

**VI. CORRIDOR TRAFFIC MANAGEMENT FOR TEMPORARY FLOW DISRUPTIONS
(Abstracts and Summaries of Recently Published Literature)**

**CORRIDOR TRAFFIC MANAGEMENT FOR TEMPORARY FLOW DISRUPTIONS
ABSTRACTS AND SUMMARIES OF RECENTLY PUBLISHED LITERATURE**

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Introduction

This document contains an annotated summary of literature pertaining to Corridor Traffic Management for Temporary Flow Disruptions and the development of a Corridor Reconstruction Project Evaluation Process (CRPEP). This document was prepared under Contract DTFH61-85-C-00152 for the Federal Highway Administration by GAI Consultants, Inc. and Carnegie Mellon University.

This review includes abstracts and summaries of literature pertaining to the five major topical areas being addressed by this study. These articles and reports have not been categorized into separate sections according to these topics for purposes of this annotated bibliography. Forthcoming reports from this project will provide state-of-the-art reviews of information obtained on the corridor reconstruction project evaluation process from the literature identified in this review and from interviews and site visits performed as a part of this research.

The topics being addressed in this study and to which the following literature pertains are:

1. Reconstruction Techniques and Scheduling

- . Shoulders
- . Bridge Decks
- . Bridge Structures
- . Drainage
- . Scheduling

2. Traffic Accomodation Strategies

- . Highway Capacity Changes
- . Preparations for Travel Impacts
- . Construction Zone Traffic Control
- . Alternative Routes
- . Special Travel Strategies
- . Public Information Programs

3. Construction Quality Issues

- . Construction
- . Special Materials

- . **Vibration and Early Loading Effects**
 - . **Material Delivery**
 - . **Quality and Performance of Labor Force**
 - . **Contract Administration**
- 4. Travel Impact Evaluation Procedures**
- . **Modal Impacts Surveys**
 - . **Sampling and Monitoring Techniques**
- 0 Impact Forecasting Techniques**
- 5. Reconstruction Project Management Teams**

Annotated Bibliography

- [Abel83]** Abel, Brown, Donnelly, O'Connor, Peterson and van den Bos. Rehabilitation of Concrete Pavements. Technical Report CDOH-R-83-a. Colorado Department of Highways and the Federal Highway Administration. 1983.

Summary: A project panel was established to provide guidelines for the rehabilitation of concrete pavements in Colorado. Techniques used by other state highway agencies were compared to the type and severity of concrete pavement distress observed in-state. Representatives from the concrete and asphalt pavement paving organizations were also invited to provide input to the study. Suggested methods are provided to renew the design life of deteriorated concrete pavements. Alternative methods of construction from which to choose are included along with examples for comparing life cycle costs.

- [Ahern83]** Ahern B.G. Variations and Claims in Construction Contracts. Australian Road Research Board. 1983.

Summary: In a construction contract, changes to the originally defined work, conditions and payment can be made as a "variation." Contractors may also claim for additional payment for producing the originally intended finished product under conditions different to that conceived at the time of tender. The greater number and value of the changes to the originally defined work and conditions the less desirable contract work becomes for both parties: owner and contractor. In order to assess the relative significance and effects of variations and claims, objective information was gathered on a number of recent civil engineering contracts within a typical public authority. Direct additional payments for variations and claims totalled almost 10 per cent in the sample of contracts researched. The majority of variations or claims were caused by events which were theoretically preventable, that is, were initiated prior to acceptance of the contractor's tender. Many measures can be taken by the owner to either prevent or control the effects of variations or claims: adequate site investigation; thorough preparation of documentation; realistic tendering requirements; accurate recording of events; awareness and impartiality of superintending staff; and distinction of the real issues in dispute will permit lower overall costs and shorter times for completion in construction contracts.

- [Ahmed86] Ahmed S.A. Urban Freeway Traffic Management Technology. *Journal of Transportation Engineering/ASCE* 112, 369-379. 1986.

Abstract: This paper presents an overview of current management techniques that are aimed at improving the efficiency and productivity of urban freeways. The major topics that are addressed include capacity management techniques (entrance ramp control, mainline control, corridor control and priority control); demand management techniques (peak period dispersion, ridesharing and improving public transit); and techniques of managing nonrecurrent congestion (traffic surveillance systems, servicing, and motorist information systems).

- [Allen831 Allen R. Georgia's Low-Cost Approach to Rehabilitating Concrete Pavements. *Civil Engineering/ASCE* magazine. August 1983.

Summary: The state of Georgia has been wrestling with the problem of how to efficiently rebuild and repair its interstate concrete pavements since the early 1970's. And its Department of Transportation has launched a cost-effective approach to pavement maintenance - known as *concrete pavement restoration* (CPR) - that other states and even local highway departments may learn from. Here's a six-step approach to rehabilitating concrete pavements that the state of Georgia is currently using to rehabilitate its interstate highways. Other highway departments may find some useful lessons here.

- [Anderson83] Anderson R.B. and Hendrickson C.T. Study of Alternative Transportation Strategies During Reconstruction of the Parkway East, I-376, Pittsburgh, Pennsylvania: Executive Summary. Prepared for the Pennsylvania Department of Transportation and the Federal Highway Administration. 1983.

Summary: Many metropolitan areas will require urban highway reconstruction in the next decades, with a potential for severe traffic disruption. This report presents results of the study of a multi-modal approach to mitigate traffic disruptions during reconstruction of a 6.5-mile section of the Parkway East (I-376) in Pittsburgh, PA. This experimental application of mitigation strategies was proposed by PaDOT, funded by the FHWA, and monitored during the 2-year construction period. Traffic was restricted to one lane each direction, March through October each year. In all, over 80,000 fewer vehicles/day entered the Parkway East reconstruction zone, where closure of most entrance ramps required alternate route usage.

To reduce negative effects of congestion delays and adverse community impacts, several people moving strategies were implemented a new commuter train, third-party vanpool program, high occupancy vehicle (HOV) ramps, new park-and-ride lots, new express bus service, and traffic operation improvements on local streets. Study of these alternative transportation strategies included pre-, during- and post-construction measurements of traffic characteristics, strategy usage, and user responses; an evaluation of strategy effectiveness; and suggestions for applications to future projects.

[Bryer84] Bryer T.E. Risk Management Analysis: Highway Maintenance Operations. *Transportation Research Record* 979, 20-24. 1984.

Abstract: Tort liability is a growing concern to transportation agencies. Pennsylvania lost sovereign immunity in 1978 and to date has experienced a considerable number of claims for damages due to alleged negligence. An analysis of the claims indicates that approximately 75 percent or more relate to maintenance operations. In-depth discussion of specific cases between attorneys defending the Pennsylvania Department of Transportation and its engineers yielded a number of strategies relating to maintenance operations that can reduce exposure to future suits. Those elements specifically addressed include complaint recording and processing, sign deficiencies, low shoulders, icy spots, potholes, and guide rail repair.

[Byrd85] Byrd, Tallamy, MacDonald and Lewis. *Techniques for Reducing Roadway Occupancy During Routine Maintenance Activities. National Cooperative Highway Research Program Report No. 161.* Washington, D.C. 1985.

Summary: Highway maintenance activities often require occupancy of traffic lanes, structures, and shoulders of the roadway by men and equipment. This situation causes conflict between these activities and the traveling public, thus endangering both workmen and motorists and restricting the flow of traffic. The resulting development of hazardous situations and interference with the orderly flow of traffic is most pronounced where high-speed and/or high-density traffic conditions exist. There are several possible approaches to minimizing the problem and to providing a high level of safety, economy, and convenience for the highway user during required maintenance activities. At this time, utilization of techniques designed to reduce occupancy of the roadway by maintenance activities appears to offer potential for alleviation of the problem with least duplication of research efforts.

