preferences of the state DOTs with and without an active framework were separated and evaluated individually. After that, they were compared with each other to make meaningful comparisons.

For the first step, a pair of choices (e.g., mobile applications and local news) was selected, and the percentage of the responses that ranked the first choice (i.e., using mobile applications) higher than the second choice (i.e., local news) was counted and used as an indicator of the level of the relative urgency (or importance) of using mobile applications over using local news. These percentages were then translated to relative importance of choices based on the pairwise comparison of the Analytic Hierarchy Process (AHP) methodology. As demonstrated in Figure 3.9, values higher than 50% were transformed to values between 1 and 9. A value of 50 shows that the considered pair of outreach strategies are equally important. Therefore, a value of 1 is assigned. A value of 100% is transformed to 9, signifying extreme importance of option A over option B.

Following the procedure shown in Figure 3.9, first, all the immediate outreach strategies were compared to each other and gathered in a table. Table 3.4 shows the percentage of DOTs with an active framework that have prioritized the option shown in the rows over the options shown in the columns. For example, the value shown in the second row, and the third column of Table 3.1 shows the percentage of DOTs that have ranked mobile applications higher than local news/ radio in their response.

The percentage values equal to or higher than 50 were then translated to values between 1 and 9. The remaining values that were lower than 50 were obtained by reversing the transformed values (the values between 1 and 9) associated with their pair. This process generates the information presented in Table 3.2.

This led to the priority vector shown in Table 3.3.

As shown in Table 3.3, using mobile applications, local news, on-site teams, and emergency signboards are the most important means for public outreach.

It should be noted that if the analysis was made only based on the alternative with the highest rank; a similar order would have been determined. Nevertheless, by considering only the choice that was assigned the highest rank in the responses, the relative importance or priority of the second, third, and fourth public outreach

TABLE 3.1
The percentage of DOTs without an active framework that have prioritized the option shown in the rows over the options shown in the columns

Public Outreach Strategies	Mobile Application	Local News or Radio	On-Site Team	Emergency Signboards
Mobile application	–	60	80	80
Local news/radio	40	–	80	80
On-site team	20	20	–	60
Emergency signboards	20	20	40	–

TABLE 3.2
The relative urgency (importance) of public outreach strategies for DOTs without an active detour mapping framework

Public Outreach Strategies	Mobile Application	Local News/Radio	On-Site Team	Emergency Signboards	Total
Mobile application	1.00	1.80[1]	3.40[2]	3.40	9.60
Local news/radio	0.63	1.00	3.40	3.40	8.36
On-site team	0.36	0.36	1.00	1.80	3.38
Emergency signboards	0.40	0.40	0.60	1.00	2.14
Total	2.14	3.38	8.36	9.60	23.48

[1]Weak or slight importance of mobile application over the local news.
[2]Moderate to moderate plus importance of mobile application over the on-site team.

TABLE 3.3
The priority vector for public outreach strategies for DOTs without an active detour mapping framework

Public Outreach Strategies	Importance	Rank
Mobile application	0.44	1
Local news/radio	0.33	2
On-site team	0.135	3
Emergency signboards	0.1	4

strategies would not have been considered. That is why a methodology based on the AHP approach is used to determine the relative importance of public outreach strategies. Following the same procedure for the DOTs with an active framework yields Table 3.4 and Table 3.5 as the outcome.

This shows that the public outreach strategies for DOTs with an active framework are local news, on-site teams, mobile applications, and emergency signboards. This is different from what is observed for DOTs without an active framework.

Mobile applications for immediate public outreach are the most common public outreach strategy among the state DOTs without an active framework. This is while DOTs with an active framework mostly rely on local news/radio stations for immediate public outreach. In addition, the use of on-site teams for diverting the traffic flow on detours is more common among DOTs with an active framework.

These differences might be either due to the preferences of the state DOTs that participated in the study, or it can be attributed to the presence of a predetermined public outreach approach that might be a part of their developed detour mapping framework. For example, DOTs with an active framework may be benefitting from guidelines or have requirements regarding the presence of an on-site team along with the detours.

3.3 Survey Questionnaire for Detour Conflict Management

The first round of the review of the outcomes of the research project by the advisory board revealed that foreseeing and addressing conflicts that might arise due to simultaneous detour routes for nearby work zones should be further explored. Therefore, a follow-up survey questionnaire was designed to obtain the practice of other state DOTs in identifying and resolving the detour conflicts in the planning stage in a proactive way.

3.3.1 Survey Structure

Figure 3.10 demonstrates the structure of the follow-up survey questionnaire. Based on this structure, the second question aims to distinguish between the state DOTs with proactive and reactive approaches to detour conflict resolution. The only difference is in question 4, which is an open-ended question that sought to identify the practice of the state DOTs that have a reactive approach to managing detour conflicts.

For more details about the survey questionnaire including the type of the question, the body of the question, as well as the provided choices, please refer to Table D.1 of Appendix D. The next section discusses the collected responses on a question-by-question basis.

3.3.2 Survey Questionnaire: Analysis and Results

The data collection process was similar to the previous round of the survey. The survey was distributed

TABLE 3.4
The percentage of the DOTs with an active framework that have prioritized the option shown in the rows over the options shown in the columns

Public Outreach Strategies	Mobile Application	Local News/Radio	On-Site Team	Emergency Signboards
Mobile application	–	25	50	75
Local news/radio	75	–	50	75
On-site team	50	50	–	75
Emergency signboards	25	25	25	–

TABLE 3.5
The public outreach strategies for DOTs with an active detour mapping framework

Public Outreach Strategies	Importance	Rank
Mobile application	0.227	3
Local news/radio	0.385	1
On-site team	0.292	2
Emergency signboards	0.095	4

by the study advisory board committee (SAC), AASHTO and FHWA members. It was open for response over a span of 2 weeks (April 12th to April 30th, 2021) and 14 state DOTs, in addition to INDOT participated in the survey. Only two of the received responses were partial, meaning that only the first question of the survey was answered. The first question asks about the state DOT the respondent is associated with.

Q2. Do you proactively analyze/identify detour conflicts ahead of time during the planning stage? In this question, a proactive approach was defined as foreseeing the conflicts greater than 6 months prior to project start date, whereas reactive would be less than 6 months prior to project start date. All the state DOTs participated in the survey responded positively to this question. This shows that all state DOTs have some mechanisms to plan for projects avoiding the conflicts. However, the extent of the effectiveness of the approach they use was further evaluated in the rest of the questionnaire and more importantly, during follow-up interviews.

Q3. How far into the future do you plan for these conflicts/resolutions? This question included five options, and respondents were asked to select as many as are applicable. The options presented to the respondents are as follows.

1. Less than 6 months
2. 6 months to 1 year
3. 1 to 3 years
4. Over 3 years
5. Within project duration

Figure 3.11 presents the responses to this question.

As reflected through the responses to this question, half of the participating DOTs work 1 to 3 years in advance on planning for detour routes by taking into consideration possible conflicts that could arise and develop resolution strategies correspondingly. According to Figure 3.11, 30% of the respondents plan the detour routes 6–12 months in advance and Only 10% of the respondents plan for projects less than 6 months before the project start time, which was defined in this questionnaire as a reactive approach to identifying/resolving detour conflicts. The remaining 10% of the state DOTs that took part in the survey, had long-term plans, i.e., more than 3 years, for projects.

Q5. Identifying conflicts with detours under Scenarios A–D. Survey respondents were asked how they identify/address conflicts with detours under four different scenarios that were different in the extent and time of the overlap. The question included six pre-defined choices as well as an option that provided them with the opportunity to add other possible solutions. The respondents were asked to select as many choices as applicable for each scenario. The options presented to the respondents are the following.

1. Modifying one of the detour routes
2. Modifying schedules
3. Add to the capacity
4. Checking for conflicts in advance
5. Night-time working
6. Separate traffic for vehicle classes
7. Others (please specify)….

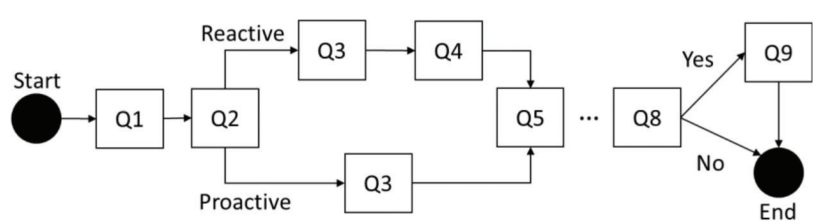


Figure 3.10 Follow-up survey questionnaire structure.

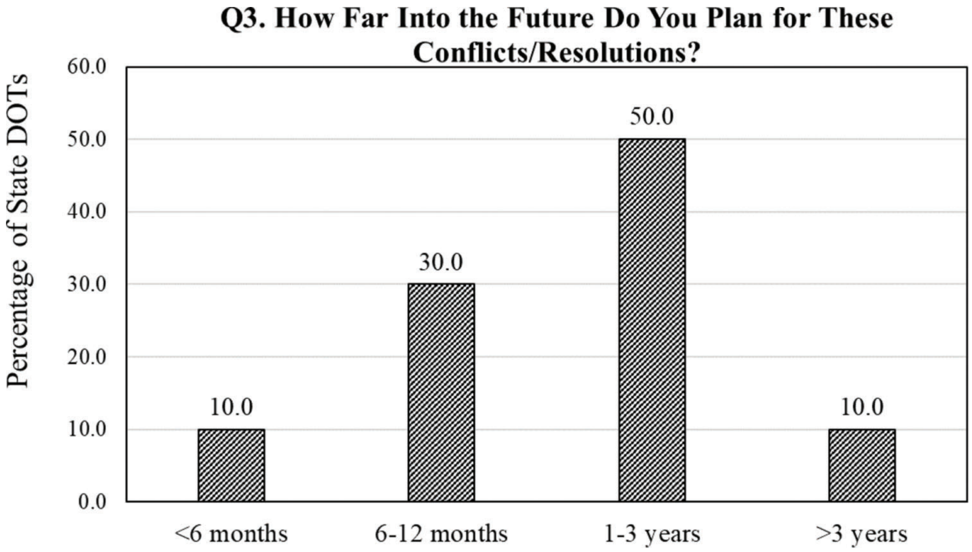


Figure 3.11 Planning horizon of state DOTs to avoid conflicts.

The four scenarios were as follows.

1. Scenario A: Less than 2 weeks overlap; Less than 2 miles overlap….
2. Scenario B: Less than 2 weeks overlap; More than 2 miles overlap….
3. Scenario C: More than 2 weeks overlap; Less than 2 miles overlap….
4. Scenario D: More than 2 weeks overlap; More than 2 miles overlap….

Figure 3.12 demonstrates the percentage of the state DOTs that selected each choice, under the described scenarios. It should be noted that since the selection of multiple choices was allowed, the sum of the percentages for each scenario can be (and is, in most cases) higher than 100.

Key takeaways

- The most common solution is to modify one of the detour routes, specifically when the duration of the overlap is shorter (i.e., for scenarios A and B).
- Altering schedules and checking for conflicts in advance are the most preferred options regardless of the defined scenarios. As expected, it is more likely for the DOTs to adapt these alternatives when the duration and extent of the overlap are higher.
- According to the bars for option 2, as the duration and extent of the overlap increases, the tendency to for modify the schedule of the detour routes increases.
- If the closure is for less than 2 weeks, no DOT chooses to invest on traffic capacity expansion of the detour routes. Even in scenarios where the closure is more than 2 weeks, adding to traffic capacity is considered by only 20%–30% of the DOTs.
- Night-time working can also be an option, which is more preferred for overlaps less than 2 weeks.
- Less than 20% of the DOTs consider segregating vehicles as per their class. This alternative is more likely to be chosen for overlaps more than 2 weeks.

Q6. What are the important factors other than time and space? In this question, the importance of other factors that affect the extent/resolution of the conflicts were asked. Similar to the previous question, selection of multiple choices was allowed. Figure 3.13 shows the importance of the following factors.

1. Road capacity
2. Traffic volume
3. Financial costs associated with MOT (additional lanes, repair/rehabilitation, etc.)
4. Overlap in terms of vehicle classes
5. The possibility of using a unified platform/committee/meeting between the state and local jurisdictions
6. Others (please specify)….

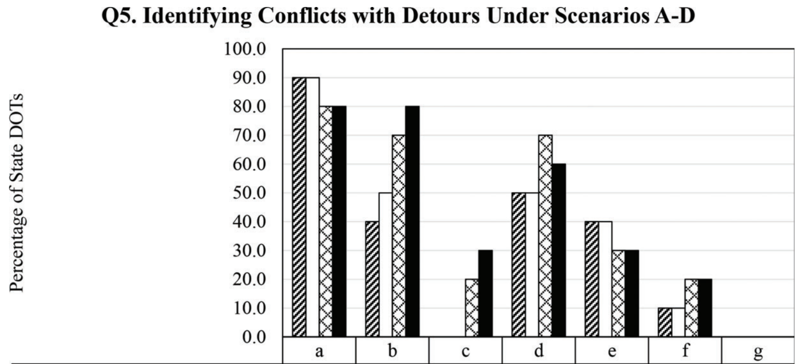
Key takeaways

- Traffic volume conflicts which possibly arise due to road capacity issues are very important to plan in advance for. As indicated in the analysis of the responses to Q5, modifying one of the detour routes or altering the schedule to suit the traffic conditions can be a good method to reduce such conflicts.
- Of the DOTs that participated in the survey, 40% believed that the existence of a unified platform or committee (wherein all the stakeholders as identified in this study can collaborate) is important for identifying/resolving potential detour conflicts.
- Financial costs associated with repair and rehabilitation of detour routes such as adding to the road capacity or adding additional lanes, after the project start, affect the extent of the conflict (assuming that different vehicle classes are not deemed to be a significant issue).

3.4 Telephone Interviews

3.4.1 Interview Questionnaire Design and Administration

As a follow up to the survey questionnaire, the research team designed an interview questionnaire. The aim of the



	a	b	c	d	e	f	g
Scenario A: <2 weeks, <2 miles	90.0	40.0	0.0	50.0	40.0	10.0	0.0
Scenario B: <2 weeks, >2 miles	90.0	50.0	0.0	50.0	40.0	10.0	0.0
Scenario C: >2 weeks, <2 miles	80.0	70.0	20.0	70.0	30.0	20.0	0.0
Scenario D: >2 weeks, >2 miles	80.0	80.0	30.0	60.0	30.0	20.0	0.0

Figure 3.12 Solutions for resolving detour conflicts based on the extent and duration of the overlap.

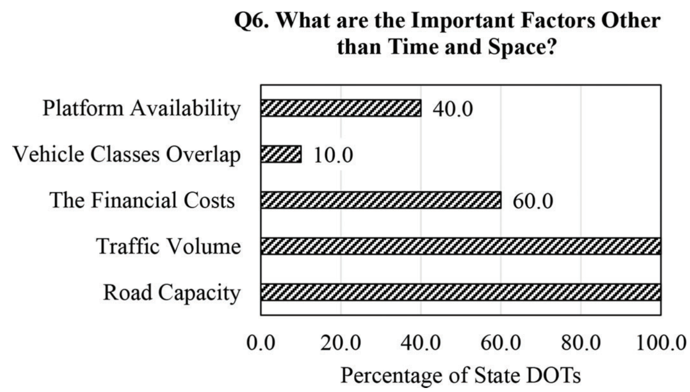


Figure 3.13 The factors that affect the extent of or solution for detour conflicts.

interviews was to follow up with the respondents of the survey to further understand the processes. Because the survey was limited in scope and length, a follow-up was necessary to draw out more information. The research team elected not to make the survey too long nor too detailed lest it deters participation and compromises the quality of the data obtained. This was also in understanding that certain responses would require an explanation and would not necessarily be well captured via a survey response. Thus, the research team designed an interview questionnaire whose structure followed the same as the survey, in which a different set of questions was asked depending on whether the respondent indicated that their agency did or did not have an active framework.

This section describes the interview process and questionnaire content, as well as presenting a summary of the result and information obtained. The interviews were conducted in two stages. The first was with personnel from INDOT and the second with the rest of the DOTs. The interviews with INDOT personnel took place first because the personnel being interviewed were part of the project SAC and were familiar with the research content and survey questions before other DOTs. As such, their responses and comments were used to improve the survey before sending it out to the rest of the DOTs.

The interview with INDOT personnel was structured in two parts, first to enable the research team to understand current INDOT practices better and the second part of understanding what practitioners would like to see from the project in terms of detour mapping guidelines. A schematic of the questionnaire layout and summary content is presented in Figure 3.14, and the full interview questionnaire can be found in Appendix E.

3.4.2 Phone Interview with INDOT Personnel: Analysis and Results

Table F.1 of Appendix F presents a summary of the comments and information provided by INDOT members during the interview. The summary lists the criteria and corresponding identifiers used by INDOT in the planning and deployment of detours. The table also presents corresponding information found in the literature to provide a comparative picture. As can be seen from the table, most of the criteria and identifiers used by INDOT are in line with what the literature suggests, as well as what other DOTs employ. The *INDOT 1996 Detour Policy* establishes some of this criterion and provides guidelines on several considerations when deploying a detour route. For example, the policy requires setting up official as well as unofficial routes for every detour deployed. Realistically, there is always a percentage of traffic that does not follow the designated official detour. The reasons for this may vary, including local and commuter traffic opting to a shorter route to individuals using online routing tools such as Google Maps whose information may not be up to date about road closures and detours. Consequently, closure of a route may disperse traffic to several other routes in the network. In the case of a local road, this may result in additional traffic load on the road, which may result in additional wear and tear on the infrastructure. To compensate for repairs and the damages caused, INDOT and local authorities agree to set up an unofficial detour route. This helps the two sides assess the level of damage and agree on appropriate compensation.

While the concept of the unofficial detour is standard practice within INDOT, the actual policy and much of its contents remain obscure, with many of the officials interviewed expressing no knowledge of its existence at all, while others indicated knowledge of its existence but have neither seen nor used it. This recurrent theme of the obscurity of the detour policy was a major concern for the officials interviewed, who expressed desire that the policies could be made more available and that practices would be made more uniform across the agency. The research team therefore developed a uniform guideline in this report, that can be applied across the agency. Specific and detailed comments provided by INDOT members concerning the current detour mapping practices and the potential for a new framework are provided herein in Table F.1 of Appendix F. The table provides a good comparison between the current practice of INDOT identified from interviews and INDOT manuals.

3.4.2.1 Expectations from project: Recommendations. Regarding their expectations from the project, INDOT officials had several recommendations on what they would like a detour mapping framework to include. In addition to addressing the shortcoming of the previous policy, which was its obscurity, the officials stressed the need to keep the framework as simple and adaptable as possible. This would allow the framework to be used in a variety of localities across the state and multiple scenarios. They recommended that the procedures be easy to break down so that people on the field can put it into practice without the need for highly skilled personnel.

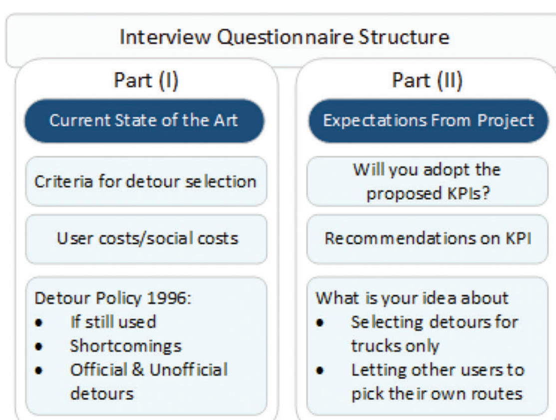


Figure 3.14 Interview structure for INDOT personnel.

Beyond the scope of this project, the interviewees also expressed views on some other improvements that they would wish to be made to the general process of detour mapping and MOT coordination. Many suggested the establishment of a Work Zone Data Initiative that would make available real-time information about active construction zones and the kind of work being conducted. This would aid in many aspects of planning not only for detours but also for coordinating timelines of other activities. However, INDOT CARS program includes details on road conditions, closures and weight restrictions are included for motorists to drive safely and efficiently, to make the dissemination of information easier, having a dedicated app containing real-time detour and other navigation information would be good. A superior alternative would be to have improved integration of this information in widely used apps such as Google Maps. Overall, the sentiment expressed was to keep the process as simple as possible and make it adaptable for use in varying scenarios and localities.

3.4.3 Initial Telephone Interviews with Other DOTs

3.4.3.1 Interview questionnaire design. In this step of the study, three follow-up interviews were conducted with the experts from other state DOTs who have reported to have an active framework for detour mapping selection and MOT of traffic. The aim of these interviews was to obtain more in-depth information about the following aspects: (1) the current state-of-the-practice on MOT strategies, (2) The promising performance indicators, and (3) the best practices for mapping and coordinating detours for Maintenance of Traffic, including risk management/mitigation strategy.

To acquire such information, four major questions that were followed by additional questions asking for more details were designed. Specific attention was paid to keeping the interview as short as possible while maintaining its adequacy to address the research objectives. The objectives of the synthesis study on best practices for mapping and coordinating detours for Maintenance of Traffic (MOT) are as follows.

1. To identify process improvements for INDOT detour planning.
2. To identify current state-of-the-practice on MOT strategies.
3. To explore the promising identifiers (e.g., design, financial, social, safety, and management perspective) to be incorporated into developing detour plans.
4. To investigate best practices for mapping and coordinating detours for MOT.
5. To provide advanced risk management/mitigation strategy based on the best practices.

Table 3.6 matches the objectives of the study with the questions of the interview questionnaire. The full interview questionnaire is provided in Appendix G.

3.4.3.2 Phone interview with other DOTs: Analysis and results. This section summarizes the findings of the phone interviews with experts from three state DOTs (Iowa, Minnesota, and Arizona) which reported having an active framework in the survey questionnaire and agreed to participate in the interview.

3.4.3.2.1 Iowa DOT. The interviewees expressed that they have an active framework for detour route selection. They mentioned that the detour assignment is done at the district level. They referred to *Manual on Uniform Traffic Control Devices* (MUTCD) as their point of reference for guidance on the design of temporary traffic control devices for road closures, which is similar to the approach of state DOTs that were covered in the literature review section. According to Iowa DOT experts, there are rare occasions with a full interstate closure. Full closures are avoided by nighttime work, adding to the road capacity, and extra work staging.

Regarding the work staging, for the selection of appropriate construction methods for bridge projects, the *Accelerated Bridge Construction (ABC) Manual* (IowaDOT, 2020) is adopted. This manual is actually Chapter 8 of the *LRFD Bridge Design Manual* (IowaDOT, 2021). Although this document has been mostly used for bridge replacement projects, it provides valuable insights about the approach to recognize societal costs as real construction costs and incorporate it into the decision-making process. Societal costs have several components, including road user costs because of the time delays and detours, revenue loss sustained by the local businesses, livability during construction, as well as the safety risk for both road users and workers. The *ABC Manual* aims to recognize the societal costs, in addition to the actual construction cost that uses public tax dollars. The following section intends to demonstrate the way through which the *ABC Manual* considers the societal costs in the planning of bridge projects.

Accelerated bridge construction. Accelerated Bridge Construction (ABC) introduces a three-stage decision-making process. This decision-making process is shown in the flow-chart shown in Figure 3.15.

These phases are summarized here and discussed in more detail in the following sections.

Phase (I): In this phase, the applicability of ABC to bridge construction projects are assessed based on the ABC rating score, which is a number between 0 to 100. Higher scores show the high suitability of the project for ABC. If the score is lower than 50, the district decides about using traditional construction methods or further evaluations by the concept design team for using ABC methods. If the score of a bridge is higher than 50, it is automatically considered for ABC methods if the concept design team approves it.

Phase (II): A qualitative assessment of construction alternatives is carried out for borderline or very large and costly projects to assure that using ABC methods is appropriate. In this phase, the ABC-AHP Decision Making Software is used to further evaluate the available construction alternatives. This step is optional.