The objectives of this project were to identify and evaluate techniques that will significantly reduce the time of occupancy of the highway travel way and shoulders by maintenance forces for at least the following specific routine maintenance activities:

1. Bridge deck repairing.
2. Travel Way patching.
3. Crack and joint sealing.
4. Mudjacking and subsealing.

Techniques for accomplishment of maintenance activities were intended to encompass the entire operation, including the necessary manpower, equipment, and materials. However, development of new materials or equipment was not considered to be within the scope of this study.

[Carrier831 Carrier R.E., Hendrickson C.T. and Anderson R.B. Planning to Reduce Traffic Disruption During Urban Highway Reconstruction - Lessons from the Pittsburgh Experiment. Presented at the 62nd Annual Meeting of the Transportation Research Board, Washington D.C. 1983.

Abstract: Reconstruction of urban expressways will be required in many metropolitan areas in the next decades. These reconstructions have the potential for severe traffic disruption since many expressways are critical traffic routes. This paper describes a multi-modal approach to mitigate traffic disruptions implemented during the reconstruction of a 6.6 mile section of the Parkway East (I-376) in Pittsburgh, PA. This experimental set of mitigation strategies was proposed by the Pennsylvania Department of Transportation, funded by the Federal Highway Administration and closely monitored during the two year reconstruction period. Some implications from the "Pittsburgh Experiment" for planning of mitigation strategies in future projects are presented.

[CC83] Repair and Rehabilitation: Converting a Bridge Crisis into a Bridge Opportunity. *Concrete Construction* magazine. 1983.

Summary: The paper deals with the repair and rehabilitation of historic Westinghouse Bridge by vertical deck supports and presents recommendations for bridge concrete maintenance.

[CEJuly85] **Biggest Highway Rebuild.** *Civil Engineering/ASCE* magazine. July 1985.

Summary: The section of Wisconsin I-90 and 94 from Madison extending 32 miles north to Portage is one of the more heavily traveled rural Interstate segments in the region. In its 23 years the old pavement carried three times the number of heavy truck axle loads it was designed for, so it was not surprising to find serious deterioration. Of the 32 miles, four miles had been constructed of continuously reinforced concrete pavement (CRCP). It was 8 inches thick and continued to perform well. The other 28 miles was 9 inch concrete with mesh reinforcement and dowel joints every 80 feet. Since the CRCP section was behaving nicely, it was decided to save that section but rip out all the mesh and dowel mileage, and replace it with CRCP pavement 10 inches thick.

Most concrete aggregate on the job is recycled, old concrete pavement, crushed to meet size specs. This was the nation's largest such project when constructed. All pavement reinforcing steel is epoxy coated. This is the first use of epoxy rebars in CRCP and represents the nation's largest epoxy rebar project. Despite all the firsts, the number one concern of Wisconsin DOT was maintaining traffic during construction - while the third lane was being added and the two existing lanes in each direction were being replaced or overlaid. Experience dictated that two traffic lanes in each direction must be kept open during the critical weekend periods when vacation traffic is heaviest.

[CEJuly84] **Redecking with Special Asphalt Saves Time, Material and Money.** *Civil Engineering/ASCE* magazine. July 1984.

Summary: Dookers Hollow Bridge in North Braddock, Pennsylvania, was redecked last November with an asphalt mix that saved Allegheny County \$100,000, another days labor, and formed a one-inch waterproof/wearing surface, eliminating two inches in overlay material.

[Chong81] **Chong G.J., Phang W.A. and Jewer F.W. Choosing Cost-Effective Maintenance.** *Transportation Research Record 800*, 41-49. 1981.

Abstract: A project is described that was conducted under the Pavement Maintenance Strategies Task Force of the Ontario Ministry of Transportation and Communications. Its objectives were (a) to develop guidelines for corrective pavement maintenance to be used by maintenance patrol staff that

suggest a method for evaluating pavement distress and the appropriate cost-effective and practical maintenance treatment alternative and (b) to conduct a pilot test of the developed guide to verify the procedures to be carried out in full later. The guidelines were developed from existing standards for pavement maintenance quality and related management systems data combined with the judgment of individuals experienced in the fields of pavement design and evaluation, construction, and maintenance. Emphasis was on the collection of subjective performance data on various maintenance treatments through personal interviews with experienced maintenance personnel. This material was incorporated into a working copy of the pavement maintenance guidelines. The pilot test was based on the working copy and a combination of an audiovisual presentation and individual instruction of selected maintenance patrol staff. This was followed by a return visit to patrols for interviews to obtain comments on the usefulness, ease of use, and validity of action levels described in the guidelines. The pilot test was conducted in 14 patrols in the five regions of the province. The results obtained confirmed that the working copy of the pavement maintenance guidelines could, with some minor change, be adopted for full use in the province.

[Darter81] Darter M.I. Patching of Continuously Reinforced Concrete Pavements. *Transportation Research Record* 900, 12-17. 1981.

Summary: The increasing amount of patching of continuously reinforced concrete pavement (CRCP) in Illinois has led to the need for procedures that are more cost-effective. Existing procedures evolved from the expensive repairs of CRCP sometimes required by the contractor to remedy errors made during new construction. CRCP is perhaps the most difficult and costly type of pavement to patch because of the unique design characteristics (e.g., continuous steel and closely spaced cracks).

This paper presents recommendations for permanent repair of localized distress in continuously reinforced concrete pavements in Illinois. Recommendations for cost-effective patching are provided for selection of patch boundaries, sawing of the concrete, removal of concrete, replacing and splicing the reinforcing steel, preparing the patch area, placement of concrete, and curing of the patch until the area is reopened to traffic. These procedures have been validated through extensive field testing. The procedures reduce costs and lane-closure time by :

- 1, adapting the patch size and type to fit the distress
2. reducing reinforcement embedment length into the patch
3. using mechanized equipment for construction
4. using concrete additives and curing techniques to facilitate early reopening to traffic.

[Denney84] Denney R.W., Jr. and Levine S.Z. Developing a Scheduling Tool for Work Zones on Houston Freeways. *Transportation Research Record* 979, 7-11. 1984.

Abstract: In Houston the condition of the existing highway network has deteriorated at a far greater rate than can be maintained without affecting traffic severely or endangering the safety of maintenance crews. Consequently, traffic managers have been required to use special techniques, such a real-time traffic control, to maintain an acceptable traffic flow around urban highway maintenance operations during weekday daylight hours. These innovative traffic control strategies require scheduling and planning procedures that have not heretofore been available. The development of just such a scheduling and planning tool is described. The concept of active traffic management in work zones is presented along with a description of a work-zone strategy computer analysis model called Queue and User Cost Evaluation of Work Zones (QUEWZ). A pilot freeway section is used to provide a data base for the development work, and special mapping procedures are used to convey the results of the analysis to traffic managers in Houston.

[Elkins81] Elkins G.E. and McCullough B.F. Precast Repair of Continuously Reinforced Concrete Pavement (*Abridgement*). *Transportation Research Record* 500, 9-12. 198 1.

Abstract. An initial investigation into the applicability of repairing continuously reinforced concrete pavement (CRCP) by using precast repair slabs is described. To maintain continuity in the longitudinal reinforcement of CRCP, steel connections at the ends of the repair slab are the critical part of this repair technique. These connections may be made by welding, clamping, or use of commercial rebar connectors. Polymer concrete is a fast-setting material that has excellent properties as a cast-in-place repair material for use around these steel connections. Calculations of volume change indicate the possible development of excessive steel stresses at these connections on slabs longer

than approximately 7 ft. (2.13 m). This is attributed to the restraint of the concrete after its development of sufficient tensile strength that resists the normal cracking, which occurs early in the age of newly constructed CRCP. The use is postulated of a weakened plane situated in the center of the slab to cause the concrete to fracture before excessive steel stresses develop.

[ENRmay84] Golden Gate is Redecked at Night. *Engineering News Record*, May 1984.