TABLE 3.6
The structure of the phone interview with other state DOTs

Question	Body	Objective
Q1	Q1.1 Description of their detour mapping framework as well as available documents and references. Q1.2 Criteria that should be added (OR removed) from their agency's framework.	(1), (2), (4)
Q2	Q2. The approach to address the criteria that may not have quantifiable thresholds or limits. Q2.1 The approach for considering the following criteria: 1. Community acceptance 2. Business interruption 3. Worker safety 4. Accessibility to essential service providers (emergency response, police, etc.) 5. Disruption to local traffic (public events, school, business, etc.) Q2.2 A list of other factors that are hard to quantify, based on their experience and knowledge as well as the way they deal with them.	(2), (3), (4)
Q3	Q3. How the user costs/social costs are determined and considered in the detour selection process. Q3.1 Whether the user costs considered in the same way as the construction costs. If Yes: Q3.2 Whether or not considering the user costs has changed a previously selected detour route. If No: Q3.2 If there is a certain ratio to convert user costs to construction costs.	(3), (4)
Q4	Q4. The existence of a pre-determined approach to mitigate risks encountered during the implementation of an MOT Strategy. Q4.1 The challenges that they have faced regarding MOT when deploying a detour route. (change orders, unpredictable situations, etc.). Q4.2 How these issues are managed and whether representatives of all stakeholders are involved in addressing the issue.	(4), (5)

Phase (III): According to Figure 3.15, after the development of the ABC alternatives and traditional alternatives, their relative cost and traffic impact is determined, and the final alternative is selected. In the following sections, these three phases are discussed in greater detail.

Phase (I): Calculating ABC Rating Score. Under two conditions, there is no need to determine the ABC score as it will automatically reach the minimum value of 50. The first condition is when the detour's out of distance travel is more than 30 miles. The second condition is when the structure is an interstate bridge.

Except for these two special cases, the ABC rating score is determined based on several factors, including AADT, out of distance travel, user costs, and economy of scale. The scores with respect to each of these criteria are calculated and added together after being weighted based on their level of importance based on Table 3.7. A maximum score of 165 can be achieved, which is then normalized to obtain a value between 0 and 100. These measures are described in Table 3.7.

Phase (II): ABC-AHP Decision-Making Tool. In this phase, ABC-AHP Decision Making tool uses 5 criteria and 24 sub-criteria to qualitatively assess the construction alternatives. These criteria and sub-criteria are summarized in Table H.1 of Appendix H.

Phase (III): Selecting the Construction Method. The traditional traffic management methods during bridge replacement projects, such as using a detour route, temporary bridge, crossovers, or staged construction, significantly affect the construction time and road users' mobility. In this regard, the mobility impact time, which is the period of time that the traffic flow is affected by construction activities, is of particular importance as it affects the construction method and costs. To that end, Iowa DOT introduces five tiers of acceleration to consider the mobility impact time with respect to complete road closures. Based on the level of mobility impact, the appropriate ABC techniques are suggested in the *ABC Manual,* as demonstrated in Table 3.8.

In addition to the criteria that were obtained from the review of the *ABC Manual*, several other considerations for the selection of the detour routes were also mentioned during the interview. One of these considerations is to prioritize interstate routes for detour routes as they are owned by the DOT. This has two primary advantages.

1. All the requirements, including the capacity to carry heavy traffic, are assured.
2. There is no need to coordinate with local officials to select the routes and pay for the reimbursement costs.

Other considerations, according to the interview, are summarized in Table H.2. These criteria are mostly the criteria that are qualitative and rather harder to

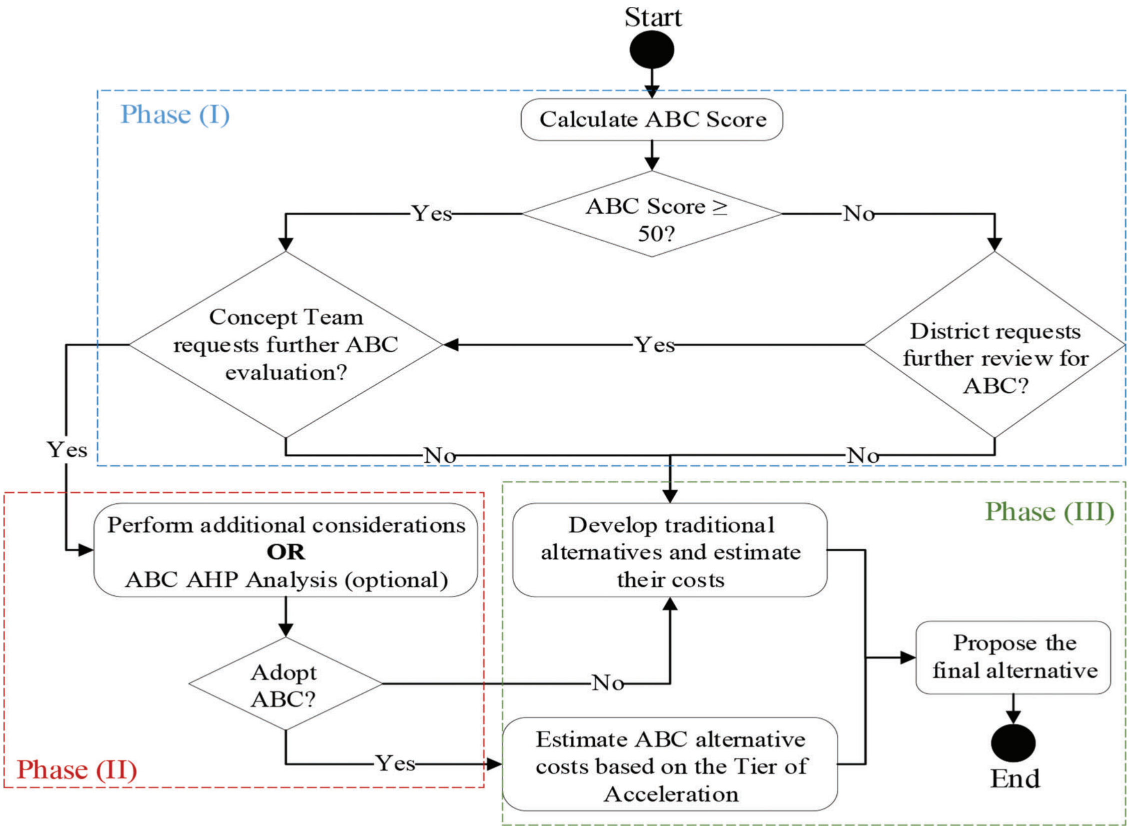


Figure 3.15 ABC decision-making steps (adapted from IowaDOT, 2020).

TABLE 3.7
The factors used for the calculation of the ABC score

Criteria	Weight	Score Range	Thresholds
AADT on the bridge + 25% of the AADT under the bridge	10	0–5	No traffic impacts 5,000; 10,000; 15,000; 20,000
Out of distance travel (OODT) additional distance traveled along a detour in miles	10	0–5	0, 5, 10, 15, 20
UC = AADT + 2 × ADTT) × (OODT) × (Mileage Rate)[1]	10	0–5	\$10,000; \$50,000; \$75,000; \$100,000
Economy of scale: Accounts for the overall cost of a project based on the total number of spans	5	0–3	1, 3, 5, 6

[1]The mileage rate is currently set at 37.5 cents per mile (2016). Average daily truck traffic (ADTT) is counted at three times the amount of other traffic.

TABLE 3.8
Suggested construction method based on the mobility impact time (adopted from Iowa DOT, 2020a)

Acceleration Level	Mobility Impact	Construction Method
Tier 1	Less than 1 day	Placing the entire bridge superstructures as a unit
Tier 2	Less than 3 days	Placing the entire bridge superstructures as a unit
Tier 3	Less than 2 weeks	Using prefabricated bridge elements
Tier 4	Less than 3 months	Using prefabricated bridge elements, or traditional construction methods
Tier 5	More than 3 months	Traditional construction methods

quantify and consider. The aim of this table is to demonstrate how these criteria are considered and dealt with by Iowa DOT.

3.4.3.2.2 Minnesota DOT. Based on interviews, engineering judgment based on similar closures and conditions are used in combination with the following criteria for the selection of the most viable alternative for the detour route.

- Type of roadway
- Volumes
- Speed
- Preferably being owned by the DOT
- Duration of the project
- Lateral and vertical clearances of exceptional vehicles
- Special events
- Emergency services
- Hospital access, fire departments
- Safety (change in the speed limit, e.g., avoiding the rerouting of traffic from a freeway to a highway.)
- Truck volume (specifically farming machinery during the harvesting season). It should be noted that it was mentioned during the interviews that heavy trucks are directed toward a different route
- Local access
- Political considerations (for instance, four districts might be involved, and the opinion of local politicians should be considered)
- User costs are also used as a basis for the comparison of the available construction methods, such as using temporary bridges and temporary crossover designs

When it comes to the planning of the construction work, the focus of Minnesota DOT is to conduct the construction work during nighttime. Consecutive weekend closures, i.e., from 10 PM on Friday to 5 AM on Monday, were stated to be quite common. This is because weekend trips are planned in advance, and the drivers can adjust their plans according to the announced closures. The dates and locations of the closures are reported by the public affairs office using news media, Facebook, and Twitter—in addition, temporary portable message signs are used to communicate information on road closures and alternate detour routes.

For large projects, specifically in metropolitan areas where the public impact is considerable, a more in-depth and comprehensive analysis is considered to model the impact of closures on the traffic and monitor the traffic flow during construction activities. This comprehensive analysis is not used for weekend closures as it requires months of works. A summary of the steps that were described during the interview is provided below.

Step 1: Predicting travel demand based on activity-based models: Activity-based models are origin-destination models that determine how much is the volume of the traffic that is going from a particular origin to a specific destination.

Step 2: Modeling the impact of closures: A combination of simulation packages like Synchro is used to model the impact of closures on the traffic flow.

Step 3: Monitoring the traffic flow through the construction phase: Traffic data and camera surveillance videos are used to effectively monitor traffic movements after the deployment of the detour route.

A part of the interview was dedicated to understanding the approach of Minnesota DOT to address the criteria that are qualitative and rather harder to quantify and consider. For the sake of brevity, a summary of MnDOT practices to address these criteria are provided in Table H.3 of Appendix H.

3.4.3.2.3 Traffic management plan. A subset of the Traffic Management Plan is the Incident Management Plan, which is developed for larger scale projects with longer durations. The agency has a budget for extraordinary and special events. The following solutions for managing incidents were mentioned during the interview.

- Permanent message signs
- Cameras
- Law enforcement units
- Monitor speeds on a daily or weekly basis
- Towing contracts
- Relying on construction personnel
- Relocating ambulance stations in once case that the access of a portion of the city was restricted to a hospital due to the closure of a bridge.

3.4.3.2.4 Arizona DOT. The MOT approach of ADOT for work zone areas depends upon the characteristics of the project, including its impact on the public as well as its duration. Some projects will likely result in significant impacts to the traveling public. On these projects, it will be necessary for project personnel to identify, assess, and document these impacts. For these projects, a Transportation Management Plan (TMP) is required, as determined by the project team. The full TMP consists of the TTC plan, a traffic operations component, a public information component, and an Emergency Vehicle Access Plan (EVAP). There are no formal checklists for the design of TMP to select the most viable alternative to be followed by the designers. Based on the interview and the *Work Zone Safety Manual* (ADOT, 2020), the following rules and criteria were identified to be important in the design of TMPs for the projects that require road closures.

Road network impacts and capacity reduction (delay, travel time, queue length, etc.)

- Emergency vehicle access
- School bus access
- Business and residential access points
- Pedestrian/bicyclist access and safety
- Public transit
- Viability of the proposed route for the road users. In this regard, the added mileage was mentioned as one of the examples. It was mentioned that an increase in the mileage of the route, with an initial length of 2 miles, to 15 miles is not acceptable.
- Structural capacity of bridges
- Pavement condition
- Holidays and special events
- Motorists' safety
- Worker safety
- Environmental impacts (noise, dust, etc.)

For more details about the approach of Arizona DOT to address the qualitative criteria, please refer to Table H.4 of Appendix H.

3.4.4 Telephone Interviews with Other DOTs Regarding Detour Conflict Management

3.4.4.1 Interview questionnaire design. In this phase of the study, six follow-up interviews were conducted with the experts from other state DOTs to acquire additional in-depth information on the following aspects: (1) the most significant factors that affect the extent/resolution of conflicts among detour routes, (2) the best practices for proactive mapping and coordinating detours to avoid/resolve the conflicts, and (3) description of the tools that state DOTs used for planning the projects so that they can foresee and resolve the conflicts.

Table 3.9 presents the three major questions that were designed where specific attention was paid to keeping the interview as short as possible while maintaining its adequacy to address the research objectives.

3.4.4.2 Follow-up interview with other DOTs: Analysis and results. This section presents the findings of the second series of phone interviews with experts from several state DOTs who participated in the follow-up survey and agreed to provide their contact information.

3.4.4.2.1 Iowa DOT. Consistent with the findings of the first series of the interviews, the interview with the experts from Iowa State DOT revealed that the policy of the state DOT is to close interstates only on rare occasions and try to avoid closures, and thereby, the need for detour routes, at the first place. Furthermore, they highlighted two important factors that contributes to lower potential for conflicts among active detour routes.

1. *Lower traffic volumes as compared to states such as Indiana and Ohio:* This not only reduces the potential for conflicts, but also reduces their impacts. According to Iowa DOT experts, if there are two detours in the vicinity, the relatively lower detoured traffic volume, does not make significant differences in the traffic flow of the original route, being used as the detour.
2. *Avoid detouring traffic on local roads:* This obviates the need for additional coordination with local authorities and the potential for schedule conflict. Furthermore, this approach has two additional benefits, i.e., lower dust control cost for gravel roads, and avoiding the challenges such as safety issues, structural upgrade requirements, and noise made by the trucks moving at high speeds on county roads. Selecting interstates, as the detour route for interstate closures, leaves limited available options, as there are limited parallel alternatives.

Detour conflict resolution mechanisms. The interview with the experts from Iowa State DOT revealed that Iowa DOT has a 5-year planning horizon for construction projects. Considering the relatively low chance for the occurrence and the extent of detour conflicts, the detour conflict resolution mechanisms used by Iowa DOT tend to be more reactive in nature and can be summarized as follows.

1. *Using GIS-based maps:* Collecting the start and end coordinates of project work zones in ArcGIS. These inputs are updated on an annual basis. In the case of conflicts among detour routes, meetings were held for resolving the conflicts, having the detour routes highlighted on the map.
2. *Using incident management routes:* Although reactive in nature, the practice of using the network of the incident management detour routes can help resolving potential and unforeseen conflicts, when needed.

During the interview, the research team asked about the possibility of using CARS system, as a tool for detour conflict resolution. Iowa DOT is among the pioneers in the use of the CARS system since 2005. According to the interviewees, CARS provides real-time information, while the detour route plans are at the scale of a year. Therefore, the time frame of the CARS system is not appropriate for detour planning and conflict resolution and they tend to use ArcGIS for having the start and end locations and dates for the detour routes.

3.4.4.2.2 Minnesota DOT. Interviewing the experts from Minnesota DOT revealed that several factors are important when determining the potential and the extent of conflicts.

1. *Traffic volume:* The traffic volume in the twin cities is high and with high volume traffic there are few potential diversionary routes. This increases both, the potential and the impact, of the conflicts between detour routes.
2. *Work type:* Type of the work activity plays an important role. The type of work being done in the work zone (e.g., reconstruction, drainage, common repairs, bridge reconstruction, etc.) affects the extent of the conflict.
3. *Vehicle classes:* Vehicle classes can be very important for interstates. The interviewees mentioned an instance about the importance of recreational vehicles. Based on their experience, they did not recommend closing a recreational route during the weekends to accommodate the recreational cars with boats.
4. *The extent of the overlap:* Spatial overlaps are extremely important. Even a 3-mile overlap can cause backup in the

TABLE 3.9
The structure of the follow-up phone interview with other state DOTs

Question	Body
Q1	Description of the important factors that can affect the extent of the conflicts?
Q2	Description of how they proactively identify/address conflicts with detours under different circumstances (considering multiple factors effecting the detour conflict).
Q3	Description of the tools (e.g., CARS, GIS, customized) available for detour conflict resolution.

upstream. As an example, they cited their experience when there was a conflict for just a weekend and project schedules demanded to continue. The decision was to continue both projects. the officials said that they have decided to accept zero spatial overlaps as the outcome could be chaotic. The Minnesota DOT engineers told us that they tend to get together with the local officials and solve the issue. The next section discusses the approach of Minnesota DOT for detour conflict resolution.

Detour conflict resolution mechanisms. During the interview, in the context of metropolitan surface transportation projects, Minnesota DOT experts mentioned that they gather and evaluate costs and needs over a 5-year period and try to juggle projects within construction years. The planning horizon is smaller for some construction projects, depending on the type of the work. Analyzing the interview scripts showed that Minnesota DOT uses the following methods for identifying/resolving detour conflicts.

1. *Using origin-destination models in combination with micro-simulation:* Engineers at the construction office use activity-based models to predict the origin-destination of individuals at a regional scale. Then, using the outputs of the analysis, they try to identify the sources of traffic and track the traffic 10–15 miles ahead of the location that may cause potential conflicts, increased travel time, or queues. For specific corridors they often carry out further analysis, i.e., micro simulation, using software including VISSIM, Coresim, and Synchro.
2. *Using intelligent work zone:* The system has 19 different sub-systems to carry out queue detection and backup analysis typically for the local system, and the analyst communicates various pieces of information such as travel time information, downstream speed notification, over-dimension warning system using portable changeable message signs to notify large trucks and construction vehicles if they are oversize, to drivers.
3. *Changing working hours:* In the case where two projects have overlaps, one of the alternatives for more regular projects is to shift the working hours of one of the projects to nighttime. However, this is not the best option for projects where day work is preferred, such as bridge projects. In that case, staggering the work schedules in the daytime can help alleviate the conflict.
4. *Coordination with local jurisdictions and public:* Local events and festival can increase the demand on local detour routes and increase the travel time and even cause backups. For example, the interviewees discussed cases where a local parade was going to be held, which required the involvements of both county and city officials to avoid conflicts. In addition to the coordination with local officials, the public affairs coordination office communicates the closures with the public.
5. *Holding weekly coordination meetings:* The planning horizon for MnDOT is 5 years. However, the planning horizon for counties is typically 2 years. This may cause potential conflicts among active detour routes. Therefore, during the construction season weekly meetings are held on every Monday afternoon to avoid conflicts. They strive to limit lengthy closures for the weekends and request the contractors to hold-off to schedule their work consecutively instead of simultaneously.
6. *Using multi-layered GIS maps:* In the weekly coordination meetings, MnDOT use a multi-layered GIS map for coordination. The multi-layered map contains the information on construction projects for the next 5 years. Each layer contains the work zone information at a specific jurisdictional level, e.g., county, city, and state levels. The map is updated at different levels by adding contractor plans.

3.4.4.2.3 Arizona DOT. Arizona DOT (ADOT) approach for detour conflict resolution addresses the conflicts during the entire project duration. As of this writing, the DOT was developing an Excel worksheet that can be used to determine the potential and extent of delays and traffic queuing that could arise from various types of work zones and closures along a given corridor. The evaluation process takes three steps and requires input of basic project information such as the project location, area type, facility type and work zone type information. This information is then used to compute the facility baseline capacity in Step 1. Step 2 utilizes the facility type and work zone type information to compute the work zone capacity. Finally, using the results from Steps 1 and 2 and the guidelines from the *Highway Capacity Manual,* Step 3 computes and displays the anticipated delay and queue length. A summary and sample inputs and outputs to the worksheet are presented in Table 3.10.

3.4.4.2.4 North Carolina DOT. The research team was able to arrange an interview with a central region work zone engineer to get insights about detour conflict resolution practices of the DOT. The results are summarized as follows.

- *Avoid detouring traffic:* In NC State DOT, they tend to avoid closures not only because of capacity issues, but also because of continuity concerns. For example, they had to close a US route for road rehabilitation about 18 months and it took 10 years for them to get all approvals and planning. The interviewee mentioned that North Carolina has one of the most populated urban areas and the continuity is important for the following reasons.
  - Emergency response access.
  - Closures on I-95 affects all commercial properties located all the way towards Florida. Therefore, there is great pressure from local division officials to reopen closed roads as soon as possible.

Detour conflict resolution mechanisms. Similar to Texas and Virginia DOT, North Carolina DOT has two levels of governance, city, and state roads. The North Carolina DOT policy is to avoid the closure of interstate routes and using detour routes. If a detour is necessary, the policy is to do the following.

1. *Change the working hours:* They do close interstates overnight (that would just be a midnight to five in the morning) and traffic is typically detoured to a parallel route with the help of law enforcement.

TABLE 3.10
Summary of input information and example results for detour conflict resolution worksheet for ADOT

Step	Input Information	Example
Step 1: Roadway Information	Route name	Ray Rd
	ADT of roadway	50,000
	No. of lanes/direction	3
	District	North Central
	Area type	Sub-urban
	Roadway classification	Freeway
	HV%	15%
	For arterials: Are signals less than 1 mile apart?	Yes
	Grade	4%–6%
	Lane width	10–11.5
Base Capacity		1,500
Step 2: Work Zone Information	Type of work zone	Lane closure
	Number of lanes in work zone	1
	WZ lane width adjustment	>11.5
	Work zone intensity	Low
	Work zone protection	TCB
	Lateral offset from barrier	>2 ft
	Lateral offset from work zone	>4 ft
	Time of work	24 hours
	Detour availability	None
	Diversion %	0%
	Work start time	0:00
	Work end time	23:59
Work Zone Capacity		1,170
Step 3: Results	Max queue length (mi) day time	8.6
	Max queue length (mi) nighttime	8.5
	Max delay (minutes) day time	243.7
	Max delay (minutes) day time	240.2

2. *Build a temporary structure:* For projects that require more than a night, the practice is to build a temporary structure adjacent to the one being replaced. For example, they have closed an interstate and detoured traffic to a parallel US route.
3. *Using custom programs:* The interviewee mentioned that they use FREEVAL program generated by North Carolina for traffic management. This program, which is designed based on HCM, contains the following.
   - Geometry (segment type, segment length, free flow speed, number of lanes, etc.).
   - Google Maps Integration.
   - Demand (flow rates, percent trucks, etc.).

The FREEVAL program provides the capability to quickly test the effects of different work-zone scenarios as well as quantify the effects of congested periods over time and space. It can be expanded to include whole-year reliability analysis. The planning level analysis includes several useful default values to aid in data entry, as well as the ability to enter daily AADT values or hourly demand flows. They have used FREEVAL for a bridge demolition project that required squeezing traffic from five to two lanes over a period of time. One of the most conspicuous benefits of FREEVAL is that it is designed for those who are not experts in traffic engineering.

3.4.4.2.5 New Jersey DOT. The research team was able to arrange an interview with a construction manager with more than 30 years field experience to acquire insights about detour conflict resolution practices of that state's DOT. The results are summarized as follows.

- New Jersey DOT policy is to avoid the closure of interstate routes and to use detour routes. Interstate detour is a very last resort. This is primarily because the state roads are generally congested and therefore there are few alternatives for detours. Consequently, the DOTs policy is to avoid closures and detours of major highways unless it is unavoidable. The following measures are taken to avoid detours.
   - Capital project delivery: All projects are planned in the same manner, in line with the federal process to streamline the process and avoid conflicts.
   - Financial costs are not significant most of the times, the DOT often opts for more expensive options that avoid detours even though detouring traffic may present cheaper alternatives.
- If a detour is necessary, the policy is to keep it short, typically no longer than 2 miles. For every detour the following is true.
   - The work zones are designed to have minimal impact on the level of service of operation, even though this increases the overall cost.

- Traffic volume is important, and traffic analysis studies are conducted for every detour to ensure no bottlenecks arise in the system.
  - Vehicle classes are important as well. They tend to separate the truck and auto traffic.
  - Message boards to communicate information to the drivers 2 miles ahead.
- There are two operation centers that monitor the condition of the routes.
- Close contact is maintained with local jurisdictions and municipalities such that every development that may cause a disruption to traffic flow needs to be approved by the police department, local officials, counties, and municipalities.

Detour conflict resolution mechanisms

1. *Building relationships with stakeholders:* Maintaining close contact with local authorities is paramount as this helps the DOT coordinate and avoid potential detour conflicts. If two or more projects are scheduled simultaneously, through this communication and coordination, the entities involved can decide which takes precedence and which can be moved up or down. That way, only projects that do not create a need for detours or result in detour conflicts are going on.
2. *14-day notice rule:* Any change in the traffic patterns needs to be communicated to the coordination office, which disseminates that information to local officials.
3. *Nighttime construction:* Due to high level of traffic volumes, most of the construction work is done during the nighttime. In this condition, proper signing and adequate lighting become important.
4. *Work staging:* With work staging, the DOT splits work projects into various stages that do not result in the need for a detour. Bridge replacement on a three-lane route for example, can be done one lane at a time while traffic uses the other two open lanes.