Summary: The \$52.5-million project to replace the deteriorated concrete deck and steel stringers of the Golden Gate Bridge - while traffic keeps moving - is a nightly exercise in precision, with severe penalties for any misstep. Between 8:00 p.m. and 5:30 a.m. every weekday night, the contractor typically removes three 10 x 50 ft. roadway sections - half of the 60 ft. wide deck - along with the adjacent sidewalk. In their place it installs two prefabricated, steel orthotropic plate panels and a precast lightweight-concrete sidewalk section. The original 7 inch concrete deck and 24 inch deep stringers and diaphragms on the on the 47 year old bridge are being replaced because of extensive corrosion caused by salt-laden fog that envelopes it almost daily.

[ENRoct85] Space, Deadlines Tight on Highway Reconstruction. *Engineering News Record*, October 3, 1985.

Summary: Since last March, contractors in the Philadelphia area have been pushing to rebuild two sections of the Schuylkill Expressway, spurred on by traffic sliding past a few feet on each side of their jobs as well as severe incentive-disincentive clauses in their contracts. The 18-mile project on the 20-mile expressway built 30 years ago and now part of Interstate 76, runs from the Pennsylvania Turnpike down to south Philadelphia. The four to eight-lane route is one of the busiest in the country. Mergentime's \$14.4-million contract with Pennsylvania's Department of Transportation (PennDOT) includes redecking three structures and concrete overlay of four others. It also includes a hefty \$21,875-per-day incentive-disincentive clause for beating or missing the deadline.

A joint venture of IA Construction Corp., Concordville, Pa., and Buckley & Co., Inc., Philadelphia, is reconstructing 4.8 miles of the expressway running from the Pennsylvania Turnpike to Interstate 476. IA-Buckley's \$26.9-million contract includes construction of a collector-distributor road to handle U.S.

Route 202 traffic and has a \$30,000-per-day incentive-disincentive clause to complete the work by Nov. 26. For IA-Buckley's project manager, A. Charles Larkin "the most serious problem is dealing with and maintaining traffic as we work." His workers have installed 35,000 ft. of temporary barriers to direct traffic away from construction. With heavy traffic, it takes longer to get material in or to move equipment from one location to another. Larkin, who has been building highways for 40 years, is critical of the incentive-disincentive clause, "The extremely tight time schedule adds a burden. Everybody is worried about being late. You get paranoid if a load of rebars is an hour late." He adds that the penalty clause limits flexibility.

During early stages of the \$175million project, there was concern that the disincentive clauses would scare off bidders on some of the jobs (ENR 3121 p. 47). Larkin says that because contractors built in a lot of overtime to squeeze work into one season, the expressway could have been reconstructed at a lower cost if contracts had been let as two-year jobs. But he adds that he can't criticize PennDOT for letting the contracts for one-season jobs to limit disruption to motorists. Because of the importance of the route to area commuters, the state will stick with its strategy. In January, Perini Corp., Framingham, Mass., will begin work on a 3.1-mile section of the expressway. Its \$38.3-million contract has a \$30,000-per-day incentive-disincentive clause with a Oct. 27, 1986, deadline. PennDOT expects to advertise the two final sections of the project, estimated at \$21 million and \$42 million, over the next two months. They too will carry significant incentive-disincentive clauses.

All in all, Robert L. Rowland, PennDOT district engineer, is pleased with the way the job is going. He is particularly relieved that some of predicted traffic snarls never materialized. He credits the lack of problems to good communications with the public and the closure of all on-ramps into work areas - a procedure learned from similar projects around the country.

[ENRsep85] Reconstruction Demands Traffic Control Savvy. *Engineering News Record*, September 19, 1985.

Summary: Work is nearing completion on rehabilitating Massachusetts' Southeast Expressway, a 8.5-mile section of Interstate 93 between Boston and the state's southern shore. The project so far has combined responsive traffic-control techniques with quick troubleshooting to ensure smooth progress

on the state's largest road contract ever. The six-lane expressway was originally designed to handle 75,000 vehicles per day. Commuters from the rapidly growing southeast corner of the state swelled traffic, and breakdown lanes became through corridors during rush hours. Those lanes did not cross bridges, creating safety problems and horrendous traffic jams. Volume climbed to 150,000 vehicles daily by 1983.

The rehabilitation that began in March, 1994, requires working around a traffic management program that keeps two lanes open in each direction at all times, plus two more in morning and afternoon peak hours. Michael D. Meyer, director of Massachusetts Department of Public Works' bureau of transportation and planning, says over \$10 million of the project cost is earmarked for traffic control alone, DPW is also spending more than \$10 million for public information programs, police support, bus route subsidies and parking facilities to smooth overall traffic flow.

Reconstruction was halted during the winter months. But after having driven for five winter months on rebuilt north-bound lanes, and the poorer but open four southbound lanes, traffic volume stayed strong with the second stage of reconstruction opened last April. Included in the contract were "crash trucks" designed to absorb the impact from cars that might stray into lanes used by construction vehicles. These "articulated trucks" were positioned behind barrels in areas where Jersey barriers were not practical, a DPW spokeswoman said, to protect work crews and to minimize damage in the event of a collision. "It's a credit to our crews' rapid repair work and also our good luck that we had no tragedies," says DPW's Meyer. He says traffic management during highway reconstruction requires an ability to analyze causes of unforeseen disruptions and to take quick action. "After a major truck accident caused substantial delays during an evening's rush hour, we received considerable pressure to ban trucks from the expressway," he recalls.

[FHWA84] Federal Highway Administration. Planning and Scheduling Work Zone Traffic Control. U.S. Department of Transportation. Washington, D.C. October 1981.

Summary: Selecting the appropriate traffic control strategy and developing the plans and specifications required to implement that strategy are two distinctly different activities. They are, however strongly interactive. The attention in the past has been focused on the field installation and traffic control plan

development aspects of the work zone. Consequently, existing guidelines and procedures pertain primarily to the applications of various delineation devices and signs as they relate to traffic and roadway characteristics.

While there have been some discussions of the factors that should be considered in selecting the traffic control strategy to be implemented, there are only limited and poorly structured procedures available for evaluating the costs and consequences of the various alternative strategies. The selection of the traffic control strategy is mostly based on subjective judgment of experienced engineers.

The primary objective of this User's Guide is to provide highway agency decision makers with analytical procedures and decision methodologies that can be used in the early planning and design stages of a long-term major street or highway project in order to select the most appropriate traffic control strategy to be implemented. The process should assist in formulating decisions regarding the type of work zone (lane closure, detour, cross-over, etc.) which is most cost-effective for the reconstruction project.

[FHWA82a] Federal Highway Administration. **FEDERALLY COORDINATED PROGRAM OF RESEARCH AND DEVELOPMENT IN HIGHWAY TRANSPORTATION**, Annual Progress Report, Fiscal Year 1982. Category 6 - Improved Technology for Highway Construction. U.S. Department of Transportation. Washington, D.C. 1982.

Summary: This is the annual progress report for fiscal year 1982 on the Federally Coordinated Program of Highway Research and Development Category 6, improved Technology for Highway Construction. It contains information on the following Projects: 6C, Use of Waste as Material for Highways; 6D, Structural Rehabilitation of Pavement Systems; 6E, Rigid Pavement Systems Design; 6F, More Significant and Rapid Test Procedures for Quality Assurance; 6G, Performance-Related Specifications for Highway Construction and Rehabilitation; 6H, Methods of Construction; 6I, Construction Personnel; and 6J, Construction Management.

[FHWA82b] Federal Highway Administration. **FEDERALLY COORDINATED PROGRAM OF RESEARCH AND DEVELOPMENT IN HIGHWAY TRANSPORTATION**, Annual Progress Report, Fiscal Year 1982. Category 7 - Improved Technology for Highway Maintenance. U.S. Department of Transportation. Washington, DC. 1982.

Summary: This is the annual progress report for fiscal year 1982 on the Federally Coordinated Program of Highway Research and Development Category 7, Improved Technology for Highway Maintenance. It contains information on the following: Project 7A, Improved Highway Maintenance Practices, and Project 7C Maintenance Management.

[FHWA84] Federal Highway Administration **Construction Handbook on PCC Pavement Rehabilitation**. U.S. Department of Transportation. Washington, DC. 1984.

Summary: This handbook is primarily intended to assist the Federal Highway Administration area engineers when they make highway construction inspections. It can also be used when reviewing specifications, and special provisions during the PS&E stage of a project. It is a companion to the design oriented Federal Highway Administration notebook entitled *Techniques for Pavement Rehabilitation*. Information contained herein is a guide and is not intended as a standard. State highway agencies should use or develop their own specifications. The information in this handbook was selected from current reports prepared by the Transportation Research Board under the National Cooperative Highway Research Program, Michael I. Darter of the University of Illinois, the Portland Cement Association, the American Concrete Pavement Association, and several State highway agencies. Most of the tables and figures contained in this handbook were duplicated from the reference reports. The number of different rehabilitation techniques covered in this handbook are limited at this time. However, the handbook will be expanded to include additional construction techniques for rehabilitating rigid and flexible pavements. The technical guidelines and recommendations have been prepared to reflect the views and opinions of the Federal Highway Administration Construction and Maintenance Division.

- [GAO84] General Accounting Office. Greater Use of Value Engineering has the Potential to Save the (DOT) Millions in Construction Costs. Report to the Secretary of Transportation, General Accounting Office. November 2, 1984.

Summary: The Department of Transportation (DOT) provides billions of dollars each year for federal aid and/or direct federal construction in highways. This report discusses and demonstrates the potential of Value Engineering to reduce costs and the extent that it is currently used in DOT administration with major construction programs.

- [Gruver83 Gruver J. and Reulein W. Estimating the Impacts of Changing Highway Conditions. *Transportation Research Record 940*. 1983.

Abstract: A discussion of the Highway Performance Monitoring System (HPMS) is presented. The analytical package is a series of computer models designed to use the annually updated HPMS sample inventory data to estimate needs, determine the relationship between highway investments and highway performance, and assess the benefits and costs associated with various investments. The models express highway performance in terms of sufficiency indexes, vehicle operating costs, fuel consumption, and overall running speed. This system-level planning tool is described and examples of the data output are given. Investment performance curves are presented to illustrate the consequences of different investment levels. Although it is concluded that the current analytical package is useful for assessing the effects of future investments on future system performance, there is a need to bring this package together with economic analyses and econometric forecasting tools to permit economic impact analyses of various sectors of the economy, including highway users and industries. As the predictive ability of the models improves, the ability to estimate the costs and benefits of alternatives will improve.

- [Haggerty83] Haggerty P. Maintaining a Continuous Flow. *Surveyor*. 1983.

Summary: Surrey county council are considering methods of carrying out a continuous maintenance commitment to cover its responsibility for a total of 80 miles of motorway when the M25 is completed. The author uses experience gained from maintenance on the M3 motorway to discuss the pre-contract decisions that need to be made as well as the policing arrangements. The police should be involved in very detailed investigations which have to be

made into possible alternative routes. On the M3 work, the police set up a self contained incident center on site which was manned 24 hours a day and acted as a base for the breakdown recovery and sign crews. Separate contracts were given for vehicle recovery and traffic engineering; the sub-contractor for recovery was required to be a member of the Association of Vehicle Recovery Operators. Temporary site access for contractors vehicles was from adjacent roads. Major motorway maintenance required consultation, discussion and agreement of temporary traffic arrangements; the work is different from either routine maintenance or new construction.

[Harrison831 Harrison I. and Parker B. Keeping the Traffic Moving. Presented at the 1 lth Annual Summer PTRC Meeting. Sussex, England. 1983.

Summary: Over the past few years there has been increasing emphasis on reconstruction of the nation's motorways and major trunk roads, as a result of traffic growth and greater axle loading. With long queues and delays caused by carriageway closures, effective management of traffic flows during maintenance was seen to be of great importance, and the design of traffic management systems for major motorways has gradually been refined, to maximize capacity and reduce safety hazards. However, severe congestion still occurs, particularly at the more difficult sites where there is inadequate capacity and poor alternative routes; the public image of highway maintenance is still at rock bottom. In many ways, the difficult schemes are not the major motorways, but dual 2 lane motorways and heavily trafficked trunk roads, where there is often inadequate carriageway width available to maintain existing traffic flows during reconstruction. Under these circumstances, the traffic management schemes can become very complex, involving many separate stages and perhaps the construction of additional sections of carriageway in order to retain movements at junctions. Based upon the experience of such reconstruction schemes on M2, M20 and A2 the authors will detail the approaches adopted in kent to keep the traffic moving. They will draw conclusions on the cost, and effectiveness of such complex traffic management systems, and will comment on the standards of signing, coning and markings used.

- [Hendrickson82] Hendrickson C.T., Carrier R.E., Dubyak T. and Anderson R.B. Traveler Responses to Reconstruction of the Parkway East (I-376) in Pittsburgh, PA. Presented at the 61st Annual Meeting of the Transportation Research Board, Washington D.C. 1982.

Abstract: Reconstruction of urban expressways will be required in many metropolitan areas in the next few decades. This paper summarizes traveler responses to a reconstruction project on the Parkway East (I-376) which normally serves 84,000 daily vehicle trips in Pittsburgh, PA. Information is derived from volume counts vehicle occupancy observations, travel time measurements and traveler survey responses. The major responses observed were in route choice and in departure time decisions. Modal diversion did not occur to any substantial degree despite transit service improvements. The roadway system in the Parkway corridor generally accommodated a major change in traffic patterns without substantially increased levels of congestion.

- [Hirten84] Hirten J.E. Managing Capital Projects. *Traffic Engineering and Control* 38. 1984.

Abstract: The growing cost and complexity of capital investment projects, when improperly managed, can jeopardize their success. Time and cost overruns on major public construction projects are the results of decisions made during planning and design, coupled with untimely management response to problems arising during construction. Better management control of project planning, scheduling and organization are essential. Examples are given of new transit projects and of other municipal and state projects. The dealing with potential problem areas, critical in managing a successful project, is sometimes called risk management. Risk programs should be implemented during the design review process. Another technique is value engineering, a function-oriented process that focuses on the function of the product, its methods and process, in order to produce the same item at lower cost. Good project and construction management includes (1) setting of goals and objectives; (2) clarifying delegated decision-making; (3) instituting effective internal communication; (4) adopting realistic policies and procedures; (5) timely securing of funding; (6) instituting management information systems; (7) carrying out risk management; (8) developing cost estimating and scheduling systems; (9) ensuring effective designs; (10) anticipating land and right-of-way needs for early acquisition; (11) designing and implementing "wrap up" insurance; (12) instituting value engineering and risk mitigation.

- [Janson86] Janson B.J., Thint S.P.T. and Hendrickson C.T. Validation and Use of Equilibrium Network Assignment for Urban Highway Reconstruction Planning. *Transportation Research 20A*, 61-73. 1986.

Abstract: The need to rehabilitate interstate highways and bridges will increase tremendously in the next decade. Due to traffic restrictions imposed during construction, these rehabilitation activities will cause major disruptions in existing traffic patterns. In order to develop mitigation strategies to reduce such travel impacts, reliable forecasts of likely travel pattern changes would be beneficial. In this paper, we examine the suitability of using an equilibrium traffic assignment model to predict the impacts of a major highway reconstruction project. A case study of travel impacts during reconstruction of I-376, the Parkway East, in Pittsburgh, Pennsylvania is made to validate the adequacy of the network assignment model. Results are compared with actual volume counts collected during periods with and without traffic restrictions. The model produced estimates of link volumes that were, on average, from 46% to 28% different from the observed link counts along two screenlines. Large discrepancies with some of the counts could be explained in part by aberrations in the observed data or in the network model's structure. A sketch planning analysis is also performed, and the results are compared with those from the network assignment model. The network assignment model is also used to predict the impacts of a hypothetical reconstruction scenario in which the Parkway East is totally closed during its reconstruction.