3.4.4.2.6 Massachusetts DOT. Similar to several other state DOTs, the policy of the Massachusetts DOT is to adopt the simplest possible detour routes—a parallel interstate route. The reason for that is to avoid truck traffic on local roads as in that case several modifications such as adding to the road capacity, adjust signal timings, etc. needs to be done to accommodate the truck traffic.

For construction work on interstates, partial closures with crossovers are used. In the case of conflicts, dedicating the northbound and southbound of the highway to each of the projects is a common option to avoid conflicts.

1. *Capacity analysis for every detour project:* Depending on the size of the project, they evaluate the traffic flow and do capacity analysis. They tend to use approved analysis programs such as Synchro and HCM. The interviewee mentioned the case of a tunnel construction which required a detour route. For that project, they measured the traffic volumes, identified the best route for the detour, and evaluated how far back they can divert the traffic.
2. *Real-time traffic management:* In addition to the traffic flow and capacity analysis, they utilized real-time traffic management systems that uses the inputs of a network of cameras to monitor the level of service near work zones. After the start of that tunnel project, they rely on real-time management systems to monitor the traffic flow.
3. *Using GIS-based tools:* There is a separate group for scheduling the project to do the planning to avoid conflicts. The interviewee mentioned that 2 years ago, they collected the information on all large construction projects. They use a tool with a color-coded map for projects that are going to start in the future (in the next 5 years).
4. *Reducing the construction time:* The interview revealed that similar to Iowa, Massachusetts DOT uses accelerated bridge construction to reduce the construction duration and consequently, the potential for overlap.

3.5 Chapter Summary

Upon completion of the review of the publicly-available manuals and guidelines from various DOTs, the research team sought to gather more information on the best practices for detour mapping and management of traffic during highway construction. This was necessary because the team recognized that not all information on the subject is necessarily formalized into a manual or guideline that is publicly available, and in fact, some information may be proprietary or be preserved only through institutional memory. As such, the research team designed a survey questionnaire and distributed it to several DOTs. The survey was designed to determine whether DOTs had active detour mapping frameworks as well as the scope and contents of the said framework. The structure of the survey was such that a different set of questions was given to DOTs based on their response to the question of whether they had an active detour mapping framework.

The survey responses opened additional questions and areas, and therefore the team decided to carry out telephone interviews with selected participants having an active detour mapping framework. Phone interviews were also conducted with INDOT personnel to investigate official and unofficial detour mentioned in the *1996 INDOT Detour Policy*. Interviews with other state DOTs were focused on reviewing the identified KPIs and their applicability in practical situation. Moreover, the objective was to gather information about the best practices followed by different DOTs nationwide. As a result, the interviews were helpful to gain insights on different aspects like MOT strategy selection criteria, detour mapping framework, decision-making tolls, and incident management plans.

The research team designed a second follow-up survey designed to address conflicts and conflict resolution in detour mapping. The follow-up survey was structured similar to the first one. The DOTs were given a different set of questions based on their response to the first question. In the follow up survey, the deciding question was whether the DOT had a proactive or reactive approach to detour conflict resolution. A proactive approach was defined as being able to foresee and address the conflict ahead of time whereas a reactive approach entails reacting to events as they occur.

Furthermore, the survey asked the DOTs for information on how they resolve detour conflicts both temporally and spatially, and the longest planning horizon for which they can foresee and resolve detours. Like the previous survey, this was also followed up with a series of telephone interviews with various DOT personnel to gather additional information on the topic.

All the responding DOTs reported that they do not have in place an active approach to detour conflict resolution. Most DOTs reported avoiding closures and detours of major highways in the first place. If detours are necessary, DOTs prioritize staggering their project schedules to avoid proactively creating conflicts in the first place. Other measures they use include staging different types of work at different times, nighttime, and weekend work schedules, and maintaining close contact with local authorities to keep pace with all works going on at different jurisdictions to avoid conflicts.

Several conflict mitigation measures were discussed during the interviews. These include the use of GIS based maps, continuous monitoring of the routes as part of incident management and the use of intelligent work zones to alert drivers on conditions ahead. Other measures include macroscopic and detailed capacity analysis of links of proposed detours to identify potential bottlenecks, analysis of traffic queuing and resulting delay, and reducing construction time using measures such as accelerated bridge construction. They also use various software packages including VISSIM, FREEVAL and Synchro, for capacity and queuing analysis.

4. DISCUSSION

The objectives of the synthesis study on best practices for mapping and coordinating detours for Maintenance of Traffic (MOT) can be summarized in five main points listed as follows.

1. Identify process improvement for INDOT detour planning.
2. Identify current state-of-the-practice on MOT strategies.
3. Investigate best practices for mapping and coordinating detours for MOT.
4. Provide advanced risk management/mitigation strategy based on the best practices.
5. Explore the promising identifiers (e.g., design, financial, social, safety, and management perspective) to be incorporated into developing detour plans.

These objectives formed the basis of the work done by the research team and this section discusses how each of these is addressed by the study in turn.

4.1 Current State-of-the-Practice on MOT Strategies (Objectives 2 and 3)

To establish the current state of the practice on detour mapping and Maintenance of Traffic, the research team conducted a comprehensive literature review of DOT manuals and documents, websites, and other publicly available sources. In addition, the team also conducted questionnaire surveys and followed up with interviews. The findings of these exercises are presented in Chapters 2 and 3 and a summary is presented herein.

The team studied the incident management plans prepared by INDOT and other state DOTs to gain insights on the typically observed risks during the life cycle of a detour route (i.e., planning stage, implementation and closing stage). Besides this, after the literature review, the survey questionnaire was distributed nationwide among state DOTs and transportation-related organizations such as AASHTO and FHWA. Served questions in the questionnaire were designed to accommodate comments regarding the perceived risks and best mitigation practices at different stages of the detour life cycle. Table 4.1 presents a detailed summary of the findings.

4.2 Proposed Criteria and KPIS for Detour Planning Strategies (Objectives 3 and 4)

4.2.1 Identification of Key Identifiers

After a review of the best practices by other departments of transportation through survey questionnaires and interviews with key transportation personnel, the research team proposed a set of key criteria and associated identifiers for use in detour planning. The criteria span seven categories that encompass the important elements of detour planning and selection. These criteria, along with their identifiers are presented in Table 4.2. The table also provides suggestions for applicable thresholds based on existing guidelines and common practices among transportation officials in various agencies. The criteria and associated identifiers are described herein. It should be noted that state DOTS might need to modify the identified weight or even the identifiers for each of KPI depending on the local conditions such as the geographical, economic, and political context to better fit the needs of their state DOT or agency.

4.2.1.1 Operational criteria. In planning of detour routes, one of the most important aspects for consideration is the operation and Maintenance of Traffic while the detour is in effect. To this end, several identifiers must be considered before a detour can be deployed, making sure that a detour is even warranted in the first place. The suggested identifiers under the operational criteria and associated applicable thresholds are discussed in Table 4.2.

4.2.1.1.1 Duration of the project. The duration of the project is an important consideration in the planning of detours as it largely dictates whether it is necessary in the first place. Except for the prolonged and planned construction work, most minor maintenance does not require full closure of the road and thus traffic detouring. Many incident management plans consider alternative ways of handling short lived disturbances to traffic flow, such as carrying out maintenance work at night when there is relatively little traffic (DCDOT,

TABLE 4.1
Summary of best practices for detour planning and MOT

Target Categories	Considerations	Practices	DOTs
Avoiding closures in the first place	Where possible	Nighttime work	MN, IA
		Adding extra capacity	IA
		Extra work staging	IA
		Consecutive weekend closures (10 PM on Friday to 5 AM on Monday)	MN
		Accelerated bridge construction	IA
Coordination of the detour	Coordination with other agencies	Coordination to prevent issues such as detouring the traffic on an existing detour route	MN
		Holding weekly meetings during construction season	MN
		Mandatory public meetings for urban areas (essential service providers)	AZ
	Closure announcement	Reporting the dates and locations of the closures by the public affairs office using news media, Facebook, and Twitter	MN
		Using temporary portable message signs about road closures and alternate detour routes	MN
	Community acceptance	Public information plans	IA
		Holding regular town hall meetings	IA, AZ
		Holding meetings with the mayor of involved cities	IA
		Informing public through 511 websites	AZ
	Disruption to local traffic (public events, school, business)	The priority is to direct the traffic on the state; therefore, commercial vehicles are not considered in the process of detour route selection	IA
		Commercial vehicles are detoured on a separate route	MN
	Business interruption (loss of revenue)	Using black and orange signs with a relatively larger sizes for several local businesses A maximum of 4 to 5 signs are used for the local businesses	IA
		Local businesses are not paid!	IA
		The benefits of a new road should also be considered as well	IA, AZ
		A worksheet for calculating liquidated damages	MN, IA
		Coordination meeting with surrounding businesses	MN
	Political considerations	For instance, four districts might be involved, and the opinion of local politicians should be considered	MN
	Detour conflict resolution	Changing working hours	MN, NC, NJ
		Reducing the construction time	MA
		Work staging	NJ
		Coordination with local jurisdictions and public	MN
		Holding weekly coordination meetings	MN
		Real-time traffic management	MA
		Using GIS-based tools	MN
		Using intelligent work zone	MN
		Using customized program	NC
		Using incident management route	IA, MA
		Build a temporary structure	NC

TABLE 4.1
(Continued)

Target Categories	Considerations	Practices	DOTs
Maintenance of Traffic	MOT strategies include coordination with other agencies, use of CMS's (or PMS), traffic monitoring, etc.	For major projects: Monitor traffic flow camera surveillance videos	MN
		Holidays and special events	AZ
Risk Management	Planning	Providing a driving environment as similar as possible to original route, incident management plan, mobile push notifications	MN
		Ensuring access to emergency response providers (e.g., relocating ambulance stations)	NJ, IA, IN
		Assess the structural capacity of the detour road pavement and the load capacity rating of the bridges	MI, WV, IN
		In order to avoid unexpected costs, the use of official and unofficial detour routes should be made in consultation with local agencies	IN
	Operation	In order to provide quick solutions, it is best to have a committee consist of representatives from each key stakeholder	NJ
		Environmental risks, in particular dust and noise pollution, should be addressed in advance.	IN
		Response times of emergency responders should be recorded in advance	MN
		Notification of mobile applications, local news/radio services and emergency signs should be the first steps in the event of emergency detour incidents	Survey
		Permanent message signs	MN
		Cameras	MN
		Law enforcement units	MN
		Monitor speeds on a daily or weekly basis	MN
		Towing contracts	MN
		Relying on construction personnel	MN
		Coordinating the work proposed on the route when there are crashes, floods, and emergency response is needed	MN
		Live incident management maps	IA
		Work Zone Data Initiative: Collecting work zone crash data	IA
		Crash modification factor: Safety performance assessment	IA
	Closure	Damage to the detour route must be addressed in cooperation with agencies involved	IA, AZ
		The official detour route is signed, and the sharing of liability is predetermined	MN
		Mobile push notifications are the most popular way to convey updates to the community	MN

TABLE 4.2
Proposed criteria and key identifiers for detour planning

	Suggested Identifier	Threshold	Reference
Operational	Duration of project	>7 days	(INDOT, 1996)
		>3 days	(DCDOT, 2006; FHWA, 2009; MDOT, 2020; HNTB-Corporation, 2011)
	Detour legs designed as part of a detour for another project		
	Official detour's route level (state hwy, public road, local)		(INDOT, 1996)
	Other projects happening in the vicinity		(INDOT, n.d.a)
	Presence of rest/fuel stations on detour route		
	Local traffic (public events, school, emergency, business)		
Technical	Length of the detour	Please refer to *INDOT Design Manual,* Ch. 503	
	Traffic volume		
	Heavy vehicle percentage (HVP)		
	Turning radius	74.5 ft	(HNTB-Corporation, 2011)
	Lane widths	11 ft	(HNTB-Corporation, 2011)
	Vertical clearance	14.5 ft	(HNTB-Corporation, 2011;
		14–16 ft	INDOT, 2013)
	Pavement strength, roughness, and age	96–105 in/mi (IRI)	(Arhin et al., 2015; Khraibani et al., 2012; Whiting et al., 2017)
	Bridges and other structures rating		(HNTB-Corporation, 2011)
	Vertical grade	≤8%	
Financial	Cost of maintaining/retrofitting detour (official and unofficial)		(INDOT, 1996)
	Increase in travel time		
	Vehicle operating cost		
Safety	Crash risk (drivers and workers)		(MDOT, 2020)
	Community land use (residential, school zone, etc.)		(Berkovitz, 2001)
	Pedestrian crossing (non-freeway)		(Bartlett et al., 2012; McLeod, 2015)
	Signage on detour routes		(DCDOT, 2006; WVDOT, 2007)
Environmental	Increased emissions due to potential intermittent driving conditions on detour		
	If detour route passes through wetlands or protected areas		
	Noise pollution		(Berglund et al., 1999; Chepesiuk, 2005; van Kempen et al., 2002)
Social	Community impact/acceptance		
	Business interruption		
	Accessibility to essential service providers (businesses, schools, hospitals, fire stations, police stations, etc.)		

2006). Accordingly, when the work is expected to be major or last longer, a detour may be necessary to sustain the flow of traffic. Several state DOTs, including West Virginia and Michigan, recommend deployment of a detour route if the project is expected to go for more than 3 days. A detour may not be necessary and other traffic management strategies may be more effective. Furthermore, based on the *INDOT Detour Policy* (1996), an auxiliary detour route, called the unofficial detour route, is required if the official (primary) detour route is along the state highway system. This recommendation is based on the best practices reviewed in this report (Section 2.2.1.1).

4.2.1.1.2 Detour legs engaged as part of a detour for another project. As shown earlier in Table 2.3, coordination with agencies, contractors, and nearby projects and the presence of adequate parking space are among the factors that should be considered in TTCP design. As part of the operational criteria, planners must ensure that the proposed detour route, or some parts thereof, are not being engaged as part of a detour for another project. This is essential so that bottlenecks are not created along the route due to a surge in traffic volumes. When more than one project is using the same route for detour, there arises the potential that the link will operate over capacity as those other routes redirect their traffic to the said link. Hence, it is paramount that traffic engineers analyze the traffic characteristics to ensure that the link's capacity will be enough to carry traffic at a reasonable level of service.

4.2.1.1.3 Other projects happening in the vicinity. Planners need to be aware of other projects scheduled for implementation in the vicinity of the project question. If there are other projects (in the vicinity) that involve road closures, a percentage of the traffic from those routes may still make it to the route in question and may introduce the same problems as discussed above.

4.2.1.2 Official detour's route level (state and local). Ideally, detour routes take the form of the route being closed, interstates are detoured onto interstates or similar NHS highways, local routes are detoured onto similar local routes. Further, to not significantly increase the travel distance on the detour, a different class or level route maybe utilized. If part or all the route is owned by a different jurisdiction, an agreement will need to be reached beforehand. This is because there needs to be an understanding of liability for the damages that may occur because of the detour activity. In some cases, the route may need to be retrofitted to meet the standards for use as a detour. This may occur when a lower-class route is being used to detour traffic from a higher-class route, such as interstate.

In the *INDOT 1996 Detour Policy,* a written agreement is required between state and local officials if part of a local route is to be used for detour purposes. Accordingly, state officials work with local officials to identify the best possible candidates and INDOT fits the bill for the repairs of any damage arising from the detour activities. The policy also requires that the agency sets up two detour routes for each project. One route is designated as official, and the other as unofficial (It should be noted that although it is not the common practice, in rare cases, the unofficial detour route may not be identified.). The purpose of the unofficial route is to cater for those for whom the official route may be too long or otherwise inconvenient. This may include part of the local population who make daily commutes and may not want to add additional distances to their travel. As stated in the detour policy, INDOT is liable for repairs on the unofficial detour route after the activities are complete. This route is selected by INDOT with significant input from local authorities.

4.2.1.2.1 Presence of rest areas and fuel stations. From an operational standpoint, rest areas and fuel stations are essential particularly for through traffic such as commercial vehicles and out-of-state travelers. Trucks and other commercial traffic will require rest stations as well as fuel stations along their routes. It is therefore essential that lengthy detour routes contain such facilities. This is particularly important for out of state travelers, as some may be stranded if run out of fuel.

4.2.1.2.2 Local traffic. When planning a detour route, particularly one that may affect a residential neighborhood, it is important to consider local traffic. This is in order not to restrict access to important facilities such as schools, hospitals, and businesses. A second factor to consider is the possibility of large traffic volume events such as sports or parades. These may cause a surge in traffic volume around an area and if a detour is routed through such areas, and the resulting bottlenecks may impair the route level of service. Emergency services must also be considered to ensure that access to such services is not hampered due to the closure of vital routes.

4.2.1.3 Technical criteria. Technical criteria are those that address the actual engineering and geometrical suitability of the route for use as a detour. Planners must consider the feasibility of the detour route to handle the traffic with respect to the following suggested identifiers and applicable thresholds. These are discussed below.

4.2.1.3.1 Length of detour. The length of the detour route is one of the most important factors of consideration in detour planning. The goal must be to keep the length of the detour route as close as possible to the length of the original route. This is because not only does the additional distance result in additional delays and added travel time, but it may also increase the vehicle operation costs in terms of fuel costs and additional wear on the vehicle. From the DOTs reviewed thus far, no specific information has been provided on what may be considered the appropriate detour length in relation to the original route. Agencies must use subjective judgement to evaluate the associated costs, such as signage, potential retrofitting and required maintenance, as well as user costs to determine if a given length of a detour is appropriate. To avoid using lengthy detours, it is most appropriate to use a route parallel to the original, if available. Otherwise, it may be advisable to keep traffic flowing onto the original route, albeit at a reduced capacity.

4.2.1.3.2 Traffic volume. It is imperative that the chosen detour route be able to handle traffic directed onto it. Transportation officials at the agency must decide the acceptable volume to capacity (v/c) ratio, and associated level of service (LOS) for the given route and functional class. This is important because not only would heavily congested roads lead to more delays, but also present safety hazards. Intermittent driving conditions that arise from traffic congestion also result in increased fuel consumption by vehicles. In addition, traffic volumes exceeding the design capacity may cause further deterioration to the pavement, leading to more expenditures by the agency. Planners and engineers must consult appropriate agency guidelines for appropriate and acceptable levels of service for a given route and functional class.

4.2.1.3.3 Heavy vehicle percentage. The percentage of heavy vehicles in the traffic stream must be considered when planning for detours. Heavy vehicles have more stringent requirements than conventional passenger cars in terms of both their geometrical and structural requirements. Heavy vehicles require high structural ratings for pavements to support their weight. That means routes must be carefully chosen to include only those that are structurally sufficient to carry the heavy traffic.

Besides the geometric and structural limitations, heavy vehicles also cause decreased road capacity. Due to their large sizes, other vehicles typically drive further away from heavy vehicles than they would to other similarly sized passenger vehicles. As a result, one heavy vehicle may be equivalent to 1.25 to 3 passenger cars depending on the terrain and travel speed (TRB, 2010). Thus, as planners consider detours for their structural strength and geometrical suitability, it is important to consider the expected proportion of heavy vehicles in the traffic stream.

4.2.1.3.4 Geometric requirements. This section encompasses criteria from Table 4.2 under the technical criteria that are related to the geometrical suitability of the route. These include the turning radius, lane widths, vertical clearance, and vertical grade. Each of these factors is discussed herein.

4.2.1.3.5 Turning radius. Similar to considerations regarding the proportion of heavy vehicles in the traffic stream, geometric considerations on detour routes are important. This is because larger vehicles will necessarily have more stringent geometric requirements. Turning radius requirements must be checked for the benefit of long vehicles such as truck and trailers. This is particularly important if part of the detour passes through an urban environment or a residential neighborhood, where some of the turns may be extremely sharp. Planners and engineers must survey the proposed route to ensure that any tightest of turns on the route will be sufficient to accommodate the largest vehicles in the traffic stream. The West Virginia DOT recommends a minimum turning radius of 74.4 ft on detour routes to accommodate long trucks (HNTB-Corporation, 2011).

4.2.1.3.6 Lane width. Lane widths must be considered in the planning of detour routes due to their impact on driving speeds, safety, and road capacity. Narrow lanes decrease the road capacity as drivers tend to slow down when the lanes are narrow. Also at undivided highways, narrow lanes pose safety hazards. As a rule of thumb, a lane width of 11 ft is regarded as sufficient for detour routes. Several DOTs (West Virginia, DC, MI) have recommended 11-ft lane widths in their traffic control and incident management manuals (DCDOT, 2006; HNTB-Corporation, 2011).

4.2.1.3.7 Vertical grade. Vertical grade may not be an issue for small vehicles and passenger cars. Nevertheless, it is particularly important for heavy vehicle operations. For heavy vehicles, the longitudinal slope must be small enough to allow them to smoothly traverse the terrain. Consequently, the West Virginia DOT, in its Turnpike Incident Management Plan, recommends grades of not exceeding 8%.

4.2.1.3.8 Vertical clearance. Vertical clearances are important in situations where routes have overpasses or underpasses. Overpass infrastructure such as bridges and road signage infrastructure may be in danger of collision with high vehicles if not properly accounted for (Sinha et al., 2009). Planners and engineers must ensure that the lowest clearances on the proposed detour routes are at least equal to those on the original route. Exact limits maybe subjective and judgment must be exercised. Based on Chapter 53 of *Indiana Design Manual*, the vertical clearance should be 14.5 for local roads and 16 for freeways. However, for urban areas, a 14-ft clearance may be used if an alternate freeway facility with a 16-ft clearance is available. This is in line with the 14.5-ft vertical clearance suggested by Chapter 55 of the *Indiana Design Manual* as well as the minimum value that West Virginia DOT proposes for vertical clearance on detour routes (HNTB-Corporation, 2011).

4.2.1.3.9 Pavement strength, roughness, and age. For a route to be used a viable detour, it must have sufficient structural strength to support the volume and weights of anticipated traffic. Additionally, the pavement must be in serviceable condition to used. Agencies and engineers must ensure that the candidate routes being considered are up to the required standards. The pavement condition information can be obtained by physical site inspection or an asset management database, if available. The pavement condition can be assessed using various measures depending on the available resources and data, such as measures include the present serviceability index (PSI), the pavement structural rating (PSR) or the international roughness index (IRI). Engineers and agencies typically have in place, a set of standards (acceptable thresholds) that may vary by jurisdiction and climatic condition. Generally, pavements are considered serviceable when their IRI is less than 104 in/mile (Arhin et al., 2015; Whiting et al., 2017).

4.2.1.3.10 Bridge rating. In addition to ensuring the inadequacy of the detour road pavement serviceability, engineers and planners must also ensure that bridge structures along the detour route are also structurally and functionally adequate to carry the loads of detoured trucks. The detour traffic induces additional live loads and moments in the structural members supporting the bridges on the detour route. These moments in turn induce stresses that may cause the structure to fail. Bridge stability and serviceability is typically given by the NBIS bridge structural rating (FHWA, 1979). The rating is given on a scale of 1 to 9, where 1 is a failed bridge and 9 means excellent. Generally, a bridge is considered to have fair condition if its rating is at least 5 (Sinha et al., 2009). This may however depend on the road class. Engineers and planners must therefore ensure that the bridges on the viable detour routes are structurally sound.

4.2.1.4 Financial criteria. Financial considerations are of utmost importance as road closures will result in additional monetary costs to users and the transportation agency. This section discusses financial considerations that detour planners consider.

4.2.1.4.1 Cost of maintaining/retrofitting a detour. A candidate detour route may be of a lower class or worse condition than the original route. In this situation, it may be necessary to retrofit or upgrade the candidate route to meet the required standards. However, this may be extremely costly, and therefore the planners and engineers must weigh the costs of such retrofit against travel time savings, safety, and other benefits.