- [Johnson84] Johnson E. and Rossman R. Value Engineering Contract Provisions on Federal-Aid Construction Projects. Federal Highway Administration, Washington, DC. December 1984.

Abstract: The FHWA Value Engineering program began with the passage of the 1970 Federal-aid Highway Act. Since that time the FHWA has encouraged State highway agencies to incorporate Value Engineering Contract Provisions (VECP) into their Federal-aid highway construction projects. As a result VECP's have been developed by over 30 State highway agencies for use in their construction contracts. The purpose of this study is to determine if the Federal-aid Highway Program is receiving the maximum benefits from the use of VECP's in Federal-aid construction contracts.

This report makes several recommendations to State highway agencies, contractors and the FHWA which should increase the use of VECP's and improve the review and acceptance process of contractor proposals.

- [Kuo85] Kuo N.M. and Mounce J.M. Operational and Safety Impacts on Freeway Traffic of High-Occupancy Vehicle Lane Construction in a Median *Transportation Research Record 1035, 58-65. 1985.*

Abstract: In this paper are presented the results of a study by the Texas Transportation Institute to evaluate the operational and safety impacts associated with the retrofit construction of an authorized high-occupancy vehicle lane in the median of the Katy Freeway (I-10W) in Houston, Texas. Because the Katy Freeway transitway is the first of a 70-mile network of transitways to be retrofitted in an existing high-volume freeway cross section in Houston, it is important to assess the traffic impacts associated with this type of construction. Operational impacts studied include travel speeds as a measure of travel demand served, and lane distributions as a measure of driver reaction to reduced lane widths and restricted lateral clearances. Safety was assessed through an analysis of reported accidents associated with various work area segments and time periods of construction. Results indicate that a detailed traffic control plan can minimize the possible adverse effects of transitway construction.

- [Lee83] Lee D.B. Evaluation of Urban Transportation Capital Investment Projects. Technical Report. Urban Mass Transit Administration. Washington, DC. 1983.

Summary: Evaluation of capital investment alternatives should encompass assessments of efficiency, effectiveness, and equity. This report approaches the definition, interpretation, and application of these concepts. Issues covered relate to user and non-user benefits, measurement techniques and principles, evaluation techniques, relationship of evaluation to goals and objectives, and relative strengths and weaknesses of the various types of assessments. More attention is paid to the question of efficiency - the selection of projects that maximize net social benefits - and the benefit-cost framework in particular, than is typical in current professional practice. One reason for this is that the concepts of benefit-cost evaluation appear to be both poorly understood and misunderstood, with the result that efficiency analysis has not been applied as insightfully as it might be in project planning. Another reason is that the transportation planning field has been searching for an organizing framework with which to make sense out of the welter of impacts, objectives, and interests that typically surround urban transportation project decision making, and the benefit-cost rubric is capable of supplying

that framework. Finally, the content of investment decisions has shifted from a problem of spatially allocating an externally determined amount of new capacity, to a problem of fine-tuning a future transportation system that is no longer expanding. It is thus important to be clearer about what is wanted and what is expected from urban transportation investments, and to know better the real costs and benefits of investment alternatives. Various kinds of effectiveness analysis are also needed, and will continue to serve an essential purpose in helping to choose among projects, but less guidance is needed in this area because the state of professional practice' is close to the state of the art.

[Leisch83] Leisch J.E. and Associates. Planning/Design Features and Case Studies in Freeway Reconstruction, Part I. *ITE Journal* 53. 1983.

Abstract: A primary reconstruction feature of the freeway proper embodies the strengthening or replacement of the traveled way pavement, usually in combination with widening to increase the number of traffic lanes and to provide adequate and continuous shoulders. An important goal in this process is the need to maintain traffic along the freeway with little reduction in travel speed and capacity. Also of significance is the objective to accomplish the improvement within existing right-of-way with only occasional taking of adjoining property, and to confine traffic movements and construction operations within such right-of-way.

[Levine84] Levine S.Z. and Kabat R.J. Planning and Operation of Urban Highway Work Zones. *Transportation Research Record* 979, 1-6. 1984.

Abstract: Three problems are encountered in the planning and operation of work-zone activities: the optimum time to perform the work, the measures to take to warn the public, and the alternative means to protect the highway workers from errant motorists. These three problems become extremely critical in a rapidly growing urban environment such as Houston, Texas. The Houston District Office of the State Department of Highways and Public Transportation has embarked on a threefold campaign to handle these problems better. This consists of developing innovative work-oriented measures and public--oriented measures and the establishment of a special traffic-handling crew to aid in the planning and operation of urban highway work zones. The success of these programs is imperative in light of the increased maintenance problems created as existing freeways deteriorate further.

- [Lutz84a] Lutz J.G.; and Scalia D.J. Deck Widening and Replacement of Woodrow Wilson Memorial. *Journal of Prestressed Concrete Institute* 29. 1984.

Abstract: Several innovative construction techniques were used in replacing the deck of the Woodrow Wilson Bridge with lightweight precast concrete deck panels. Rehabilitation was completed 8 months ahead of schedule, \$6 million under budget, and without disrupting the flow of traffic. The paper discusses the project in terms of traffic maintenance, design of the replacement deck system, precast concrete deck panels, polymer concrete applications, panel fabrication, and construction operations.

- [Lutz84b] Lutz J.G. Woodrow Wilson Memorial Bridge, Washington, DC.; Concrete Deck Reconstruction. *Transportation Research News/TRB* No. 111. 1984.

Summary: After 20 years of heavy traffic and exposure to deicing chemicals, the Woodrow Wilson Memorial Bridge, which spans the Potomac River south of Washington, D.C., was in such poor condition that motorists were reluctant to drive on the bridge. The deck obviously had to be replaced; however, about 125,000 vehicles cross the bridge each day and closing it to traffic, even for a short time, was an impossible solution.

The project to replace the deck of this six-lane, 5,900 ft., steel girder bridge with precast, post-tensioned, lightweight concrete panels was completed during a period of 12 months with minimum disruption to traffic. The application of innovative construction techniques and new materials based on research findings and recent test results enabled the bridge to remain open to traffic during construction while the contractor completed the project at reduced cost more than 3 months ahead of schedule. The innovative techniques developed to replace and widen the concrete deck of the Woodrow Wilson Bridge may well be applicable to other bridge rehabilitation projects throughout the country.

- [McCann85] McCann H., Troxell L. and King G. Managing Traffic in Residential Areas. Presented at the 64th Annual Meeting of the Transportation Research Board, Washington D.C. 1985.

Abstract: This report presents traffic management concepts developed as part of a traffic plan for the City of Greenwood Village, a suburb of Denver.

Greenwood Village includes established neighborhoods in addition to extensive commercial development in the Interstate 25 corridor. The community wishes to preserve its environmental quality, while considering the traffic demands of commercial development and residential growth.

Travel demand modeling demonstrated that substantial roadway improvements would be necessary in order to resolve the area's traffic problems. The magnitude of these improvements was environmentally unacceptable. As the forecasted demand exceeded the system capacity, a primary concern was the "spill-over" effect of arterial traffic onto residential streets. This led to the development of a traffic "management" strategy, which considered the legal aspects of traffic diversion.

The recommended plan attempts to manage system wide traffic by encouraging traffic on selected streets and discouraging it on others. These objectives were accomplished by controlling roadway capacity through allocations of green time at signalized intersections, roadway design features, and travel time penalties. The plan does not totally satisfy the travel demand, yet it does provide reasonable travel routes for through traffic while minimizing the traffic impact on residential areas.

[Maslin83] Maslin W.R. and Arnoult J.D. Quality Assurance for Local Governments. Federal Highway Administration, Washington, D.C. February 1983.

Abstract: Poorly built and maintained roads are both expensive and inconvenient to taxpayers. The quality of work performed on roads and streets directly influences the useful life of the facility, maintenance costs, levels of service and user costs. The techniques being promoted by the Federal Highway Administration are primarily for State highway agency use. Realizing that these techniques could not be implemented at the local level without significant revisions, PHWA approved the preparation of this manual to develop a program for improved highway construction management, including development of a highway quality control and testing program for use by local government units.

[Memcott84] Memcott J.L. and Dudek C.L. Queue and User Cost Evaluation of Work Zones (QUEWZ). *Transportation Research Record* 979, 12-19.

Abstract: An important aspect of a highway work zone is the lane-closure.

strategy and the movement of traffic through the work zone. As part of the evaluation to determine the effects of different lane-closure strategies (e.g., one-, two-, or three-lane closures on a four-lane section), the additional costs to vehicle users should be considered. It is therefore necessary to have a model that will improve the accuracy of user cost estimates resulting from the forced movement through a restricted work zone. A computer model, Queue and User Cost Evaluation of Work Zones (QUEWZ), developed to estimate the additional user costs resulting from lane closures in one or both directions of travel is described. User costs can be estimated when one or more lanes are closed in just one direction of travel or when a crossover is used. Hourly as well as daily user costs are estimated, and when vehicle demand exceeds capacity, the model also estimates the length of queue. The model is designed specifically for freeway conditions, but it can be used in other situations if appropriate adjustments are made in the input data. Two vehicle types are used in the model--passenger cars and trucks.

- [Meyer81] Meyer A.H., McCollough B.F. and Fowler D.W. Highway Pavement Repairs by Using Polymer Concrete. *Transportation Research Record* 800, 33-40. 1981.

Abstract: As traffic, particularly truck traffic, has increased on the primary highway system, the need for rapid repair methods has increased. Polymer concrete (PC) has been used effectively for rapid repair of portland cement concrete pavements, both jointed and continuously reinforced. Basic formulations for PC are presented and both user-formulated and prepackaged systems are described. Methodology for the repair of cracks, joints, spills, and punchouts is illustrated. The results of several PC repairs are presented. Deflection measurements that illustrate the restoration of structural integrity, which means a prolonged pavement life, are given.

- [Meyer83] Meyer A.H. and McCullough B.F. Precast Repair of Crc Pavements. *Journal of Transportation Engineering/ASCE* 109, 6 1 B-630. 1983.

Abstract: This report presents a summary of the results of an investigation into the design, fabrication and installation of precast concrete panels for the repair of continuously reinforced concrete (CRC) pavements. Factors affecting the design of precast panels for CRC repairs are presented. Problems associated with transporting and placing the panels are discussed. Two field

installations using the method are presented and illustrated. Conclusions presented include: (1) The use of precast panels for the repair of CRC pavements is a viable alternative; (2) repairs can be made with less than a 6 hour lane closure time; and (3) the method is cost effective when user delay costs are included.

[Neveu85] Neveu A.J. and Maynus L. *How to Manage Traffic During Highway Reconstruction* New York State Department of Transportation, Albany, New York. October 1985.

Summary: The freeway systems now present in many urban areas were planned and constructed during the 1960's and early 1970's. As those highways begin to reach their design service life, the emphasis of state transportation agency is shifting away from building new facilities to rebuilding the older, deteriorating systems. As this reconstruction activity continues to *grow* in importance, a problem which was not a concern when constructing a new facility rises to the forefront. During the reconstruction of a highway section, the designer has to be concerned with what to do with the existing traffic on the facility. A concerted effort involving every level of government, labor, and business must be brought to focus to alleviate traffic disruptions due to reconstruction activities on high volume roadways.

The major emphasis of this manual is devoted to specific Traffic Systems Management (TSM) actions which have been or may be utilized in traffic management efforts. This section draws heavily on the experiences in Pittsburgh, Syracuse, and Boston in using TSM strategies in their reconstruction projects. Each action is presented as a separate unit. Information is presented on where the action was implemented, a description of the specific program that was developed, estimates of its effectiveness and cost, and general comments on its applicability, special circumstances, or possible improvements. In addition, sample contracts or arrangements between major parties involved in the implementation of specific TSM actions are included where possible. By utilizing this manual, the highway planner can begin identifying reconstruction projects which may need special attention to the traffic management plans, and can select which types of actions may be applicable for these projects.

[Nemeth83] Nemeth A.A. and Roupail N.M. *Traffic Control at Freeway Work Sites. Journal of Transportation Engineering/ASCE* 109, 4 - 15. 1903.

Abstract: A comprehensive, multidisciplinary study of traffic control needs of freeway lane closures at work zones included surveys of drivers and highway patrolmen, test driver studies, field measurements of merging and speed characteristics, a digital simulation study, and the field testing of novel signs. Construction accident data, collected on a turnpike facility, was dominated by collisions with objects, many involving trucks at night in the transition area at crossovers. Rear-end accidents resulted in higher injury rates than other accidents, most occurring in the closed lane or bidirectional area. The simulation study indicated that potential problems increase rapidly as approach volumes increase toward open-lane capacity, but these problems can be greatly reduced if closed lane drivers can be induced to initiate early merges. Several signs designed to influence driver behavior were field tested. The results were largely inconclusive, but the "Merge Soon With Caution" sign was found to increase early merge frequencies. It is recommended that developers of traffic control plans emphasize methods to encourage early merges where higher volumes are expected.

[Nemeth85] Nemeth Z.A. and Rathi AK. Potential Impact of Speed Reduction at Freeway Lane Closures: A Simulation Study. *Transportation Research Record* 1035, 82-84. 1985.

Abstract: The objective of this study was to evaluate the potential impact of reduced speed limits at temporary freeway lane closures at work zones at arbitrarily assumed levels of compliance. Although some transportation engineers prefer to reduce speeds at work zones to protect the working crew, others are hesitant to introduce such a disturbance to the traffic flow. The study approach involved simulation experimentation, using FREESIM, a microscopic, stochastic model. A fractional factorial design was developed for the analysis of three independent variables: two-lane volumes (800, 1200, 1500, and 1800 vehicles per hour); speed limits (55, 50, and 45 mph); and assumed compliance with speed limit (33, 66, and 100 percent). The number of uncomfortable decelerations and the variance of the speed distribution were selected as the dependent variables. These two variables were offered as a measure of the internal friction created by the merging two-lane traffic into a single lane. It was hypothesized that this internal friction is increased by the introduction of lower speed limits. The results of this simulation study indicate that compliance with reduced speed limits will have no significant impact on the number of uncomfortable decelerations but will reduce variance

in speed distribution. These results, therefore, do not support the assumption that effective speed reduction at work zones would create a potentially hazardous disturbance in the flow of traffic.

KNickerson Nickerson R.L. Bridge Rehabilitation: Construction View. Expediting Bridge Redecking. Presented at the 2nd Annual International Bridge Conference. Pittsburgh, PA. 1985.

Summary: How do we remove and replace a material that takes 28 days to gain strength, between fixed limits such as bridge rails or right-of-way limits and still maintain this flow of vehicles safely and with minimum or no disruption? Events of the recent past have proven that this is not only feasible, but practical, and definitely advantageous. This paper will document experiences on three specific structures in the Maryland/Washington, D.C. area and points out the lessons learned that we must start applying to all our work. The goals were to provide complete, permanent rehabilitation, in the shortest time possible, minimizing total cost, and without sacrificing quality for these projects. Total cost is defined as the low bid plus delay and detour costs to the roadway user. Special attention was given at the engineering phase to produce a set of contract documents, which attracted efficient contractors to allow these goals to be achieved.

Some of the lessons learned as a result of these projects are:

- . we should use total cost, not engineers estimate, in determining traffic maintenance and contract time requirements,
- . quality of end product is no less, and may be better on expedited work, than longer term contracts,
- . contracts with expediting provisions that are properly engineered attract the most efficient contractors available,
- . an incentive/disincentive clause, by itself, is not sufficient to ensure expedited work,
- . virtually all bridge decks can be removed and replaced in one construction season, and
- current contract times are excessive.