Another scenario where the agency's financial responsibility must be considered is in the deployment of an unofficial detour or use of a section of route that is controlled by a different jurisdiction. The *1996 INDOT Detour Policy* establishes that the agency (in consultation with local authorities) provides an unofficial detour route in addition to the designated official detour route. The unofficial route is meant to cater for drivers who may not necessarily adhere to the official designated route. Such may include daily commuters who may opt to use a shorter, locally known route rather than the officially designated detour. The latter for the purposes of accommodating heavy traffic, may be longer. The rerouting of traffic through the local streets may result in additional wear and damage that would not otherwise occur. Hence, the state agency is liable for the cost of repairs that may arise as a result. Consequently, the unofficial detour is provided so that the agency is not responsible for additional work that necessary. Similarly, an agreement may be set up for an agency to pay for repairs if part of the detour route is owned by a different jurisdiction (state, county, etc.).

4.2.1.4.2 User costs. According to the Texas DOT manual, road user cost calculations typically involve quantifiable and non-quantifiable impacts. Generally, most road user cost calculations include quantifiable impacts. The monetary factor comprises of two cost elements—the increased travel time and the vehicle maintenance and ownership costs.

Increased travel time. The additional distance that must be covered as part of the detour process add to the overall delays that road users must endure. Furthermore, depending on the condition of the detour route, traffic flow may be slow, resulting in additional travel delays. These delays translate into costs for users in terms of lost time. The vehicle operating costs (C_v) can be calculated as follows (Qin & Cutler, 2013):

$$C_t = w \times m \times \Delta t \times ADT \qquad \text{(Eq. 4.1)}$$

where, m is average vehicle occupancy, Δt is delay per vehicle, ADT is Average Daily Traffic, and w is value of time. The value of time depends on the travel context, the characteristics of the traveler (particularly the wage). The value of time varies according to the prevailing conditions, the location and time of day. However, the Federal Highway Administration estimates that $16/hr could be used. Agencies may use their in-house values of travel time to assess the impacts of the delays, or use the FHWA recommended average of $16/hr.

Vehicle operation cost. As with the travel time, vehicle operating costs are an additional cost that users of the road will endure. This includes the following.

- Fuel consumption
- Tire wear
- Oil consumption
- Maintenance parts and labor
- Depreciation and interest

The vehicle operating costs (C_v) can be calculated as follows (Qin & Cutler, 2013):

$$C_v = c \times d \times v \qquad \text{(Eq. 4.2)}$$

where, d extra distance traveled on detour, ν is daily volume, and c is vehicle operating cost per mile. According to the *Indiana Design Manual*, the average user cost is rated at $0.55/mile. Users driving on these routes can expect to incur on average $0.55/mile in terms of fuel costs, vehicle maintenance, etc. Detours often have lower quality pavements compared to the original road. This means that such pavements may be rougher to drive on and consequently result in more wear and tear for the vehicle components, leading to higher vehicle operating costs.

4.2.1.5 Safety criteria. As shown in Table 4.2, the set of safety criteria represent an important but often overlooked aspect of road detour planning. Safety criteria tend to be qualitative in nature, and therefore, difficult to consider. Therefore, this research study reviewed the work-zone safety manuals of other state DOTs and interviewed experts at other state DOT to document and assess the state of practice. These criteria include the safety of road users, workers, and the community as summarized in Table 4.3. "Yes" indicates that the state DOT considers the indicated criteria in their traffic management manual.

Additional details on these criteria, the reasons behind their consideration, and the approach of other state DOTs to address them, are discussed in the following sections.

4.2.1.5.1 Road users and workers. Construction work on highways are the primary reasons for detours. Detours may be onsite or offsite. In the case of onsite detours, it is important that traffic flow is properly controlled and managed so that worker safety is not jeopardized. Also, the safety of the drivers is important. At construction zones, traffic lanes and the road itself are likely to include frequent turns and winds. As such, drivers must be properly alerted (through road signs) to

TABLE 4.3
Safety criteria based on the literature review and interview results

	State DOT	Worker and User Safety	Community Safety	Signage on Detour Routes
Literature Review	West Virginia	Yes	–	Yes
	D.C.	Yes	–	Yes
	New Jersey	Yes	–	Yes
	Indiana	Yes	Yes	Yes
Interview	Iowa	Yes	–	N/A[1]
	Minnesota	Yes	–	N/A
	Arizona	Yes	Yes	N/A

[1]Not Applicable: Signifying that no question was asked about this topic during the interview.

the impending twists and turns ahead, to ensure their safety (MDOT, 2020).

4.2.1.5.2 Community safety. As a part of detour planning, the planners and engineers strive to ensure the safety of motorists and the community by constructing pedestrian walkways and crossing facilities. If part of the detour route passes through a residential neighborhood, planners and engineers must ensure that the safety of the community is not jeopardized by the potential increase in traffic that is likely to arise from the detouring traffic in the area. This means that proper signage and speed limits must be properly marked, and drivers be made aware of traffic sign violation penalties (Berkovitz, 2001). In some cases, part of the route may be passing through a school zone or area with a predominantly elderly population. From a safety standpoint, planners and engineers must avoid routing detours through residential neighborhoods or school zones. However, if this is unavoidable, discretion must be exercised by engineers and planners in specific situations and at specific areas to ensure community safety. This is not particularly relevant for detours executed on freeways and major highways; however, it should be a top priority for those that are routed through residential neighborhoods. The presence of proper pedestrian facilities has been proven to significantly reduce pedestrian crashes and improve overall road safety (Bartlett et al., 2012; McLeod, 2015).

4.2.1.5.3 Signage on detour routes. Detours often contain unexpected turns and changes in speed and traffic flow patterns. Therefore, it is important that drivers are given advance warnings of impending changes. This is particularly important for driving during the night where visibility may be limited. Some drivers, particularly non-locals, may be unfamiliar with the routes, particularly if part of the route passes through a residential community and therefore could benefit from adequate signage at every stage (DCDOT, 2006; WVDOT, 2007).

4.2.1.6 Environmental criteria. As demonstrated in Table 2.1, INDOT's framework for detour route generation does not place much emphasis on social and environmental criteria. In addition, none of the criteria listed in the *INDOT Detour Policy* (1996) are related to environmental issues. The only opportunity for considering environmental impacts is the environmental impact report, which (according to *2013 INDOT Design Manual*) should be prepared at the hearing phase of the traffic control plan design, before the final field check and the district's review. The literature review results for other state DOTs showed the widespread non-consideration of environmental factors in the design of MOT strategies and detour mapping.

Also, the survey results show that of all criteria environmental issues are assigned relatively low levels of importance. There are two questions in the survey questionnaire, i.e., Q2 and Q3, that can be used to evaluate the role of environmental considerations in the detour route mapping process. According to Figure 3.3, regardless of the presence of an active detour mapping framework, only 15% of state DOTs reported to have an environmental engineer in the panel that selects detour routes. In addition, responses to Q3 (Figure 3.4, Figure 3.5, and Figure 3.6) demonstrate that regardless of having an active framework for detour mapping, of all the criteria provided in the question environmental issues receive the lowest rating. Although the respondents' perceptions regarding the definition of each criterion infuses some subjectivity in their responses, it can be concluded from the literature review and survey results that in detour route mapping a relatively lower attention is explicitly paid to environmental issues.

Of all the manuals and guidelines reviewed, only the *Accelerated Bridge Construction Manual* used by the Iowa DOT includes environmental considerations in the selection of appropriate construction methods, which in turn, affects the road closure type. Even in that manual, the step that involves the consideration of qualitative factors such as environmental issues, is optional. Nevertheless, the factors that are introduced in the guideline can be included in detour route selection. The *ABC Manual* considers the impact of construction projects on natural resources including marine and wildlife.

To address environmental issues, three factors (increased emissions due to the intermittent driving, the impact on sensitive ecological areas, and noise pollution) are suggested as discussed below.

4.2.1.6.1 Increased emissions due to intermittent driving conditions. As discussed in earlier sections, driving on detour routes may not be as smooth or predictable compared to the original route. This is particularly true if the detour route is of a lower class compared to the original, or if a part of it is routed through an urban or residential locality. As a result, driving may be intermittent, and the repeated acceleration and deceleration may lead to increased tailpipe emissions. As a stand-alone issue this may not have significant impacts on overall emissions because detour routes often constitute only a small percentage of the total route-miles travelled and therefore their contributions may be minuscule.

4.2.1.6.2 Sensitive ecological areas. Detour routes passing through potentially sensitive ecological areas is a more critical issue compared to increased tailpipe emissions at such road sections. As much as possible, ecologically sensitive areas must be avoided. Where such areas cannot be avoided, a comprehensive environmental assessment must be conducted before the route can be deployed. This is because ecosystems are generally fragile, and any disruptions thereof can have far-reaching consequences and sometimes may be even irreversible.

4.2.1.6.3 Noise pollution. Noise pollution is most relevant for routes that are planned through residential neighborhoods. An increase in traffic will likely result in increased noise, particularly at nighttime, and may not be acceptable to the community. Thus, engineers and planners must ensure that the noise levels are kept within acceptable limits. According to literature and EPA guidelines, the recommended noise levels in a residential neighborhood is between 45 dBA to 55 dBA (Chepesiuk, 2005; van Kempen et al., 2002). If noise levels exceed these limits, the agency may consider restricting certain kinds of vehicles (e.g., trucks) on the detour route. In one of the interviews, it was mentioned that the noise pollution is one of the factors affecting detour route mapping.

4.2.1.7 Social criteria. As a part of literature review, the traffic control manuals of several state DOTs were reviewed to identify the fundamental aspects and considerations in the design of TTCPs. Since road closures and deploying detours are among recommended alternatives, the factors and consideration introduced in the reviewed manuals can provide the basic factors applicable to the mapping and coordination of detours and risk management. As it is shown earlier in Table 2.3, several social factors are introduced to be considered in TTCP design and are summarized as follows.

- Residential or commercial land use.
- Access to businesses, neighborhoods, and major activity centers.

However, as demonstrated in Table 2.2, the review of the previously-developed detour routing and incident management plans (INDOT, Michigan DOT, West Virginia DOT) revealed that in the selection of incident management routes, the focus is more on technical, financial, and operational, rather than social aspects.

One of the reasons for the lower emphasis on social aspects could be the qualitative nature of social impacts. To evaluate this, a large portion of the interviews of the other state DOT experts the assessed their practices regarding criteria of a qualitative nature or are difficult to measure. These criteria included the community acceptance, accessibility to essential service providers, disruption to local traffic (public events, school, business), business interruption (loss of revenue), worker safety, and road user costs. The first four criteria can be categorized under social criteria and are discussed in this section.

The result of the interviews showed that these criteria are being considered in the selection of the best detour route without necessarily being documented in the manuals or guidelines of the interviewed state DOTs. They were rather being measured using the judgment of engineers involved in the detour planning process. An introduction to each of these criteria as well as the approach of the state DOTs that reported to have an active detour mapping framework to address these criteria are discussed below.

4.2.1.7.1 Community impact/acceptance. Planners and engineers must engage with community leaders to discuss the best possible options before identifying the best detour route. Engaging the community will enable them to have a voice on what they think are the best available options. For example, communities may for example prefer to not have any traffic routed through their residential areas or school zones. Therefore, although community acceptance is difficult to accurately measure or quantify, planners and engineers must engage the community in the process to ensure community cooperation.

According to an interviewee from a state DOT with an active detour mapping framework, although the use of navigation devices is common, almost 75% of the commuters still follow the proposed detour routes. Therefore, the selection of the detour route according to the needs of the involved community is important. The following practices were mentioned during the interviews as means to seeking community acceptance and reducing the community impact.

1. Public information plans.
2. Holding regular town hall meetings.
3. Holding meetings with the mayor of involved cities.
4. Using 511 websites to inform the public for significant projects.
5. Arranging the work when schools are closed.
6. Coordinating with adjacent projects.
7. Planning weekly “look-ahead meetings.”

From interviews, it was observed that the community impact is measured based on the following criteria, according to the interviews.

- Holidays and special events.
- School bus access.
- Local/residential access points.
- Public transit.

4.2.1.7.2 Business interruptions. In line with community acceptance, another aspect to consider is the potential impact of a road closure and detour of traffic on businesses. If a business, say a fuel station is located on a route that is to be closed, the closure could potentially bankrupt the business if prolonged. As such, due diligence must be carried out and business and community leaders must engage in the detour mapping process. The solution may be different and potentially unique to each site and project type. However, planners and engineers must ensure that these factors are considered in the decision-making process.

During the interviews, it was revealed that state DOTs, even those having an active detour mapping framework, do not pay local businesses to compensate the lost revenues due to road closures. During one of the interviews an interesting point was mentioned about considering the benefits of a new road to local businesses in addition to the losses. Even though state DOTs may not necessarily pay the local businesses, the following considerations are made to mitigate the disruption to local business operations.

- Coordination meeting with surrounding businesses.
- Accommodating access to local businesses.
- Using black and orange signs with a relatively larger sizes for several local businesses. A maximum of 4 to 5 signs are used for the local businesses.
- Inclusion of liquidated damages in contract documents. Although contract documents are primarily for legal purposes in case of delayed project delivery, they provide a guideline and legal basis for the consideration and calculation of the losses sustained by the road users and local businesses as real lost dollars.

4.2.1.7.3 Access to essential/emergency services. As briefly discussed under the operational criteria, detour routes must not hinder or otherwise impact a community's access to essential and emergency services. If the route being closed off is used by a school bus for example, planners must ensure that an alternative route is provided that does not significantly hinder the service in question. More importantly, important services such as fire and ambulance must be accounted for in the detour planning process. While passengers may reasonably be accommodated on any road, fire equipment is larger than the passenger car and thus needs carefully planned out routes to operate. The detour route must not be too restrictive that fire services operations are hindered.

The interviews with the state DOTs with an active detour mapping framework confirmed the consideration of these factors. During one of the interviews, it was mentioned that providing access for emergency vehicles such as police, fire, and ambulance is important to avoid legal issues as they are owned and operated by private companies in most cases. The interviewees mentioned that in this regard, the following criteria are considered.

- Emergency vehicle access.
- Hospital access, fire departments: In one case, the interviewees discussed the relocation of ambulance stations to ensure access to a hospital when a bridge, or road section is closed.
- Coordinating the work proposed on the route in case of crashes or floods for example, and where emergency response is needed.

They also mentioned that the coordination helps prevent detour conflict issues such as detouring the traffic to an existing detour route.

4.2.2 Identifiers and Impacted Stakeholders

The suggested identifiers indicated in Table 4.2 impact various stakeholders differently. In the context of detour planning and mapping, impacted stakeholders include the transportation agency (state DOT, city or county transportation offices), the road users (including drivers and construction workers) and the community through which the detour may be routed. While the agency and drivers are typically the primary focus of detour planning, the community has historically been considered only to small extent. The proposed framework outlines which stakeholders are impacted by each identifier to ensure a more equitable approach. For brevity, the impacted stakeholders associated with each criterion are summarized in Appendix I.

4.2.3 Sample Application of the Proposed KPI Table

To provide an application of the proposed KPIs to real-world example, two sample case studies have been conducted. Figure 4.1 shows the steps followed for conducting each the case study.

Step 1: Identifying the relative importance of the criteria

As the first step, the weights (or the levels of importance) of each of the proposed KPIs were determined based on the answers of the respondents to the third question of the survey that inquired about the relative importance of operational, technical, financial, social, safety, political, and environmental criteria. To that end, the average rate assigned by the state DOTs with an active detour mapping framework to each of these criteria was utilized. To extract the weights, the criterion to which the maximum rate was assigned (i.e., technical criterion) was assigned a relative importance of 1. The relative importance of all remaining criteria was determined by dividing the rates the

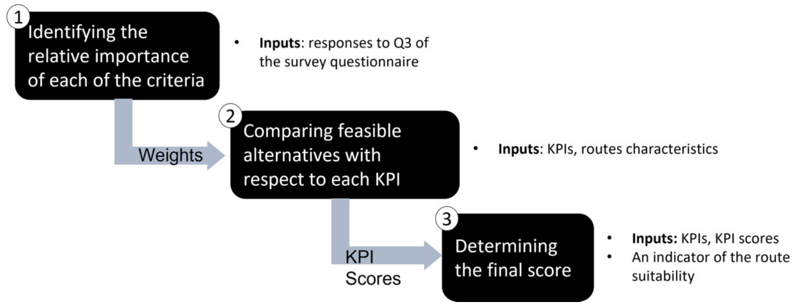


Figure 4.1 Steps of the conducted case studies.

	Technical	Operational	Safety	Financial	Social	Political	Environmental
Average rates on a scale of 5	4.4	4	3.8	3.6	3	3	2
Relative importance	1	0.91	0.86	0.82	0.68	0.68	0.45
Weights	**0.2**	**0.18**	**0.17**	**0.17**	**0.14**	**0.14**	**0.09**

Figure 4.2 The process for determining the weights for each of the criteria.

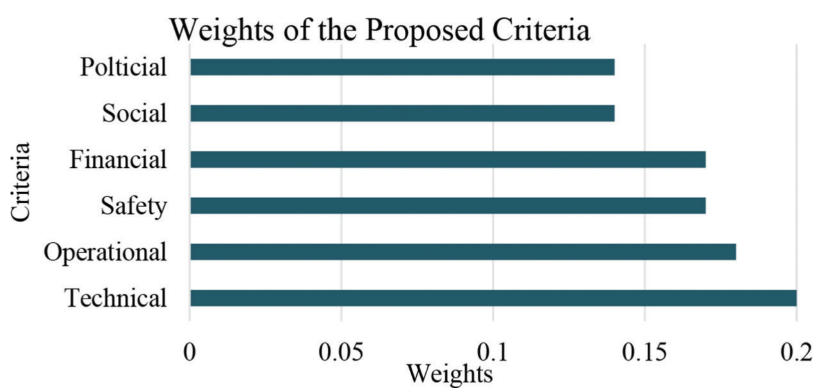


Figure 4.3 The weights of the proposed criteria.

respondents assigned to them by the rate of the technical criterion. At the end, the weights of each of the identified criteria were determined by normalizing the relative importance values so that their total sum is 1. These steps can be observed in Figure 4.2.

Figure 4.3 shows the final weights of each of the identified KPIs in comparing the potential alternatives for a detour route in case of an interstate closure. It should be noted that since these weights are determined based on the survey results there is an inevitable and inherent tendency for having a level of subjectivity. This subjectivity stems from the perception and understanding of the respondents about the meaning and the sub-criteria they assume for each of the criteria. Therefore, the provided weights are more of a guideline that is determined based on the subjective opinion of the members of state DOTs with an active framework for detour mapping and care should be exercised in generalizing the results.

Step 2: Comparing alternatives

At this stage, the potential alternatives for the detour route are compared with each other based on the proposed criteria and its associated KPIs. To that end, a point is given to each candidate with respect to each identifier under a given criteria. For instance, for the operational criteria there are three KPIs. Assuming there are four alternatives for detouring the traffic a point between 1 to 5 is assigned to each of the four alternatives for each of the three indicators. The scores are then added to obtain the total score for each candidate under the operational criteria, using Equation 4.3.

$$Score_{operational,\, candidate\,(i)} = \sum_{j = identifier\ 1}^{identifier\ n} points_j^{(i)} \quad \text{(Eq. 4.3)}$$

Step 2 is then repeated for all other criteria to provide inputs for Step 3.

Step 3: Determining the final score

After identifying the weights and scores associated with each KPI in Steps 1 and 2, the final score is determined based on Equation 4.4.

$$Total_{candidate\,(i)} = \sum_{k=criteria\,1}^{criteria\,n} w_k Score_{k,\,candidate\,(i)} \quad \text{(Eq. 4.4)}$$

Where W_k is the weight of each criterion that are determined in Step 1. The overall score of each of the candidates can be an indicator of the appropriateness of each candidate with respect to each of the criteria. The overall and criteria scores can be used as guides for comparing the available alternatives.

4.2.3.1 Sample case studies. This section presents two sample case studies of the application of the proposed KPI table as well as the weights for each of the identified criteria, which were determined based on the survey data. In the evaluated projects, an interstate is fully closed, and a detour route is deployed for the construction period. In the case studies, several alternatives for the detour route are identified and compared with each other in terms of their suitability with respect to criteria and their associated KPIs.

4.2.3.1.1 Portland, Oregon I-84 closure. The I-84 corridors in Portland, Oregon serves a major interstate freight and commuter driver route to downtown Portland. It is one of the most heavily traveled roads in the State of Oregon. As a result of the heavy traffic on the corridor, the pavement had suffered severe rutting. In 2002, the Oregon Department of Transportation (ODOT) decided to perform rehabilitation works to maintain the roadway. To expedite the project, ODOT engineers suggested that a full road closure strategy be implemented, instead of the traditional Maintenance of Traffic used during half-width construction. Work on the corridor occurred over two consecutive weekend full closures, with the eastbound closed on the first weekend and traffic detoured and the westbound closed the following weekend and similarly, traffic detoured. Some corridor and project details include the following.

- $5 million total construction cost.
- 180,000 average daily traffic (ADT).
- 7% commercial vehicle traffic.
- Section length of 5.5 miles (33 lane miles).
- Project dates: August 2, 2002–August 12, 2002.

Figure 4.4 shows a map indicating the proposed closure and potential detour route candidates marked.

In considering the criteria and KPIs for detour planning, we refer to Table 4.2 in Section 4.2, outlining important criteria for consideration, and filtering out non-applicable criteria as necessary. For example, none of the candidate detour routes pass through sensitive ecological areas, therefore that KPI can be excluded from consideration. Similarly, because the project employs a full closure strategy, the crash risk for construction workers is minimal, and therefore that KPI can also be excluded from consideration. Repeating this process for all the KPIs in Table 4.2, and working with the available information about the project, we remain with KPIs shown in Table 4.4.

Following the allocation of points to each candidate route as shown in Table 4.5 total scores on each criterion are determined for each candidate, and these totals are then weighted and summed using Equations 4.3 and 4.4. The results of this process are presented in Table 4.5.

A sample calculation for I-205 is presented here.

$$Score_{Operational,\,I\,205} = 5 + 5 = 10$$

$$Score_{Technical,\,I\,205} = 3 + 5(5) = 28$$

$$Score_{Financial,\,I\,205} = 2(5) + 3 = 1$$

$$Score_{Safety,\,I\,205} = 5 + 5 = 10$$

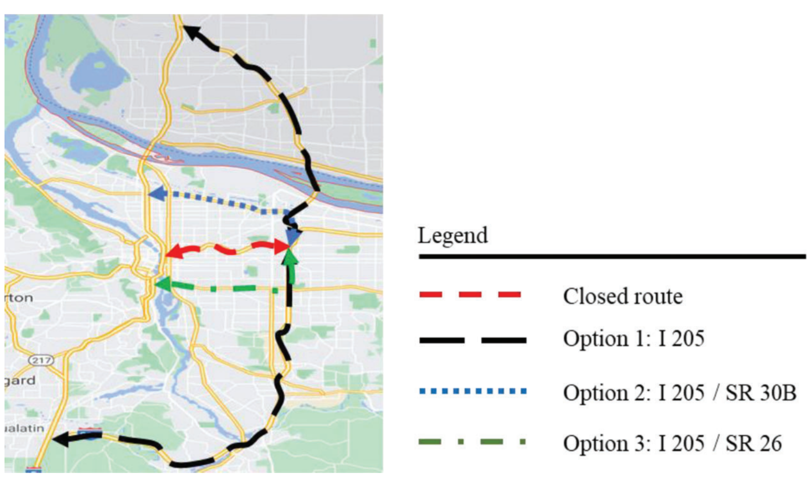


Figure 4.4 Map showing I-84 closure project—Portland, Oregon.

TABLE 4.4
Relative scores with respect to KPIs for candidate detour routes: Case study 1

	Suggested Identifier	Detour Options		
		I-205	SR 305	I-205/SR 306
Operational	Duration of project	5	5	5
	Official detour's route level (state hwy, public road, local)	5	3	3
Technical	Length of the detour	3	5	4
	Traffic volume	5	4	3
	Heavy vehicle percentage (HVP)	5	4	3
	Turning radius	5	4	3
	Lane widths	5	4	4
	Pavement strength, roughness, and age	5	4	4
Financial	Cost of maintaining/ retrofitting detour (official and unofficial)	5	4	3
	Increase in travel time	3	4	4
	Vehicle operating cost	5	4	3
Safety	Community land use (residential, school zone, etc.)			
	Pedestrian crossing (non-freeway)	5	3	3
	Signage on detour routes	5	4	4
Environmental	Increased emissions due to potential intermittent driving conditions on detour	5	3	3
	Noise pollution	5	3	3
Social	Community impact/acceptance	–	–	–
	Business interruption	3	5	5

TABLE 4.5
Weighted sum computations for detour options: Case study 1

Criteria	Weight (%)	Detour Options Scores		
		I-205	SR 305	I-205/SR 306
Operational	20	10	8	8
Technical	18	28	25	21
Financial	17	13	12	10
Safety	17	10	7	7
Environmental	14	10	6	6
Social	14	3	5	5
Total		*12.77*	*10.59*	*9.81*

$$Score_{Environmental,\,I\,205} = 5 + 5 = 10$$

$$Score_{Social,\,I\,205} = 3$$

$$\therefore Total_{I\,205} = 0.2(10) + 0.18(28) + 0.17(13) + 0.17(10) + 0.14(10) + 0.14(3) = 12.77$$

The results for all other options are calculated similarly and the results are presented in the Table 4.5.

Looking at Table 4.5, we can conclude that Interstate 205 is the best detour option for this project. As can be seen, its overall weighted score is highest of the alternatives considered and it has a superior performance with respect to all criteria except for the social criterion. This outcome is consistent with the decision made by ODOT during the construction process. In reaching this conclusion, some of the KPIs were excluded from consideration as stated earlier in this section. This is because not every KPI presented in this report is applicable to every project, and as such, engineers and planners must still use their best engineering judgement to decide which ones are applicable at any one time. Political/jurisdictional considerations for example, were not considered in this case study because barring any additional information, it was assumed that all candidate routes being considered were under the control/jurisdiction of the state DOT. Similarly, the authors of the report did not have any information to ascertain whether any projects were underway in the vicinity of this project, whose detour routes could overlap with any of the selected candidates. Thus, that KPI was also excluded from consideration. Similar arguments can be made for any other KPIs excluded, such that the authors of the report determined that only the KPIs shown in Table 4.4 were considered to determine the detour route.

The points were assigned to each candidate based on its ability to meet the demands set by that particular KPI, with 5 indicating the best and 1 indicating the worst. In this regard, Interstate 205 was assigned 5 points on the traffic volume KPI for example, for its ability to handle the highest volume of traffic of any of the candidates being considered, while the SR 305 was assigned a 4 because it is a freeway with a lower functional class than an interstate. The other candidate, SR 306 was assigned a score of 3 because it has a high density of at-grade intersections which severely impairs its ability to serve high traffic volumes compared with the other two candidates. Similar reasoning and arguments were made for all other KPIs being considered, making necessary assumptions where the required information was not readily available. For example, the pavement strength and grade of interstates is generally superior compared to other highway functional class. Therefore, in the absence of specific information on the exact state of each pavement, the interstate was assigned a score higher than the state route.

4.2.3.1.2 St. Louis, Illinois, I-255 closure. The second case study is about resurfacing, restoring, and rehabilitating Interstate 255 in the St. Louis Metro East area. The Illinois Department of Transportation (IDOT) decided to implement project Interstate 255 on February 2020. IDOT chose to fully close the interstate because it enables the project to be completed cheaper, faster, and safer. The major benefits supporting the decision to use a full closure are as follows (IDOT, 2020).

- Reducing project duration from 4 years to 10 months.
- Saving $14 million.
- Increasing the safety of the workers by keeping traffic out of the work zone.
- Reducing accidents by obviating the need for lane shifts.

The project consists of rehabilitating and resurfacing approximately 7 miles of I-255 from I-55/70 to Illinois 15 in two sections separated by Interstate 64, with significant bridge repairs, safety improvements and drainage upgrades. This project was intended to restore the roadway and bridges to a smooth and safe condition for motorists and to support future investments and economic developments in the region. Figure 4.5 shows a map indicating the proposed closure and potential detour route candidates marked.

Following a procedure similar to the one used for the previous case study, alternate detour routes for I-255 closure were identified and compared with each other in terms of the proposed KPIs. It should be noted some of the KPIs were excluded from consideration while evaluating the alternatives based on engineering judgement and due to limited information about the characteristics of the construction activity as well as the nearby on-going projects. Similar arguments can be made for any of the KPI excluded from the assessments, such that the only the KPIs shown in Table 4.6 were considered to determine the detour route.

The total scores for each criterion are calculated for each candidate following the allocation of points for each candidate route, as shown in Table 4.7, and these sums are then weighted and summed using the above Equations 4.3 and 4.4. Table 4.7 which presents the results of this method, shows that the best detour option for this project is I-55 as its overall weighted score is the highest of the alternatives and, with respect to all criteria except the social criterion, it has a consistently superior rating. This finding is consistent with the decision taken by IDOT.

By leveraging available information, using engineering judgement and making assumptions where necessary, we have been able to demonstrate how the KPIs presented in this study can be used to successfully determine the most suitable detour route from a list of suitable candidates. The KPIs encompass various considerations in addition to the traditional technical and financial aspects, including social, safety, and environmental considerations. This process can be adapted and used with any project, making adjustments as necessary.

4.3 Recommendations for INDOT Detour Policy Improvement

This section provides recommendations for enhancing the current practice of INDOT for detour planning. First, based on *INDOT Detour Mapping Guideline*, Chapter 503 of the *2013 Indiana Design Manual*, as well as the *INDOT Detour Policy*, the considered criteria for detour mapping are evaluated. This is followed by a discussion of defects with regards to the application of the current detour policy in practice and acquiring the recommendations for its improvement based on INDOT experts. Finally, the findings of this study, including the developed KPI table and the practices obtained during interviews with other state DOTs are then leveraged to propose suggestions for enhancing the current *INDOT Detour Policy.*

4.3.1 Current Status of INDOT Detour Planning

INDOT Detour Mapping Guideline involves the use of a detailed framework to generate a detour route (INDOT, n.d.a). A summary of the criteria that were considered in framework are shown in Table 4.8.

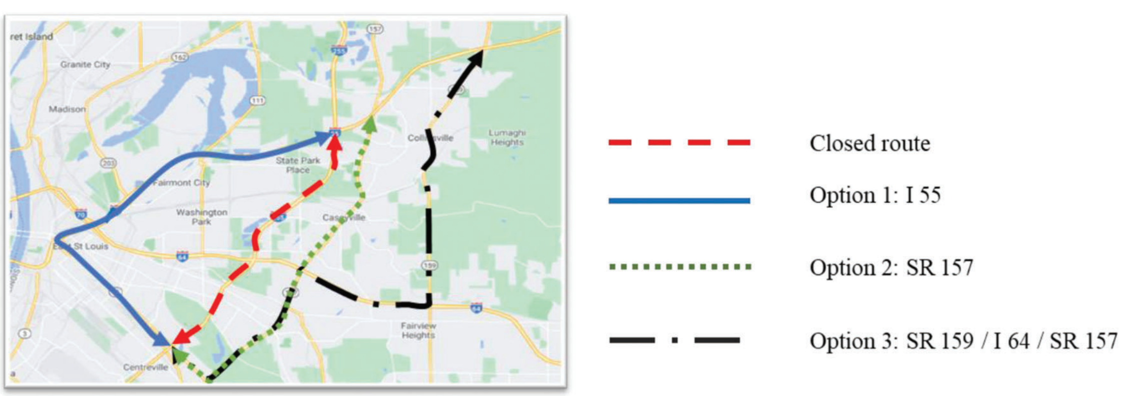


Figure 4.5 Map showing I-255 closure project, Illinois, St. Louis Metro East Area.

TABLE 4.6
Relative scores with respect to KPIs for candidate detour routes: Case study 2

		Detour Options		
	Suggested Identifier	**I-55**	**SR 157**	**SR 159/I-64/SR 157**
Operational	Official detour's route level (state hwy, public road, local)	5	4	4
	Presence of rest/fuel stations on detour route	5	5	5
	Local traffic (public events, school, emergency, business)	5	4	4
Technical	Length of the detour	4	5	3
	Traffic volume	5	4	3
	Heavy vehicle percentage (HVP)	5	4	4
	Turning radius	5	5	5
	Pavement strength, roughness, and age	5	4	4
Financial	Increase in travel time	5	4	3
	Vehicle operating cost	5	4	3
Safety	Community land use (residential, school zone, etc.)	5	4	4
	Pedestrian crossing (non-freeway)	5	3	3
Environmental	Noise pollution	5	4	4
Social	Business interruption	3	5	5

TABLE 4.7
Weighted sum computations for detour options: Case study 2

		Detour Option Scores		
Criteria	**Weight (%)**	**I-55**	**SR 157**	**SR 159/I-64/SR 157**
Operational	20	15	13	13
Technical	18	24	22	19
Financial	17	10	8	6
Safety	17	10	7	7
Environmental	14	5	4	4
Social	14	3	5	5
Total	–	11.84	10.37	9.49

According to Table 4.8, the criteria considered are limited to technical, operational, and financial aspects.

Chapter 503 of the *2013 Indiana Design Manual* the evaluation by considering the financial impacts as it provides guidelines on the calculation of the user cost associated with the extra travel distance and the extra travel time. INDOT's detour policy, which dates to 1996, provides a six-step procedure for the selecting an appropriate detour route through coordination of the district with local transportation officials during interstate route closures. The second major focus of the policy is to provide legal basis for reimbursing the costs associated with any damage to the local routes. The policy introduces the criteria summarized in Table 4.9 for the selection of official and unofficial detour routes.

As seen in Table 4.9, similar to INDOT's detour mapping guideline, most of the criteria suggested by the

TABLE 4.8
The criteria considered in INDOT detour mapping framework (adapted from INDOT Editable Interstate Detour figure)

Criteria	**Identifier**
Technical	Structure ratings/condition on detour
	Traffic volume to capacity
	Pavement condition on detour
	Vertical clearance on detour
	Bridge ratings on detour
Operational	Detour legs restricted by construction or special events
	Detour legs engaged as part of a detour for another project
	Duration of work
Financial	Travel distance along detour
Other concerns	–

TABLE 4.9
Detour planning criteria based on *INDOT's Detour Policy* (1996)

	Detour Type	
Criteria	**Official**	**Unofficial**
Technical	Needs of local traffic (emergency, school, public events, business, etc.)	NA
	Volume of the traffic flow	NA
	Pavement width	NA
	Structural capacity of the pavement	Route condition
	Structural capacity of bridges	Capacity, load limits
Financial	Construction costs to bring the official detour to minimum standards	Cost of maintaining/restoring the unofficial detour
	Cost of official detour signing	NA
	User costs based on travel time and length of the detour route (both official and unofficial if applicable)	–
Safety	Minimum safety standards	–
Social	–	Community acceptance

INDOT Detour Policy are related to operational and technical aspects of the selection process. However, the policy seems to assign safety, social, and environmental considerations relatively lower importance. In addition, a portion of the proposed criteria in the detour policy, such as community acceptance, require additional information and guidelines for measurements and consideration.

4.3.2 INDOT Experts' Opinion on the Detour Policy

The *1996 Detour Policy* is the official detour policy guideline INDOT currently relies on. Even so, as reflected in our interviews, the document seems to be obscure and largely unknown to several relevant agency officials. Some expressed knowledge of the existence of the document while acknowledging never to have used it nor seen it being used in practice. Some of the important recommendations of the policy, however, such as the requirement to provide an unofficial detour route, are widely practiced and considered standard institutional practice, without necessarily any ties to the detour policy per se.

During the interview it was established that the policy was drafted as a response to a legislative statute, in part to eliminate the need for litigation in determining compensation and reimbursements to local administrations for damage that may occur following the use of their facilities for detour purposes. For official detours, it is customary that state routes are used as these are owned by INDOT, and thus all repair and retrofitting costs are automatically handled by INDOT. In the rare case that a suitable state route is not available, a local route is used. More commonly however, local routes are used as unofficial detour routes to accommodate commuter and local traffic that may not necessarily want to follow the official detour. The policy was introduced to standardize this process. The policy thus stipulates the following.

- The project manager will work with the local agency to identify the unofficial local detour (series of local streets or roads).
- A formal agreement is written with the officials.
- A video inventory of the road condition is made before and after the project to document and determine the repair costs.

The interviews uncovered that the policy was in part drafted to eliminate the need for litigation in determining compensation and reimbursements to local administrations for damage to the detour route. The following key shortcomings were discussed during the interviews.

- Only one local unofficial detour route is identified, even though drivers may take other routes as well. The policy currently does not allow for introducing two unofficial detour routes. Introducing one route is advantageous for the INDOT. However, it is not the best outcome for the local agencies, as the drivers may choose several different routes other than the unofficial detour.
- The other issue that was uncovered during the interview was the fact that the road users' costs are not actually considered directly, if considered at all. The interviews showed that the user cost values are too high to the extent that if decision makers were supposed to treat them in the same way as real construction dollars, no road closure would have occurred.

In addition to the limitations mentioned above, there are other shortcomings discussed in the interviews have less to do with the actual policy than the implementation and smooth operation of the procedure. These limitations are as follows.

- Having a point of contact in the district to coordinate activities and for smooth information transfer.
- Lack of clarity on the amount for reimbursement is sought, since local authorities may claim losses since drivers use routes which are not necessarily designated as the unofficial detour route by INDOT. Therefore, the local agency must arrange for the repair and maintenance of such routes as well.

During the interview, it was also mentioned that there is an ongoing project to address these subsequent issues that are related to the implementation aspects.

4.3.3 Recommendations

To address the identified defects in INDOT detour mapping practice, a part of the interview questionnaire with other state DOTs with an active detour mapping framework was dedicated to the identification of the key criteria that are considered by other state DOTs. It should be noted that a portion of these criteria were not necessarily documented in the guidelines and were observed by other state DOT engineers through expert judgement. The performance indicators that are derived in this study, can expand the range of the factors considered by the detour policy.

Another target of the interviews with other state DOTs was to identify the way they calculate and incorporate user costs into account. In this regard, there was a consensus among other state DOTs on the fact that the user costs are considered indirectly rather directly. According to one of the interviewees, the reason is the agencies' budget is fixed regardless of the obviated amount of the user costs. The following tree major pathways were identified for the incorporation of societal costs.

- Selecting a set of candidate routes based on several factors, excluding the user costs, and then select the final choice considering the user costs as an indicator of the measure of inconvenience to the public, specifically the road users, using engineering judgment.
- Including the user costs in the contractual documents and counting them in the determination of the liquidated damages/bonuses to the contractor based on the completion date.
- Considering several factors, including the users' delay cost in a qualitative way using the Analytic Hierarchy Process (AHP) methodology for the selection of the construction method, which can, in turn, affect the extent of the required closure, and the duration of the project.

The first choice is close to what was described by INDOT personnel during the interviews. However, the second and third alternatives can also be adopted. Specifically, the proposed KPI table can be taken as the basis for the development of a decision-making tool that enables the decision makers to consider the qualitative as well as quantitative criteria for each of the candidate detour routes.

5. CONCLUDING REMARKS

Maintaining traffic flow during construction periods is critical to the success of project delivery and the overall mission of transportation agencies. Maintenance of Traffic (MOT) plans include partial and/or full closures of corridors as well as mapping and coordination of detours near construction areas. In the case of partial closures, one of the main challenges is to ensure working safety while maintaining the efficient movement of traffic and minimizing the influence on the construction work. In the case of closures, the traffic needs to be rerouted through detour routes.

Several state DOTs have designed their own design manuals to provide their detour mapping and coordination. However, very limited information is provided to select optimal detour routes. Past endeavors have led to considerable progress (e.g., *Alternate Route Handbook* (Dunn Engineering Associates, 2006)). Nevertheless, there is insufficient information to determine the appropriate detour mapping and coordination (FHWA, 2009; Liu et al., 2013). Moreover, since the qualitative aspects are not so easily measurable, they tend to be neglected in systematic evaluation approaches and decision-making processes.

The best practices with defined identifiers can help INDOT personnel facilitate optimal detour mapping and coordination plans and improve service quality management for MOT. Additionally, risk managers will manage and evaluate the potential risks through integration of social and multidisciplinary identifiers for the detour, which will entail the development of standardized practices. Therefore, the cost-effective detour plans will help in minimizing not only potential social, financial, and technical losses, but also potential risks and maintenance duration.

5.1 Contributions

This study was dedicated to identifying the possible improvements on the MOT plans for INDOT based on the identified best practices for mapping and coordinating detour strategies in terms of quantitative and qualitative aspects. The contributions of this study can be summarized as follows.

1. Identified current state-of-the-practice on MOT strategies.
2. Explored the promising identifiers (e.g., design, financial, social, safety, and management perspective) to be incorporated into developing detour plans.
3. Investigated best practices for mapping and coordinating detours for MOT.
4. Identified process improvement for INDOT detour planning.
5. Provided advanced risk management/mitigation strategy based on the best practices.

5.2 Summary of the Study Methodology

First, an extensive literature review was conducted to identify the current state-of-the-art and practice on mapping and coordinating detours for the Maintenance of Traffic. Throughout the literature review process, the design manuals, current MOT plans, and risk management strategies for detours pursued by (1) INDOT and (2) other state DOTs were evaluated to seek out information on the following main aspects: (1) the key factors that are considered in mapping detour routes, (2) appropriate MOT strategies and TTCPs near the work zone, (3) how the occurred incidents are managed, and (4) how to ensure work zone safety, including the safety of the workers, the passing vehicular traffic, and pedestrians.

In the second phase of the study, based on the findings of the literature review, a survey questionnaire was designed to complement our goals of ascertaining the best practices for detour mapping by collecting additional information from transportation agencies and departments of transportation across the country about their detour mapping practices. For those agencies that may have proprietary methods or otherwise rely on information that they have not made public, the survey would helped acquire such information.

In the third phase, follow-up interviews were conducted with the experts from INDOT as well as other state DOTs that had reported to have an active framework for detour mapping selection and the Maintenance of Traffic. The aim of these interviews was to obtain more in-depth information on the following aspects: (1) the current state-of-the-practice on MOT strategies, (2) promising performance indicators, and (3) the best practices for mapping and coordinating detours for Maintenance of Traffic, including risk management/mitigation strategy.

In phase four, a follow-up survey was conducted to gather additional information on the practices at other state DOTs regarding detour conflict identification/resolution. This was followed by a series of interviews with the respondents who were willing to take part in interviews. The interviews provided additional in-depth information on the approaches and tools that state DOTs use for proactive identification and management of detour conflicts.

As the last step, a mixed-methods analysis was used to analyze the results of the survey data and interview scripts. Based on analysis outcomes, recommendations and ensuing insights were provided to enhance the current detour mapping practice of INDOT.

5.3 Summary of Findings and Conclusions

This study documented and leveraged information on current practices based on an extensive literature review, and two nation-wide surveys, followed by phone interviews with INDOT and other state DOTs, to recommend process improvements for INDOT detour mapping guidelines. In a nutshell, the outcomes of this study can be summarized as follows.

A summary of the current practices based on an extensive literature review. Specifically, Table 2.2 provides a summary of the criteria considered in the selection of incident management routes. Table 2.3 summarizes the fundamental aspects and considerations in the design of TTCPs. Table 2.4 and Table 2.5 discuss the most feasible alternatives for incident management on detour routes and enhancing safety conditions on work zones. This delivery addresses Objective (2) of the study as stated in the introduction (Chapter 1).

The literature review results also provided several criteria for detour mapping, most of which were technical, operational, and financial. However, there are other important safety, social, and environmental factors that should be considered adequately in the detour route mapping process. The interviews helped in complementing the findings from the literature review with more in-depth information about the way through which these qualitative factors are being addressed by other state DOTs through their framework and engineering judgement. These findings are in line with Objective (1), Objective (2), and Objective (3), as stated in Chapter 3.

Regarding the qualitative criteria, the state DOTs interviewed stated that they had their in-house approaches for calculating and incorporating user costs in the analysis. In this regard, there was a consensus among other state DOTs on the fact that the user costs are considered indirectly rather than directly. According to one of the interviewees, this is because the agencies' budgets are fixed regardless of the obviated amount of the user costs. The following three major pathways were identified for the incorporation of user costs.

- Selecting a set of candidate routes based on several factors, excluding the user costs, and then select the final choice considering the user costs as an indicator of the measure of inconvenience to the public, specifically the road users, using engineering judgment.
- Including the user costs in the contract documents and counting them in the determination of the liquidated damages/bonuses to the contractor based on the completion date.
- Considering users' delay cost in a qualitative way using the Analytic Hierarchy Process (AHP) methodology for the selection of the construction method, which can, in turn, affect the extent of the required closure, and the duration of the project.

The first choice is close to what was described by INDOT personnel during the interviews. In line with the third approach, a list of key performance indicators (KPIs), their associated thresholds, and involved stakeholders were identified and presented in Chapter 4, addressing Objective (2), Objective (3), and Objective (4). The derived KPIs can be leveraged to expand the range of the factors considered by the current detour policy of INDOT. Furthermore, the KPI table can serve as the basis for developing a decision-making tool that enables decision makers to consider both qualitative and quantitative criteria for each candidate detour route.

To fully address Objective (4) of this study, in addition to the KPI table, information on the major shortcomings of the *INDOT Detour Policy* from an implementation point of view was collected based on a series of interviews with INDOT experts from a wide range of backgrounds. These limitations are discussed in Section 4.3 and can be addressed in future revisions of the detour policy.

Addressing Objective (1), Objective (3), and Objective (4), one of the major findings of this study is a summary of the most important factors that affect the extent and resolution of conflicts among active detours that were identified through the follow-up survey and interviews. The best practices, platforms, and tools for foreseeing and addressing these conflicts were identified and summarized in Table 4.1 in Section 4.1.

The results showed that state DOTs utilize a combination of proactive and reactive approaches to identify and resolve detour conflicts depending on several factors including traffic volumes and the work type. From the proactive perspective, most of the interviewed DOTs reported avoiding closures and detours of major highways in the first place. However, if detours are unavoidable, then the DOTs stagger their project schedules and carry out other initiatives to avoid detour conflicts in the first place. These include the use of GIS based maps, reducing construction time using measures such as accelerated bridge construction, using intelligent work zones to alert drivers on conditions ahead and therefore change their paths to alleviate queues and to avoid the formation of backups. Other measures include macroscopic and detailed capacity and queuing analysis including VISSIM, FREEVAL, and Synchro of proposed detours to identify potential traffic bottlenecks.

From the reactive perspective, other measures used include staging different types of work at different times, employing nighttime and weekend work schedules, continuous monitoring of the routes as part of incident management, and maintaining close contact with local authorities to keep pace with all projects going on simultaneously at different jurisdictions, to avoid conflicts.

The last, but not least, a summary of the best risk mitigation practices during planning, service, and closure stages of detour routes were identified based on the follow-up survey and interviews and are presented in Table 4.1.

5.4 Limitations

In addition to conducting a nationwide survey questionnaire and holding several interviews, supplementary data could enhance the quality of this research. The interviewees mentioned that currently the Work Zone Data Initiative aims to collect and store online data about the traffic flow in the vicinity of the work area. In fact, interviewees from Iowa State DOT mentioned that Iowa State has started gathering work zone crash data. In the presence of the data, the impact of implemented Maintenance of Traffic and detour mapping strategies can be assessed more effectively. In that case, the project and location-specific characteristics can be considered to provide a basis for the selection of the best practices.

5.5 Future Research

As demonstrated in sample case studies, the proposed KPI table can be taken as a basis for developing a decision-support tool to enable decision makers to consider the qualitative as well as quantitative criteria for selecting optimal detour routes. In future projects, an automated GIS-based tool could be developed to automatically identify the best detour route for interstate and non-interstate highways among the possible candidates having the coordinates of the work zone on the map, as well as multiple project characteristics including the duration and location (urban/rural) of the work, as well as the AADT and vehicle mix of the passing traffic. This allows for (1) fast and optimal MOT strategy selection and detour mapping, (2) consideration of various involved stakeholder needs, and (3) reduced subjectivity in the selection of MOT strategy.

As discussed, the operational aspects tied with the projects planned for implementation in the same time span are among the factors that should be considered when planning construction projects that involve partial/full road closures. Another opportunity for expanding this research is the incorporation of detour management in the optimization of project scheduling and project bundling policy development.