[OBrien85] OBrien J.J. Quality Control: A Neglected Factor. *Civil Engineering/ASCE* magazine. February 1985.

Summary: Quality in construction is too important to be left to chance. Engineers must educate owners to insist upon a quality control plan, comprehensive inspection and a competent testing program. In the 1950's and

1960's, owners became increasingly concerned with cost and schedule, areas where the design professionals were not providing good control. One way in which more attention will be given to quality control is development of a *project quality control plan*. Presently, testing and inspection requirements are scattered throughout the contract specifications. To develop a firm, plan, the testing and inspection requirements can be combined into a new division of the specs. This would emphasize quality control and provide an organized location in which all quality control requirements are identified to the bidders. As part of the quality control plan, the manner in which the construction manager (or project manager) will apply quality control procedures should be described to the bidder. This will permit them to assign appropriate costs to the testing procedures. Quality control is a vital factor in all construction projects. The evolution of construction management methods has resulted in situations where quality control is whether ignored or delegated out of existence. Because quality is too important to be left to chance, engineers must persuade owners to insist on a quality control plan, and pay for comprehensive inspection.

[Pool83] Pool M.R. and Cribbins P.D. Benefits Matrix Model for Transportation Project Evaluation. *Transportation Research Record* 931. 1983.

Abstract: A procedure for evaluating proposed urban highway projects that can serve as a framework for establishing statewide construction priorities is described. Guidelines are provided for local officials who need to select and establish priorities for projects on an urban-area basis. The sequential steps followed in the research methodology included evaluation of previously developed priority models, definition of criteria for the model, building the models, and application and testing of the model by using candidate urban highway projects from three North Carolina test cities: New Bern, Kinston, and Durham. A benefits matrix model for transportation project evaluation was developed during the study. The model consists of five elements designed to provide the decision maker with relevant project evaluation information that directly relates to transportation planning objectives. These five elements are user benefits, cost economic development potential, environmental impact, end relationship of the project to the state arterial system. Evaluation of the model indicated that it can be used at both the local and state levels to analyze a wide range of urban highway projects. The model can also be used

to evaluate rural highway projects and, with some modifications, projects involving other transportation models.

- [Richards85a] Richards S.H. and Dudek CL. Special Traffic Management Requirements for Freeway Maintenance Work Zones. Presented at the 64th Annual Meeting of the Transportation Research Board, Washington D.C. 1985.

Summary: This paper identifies and describes the special traffic handling requirements for maintenance workzones on urban freeways. These special requirements stem from the high speeds, heavy traffic volumes, and unique design features (e.g., ramps and frontage roads) which characterize urban freeways. The information and guidelines presented herein are based on field studies and interviews conducted at over 50 work zones in six Texas cities.

Recommended procedures and devices for managing traffic at entrance and exit ramps and on frontage roads during freeway maintenance activities are presented. Special requirements for traffic control personnel, including Traffic Control Coordinators, Traffic Control Specialists (flagmen), and police, are discussed. The paper also discusses the importance of advance public notification of freeway work activities and identifies several effective techniques for advance notification.

- [Richards85b] Richards S.H., Wunderlich R.C. and Dudek C.L. Field Evaluation of Work Zone Speed Control Techniques. *Transportation Research Record* 1635, 66-78. 1985.

Abstract: The results of field studies conducted in Texas to evaluate selected methods of slowing work zone traffic to acceptable speeds are presented. The studies were performed at six work zone sites, one urban freeway site, one urban arterial site, and two rural freeway sites. The following work zone speed control methods were studied: flagging, law enforcement, changeable message signs (CMS's), effective lane width reduction, rumble strips, and conventional regulatory and advisory speed signing. The study results indicate that flagging and law enforcement are effective methods for controlling speeds at work zones. The best flagging treatment tested reduced speeds an average of 19 percent for all sites, and best law enforcement treatment reduced speeds an average of 18 percent. In contrast, the best changeable message sign and effective lane width reduction treatments tested each reduced speeds by only 7 percent. An innovative flagging procedure, a police

traffic controller, and a stationary patrol car were found to be the most effective treatments on most highway types. A circulating patrol car and rumble strips were found to be ineffective treatments for controlling work zone speeds. Although conventional regulatory and advisory signing was found to be ineffective in reducing work zone speeds, conventional speed signs are an essential component of any work zone speed control effort.

- [Richards85c] Richards S.H. and Dudek CL. Selection of Work Zone Channeling Devices Using the Value Engineering Approach
(Abridgement). *Transportation Research Record 1035, 78-84. 1985.*

Abstract: The use of value engineering for selecting work zone channeling devices is investigated. For illustration, the approach is used to select devices for a lane closure taper at a rural freeway work zone. The results of the investigation indicate that value engineering can be a useful tool. It provides an objective means of evaluating any number of alternative channeling devices using whatever performance and cost data are available. Most important, it encourages the selection of low-cost devices that are safe and effective under the prevailing work zone conditions.

- [Robson84] Robson J. and Cohen M. City Investigates Different Roadway Repair Methods. *Public Works 916(4), 1984.*

Abstract: Although total reconstruction was the best engineering solution for a long lasting road, this option was dismissed because of economic constraints and the fact that significant portions of the roadway had already been patched. Also ruled out was the use of a simple, thin asphalt overlay, which would eventually show extensive reflective cracking and allow water to seep through the pavement, again promoting deterioration. Using a non-woven engineering fabric in conjunction with a tack-coat application and a thin asphalt overlay is an accepted approach to solving crack retardation problems and appeared to be a viable solution. However, while exploring this method further, the Maryland State Highway Administration's Northern Regional Laboratory informed that a new method of fiber reinforced pavement existed. The process uses short polymer fibers and is an offshoot of the now-banned asbestos reinforcement, and rubber-reinforced asphalt paving techniques.

- [Rouphail85] Rouphail N.M. and Tiwari G. Flow Characteristics at Freeway Lane Closures. *Transportation Research Record 1036, 50-57. 1985.*

Abstract: The findings of a limited study aimed at examining the basic characteristics of freeway traffic flow at construction zones are presented. The intent is to expand the scope of previous research efforts in this area, which have focused on the determination of point estimates of work zone capacity, under a variety of freeway lane configurations upstream of and in the vicinity of the the work area. Field studies conducted in Illinois, encompassing more than 21,000 vehicle observations, were used to examine the entire range of the speed-flow relationship in the open lane of traffic. A normalizing procedure was devised to isolate and quantify the impact of work zone activity descriptors, such as the location of work relative to traveled lanes, crew size, equipment, and other pertinent parameters, on the observed traffic speed. It was found that the effect of work activity on traffic flow is significant in periods of (a) high approach flow rates, (b) high truck percentages, and (c) intense work activity near the traveled lanes.

[Shober83] Shober J. Experimental Rehabilitation of Jointed Portland Cement Concrete Pavement. Interim Report. Wisconsin Department of Transportation and the Federal Highway Administration. 1983.

Summary: A study of innovative rehabilitation techniques was initiated by the Wisconsin Department of Transportation in 1981 on a section of I-90 in Dane County. Eight different, full depth, full lane width, PCC patching techniques were used with patch lengths of four, five and six feet, with a few longer ones included. The patching techniques included cast-in-place (with and without load transfer), patches with an undercut lip beneath the existing pavement, and with perpendicular and skewed transverse joints. After patching, one dual lane pavement was intermittently diamond ground and the other dual lane pavement was continuously ground. Several shoulder rehabilitation techniques were used, including cold recycling, heater scarifying, and spot patching. One-half of the cold recycled and heater scarified sections were surface sealed with a fog seal. A slurry seal was used on the remaining sections. After one year of performance it is apparent that those patches with load transfer capability are not moving under load as much as those without. The ride quality of the continuous ground pavement remains much better than that obtained for the intermittently ground pavement.