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APPENDICES

Appendix A. Review of Current State-of-the-Art Practices for MOT Strategies in Other State DOTs

Appendix B. The Survey Questionnaire

Appendix C. Sample Invitation Email for the Survey Questionnaire

Appendix D. The Follow-Up Survey Questionnaire

Appendix E. Interview Questionnaire with INDOT Personnel

Appendix F. Comparison Between the Current Practices of INDOT Identified from Interviews and INDOT Manuals

Appendix G. Interview Questionnaire with Other State DOTs

Appendix H. Supplemental Information from Interviews with Iowa, Minnesota, and Arizona State Highway Agency Personnel

Appendix I. Impacted Stakeholders Associated with Each Criterion

APPENDIX A. REVIEW OF CURRENT STATE-OF-THE-ART PRACTICES FOR MOT STRATEGIES IN OTHER STATE DOTs

This section is dedicated to the evaluation of the guidelines and practices that other state DOTs pursue for the Maintenance of Traffic (MOT) and detour mapping. In this regard, two sets of documents (the Incident Management Plans, the Temporary Traffic Control) and *Work Zone Safety Manuals* of four other state DOTs are reviewed, and the ensuing insights are summarized.

Review of the Incident Management Plans, which in many cases involve the deployment of a detour route, provides valuable insights and recommendation about the criteria that are used for the selection of pre-determined detour routes that are selected for incident management. The proposed criteria in these manuals may be also applied to mapping the detour routes for managing full road closures due to construction activities.

Reviewing traffic control and work zone safety manuals provides recommendations about selecting appropriate devices and plans for the maintenance of traffic near temporary traffic control zones. This includes the selection of appropriate Temporary Traffic Control Plans (TTCPs) and MOT strategies to provide for traffic to move efficiently near work zone area. Since road closures and deploying detours are among recommended alternatives, the factors and considerations outlined in the reviewed manuals can provide valuable insights about the basic factors applicable to the mapping and coordination of detours and risk management.

Section 4.1 and Table A.1 provides a summary of the reviewed manuals and their content relevant to the scope of this study. The reviewed material is organized in a way to cover the following topics based on the current practice of other state DOTs.

1. The key factors that are considered in mapping detour routes.
2. Appropriate MOT strategies and temporary traffic control plans near the work zone.
3. How the incidents occurred in work zones are managed.
4. How to ensure work zone safety, including the safety of the workers and the passing vehicular traffic.

The next sections elaborate more on the four state DOTs regarding the four points of discussion mentioned above.

Table A.1 A summary of the reviewed manuals

Reference	Manual	Content
(HNTB-Corporation, 2011)	*West Virginia Turnpike Incident Management Emergency Traffic Control Plan*	Topic (I) & (III)
(DCDOT, 2006)	*Temporary Traffic Control Manual*–D.C. Department of Transportation–2006	Topic (II) & (IV)
(WVDOT, 2007)	*Manual on Temporary Traffic Control for Streets and Highways*–West Virginia DOT–2006 Edition	All topics
(MDOT, 2018)	*Work Zone Safety and Mobility Manual*–Michigan Department of Transportation	All topics
(NJDOT, 2007)	*Traffic Mitigation Guidelines for Work Zone Safety and Mobility*–New Jersey Department of Transportation	All topics

A.1 West Virginia DOT

A.1.1 Key Factors in Detour Mapping

Based on the *West Virginia Temporary Traffic Control Manual* (WVDOT, 2007), a detour is defined as temporarily rerouting road users on an existing highway to an alternate route to avoid the temporary traffic control zone. A detour must be provided when an entire roadway is closed. A diversion, on the other hand, is a temporary rerouting of road users around the work zone. At diversions, the temporary roadway is located within or close to the current right-of-way.

The *West Virginia Incident Management Plan* provides guidelines about selecting pre-determined detour route for emergency management purposes. The identified detour routes should satisfy the following minimum requirements (WVDOT, 2007).

The roadways should be paved, and the pavement lane widths must be 11′ or greater. Routes with high truck traffic volumes must have a vertical clearance of 14′ 6″ to accommodate tractor trailer. In addition, the vertical clearance should be announced prior to vehicles entering the detour route.

Detour routes curves must be wide enough to accommodate 73.5′ long tractor trailer combinations. In addition, the grades must be less than 8%.

In addition to the requirements mentioned above, which are mostly geometric and structural requirements, the following characteristics are desirable.

- Shoulders must be paved
- Presence of food and lodging facilities
- Presence of Fueling/service stations

A.1.2 MOT Strategies and Temporary Traffic Control Plans (TTCP) in Work Zones

Maintaining the continuity of the road user flow through a work zone or an incident area while protecting the workers, traffic incident responders, and equipment is an essential part of construction projects, maintenance activities, traffic incident managements.

TTCPs involve using temporary traffic control devices, barriers, and signals that should be designed based on the considerations mentioned in the following sections.

A.1.2.1 Temporary traffic control zone devices

Traffic control devices can be thought of as "all signs, signals and devices used to regulate, warn, or guide road users (WVDOT, 2007)." Considering the scope of this study, the temporary control devices that are used in combination with detours are discussed in this section. According to West Virginia Temporary Traffic Control manual, detours should be used for works within the traveled way of two-lane highways. They can be used in combination with pilot vehicles for works on one-lane, two-way routes. Other traffic control methods are summarized in Table A.2.

In addition to the Temporary Traffic Control Devices (TTCDs) mentioned in Table A.2, there are other devices that can be used near the work zone, and specifically, when a detour route is in place. These devices are summarized in Table A.3.

Table A.1 Methods for one-lane, two-way traffic control (adopted from WVDOT, 2007)

Method	**Description and Application**
Pilot vehicle method	To guide the traffic through the temporary traffic control zone or the detour route, a pilot vehicle can be used the sing mounted on the shall be installed on the rear of the vehicle.
Flagger method	This method is used when the length of the temporary traffic control zone is short enough so that the flagger can see the whole length of the zone.
Flag transfer method	Employed only where the length of the road that carries one-way is shorter than 1 mile.
Temporary traffic control signals	Traffic control signals are for vehicular traffic control.
Stop or yield	For low-volume roads when drivers can see the end of the operation zone as well as the approaching vehicles.

Table A.2 Types of temporary traffic control devices (adopted from WVDOT, 2007)

TTCD	**Description**
The local traffic only	Used before reaching the detours that are assigned to avoid a closure.
Temporary traffic barriers	Used to prevent pedestrians from entering the workspace.
Temporary traffic control signals	Only where preferable to other traffic control methods.
Other Used (supplement to traffic control signals)	Channelizing devices, warning signs, and pavement markings.

A.1.2.2 Temporary traffic barriers

(TTBs) are the devices that are designed based on an engineering study and their aim is to minimize injuries to vehicle occupants, pedestrians, workers, cyclists. The main function of TTBs is to separate motor vehicle traffic workers, bicyclists, and pedestrians and to keep them from entering the work area. Also, movable Temporary Traffic Barriers can be used for closing an additional lane during work periods and widening the workspace during off-peak hours.

In the next sections, the TTCDs are discussed in greater detail with the aim of identifying the considerations and criteria that should be considered when a TTCD is being designed. These guidelines can be considered as basic and general consideration when designing MOT plans near work zone areas.

A.1.2.3 Factors affecting TTCP design

The characteristics of the temporary traffic control zone should be considered while developing a temporary traffic control plan (TTCP). These characteristics include work location, the characteristics of the road including its, geometrics and alignments, intersections, and interchanges. The characteristics of the passing traffic, such as the volume, speed, and the vehicle mix (buses, trucks, and cars) are important as well. In addition, the following factors must be considered in designing temporary traffic control signals:

- Sight distance restrictions
- Roadway and intersection capacity
- Vehicle speeds
- Road-user volumes
- Turning restrictions
- Pedestrians
- Feasibility of detouring road users, or providing space for two lanes
- Full-time or part-time operation
- Actuated, fixed-time, or manual operation
- Work staging and operations
- Power failures or other emergencies
- Placement of other temporary traffic control devices
- Signal phasing and timing requirements
- Inspection and maintenance needs
- Safety of road user
- Legal authority
- Operation by contractors or by others
- Human factors (drivers' familiarity with TTC signals)
- Road user needs
- Affected side streets and driveways
- Residential or commercial land use
- Parking

Among the abovementioned factors the needs of all road users and stakeholders significantly affects the successful implementation of TTCPs. Therefore, the considerations to address road users' needs is discussed in greater detail in the next sections.

Road Users' Needs

Public relations information on the characteristics of the work, its time and duration, as well as possible alternative routes and modes of travel, are essential to enhanced road user performance. Appropriate communication reduces the traffic volumes through the temporary traffic control zone significantly. Furthermore, to avoid unexpected situations, it is necessary to coordinate with other highway agencies, transit and rail services, emergency units, utility companies, and schools. Good public relations are realized through considering the needs of the following entities:

1. All road users (drivers, pedestrians, and bicyclists)
2. Neighboring property owners, residents, and businesses
3. Emergency service providers (law enforcement, fire, and medical)
4. Railroads and transit
5. Commercial vehicles such as buses and large truck

Transit Services

Public transit buses are often detoured differently compared to other vehicles. The continuity of transit services and using bus stop signs are considered in the design of the temporary traffic control plan, particularly for short-term projects.

Commercial Vehicles

The detour route used for commercial vehicles as well as vehicles carrying hazardous materials might be different from that used for other vehicles due to technical requirements such as clearance, geometric restrictions, weights, and environmental requirements.

A.1.3 West Virginia Incident Management

The West Virginia manual has two primary purposes: (1) to propose a procedure for the maintenance of traffic strategies in the case of incidents and severe weather conditions, and (2) to identify acceptable detour routes and traffic control measures.

On rare occasions where accident clearances times are expected to exceed 1 hour, road closures may be required. In this condition, the traffic lined up upstream of the incident may be diverted to a "traffic abatement facility" and guided towards pre-approved detour routes to bypass the incident area. To determine whether the use of detour routes is necessary, a three-step protocol, which is discussed below, is introduced.

Step 1: First, the severity of the incident in terms of the number of lanes that need to be closed in one direction as well as the duration of the closure is assessed. If the full directional closure time is estimated to be less than 2 hours, no traffic abatement takes place. For closures of more than 2 hours, step 2 that involves using abatement facilities and detour routes is followed.

Step 2: Maintenance employees set up traffic control devices for using temporary detours and abatement facilities. Traffic control devices shall be installed at the nearest exit interchanges, cross-over and/or the removable concrete median barrier gate. Traffic in the opposing direction is stopped intermittently to allow the waiting traffic to make U-turns through abatement facilities. To avoid excessive delays in the opposite direction, traffic shall be stopped intermittently, with the duration of no more than 30 minutes.

Step 3: Once the traffic is cleared, while the detour route is still being kept in place, emergency agencies and maintenance crews manage the incident. After that, the traffic control at the abatement facilities as well as the detour messages are removed, and the closed lanes are opened again to traffic.

The West Virginia Incident Management Plan recommends the following MOT plans for facilitating the incident management, which can be considered in the MOT strategies for detours due to construction works. To enhance the safety and efficiency of the most feasible alternatives for detour routes for incident management, operational and physical modifications might be required, as discussed below.

A.1.3.1 Operational Upgrades

The following short-term operational upgrades are recommended.

- Using law enforcement control at intersections to facilitate the efficient movement of vehicles, particularly in downtown and central business district areas.

- Coordination between all jurisdictions and involved parties along the detour route.

In addition to these solutions, more long-term solutions are also recommended for long-duration alternate detour route. Examples of these long-term solutions are as follows.

A.1.3.2 Temporary Traffic Control

Temporary traffic control in combination with enhanced signal timing can be used in multi-lane urban areas. For example, a four-lane roadway with two lanes for each direction can be altered temporarily so that three lanes can be used for the detour route.

A.1.3.3 Traffic Control Signals

Deployment of detours can reduce the level of service (LOS) on the roadways that intersect the detour route. Local traffic will choose the route with the least amount of delay based on familiarity with the local roads and experience. Nevertheless, modification of existing signal systems timing to accommodate the additional traffic flow from the detour route into the system may be required. To minimize the traffic disruption at intersections along a detour, the following options may be used (HNTB-Corporation, 2011).

- Adjusting traffic patterns.
- Using police push buttons.
- Automatic adjustment of green time at intersections.

Suspension of Roadwork Activities

Work activities should be postponed along long-term detour routes. Where it is impossible to fully interrupt the operations, off-peak hours should be considered for those tasks that cause the greatest impact to motorists.

Parking Restrictions

Applying more strict parking limitation along temporary detours, particularly in downtown areas where turning movements of large vehicles may cause potential conflict, should be considered to facilitate the efficient movement of motorists. Parking restriction has the following several advantages.

- Additional sight clearance for turning movements at intersections.
- Additional lane-width for large trucks and buses.
- Higher traffic flow speed considering additional lateral clearances in the absence of parked vehicles.
- Enforcing parking restrictions along the detour route.

Physical Upgrades

Physical upgrades and maintenance of detour routes might be necessary to ensure a safe and efficient traffic movement along the most-feasible detour route.

- Installation of a short detour connector road for emergency access to secondary roads.
- Adding acceleration and deceleration lanes to median crossovers. The extra pavement width would also enhance turning movements to crossovers.
- Provision of adequate turning movements at all intersections of alternate detour routes to accommodate large trucks and all other traffic traveling the interstate.
- Prioritizing the repair of deteriorated asphalt surface of the detour routes in the annual paving program.

A.1.4 Work Zone Safety

A.1.4.1 Road user safety

Speed limits should only be reduced when restrictive features exist. Research shows that reductions of more than 30 miles per hour increase the speed variance and therefore the potential for crashes.

A.1.4.2 Pedestrian safety

Pedestrian traffic controls such as channelizing devices, signs, and flags are used to guide the pedestrians around or through the work zone when their walkways are blocked or disrupted due to construction and maintenance activities.

A.1.4.3 Worker safety

Temporary traffic control zones produce unexpected conditions for the road users, posing safety risks to workers. Maintaining TTC zones with minimum interruption to road user flow is important. The key elements of temporary traffic control management to improve worker safety are summarized in Table A.4. In addition, the temporary traffic control management methods, including road closures, that are summarized in Table A.5 may be considered to improve worker safety.

Table A.3 Key elements for improving worker safety (adopted from WVDOT, 2007)

Element	Considerations
Training	• Workers should learn how to work near vehicle traffic.
Worker safety apparel	• All the workers that are exposed to moving traffic or construction equipment risk should wear clothing that ensure a high level of visibility based on the requirements of ISEA (American National Standard for High Visibility Safety Apparel).
Temporary traffic barriers	• Barriers must be placed along the work zone based on the following factors: o Lateral clearance o Traffic speed o Traffic volume o Duration of operation o Operation type o Time of the day
Speed reduction	• Reducing traffic speed using speed zoning, funneling, and flaggers.
Activity area	• The work area should be planned so that the back-up maneuvers of construction vehicles, and thereby the risk is minimized.

Table A.4 Temporary traffic control plans to improve worker safety (adopted from WVDOT, 2007)

Element	Description	Application
Road closure	Temporary road closure may facilitate project completion, and thereby, reduce the vulnerability of workers.	Existence of alternative routes for managing road users.
Police use	Police units can enhance the awareness and the safety through the work zone.	Highly vulnerable work situations, particularly with short duration works.

Lighting	Lighting of the temporary traffic control zone.	Nighttime work.
Special devices	Warning lights, rumble strips, flags, portable changeable message signs, and intrusion warning devices.	Certain difficult temporary traffic control situations.

A.1.4.4 Night-time work

Night-time working has two basic advantages, i.e., reduced traffic volume and less business activities. Lower night-time traffic allows the drivers to drive at higher speeds. Therefore, to ensure the safety of workers during night work, traffic controls should be adjusted to provide extra visibility and protection for workers, as well as enhanced driver guidance. Where possible, the roadway should be closed and traffic detoured to alternate facilities, thus removing the traffic risk from the activity area.

A.2 District of Columbia (DC) DOT

A.2.1 Key Factors In Detour Mapping

At D.C., a temporary traffic control manual provides guidelines on selecting detour routes for incident management. According to this manual, the major concern is about large trucks and vehicles carrying hazardous cargo. To address this concern, the manual suggests deploying separate routes for such vehicles. To accommodate the passage of trucks, the selected detour routes should be determined based on the following criteria.

- Structural capacity of bridges
- Truck weight
- Clearances
- Geometric restrictions

In addition to the above considerations that are mainly related to technical aspects, the detour route and the required temporary traffic control plans should be determined. The following section provides a summary of temporary traffic control plans in work zones.

A.2.2 MOT Strategies and Temporary Traffic Control Plans (TTCP) in Work Zones

The dynamic nature of work zone activities may require frequent readjustments of traffic control devices. Therefore, temporary traffic control installations must be reviewed on a daily-basis and documented on a weekly-basis to ensure the functionality of the temporary traffic control devices. Two main checklists are listed in the manual: Daily Checklist for Temporary Traffic Control Form and the Field Inspection Report. Inspections should be also conducted under the following circumstances.

- During night-time
- During holidays for high speed and high traffic volume projects
- During severe weather conditions for all projects

A.2.2.1 Temporary Traffic Control Plans (TTCPs)

A Temporary Traffic Control Plan (TTCP) "describes temporary traffic control measures to be used for facilitating road users through a work zone." TTCPs are critical for ensuring an efficient and safe road user flow when the normal user flow is disrupted because of construction work, incidents, or other events. It is clearly stated in the manual that "The Manual is not a substitute for engineering judgment." Nevertheless, to set boundaries for the engineering judgement, the manual introduces the following factors to be considered while designing TTCPs.

Factors Affecting TTCP Design

TTCPs involve using temporary traffic control devices, barriers, and signals. The design and application of such devices should consider the needs of all road users (motorists, pedestrians, and bicyclists) based on engineering judgment. Temporary traffic control zones are different in terms of their characteristics, including the work location and duration, road type, user volumes, vehicle mix (buses, trucks, and cars), speeds, geometrics, vertical and horizontal alignment, as well as intersections and interchanges.

Stakeholders' needs

Temporary traffic control plans should not hinder the operation of railroad and/or METRO service. In addition, proper access to abutting property owners and businesses can help minimize negative economic impacts to the businesses located near the work zone area.

Transit services

Detouring public transit buses is often more complicated than other vehicles. Therefore, provisions must be considered to ensure continuity of service while designing temporary traffic control zone devices.

Coordination

To avoid duplications in signing, compatibility of TTCPs between adjacent or overlapping projects are controlled.

Work duration

Temporary traffic control zones needs are different depending upon the characteristics of the zone. Duration of the work is among one of the key factors that affects the regulations and recommendations for TTCPs. Operations are divided into four categories, i.e., Mobile, Short Duration, Moderate Duration, and Stationary based on their durations. Stationary operations can be further categorized into three short-term, intermediate term, and long-term classes. Figure A.1 shows these categories and their associated management of traffic recommendations, depending upon several factors, including the traffic volume and speed, the operation speed, and the presence of crew to align the overturned devices. Mobile operations include work activities that involve the movement of the workers and equipment with intermittent and frequent stops, each less than 15 minutes. The key goal in performing mobile operations is maintaining the safety and road user conditions. In this regard, as Figure A.1 shows the operation's speed as well as the speed and volume of the traffic are important in the selection of traffic control devices.

For short-duration and intermediate-term stationary operations, it may not be practical to install and remove devices as it could increase the project time, thereby increasing workers' exposure time to hazards. In this condition, the presence of the work crew to align overturned devices, determines the appropriate channelizing devices including tubular markers, plastic drums, and temporary raised islands to warn road users and guide motor vehicle traffic flow onto a detour, or into a narrower traveled way.

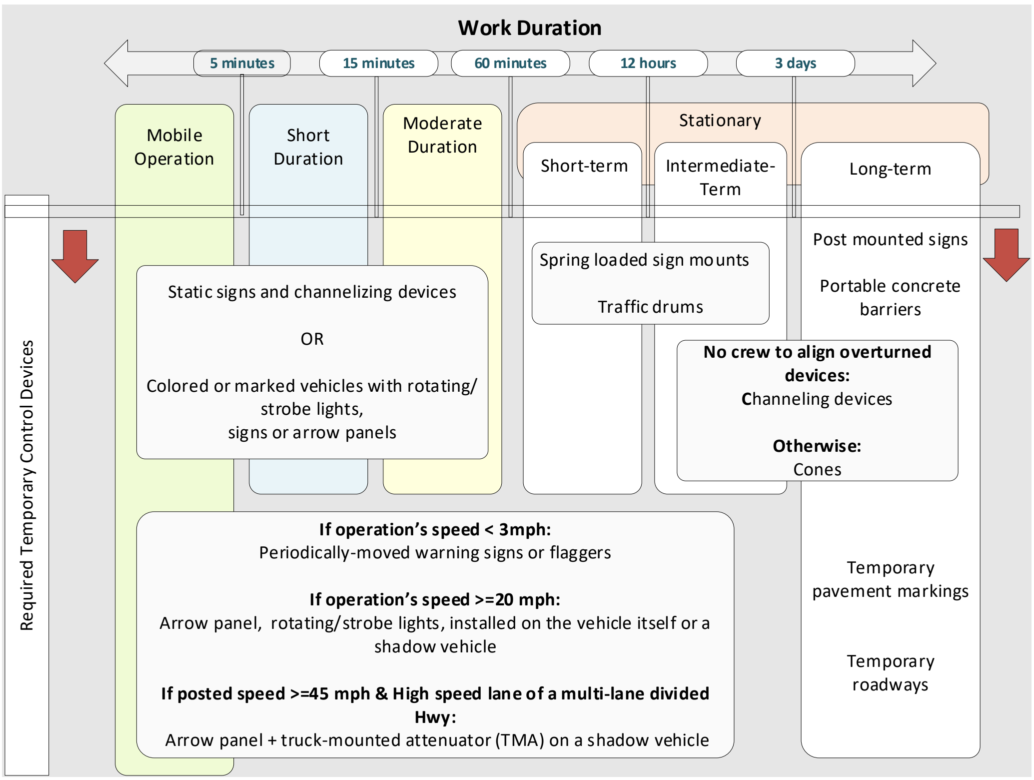

Figure A.1 Maintenance of traffic plans based on the duration of the construction activity (based on the recommendation of DC-DOT).

At long-term stationary work zones there is enough time to install and use a full range of temporary traffic control devices. Temporary roadways and detours, temporary traffic barriers, and temporary pavement markings are often used for long-term stationary temporary traffic control zones. Since intermediate-term and long-term operations last more than 12 hours they extend into nighttime. Therefore, retroreflective and/or illuminated devices are used.

A.2.3 D.C. Incident Management

A part of a highway where temporary traffic control devices are put in place to manage a special event such as accidents or natural disasters is called an incident area. TTC devices such as warning sign or rotating/strobe lights on a vehicle are used at the beginning and the end of the incident area, to avoid secondary crashes and ensure the safe and expedited movement of the road users through or around the incident. Based on the D.C. traffic control manual (DCDOT, 2006), if the anticipated time for the incident management is more than three days, the following procedures and guidelines may be used.

- Deploying detours: in the incidents that involve hazardous spills or the blockage of the traveled way, road users are detoured around the incident and back to the original route.
- Provision of storage spaces for emergency response vehicles, e.g., tow trucks and fire apparatus, for high-volume and congested facilities.
- Parking controls.
- Speed zoning.
- Suspension of planned work activities in the face of extreme weather conditions: extreme weather conditions also cause lack of visibility, increased stop distance, controlling difficulty, as well as distraction and anxiety for road users. if possible, during inclement weather conditions.

In addition, to the proposed solutions, the following considerations are mentioned:

- Road users must be guided around the incident.
- It is desirable to maintain good public relations through news media.
- Coordination and legislative authority are required to enforce road user regulations.

A.2.4 Work Zone Safety

The guidelines provided by the D.C. DOT on the speed reduction limits, worker safety, and pedestrian safety are consistent with those proposed by West Virginia DOT. Therefore, for the sake of brevity they are not repeated in this report.

A.3 New Jersey DOT

A.3.1 Key Factors in Detour Mapping

The purpose of the New Jersey DOT manual is to provide a strategy for work zone traffic mitigation. The goal of traffic control and operation is to navigate motorists to, and around, construction areas in a clear and secure manner. Detour routes are viable strategy to navigate motorists. Detour routes can be utilized when (1) the work zone needs to be closed to perform construction activities, and (2) detouring traffic will result in a significant reduction traffic volume. This strategy is most suitable if routes parallel to the road under construction have enough capacity to accommodate the diverted traffic. Detour routes might require upgrades to increase their capacity, make the traffic flow more efficient so that the route becomes more attractive to motorists.

A.3.2 MOT Strategies and Temporary Traffic Control Plans (TTCP) in Work Zones

MOT strategies and temporary traffic control plans (TTCP) can benefit the public, the agency and other government and local agencies participating in construction projects. TTCP strategies allow for efficiently flowing traffic along the detour route as well as across the construction site, mitigating damage to both vehicles and businesses. Typically, TTCPs require the use of temporary traffic control structures, barriers, as explained in following sections.

A.3.2.1 Temporary Traffic Barriers (TTBs)

Effective traffic control enhances safety and performance, while reducing stress on the driver. Traffic control devices, such as barriers, play a significant role in the prevention of incidents involving construction workers. Physical barriers separating traffic from the work zone will improve the safety of both the motorist and the construction workers. Channeling systems can boost the flow of traffic by forewarning users of potential construction activities and allowing them time to respond to changes in travel patterns. Significant consideration is given to snow removal using permanent physical barriers. The selection of suitable traffic control equipment is determined by the distances of sight, traffic speed, volume, and the work type.

For detour routes, signage is used to inform motorists about the start and end of the detour route, as well as the turns along the route. Signage assures motorists that have not skipped any turns and they are still on the detour route. Flashing arrow signs are often used to increase the number of traditional traffic control systems where supplementary alerts and navigation information is needed to control the flow of traffic through the work zone. Pavement markings, including reflective devices, stripes, and arrows may also be used to mark the location of the lanes and to indicate the direction of travel. Screens that shield construction operation from the eyes of motorists will discourage staring, thus sustaining past construction speeds and minimizing the potential for accidents caused by drivers.

A.3.2.2 Temporary traffic control signals

Detour routes might require upgrades and/or signal timing adjustments to enhance their capacity, traffic flow, and hence, their attractiveness to motorists. Therefore, adjusting the timing of traffic signals should be considered. The addition or deletion of signal phases may be necessary to accommodate changes in travel patterns.

A.3.2.3 Factors affecting TTCP design

TTCP used in the traffic mitigation program would depend on a variety of factors, such as the nature and length of the project and construction site, as well as the traffic volume. Many of the project characteristics may affect the need for traffic mitigation. Various characteristics are known to be of particular significance, including the characteristics that determine the likely impact of the project on motorists and on the nearby community members. These characteristics are described as follows.

1. Road User Cost (RUC): The cost of road users is a measure that quantifies the economic impact of construction activities on road users. RUC depends on the work characteristics such as its timing, scope, and duration.
2. Impacts to Businesses and Neighborhoods: Construction projects directly impact businesses and neighborhoods because they can render businesses and neighborhoods inaccessible.
3. Impacts on Military and Emergency Response: the efficiency of emergency response activities may be disrupted by construction projects. This is considered when developing road maps, temporary detours or changing access to residential and commercial areas.

4. Impacts on Access to Major Activity Centers or Employers: Construction zones that go through or close to major centers of activity or employment can create traffic backups. Travel Demand Preparation concentrates on public awareness and alternate routes. TDM strategies, such as riding facilities, infrastructure improvements, as well as Park & Ride lots are emphasized.
5. Political Sensitivity: Projects that are under threat of or have ongoing lawsuits with are deemed as projects with high political sensitivity. These projects need special attention to public information and information for motorists. Legislative offices are kept notified of the progress of the project through legislative liaisons and other means.
6. Duration of Construction (months): The amount of time that construction is supposed to last would have a direct effect on both the nature of the TM and the types of strategies chosen. Long projects typically involve a greater number and more aggressive strategies than short-term projects.
7. Type of Roadway: Due to their high volume of traffic and their vital role in the road network, interstates and state expressways typically require more comprehensive TM compared to other roads.
8. Average Daily Traffic Volume: The volume of traffic through the corridor significantly influences the level of TM required. The higher the volume, the more affected the motorists, the higher the total delay costs.
9. Seasonal Traffic Volume Increase: Some highways may face significant travel demand during seasonal recreation periods.
10. Expected Delay (vehicle hours per day and per project duration) or Queue Length (miles): Delay is an important feature of TM since it is a crucial measure of the extent of disturbance experienced by motorists.
11. Project Distance (miles): Projects extending over large geographic areas should guarantee a broad use of detours and public information.
12. Significant Truck Volume: In the projects with large volumes of trucks that increase the need for TM require detour strategies for diverting trucks.
13. Nearby Projects: Consideration of the proposed development of parallel routes or other nearby projects is required.
14. Holidays and Schools: Specific efforts will be put in place to protect school bus lines, street crossings and the needs of school children. Holiday shopping may influence the traffic in the corridor and should be considered.

A.3.3 New Jersey Incident Management

Crash levels rise in construction areas, and traffic management and regulation techniques help reduce the number of accidents. Incident response techniques are designed to easily identify and handle accidents. Such techniques are useful for complicated route layouts with detours and lane closures.

- Incident Management Plan/Event Planning: Typically, an emergency response program describes a framework for accelerated accident identification. This specifies the location of the movable traffic control system stores that are available during an accident. Both crisis response procedures and disaster planning are implemented in conjunction with emergency services and municipal authorities and organizations in the vicinity of the construction area. The schedule includes a timeline for the scheduled activities and the steps to be taken to manage traffic.

- Onsite Tow Vehicles: Quick response to accidents is important for restoring traffic flow; one effective tactic involves using tow trucks located at the work zone, during the whole day or only peak hours, to promptly remove any damaged vehicles. This technique is recommended for use in the occasions where the traffic flow is impeded by a collision or accident and emergency pull-outs are far away or unavailable.
- Enhanced Police Presence: The presence of police patrols having inside the construction area ensures that the passing traffic observes the speed limits. In addition, the flashing lights warn the motorists when they are approaching a work zone.
- CCTV/Traffic Monitoring Station: In the case of large or long-term projects, a traffic monitoring station may provide immediate notice of accidents. Detectors can also be useful for calculating traffic flow variables.

A.3.4 Work Zone Safety

The level of exposure for construction workers, stakeholders and transportation users is a measure of the level of safety. The widely used road safety indicators are the number of collisions or the effects of accidents (deaths and injuries) at or along a given section of road over a certain time period. The entire agency is required to guarantee safety and accessibility for road workers and for passengers. Construction and work zone staff shall be qualified in the protection of the work zone in compliance with the agency's standards for implementation, service, inspection, and enforcement. Guidance and guidelines for the proper construction of secure and productive work zones shall be given to the designers.

A full Transportation Management Plan (TMP) is recommended to be built for major projects that occupy a lane for more than four days with sporadic or continuous lane closures to resolve the safety and mobility impacts.

A.4 Michigan DOT

A.4.1 Key Factors in Detour Mapping

The *Work Zone Safety and Mobility Manual* published by the Michigan DOT outlines procedures and criteria of consideration for planning and deployment of detour routes for construction and incidence response. The manual lists several criteria that must be considered in the planning of detours including the adequacy of the detour to handle additional traffic, its structural integrity and geometric state, signage, etc. According to the manual, the project designer must take care to ensure that sign placement fits the locations shown along the detour route and that the signage does not conflict with existing signs for bridges, driveways, tress, landscaping, or pedestrian movements. The manual also recommends upgrades to existing signage, pavement markings and traffic signals on detour routes where necessary. For signalized intersections, timing on signals may need to be adjusted. Other important features on detours include adequacy of shoulders, lane widths, turning radius for commercial vehicles, and structural condition of pavement.

To ensure smooth operation and reduce potential conflicts, the manual recommends that projects must coordinate with local transportation officials and approval of detours must be document. Additionally, a field review of the detour must be conducted to assess the condition of the detour, observe traffic volumes, and note anticipated or potential modifications. Special attention must be given to existing restrictions such as height, weight, and horizontal curvature. These must be evaluated on the proposed detour to ensure traffic is not further impeded or restricted. Emergency services must always be provided access to the worksite for any emergency related events within or adjacent to the work zone. Special consideration must be given to detour routes that cross railroads at grade. The increased traffic volume may present increased risk of collisions and may therefore require the use of gates at the crossings.

1. **Full Road Closures**

Full closures should be considered whenever possible as they provide the most secure separation of road users from workers. The manual recommends that they are considered and evaluated for projects with underground utility work, and bridge replacements. Even so, it is recommended that the work be completed, and the roads returned to normal operation as fast as possible, as road closures impact travel times and there may not be viable detour routes around the project site. Detour routes for a full closure must be reviewed for capacity, existing crash patterns, and signal timing to avoid crashes and delay.

For safety purposes, it is recommended that in advance of the closure, lighted Type III barricades must be placed on the shoulder or behind the curb at the nearest crossroad. At a road closure point, Type III must be placed across the entire closed area. R11-2 or other R11 series sign must be placed on or above and behind the Type III barricades in the center of the closure.

2. **Partial Road Closures/Directional Closures**

If a full closure is not possible or inconvenient, a partial or directional closure may be affected. Directional detours provide additional workspace for part-width construction. The manual recommends that these detours be assessed in the same way as full road closures where only one travel direction needs to be detoured. Projects must be evaluated carefully to determine the direction of the travel that should be detoured, considering impacts on road user flow and their ability to change their path. In the case of non-freeway projects, it is recommended to detour traffic in the same direction for the same project. This provides motorists with consistent routes and travel paths as changing back and forth could lead to head-on traffic crashes. This consistency is crucial for areas that have residential or business driveway access. In residential and business areas, it may be helpful to obtain community feedback on which direction to detour. Public input should be taken into consideration, but engineering judgement should be utilized when making the final MOT selection. Turning movements and existing capacity of the detour route, along with public input, should be a factor in the design. A detour route that has all right hand turns and free flow movements would be desirable over left-hand turns.

Freeway projects have controlled access points so the need to maintain the same direction of traffic for the duration is not as critical as for non-freeways. The traffic volumes and viable detour routes should be considered when determining which direction to maintain during the project.

A.4.2 MOT Strategies and Temporary Traffic Control Plans (TTCP) in Work Zones

The Transportation Management Plan (TMP) is usually introduced early in a project's lifecycle and is updated, and sometimes expanded as the project moves along. Regional and transportation service center staff play a critical role in determining the significance of a project in relation to mobility impacts. A project is considered significant if it is predicted to result in 10 minutes or more of additional work zone delay, over normal conditions for the entire duration of the project. A TMP for a significant project must include: (a) Temporary Traffic Control Plan, (b) Traffic Operations Plan, (c) Public Information Plan, and (d) Performance Assessment Plan.

A.4.2.1 Temporary Traffic Control Plan (TTCP)

A TTCP must include maintaining traffic typical plans, possible detours and potential alternate routes during construction, list of special provisions for maintaining traffic, preliminary MOT cost estimate. If the cost of maintaining traffic exceeds 25% of the total project cost, Regional Engineer notification is required. Internal Traffic Control Plan is also expected to monitor the contractor's workers' movement and the course of construction equipment for safe traffic conditions.

A.4.2.2 Traffic Operations Plan (TOP)

A TOP must include work zone mobility analysis (collecting data such as AADT, CAADT, traffic growth rate and operational traffic studies which can provide information such as travel time, turning movements, etc.), queue length analysis, work zone crash analysis and agency coordination strategies. Some TOP strategies include demand management (viz. providing shuttle services, HOV lanes, varying office work hours), work zone safety enhancement (viz. parking restrictions, ramp closures, separate truck lanes, moveable traffic barrier systems, and signaling improvements). MDOT also mandates the development of a traffic incident plan.

A.4.2.3 Public Information Plan (PIP)

The PIP alerts the public through representatives from nearby schools, parks, community centers, transit services, and businesses of forthcoming changes and communicate the taken efforts for accommodating pedestrian needs.

A.4.2.4 Performance Assessment Plan (PAP)

MDOT measures performance of their work zone with data obtained from work zone monitoring reports, crash reports, traffic measuring device information, video camera surveillance. Having a work zone travel time delay form to collect throughput, delays, unit travel times, travel time reliability, traffic queue lengths, and any additional travel time delay calculations helps in developing future strategies to improve the shortcomings observed in past work zones. MDOT has set the following performance measurement metrics for yearly performance analysis.

1. *Travel time delay:* The number of projects that were able to meet 10-minute work zone delay threshold.
2. *TMP:* The number of projects that were entirely complied with TMP requirements.
3. *Work zone compliance:* The number of projects deemed to have satisfied the work zone safety review ratings.

4. *Work zone crashes:* The number of projects that experienced both positive and negative changes in crash patterns and/or rates, over the project duration.

A.4.3 Michigan DOT Incident Management

Traffic Incident Management (TIM) strategies suitable for the type of work zone should be established, implemented, and detailed in the TMP. The process followed by MDOT to create a TIM, is as follows.

- Identify stakeholders: MDOT and local transportation agencies, state and local law enforcement, Emergency service providers, contractor, media, etc.
- Determine response objectives and procedure guidelines: Minimize detection, notification, and verification time for crashes, maximize the use of existing communication resources, and provide timely and accurate information to the public so that they can make informed decisions.
- Determine appropriate levels of response: Classify the crash based on whether it is a major, intermediate or a minor crash. The conditions for the classifications should be made clear beforehand and appropriate response strategies such as closing one direction, making a U-turn, and diverting the traffic, etc. should be pre-determined.
- Provide sufficient training to the decision-makers and responders on the strategies for commonly observed incidents such as rear end crashes, etc.

A.4.4 Work Zone Safety

The performance assessment plan designed to have a yearly check on the quality of the MOT plans designed by the MDOT, helps them to keep a track on the commonly observed problems in the work zone. MDOT utilizes a spreadsheet style worksheet, called the Work zone Audit report sheet which needs to be filled out by the traffic control engineer (MDOT, 2017). The report has a set of key performance indicators and variables mentioned which can be used a checklist to ensure the compliance of a work zone with the MDOT-prescribed guidelines.

Based on accumulated experience over the years, MDOT has prepared detailed strategies to tackle work zone crashes due to rear end crashes, crashes due to sideswipes, etc. Also, the agency has summarized certain traffic control devices which can also be useful to avoid crash situations. Overall, MDOT has prepared an entire *Work Zone Safety and Mobility Manual* to summarize their action plan.

A.5 Nebraska DOT

A.5.1 Review of Best Practices in Alternate Route Planning

Nebraska Department of Roads conducted a comprehensive review of best practices on alternate route planning, following which they developed an alternate route and incident management plan for use throughout the state as part of a comprehensive statewide transportation systems management program. Elements of the plan include the following.

- Developing and deploying the 5 1 1 traveler information program. This is accessible by dialing 5-1-1 anywhere in the state.
- Developing and deploying an extension of the 5 1 1 program, called 5-1-1 on the web. This site hosts Traveler Information Portal (TIP).
- Designating Interstate and Expressway alternate routes that can be utilized in case of an emergency.
- Coordinating with metro area freeway incident management plans.

The alternate route planning process, methods and assumptions are documented in the *Nebraska Statewide Interstate and Expressway Alternate Route Study* (NDOR, 2007).

The report documents a list of universal criteria put forth by a conveyed panel of experts from which a committee recommends alternate route evaluation criteria. The universe of criteria as proposed by the panel includes the following.

- Bridge restrictions: Overhead clearance limits, narrow cross section, posted weight restrictions, structural deficiencies, and truss bridges (bridges with trusses are excluded).
- Mainline at-grade railroad crossings: Grade separated crossings along a potential route can be considered a neutral or positive. If the crossing is at grade, it would be considered a negative. For non-mainline routes, the frequency of the trains would need to be considered before deciding regarding the potential for impacts. At grade rail crossings are considered a negative.
- Lane widths on the alternate route. Desirable lane widths should be 11 ft or 12 ft.
- Signalized intersections on the detour route: signalization is considered a negative because additional traffic would result in increased delay at the intersections. Therefore, traffic control personnel may be required to manually operate the signal, further adding to the coordination, and staffing issue.
- Shoulders: A minimum width of shoulder should be determined as the situation requires.
- Maintenance and construction activities: Care must be taken during the construction period to ensure that interstate traffic is not diverted through a construction site.
- Access to emergency responders
- Pedestrian and/or school crossings along the alternate route: Presence of crossings is a negative attribute for the alternate route. The fewer of them are present, the better.
- Pavement condition on the alternate route.
- Speed limits along the alternate route: Low speed limits on the route are a negative attribute for the alternate route. Placing high speed through traffic on a low-speed route will likely result in an undesirable condition.

- Functional classification between the primary route and alternate route: Ideally, alternate routes should be of the same functional class as the primary routes being diverted.

From the universe of criteria proposed and listed above, a shortlist of criteria to be used to screen and evaluate alternate routes was identified and is discussed as follows.

Structures along the route should exceed some minimum thresholds. See the following.

- Overhead clearance should be at least 16 ft
- Cross section should be no less than 24 ft
- No structural deficiencies
- No posted weight restrictions
- No truss bridges on alternate routes
- The route should not include mainline (BNSF and/or UPRR) at-grade railroad crossings
- The alternate route has a reasonable level of reserve capacity: If part of the alternate route is on rural, two-lane highways, it should be noted that diverting traffic from any segment of an interstate will result in overcapacity conditions on the two-lane highway. Typically, two-lane highways have threshold capacities of about 5,000 vehicles per day, whereas the lowest volume segments of interstates carry approximately 6,600 vehicles per day
- No signalized intersections along the alternate route. At signalized intersections, signal timings/phasing are determined from estimated traffic flows. Therefore, adding substantial traffic would result in congestion if the signals were not adjusted. Thus, traffic operations at signalized intersections would likely drop off substantially
- The route provides adequate surface width. The criteria are a combination of the following
    - Minimum lane width threshold of 11 ft
    - Minimum paved shoulder width of 4 ft on either side
    - Pavement condition on the alternate route. Minimum threshold of an NSI rating of 60 and a maximum rutting of 13 mm

APPENDIX B. THE SURVEY QUESTIONNAIRE

Does your agency have an active framework for generating detour route alternatives for an interstate project? Please note that you will not be able to change this answer later in the survey. Active Framework is a guide to the detour decision making process which documents the best practices associated with mapping and coordinating of detour plans and assists in developing risk management/mitigation plans for selected detour options.

- Yes
- No
- Unsure

1. Which of the following are collectively involved at the final stages of finalizing a detour strategy for a project? Please select all that apply.
   - Traffic Management Committee (e.g., TMC Input)
   - Transportation Management Plan (TMP) team/committee/stakeholders
   - Maintenance Director/Foreman
   - Work Zone Safety Engineer
   - Construction Engineer (e.g., Area engineer)
   - Pavement Engineer (for health assessment of alternate detour options)
   - Environmental Engineer (to evaluate possible environmental/social/historical concerns)
   - Project Manager
   - Detour Route Selection Committee
   - District Traffic Engineer (DTE)

No Group Questions

1. Why does your agency not use a framework for detour route decision making?
   - The agency has decided that a framework is not necessary
   - The agency is researching whether to develop a framework
   - The agency is planning to develop a framework
       - The agency is actively developing a framework
       - Additional comments on what led your agency to the above selected option

2. Rate the importance of the below-mentioned criteria when selecting a detour route in accordance with your agency's policies and guidelines. Use a scale from 1 to 5 where 1 signifies the least and 5 the most importance. Also, there is a text box located below each criterion, wherein you can add comments/thresholds that you feel are important to note for that criterion.

	Least importance			Most importance	
	1	2	3	4	5
Technical (e.g., detour's lane width, vertical clearance, turning radius, traffic control devices)					
Operational (e.g., duration of the project, presence of rest and fuel stations on detour)					
Financial (e.g., cost of project, maintenance cost of detour route, costs incurred to drivers)					
Accessibility (e.g., police station, hospital, fire services, schools)					
Safety (e.g., crash risk for drivers, pedestrians)					
Environmental (e.g., sensitive ecology around detour route)					
Social (e.g., community and business impacts, acceptance levels)					
Political/Jurisdictional (e.g., stakeholders involved in planning)					
Route suitability for Commercial Motor Vehicles (CMVs)					
Additional consideration					

3. For criteria specified above that may not have quantifiable thresholds or limits, how do you address them? Note that you can select multiple choices.
   - We have adopted a guideline provided by the state
   - We have our own manual, but it's not publicly available
   - We use professional/expertise judgement
   - Development of manual for detour decision is currently in progress.
     - We have future plans to develop a manual
   - Additional comments

4. What are some challenges for deploying the detour route? Please select all that apply.
   - Project schedule and MOT Issues
   - Lack of a Decision Support System
   - Lack of a list of criteria to determine a detour route
     - Lack of a decision-maker
     - Other, please specify

5. When was the last time a detour route was deployed in your jurisdiction?
   - Within 6 months
   - Within the past year
   - 1 to 2 years ago
   - 2 to 4 years ago
   - 4+ years ago

6. In-case of unforeseen conditions arising on the detour route, please rank the following immediate public outreach strategies in the order you might follow them. Rank 1 for the immediate response and Rank 4 for the last response step. Please move the choices with your cursor as per your desired ranking.

______ Installing emergency signboards at the start of the route
______ Deploying a team on-site to divert the flow of traffic
______ Have developed a mobile application wherein users can be sent push notifications immediately
______ Depend on the use of local news/radio stations to spread the information

Yes Group Questions

1. Which of the following are collectively involved at the final stages of finalizing a detour strategy for a project? Please select all that apply.
   - Traffic Management Committee (e.g., TMC Input)
   - Transportation Management Plan (TMP) team/committee/stakeholders
   - Maintenance Director/Foreman
   - Work Zone Safety Engineer
   - Construction Engineer (e.g., Area engineer)
   - Pavement Engineer (for health assessment of alternate detour options)
   - Environmental Engineer (to evaluate possible environmental/social/historical concerns)
   - Project Manager
   - Detour Route Selection Committee
   - District Traffic Engineer (DTE)
2. Rate the importance of the below-mentioned criterion when selecting a detour route in accordance with your agency's policies and guidelines. Use a scale from 1 to 5 where 1 signifies the least importance and 5 the most. Also, there is text box located below each criterion, wherein you can add comments/thresholds that you feel are important to note for that criterion.

	Less importance				Most importance
	1	2	3	4	5
Technical (e.g., detour's lane width, vertical clearance, turning radius, traffic control devices)					
Operational (e.g., duration of the project, presence of rest and fuel stations on detour)					
Financial (e.g., cost of project, maintenance cost of detour route, costs incurred to drivers)					
Accessibility (e.g., police station, hospital, fire services, schools)					
Safety (e.g., crash risk for drivers, pedestrians)					
Environmental (e.g., sensitive ecology around detour route)					
Social (e.g., community and business impacts, acceptance levels)					
Political/Jurisdictional (e.g., stakeholders involved in planning)					
Route suitability for Commercial Motor Vehicles (CMVs)					
Additional consideration					

3. For criteria specified above that may not have quantifiable thresholds or limits, how do you address them? Note that you can select multiple choices.
   - We have adopted a guideline provided by the state
   - We have our own manual, but it's not publicly available
   - We use professional/expertise judgement
   - Development of manual for detour decision is currently in progress.
   - We have future plans to develop a manual
   - Additional comments

4. How does your state DOT mitigate risks encountered during the implementation of a MOT Strategy? Note that you can select multiple choices.
   - Have a pre-determined approach in the form of a manual which states measures to be taken for possible scenarios.
   - Assign a person/team whose instantaneous decisions are trusted and can be immediately implemented.
   - Have a collaborative platform wherein involved stakeholders can immediately assess and coordinate solutions
   - Additional comments

5. In-case of unforeseen conditions arising on the detour route, please rank the following immediate public outreach strategies in the order you might follow them. Please move the choices with your cursor as per your desired ranking.

______ Installing emergency signboards at the start of the route
______ Deploying a team on-site to divert the flow of traffic
______ Have developed a mobile application wherein users can be sent push notifications immediately
______ Depend on the use of local news/radio stations to spread the information

6. How recently did you use your framework to generate any detour map for a project?
   - Within 6 months
   - Within the past year
   - 1 to 2 years ago
   - 2 to 4 years ago
   - 4+ years ago

7. How can your current framework be improved? Note that you can select multiple choices.
   - Addition of a graphical user interface
   - Inclusion of more criteria / refinement of the criteria
   - Removal of criterion which are seldom used
   - Additional comments

Unsure Group Question

1. Which of the following entities are collectively involved at the final stages of finalizing a detour strategy for a project? Please select all that apply.
   - Traffic Management Committee (e.g., TMC Input)
   - Transportation Management Plan (TMP) team/committee/stakeholders
   - Maintenance Director/Foreman
   - Work Zone Safety Engineer
   - Construction Engineer (e.g., Area engineer)
   - Pavement Engineer (for health assessment of alternate detour options)
   - Environmental Engineer (to evaluate possible environmental/social/historical concerns)
   - Project Manager
   - Detour Route Selection Committee
   - District Traffic Engineer (DTE)

2. Rate the importance of the below-mentioned criteria when selecting a detour route in accordance with your agency's policies and guidelines. Use a scale from 1 to 5 where 1 signifies the least importance and 5 the most.

   Also, there is a text box located below each criterion, wherein you can add comments/thresholds that you feel are important to note for that criterion.

	Less importance 1	2	3	4	Most importance 5
Technical (e.g., detour's lane width, vertical clearance, turning radius, traffic control devices)					
Operational (e.g., duration of the project, presence of rest and fuel stations on detour)					
Financial (e.g., cost of project, maintenance cost of detour route, costs incurred to drivers)					
Accessibility (e.g., police station, hospital, fire services, schools)					
Safety (e.g., crash risk for drivers, pedestrians)					
Environmental (e.g., sensitive ecology around detour route)					
Social (e.g., community and business impacts, acceptance levels)					
Political/Jurisdictional (e.g., stakeholders involved in planning)					
Route suitability for Commercial Motor Vehicles (CMVs)					
Additional Consideration					

3. For those criteria specified above that may not have quantifiable thresholds or limits, how do you address them? Can select multiple choices.
   - We have adopted a guideline provided by the state
   - We have our own manual, but it's not publicly available
   - We use professional/expertise judgement
   - Development of manual for detour decision is currently in progress.
   - We have future plans to develop a manual
   - Additional comments

4. How does your state DOT mitigate risks encountered during the implementation of a MOT Strategy? Note that you can select multiple choices.
   - Have a pre-determined approach in the form of a manual which states measures to be taken for possible scenarios.
   - Assign a person/team whose instantaneous decisions are trusted and can be immediately implemented.
   - Have a collaborative platform wherein involved stakeholders can immediately assess and coordinate solutions
   - Additional comments

5. In-case of unforeseen conditions arising on the detour route, please rank the following immediate public outreach strategies in the order you might follow them. Please move the choices with your cursor as per your desired ranking.

______ Installing emergency signboards at the start of the route
______ Deploying a team on-site to divert the flow of traffic
______ Have developed a mobile application wherein users can be sent push notifications immediately
______ Depend on the use of local news/radio stations to spread the information

6. When was the last time a detour route was deployed in your jurisdiction?
   - Within 6 months
   - Within the past year
   - 1 to 2 years ago
   - 2 to 4 years ago
   - 4+ years ago

7. What are some challenges for deploying the detour route? Please select all that apply.
   - Project schedule and MOT Issues
   - Lack of a Decision Support System
   - Lack of a list of criteria to determine a detour route
   - Lack of a decision-maker
   - Other, please specify

8. You selected the "Unsure" option to the Q1 which asked whether your state DOT had an active framework to help in detour selection decision making and risk management. After answering the questionnaire, which of the following you now think is applicable to your state DOT's current situation?
   - The agency has a similar framework in practice
   - The agency is researching whether to develop a framework
   - The agency is planning to develop a framework
   - The agency is actively developing a framework
   - The agency has deemed that it does NOT need such a framework
   - Additional comments

General Questions for All Groups

1. In a case that you could not find an appropriate option for detour what is your strategy? Note that you can select multiple choices.
   - We change the project schedule
   - We do the construction project in night-time work or in weekends
   - We choose the best option even if it does not meet the standards
   - Other, please specify

2. Please provide your personal details
   - Name
   - Designation

- State DOT associated with
- Phone (xxx-xxx-xxxx)
- Email

3. Would it be fine if we follow-up with you for a possible interview to seek more details?
    - Yes
    - Maybe, email me to ask about my availability
    - No

APPENDIX C. SAMPLE INVITATION EMAIL FOR THE SURVEY QUESTIONNAIRE

Hello "SAC member!",
Good morning,

I am contacting you on behalf of our team at Purdue University that collaborates with Indiana DOT on project SPR #4405, **"Synthesis Study on Best Practices for Mapping and Coordinating Detours for Maintenance of Traffic including Risk Assessment/Management for Duration of Traffic Control Activities."** This study is under the supervision of Prof. Makarand Hastak (principal investigator), Professor and Head of Construction Engineering and Management, and Prof. Samuel Labi (co-principal investigator), Professor of Civil Engineering. The study has been reviewed by Purdue University's IRB (IRB-2020-885).

As you are aware, we have developed a short survey and we are conducting interviews with experts in the field. The survey is only for research purposes and no personal information will be collected. The participation of the respondents is voluntary, but it will be greatly appreciated.

We would appreciate it if you could share the survey link with those experts who might be good candidates for filling our survey questionnaire. The survey can be reached at: https://purdue.ca1.qualtrics.com/jfe/form/SV_e8tgm6CBEOUfayV
Thank you very much for your time and collaboration.

Best regards,
SPR 4405 team member
Affiliation

APPENDIX D. THE FOLLOW-UP SURVEY QUESTIONNAIRE

Table D.1 Follow-up survey questions

Question	Type	Content
Q1	Text	Please provide the state DOT you represent….
Q2	MC*	Do you proactively analyze/identify detour conflicts ahead of time during the planning stage? (A proactive approach is foreseeing the conflicts in advance, i.e., greater than six months prior to project start date, whereas reactive would be less than six months prior to project start date) (Please also note that you need to answer this question to proceed with the rest of the questionnaire.) 1. Yes 2. No
Q3	MS**	How far into the future do you plan for these conflicts/resolutions thereof? (If more than one applies, pick the longest horizon.) 1. Less than six months 2. Six months to one year 3. One to three years 4. Over three years 5. Within project duration
Q4	Text	How do you resolve detour conflicts?
Q5	MS**	How do you identify/address conflicts with detours under Scenarios A-D (please select the applicable numbers from the following options)? 1. Changing one of the detour routes 2. Modifying schedules 3. Add to the capacity 4. Checking for conflicts in advance 5. Night-time working 6. Separate traffic for vehicle classes 7. Others (please specify) Scenario A: Less than 2 weeks overlap; Less than 2 miles overlap …. Scenario B: Less than 2 weeks overlap; More than 2 miles overlap …. Scenario C: More than 2 weeks overlap; Less than 2 miles overlap …. Scenario D: More than 2 weeks overlap; More than 2 miles overlap ….

Q6	MS	What are the important factors other than time and space that can affect the extent/resolution of the conflicts? (Selection of multiple choices is allowed) 1. Road capacity 2. Traffic volume 3. The financial costs (adding an extra lane, rehabilitation) 4. Overlap in terms of vehicle classes 5. The possibility of using a unified platform/committee/meeting between the state and local jurisdictions. 6. Others (please specify) …...
Q7	MC & text	Do you use custom or off the shelf software/programs for detour conflict resolution? 1. Custom (please specify) ……. 2. Off the shelf (please specify) ……
Q8	MC	Can we follow-up with you for a possible interview to seek more details? 1. Yes 2. No
Q9	Text	Please use the following link to register for an interview: If the link is selected: "Thank you for your interest in a possible interview! Our team will contact you accordingly and set it up with you. Please fill out the below details for correspondence! Thanks again" 1. Name…. 2. Designation …… 3. Email…. 4. State DOT …….

* MC: Multiple Choice
** MS: Multiple Choice with multiple selections allowed

APPENDIX E. INTERVIEW QUESTIONNAIRE WITH INDOT PERSONNEL

This interview is set to follow up on the initial survey to gather more in-depth information about:

(1) The current state-of-the-practice on MOT strategies, (2) The promising performance indicators, and (3) The best practices for mapping and coordinating detours for Maintenance of Traffic, including risk management/mitigation strategy. *You can find a copy of the Survey Questionnaire as well as its link at the end of your interview questionnaire.*

Part 1: Current state of the art:

1. **What are the criteria that are currently considered for selecting the optimal detour route?**

   Further questions in this regard:

   a. Could you please share your experience for the user costs/social costs/economic costs that are included in the analysis?

2. **Is the 1996 INDOT detour policy still in use, any updates are needed?**

   If Still Used:

   a. Why do you feel it is necessary to provide an unofficial detour, when the official detour is on the state system?
   b. Are there any collaborations with the local officials for selecting the detour routes?
   c. Are there any shortcomings regarding this detour policy? What are your suggestions for addressing them?

   If Updated:

   a. What were the shortcomings of the previous detour policy? and how were they addressed?

Part 2: Expectations from this project:

3. **What is your expected outcome from the project 4405?**

   Further questions in this regard:

   a. If the new guideline for the detour is provided with several dimensions, Key performance index, and metrics, are you willing to adopt it?
   b. Are there any issues or suggestion that you want us to address in the key performance index that we are going to propose?
   c. What is your idea about selecting detour routes just for the trucks, and let people pick which route they believe will best suit their needs, rather than planning for it?

APPENDIX F. COMPARISON BETWEEN THE CURRENT PRACTICES OF INDOT IDENTIFIED FROM INTERVIEWS AND INDOT MANUALS

Table F.1 Summary of responses from the interview with INDOT members on criteria considered for detour mapping

		Consideration	
Criteria	**Identifier**	**Interview**	**Literature**
Technical	Geometry–Turning radius, shoulder width, lane width, vertical curves.	Yes	Yes
	Structural Condition–Bridges	Yes	Yes–Bridge and other structures rating.
	Structural Condition–pavement	Yes–General condition and thickness of pavement	Yes–Pavement strength, roughness, and age.
	Vertical Clearance	–	Yes–About 14 to 16 ft minimum.
	Length of detour	Yes–typically no more than 10–25 miles additional distance	Yes
	Vertical grade	–	Yes–No more than 8%
Operational	Closest parallel state route (if available)	Yes	–
	Added travel time	Yes	Yes
	Coordination–simultaneous works on detour, detour on detour.	Yes	Yes
	incident management	Yes–Traffic Management Plans (TMP)	Yes–TMP, MOT
	Local access	Yes–Emergency services (fire, police, medical, etc.)	Yes–Local traffic (public events, school, emergency, business)
	Convenience features	–	Yes–Presence of rest/fuel stations on detour route
Financial	User Costs	Yes–Fuel, time delay ($ 16/hr.)	Yes–Vehicle operating costs
	Compensation to locals	Yes–An average reimbursement is used	Yes–Cost of retrofitting or upgrading sections on detour route.
Safety	Crash risk for pedestrians	Yes	Yes
	Crash rates	Yes	Yes
	Severity of crashes	Yes	–
	Crash risk for workers	Yes	Yes
	Intersections	Yes–Analysis of traffic, as well as appropriate signals, and signing	Yes–appropriate signage on detours
Environmental	Local pollution	Yes	Yes–Increased emissions due to potential intermittent driving conditions on detour

	Environmental cost	Yes	Yes–Sensitive ecosystems, etc.
Social	Community outreach/acceptance	Yes–Public information meetings	Yes–Public information meetings
	Local/commuter traffic	Yes–Small percentage of commuter traffic not using the official detour	–
	Access to businesses, schools, etc.	Yes	Yes
	Noise pollution	Yes	Yes
Unofficial detour route	Chosen by the local agencies, putting constraints on local authorities	Yes	–

APPENDIX G. INTERVIEW QUESTIONNAIRE WITH OTHER STATE DOTs

This interview is set to follow up on the initial survey to gather more in-depth information about the following.

1. The current state-of-the-practice on MOT strategies.
2. The promising performance indicators.
3. The best practices for Mapping and coordinating detours for Maintenance of Traffic, including risk management/mitigation strategy.

You can find a copy of the Survey Questionnaire as well as its link at the end of your interview questionnaire.
The objectives of the synthesis study on best practices for mapping and coordinating detours for Maintenance of Traffic (MOT) are as follows.

1. To identify process improvements for INDOT detour planning.
2. To identify current state-of-the-practice on MOT strategies.
3. To explore the promising identifiers (e.g., design, financial, social, safety, and management perspective) to be incorporated into developing detour plans.
4. To investigate best practices for mapping and coordinating detours for MOT.
5. To provide advanced risk management/mitigation strategy based on the best practices.

Q1. Does your agency have a detour mapping framework? (Objective: 1, 2, 4)

1. Could you please describe your agency's detour route selection approach? do you have specific checklists, excel sheets or an application or software? If yes, is it publicly available?
2. Are there certain sets of criteria that should be added (OR removed) from your agency's methodology?

Q2. Does your state DOT have a guideline for the criteria that may not have quantifiable thresholds or limits? (Objective: 2, 3, 4)

If yes:

1. Could you please provide more details about the approach proposed by your state DOT regarding the consideration of the criteria listed below?
    - Community acceptance
    - Business interruption (loss of revenue)
    - Worker safety
    - Accessibility to essential service providers (fire services, emergency response, police, …)
    - Disruption to local traffic (public events, school, business, …)

2. Based on your experience and knowledge, what are other factors that are hard to quantify? How do you deal with them?

If no (they rely on expert judgement):

1. If your DOT does not have a guideline, how do you deal with the criteria listed below? Is there some rule of thumb?

- Community acceptance
- Business interruption (loss of revenue)
- Worker safety
- Accessibility to essential service providers (fire services, emergency response, police, …)
- Disruption to local traffic (public events, school, business, …)

2. Based on your experience and knowledge, what are other factors that are hard to quantify or measure? How do you deal with them?

Q3. Based on INDOT manual, the user costs are $16/hour and $0.55/mile. Considering these costs can significantly affect the selected MOT approach for interstate closures. Could you please explain how the user costs/social costs are determined and considered in the detour selection process? (Objective: 3, 4)

1. Do you consider the same weight for the user costs and the construction costs while evaluating the alternatives for the detour route?

If Yes:

2. Has considering the user costs changed the previously selected detour route?

If No:

2. Do you use certain ratios to convert the user costs to dollar values?
   Based on your experience, could you please provide an estimate for the magnitude of the user costs compared to project's construction cost for different project characteristics? For instance, for rural or urban areas, AADT, etc.

Q4. Does your DOT have a pre-determined approach to mitigate risks encountered during the implementation of a MOT Strategy? (Objective: 4, 5)

1. What are the challenges that you have faced regarding MOT when deploying a detour route? For instance, changes to the schedule, change orders, unpredictable situations such as accidents or low visibility on the deployed detour route.

2. How do you handle the faced issues? Are there any certain committees with representatives for the state DOT and all the involved stakeholders?

APPENDIX H. SUPPLEMENTAL INFORMATION FROM INTERVIEWS WITH IOWA, MINNESOTA, AND ARIZONA STATE HIGHWAY AGENCY PERSONNEL

This section provides supplemental details and information about the findings of the interview with Iowa, Minnesota, and Arizona state DOTs. Table H.1 summarizes the criteria and sub-criteria used in the ABC-AHP decision-making tool, which is adopted by Iowa DOT to consider both qualitative and quantitative criteria.

Table H.1 The criteria and sub-criteria used in the ABC-AHP decision-making tool (adapted from IowaDOT, 2020a)

Criteria	Sub-criteria	Definition
Direct costs	Construction	Permanent structures and roadways + contractor and material availability. It may include incentive/bonus payments.
	Maintenance of Traffic	Detours' maintenance costs before, during, and after construction: including the installation and shifting of traffic control devices during staged construction
	Design and Construct Detours	Costs to design and construct temporary structures and roadways
	Right of Way	Costs to procure right of way
	Project Design and Development	Project design and development, including the bridge design
	Maintenance of Essential Services	Addressing essential service's needs: Costs to the deployment of alternate routes or modes of transportation for evacuation, emergency access to hospitals, fire stations, law enforcement, etc.
	Construction Engineering	Owner's contract administration costs
	Maintenance costs	Inspection and preservation costs of individual bridge elements
Indirect costs	User Delay	Users' delay due to reduced speeds and/or off-site detour routes
	Revenue Loss	lost revenues due to limited access to local businesses
	Freight Mobility	Freight delay due to reduced speeds and/or off-site detour routes
	Livability During Construction	Community impacts like noise, air quality, and limited access.
	Road Users Exposure	Safety risks resulted from user exposure to the work zone
	Construction Personnel Exposure	Risks resulted from worker exposure to the work zone

Schedule constraints	Calendar, railroad, utility, navigational	Impact of several factors including weather windows, significant or special events, railroad, or navigational channels
	Marine and Wildlife	Comply with marine or wildlife constraints
	Resource availability	Availability of staff to design and oversee construction
Site constraints	Bridge Span	Owner preferences about bridge span, structure type, or aesthetics
	Horizontal/Vertical Obstructions	Physical constraints such as tunnels, sharp curves or steep grades, or other urban area structures
	Environmental	Impacts on natural resources such as wildlife and vegetation
	Historical	Historical constraints of the project site
	Archaeological Constraints	Archaeological constraints of the project site
Customer service	Public Perception	This factor captures both the public's opinion regarding the
	Public Relations	Costs associated with the communication and management of public relations before and during construction.

Furthermore, the interview with three Iowa DOT engineers showed that they follow the practices summarized in Table H.2 to consider qualitative criteria in developing and implementing MOT plans. Similarly, the practice of Minnesota and Arizona DOTs with respect to addressing qualitative criteria are summarized in Table H.3, Table H.4, and Table H.5.

Table H.2 Iowa DOT practice toward the consideration of qualitative criteria in detour mapping

Qualitative Criteria	**Practice**
Community acceptance	• Public information plans • Holding regular town hall meetings • Holding meetings with the mayor of involved cities
Accessibility to essential service providers	• Coordinating the work proposed on the route when there are crashes, floods, and emergency response is needed. • The coordination also helps to prevent issues such as detouring the traffic on an existing detour route.
Disruption to local traffic (public events, school, business)	• The priority is to direct the traffic on the state; therefore, commercial vehicles are not considered in the process of detour route selection.
Worker safety	• Live incident management maps • Work zone data initiative: collecting work zone crash data

	• Crash modification factor: safety performance assessment based on inputs such as AADT, presence of a horizontal curve, lane and shoulder width, presence of rumble strips, and section length.
Road user costs	• User cost includes the costs of extra travel, and it is used in a rather indirect way to help to justify the damages. The main issue, in their opinion, was stated to be the fixed budget of the agency. They mentioned that regardless of the saved user costs, the budget of the agency is fixed, and they do not get compensated for the saved user costs so that they can use the saved money for their future projects.
Business interruption (loss of revenue)	• Accommodating access to local businesses • Local businesses are not paid • The benefits of a new road should also be considered as well. • There is a worksheet for calculating liquidated damages. Although this document is for legal purposes in case of delayed delivery of the project, it provides valuable insights about the factors that are considered in the calculation of the losses sustained by the road users and local businesses. This worksheet can be found at the following link: • https://iowadot.seamlessdocs.com/f/LiquidatedDamagesWorksheet

Table H.3 Minnesota DOT practice toward the consideration of qualitative criteria in detour mapping

Qualitative Criteria	Practice
Community acceptance	• The usage of navigation devices is common and according to the interviewees, roughly 75 percent of the commuters follow the proposed detour routes.
Accessibility to essential service providers (fire services, emergency response, police, …)	• Access for emergency vehicles like police, fire, and ambulance that are private companies in most cases should be provided to avoid legal issues.
Disruption to local traffic (public events, school, business, …)	• Preferably arranged when schools are closed. Coordinating with adjacent projects is important. Look-ahead meetings are planned every week.
Worker safety	• Pedestrians need special attention for the projects on urban areas as they tend to walk directly, following the shortest path. • Chapter 8 of the traffic manual (MnDOT, 2015) is a point of reference for mitigating the operational and safety of construction works. It focuses on thresholds for temporary traffic control and

	distance charts. To be more specific, the chapter lists suggested values for advance warning sign spacing, decision sight distance, taper length, shifting taper, typical shoulder taper, and buffer space. These thresholds are suggested for different intervals of speeds.
Road users' costs	• Even though user cost dollars are not deemed equivalent to construction dollars, user costs are considered in an indirect way by incentivizing the contractor to reduce the construction period. Based on the saved user costs, an amount between $10–25 k/day is considered as a bonus/penalty. • The amount of user costs is reported by the central office.
Business interruption (loss of revenue)	• Coordination meeting with surrounding businesses • Using black & orange signs with a relatively larger sizes for several local businesses. A maximum of 4 to 5 signs are used for the local businesses.

Table H.4 Arizona DOT practice toward the consideration of qualitative criteria in detour mapping

Qualitative Criteria	Practices
Community acceptance	1. The construction office informs the public based on the level of project significance through 511 websites.
Accessibility to essential service providers	2. The public meetings are mandatory for urban areas.
Disruption to local traffic (public events, school, business)	3. For major projects, public meetings are held to get community feedback. The time for the public meetings depends on the contract type. For instance, for design-build contracts, the meetings are held before the construction phase.
Worker safety	4. For the maintenance of traffic, they rely on the Traffic Management Plan that contains a checklist. 5. In this regard, the significance of the project and the duration of the detour route are important.

Road users' costs	6.	ADOT determines the road users' costs based on several factors for short-term and long-term projects. The factors are summarized in Table H.5.
Business interruption (loss of revenue)	7.	There is a worksheet for the calculation of user costs, which is not used by the designers, and it is only used for calculating the liquidated damages for contractual documents.

Table H.5 Factors considered in calculating the user cost

Factors	Short-Term Project (15 min–1 hour)	Long-Term Project (More than 24 hours)
Detour length	Yes	Yes
Detour travel speed	Yes	Yes
Peak hour volume	Yes	–
AADT	–	Yes
Percentage of truck traffic	Yes	Yes
Impact to business	Yes	Yes
Safety	Yes	Yes

APPENDIX I. IMPACTED STAKEHOLDERS ASSOCIATED WITH EACH CRITERION

Table I.1 shows the impacted stakeholders associated with each of the identified criteria. In this table, the stakeholder impacted by a given identifier is marked with an “x.” It is important to note that each identifier impacts everyone involved. However, the table marks only the primary impact. For example, the duration of the project no doubt impacts the community and the road users (drivers), but at the time of planning, only the agency is concerned about that. This is because as the agency plans and deliberates the detour process, they need to account if a detour is even needed in the first place. As shown in Table I.1, a detour route may not even be necessary unless the project is going to last at least seven days. Hence, Table I.1 shows that the primary impact of the duration of the project is on the agency. Nevertheless, after deployment, both the road users (drivers) and community will also be impacted. A similar reasoning can be used for the rest of the “x” marks in the table.

Table I.1 Suggested identifiers and the impacted stakeholders

	Stakeholders		
Suggested Identifier	**Agency**	**Drivers**	**Community**
Duration of project	x		x
Detour legs engaged as part of a detour for another project	x		
Official detour’s route level (state hwy, public road, local)	x		
Other projects happening in the vicinity	x		
Presence of rest/fuel stations on detour route	x	x	x
Local traffic (public events, school, emergency, business)		x	x
Length of detour	x	x	
Traffic volume	x	x	
Heavy vehicle percentage (HVP)	x	x	
Turning radius	x	x	
Lane widths	x	x	
Vertical clearance	x	x	
Pavement strength, roughness, and age	x	x	
Bridges and other structures rating	x	x	
Vertical grade	x	x	
Cost of maintaining/retrofitting detour (official and unofficial)	x		
Increase in travel time	x	x	x
Vehicle operating cost		x	
Crash risk (drivers and workers)	x	x	x
Community land use (residential, school zone, etc.)		x	x
Pedestrian crossing (non-freeway)			x
Signage on detour routes	x	x	x
Increased emissions due to potential intermittent driving conditions on detour			x
If detour route passes through wetlands or protected areas	x		x
Community impact/acceptance	x		x
Business interruption			x
Accessibility to essential service providers (business, schools, hospitals, fire stations, police stations, etc.)			x
Noise pollution			x

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

Further information about JTRP and its current research program is available at http://www.purdue.edu/jtrp.

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