[Sicking85] Sicking D.L. Guidelines for Positive Barrier Use in Construction Zones. *Transportation Research Record 1035, 85-93.* 1985.

Abstract: The need for positive barriers in construction zones is now based on individual judgement, and there is an expressed need for objective barrier placement criteria. The number, diversity, and variability of factors that affect barrier need within eliminate the possibility Of development of a set of totally objective guidelines appropriate for any given circumstance. In an effort to develop procedures for determining barrier need at a given site, a computer program, which determines barrier warrants based on a benefit-cost algorithm, was developed. This program was adapted for use on microcomputers with a user friendly system that greatly simplifies its use. Further, a set of use guidelines for portable concrete barriers (PCBs) was developed for typical work zones sites through the application of the benefit-cost computer program. Barrier end treatment use guidelines were also developed with the computer program. End treatments studied included flaring the barrier away from the travelway and two crash cushions. The optimum flare rate for flared end treatments was found to be 10:1. Crash cushion end treatments were found to be cost beneficial relative to flared end treatments only at extremely high traffic volumes.

[TRR85] Transportation Research Board. *Traf fic Management in Highway Work Zones and Setting Optimal Maintenance Levels and Frequencies. Transportation Research Record 1053.* Transportation Research Board. Washington, D.C. 1985.

Summary: This issue of the Transportation Research Record contains several papers related to this literature review. Of particular relevance to traffic management in work zones and work zone safety are papers by Roupail and Tiwari [Roupail85], Kuo and Mounce [Kuo85], Richards and Dudek [Richards85b], Richards et al. [Richards85c], Nemeth and Rathi [Nemeth85], a n d Sicking [Sicking85]. Annotations of these papers are included in this review.

[Vecellio84] Vecellio R.L. and Culpepper T.H. Work Area Traffic Control: Evaluation and Design *Journal of Transportation Engineering/ASCE* 110. 412-430. 1984.

Abstract: Comprehensive evaluations of traffic controls for three highway construction projects are conducted. These evaluations consist of reviews of the traffic control plans, field checks of the implemented traffic controls, and observation of actual motorist behavior in response to the work area traffic

controls. The project sites include suburban interstate, urban arterial, and rural highway locations. Field data were collected to develop spot speed characteristics, traffic flow rates, overall and average running speeds, and acceleration noise and mean velocity gradient profiles. Based on these evaluations, guidelines are developed to assist in the design and operation of more effective work area traffic control.

[Viljoen81] Viljoen P.S. Incentive Management Techniques for Pavement Rehabilitation Construction. Ph.D. Dissertation, University of California, Berkeley 1981.

Summary: The purpose of this study was to investigate incentive management techniques that will assist in the timely completion of pavement rehabilitation contracts. A questionnaire was sent out to 51 state transportation agencies in the United States, and interviews were conducted with California Department of Transportation Agency personnel and contractors. Using the results from the questionnaire, and information from published *sources*, a state-of-the-art study was performed on current incentive management techniques. Four models were then developed to explain the information obtained from the questionnaire and interviews.

First, a cash flow model was developed to analyze what effect agency-controlled incentives have on markup, cash flow, and the profitability of a contractor on a rehabilitation contract. Incentives analyzed included: liquidated damages and bonus rates, retention and mobilization schedules, percentage of work subcontracted, and payment lag times.

Second, a decision-tree model was developed to describe the decisions, made under conditions of uncertainty, which lead a contractor to complete a project early, on time, or late.

Third, an adaptation model was developed which described a contractor's process of learning in response to an agency's policies about enforcing incentives and disincentives. This learning process is directly related to the contractor's decision whether or not to complete a project on time.

Fourth, a traffic handling decision model was developed, based on multiattribute utility theory, which enables a design engineer to choose the best alternatives in a given pavement rehabilitation project.

Finally, an illustrative case was developed to demonstrate the requirements, mechanics, and solution format of the multiattribute utility theory model. To illustrate the sensitivity of the model's scaling constants, and the certainty equivalents of the attributes of each alternative in the model, a sensitivity analysis was performed.

[USDOT84] U.S. Department of Transportation. Whitehurst Freeway Corridor System Modification Study. Federal Highway Administration and the District of Columbia Department of Transportation, Washington, D.C. April 1984.

Summary: The District of Columbia Department of Transportation is proposing improvements to the Whitehurst Freeway in Washington, D.C. Four alternative actions have been evaluated and are presented in this Draft Environmental Impact Statement: (1) a no-build alternative, (2) rehabilitation of the existing four-lane elevated freeway with modifications at the east and west ends, (3) a new, lower elevated freeway, also four lanes, with modifications at the east and west ends, and (4) replacement of the freeway by a six-lane arterial road at the K Street level, with reversible lanes and modifications at the east and west ends.

[Weed85] Weed R.M. Positive Incentives Produce Positive Results: NJDOT Survey. *Transportation Research News/TRB* No. 119. 1985.

Summary: Positive incentive (bonus) clauses, under which a contractor can earn payment in excess of the contract price, are currently being used by about half of the state transportation departments in this country. In a recent survey conducted by the New Jersey Department of Transportation, the responses indicated that 26 states had experimented with bonus clauses for early completion of critical work. All 26 states reported that their experience had been successful in that most of the contractors completed the work in sufficient time to claim the maximum bonus. Of the 26 states, 20 planned to continue using this approach when justified by the nature of the work (for example, bridge out of service, lengthy detour, excessive disruption of traffic). Three states expressed a neutral opinion and three reported that although the incentives had been effective, it was believed that they could accomplish the desired results with standard liquidated damages clause that assesses penalties for each day that the work extends beyond the specified completion date.

For those contemplating the use of an incentive clause for early completion, the following advice was offered:

1. The incentive clause should be reserved for projects that are highly critical and for which there is an obvious public benefit associated with early completion.
2. Great care must be exercised in determining a reasonable and fair completion time. Uncertain factors such as weather and labor strikes tend to complicate this.
3. Incentive clauses open the door for successful claims if there should be any changes in the contract after it has been awarded.

[Willenbrock76] Willenbrock J.H. A Manual for Statistical Quality Control of Highway Construction: Volumes I and II. Federal Highway Administration, Washington, D.C. January 1976.

Summary: A number of state highway agencies are currently implementing or are seriously considering the implementation of highway construction specifications which are based on the principles of statistical quality control. It is the writer's opinion that the process of implementation of these types of specifications will be considerably smoother if a broad based training program for highway agency as well as industry personnel is undertaken at the beginning of the implementation process. The common foundation of understanding which can be achieved in the involved departments within the state highway agency as well as among the various contractors and material suppliers groups will enable everyone to approach these specifications without suspicion, misunderstanding and outright opposition which might otherwise occur.

This two-volume manual may be used as the basic instructional text in a training program which could be uniformly presented throughout a particular state in a series of four-day seminars. The first volume has been designed to provide a coverage of the basic statistical concepts and techniques which form the foundation for a statistically based specification. It can therefore be used, with minor additions or deletions, in almost all states. The second volume has been designed to provide an example of the type of coverage which a particular state might want to use in order to develop the details of its own particular specification.

- [Woltmen84] Woltman H.L. Sign Maintenance Management. *Transportation Research Record* 979, 24-28. 1984,

Abstract: Sign maintenance management requires a systematic approach beginning with an inventory of traffic control devices that is updated with work orders. The initial inventory procedure can be accomplished either manually or by photologging followed by data entry in a computer file. The data base is required for management of maintenance procedures, materials purchase, inventory control, forecasting, and budget planning. A benefit of an ongoing inventory is the accurate identification of such problems as theft, vandalism, installation deficiency, and durability. Suggestions for correcting such chronic sign maintenance problems as weathering failure, accident damage, vandalism, theft, defacement, and gunshot damage are made. Refurbishment of sign faces in the field may be possible in a number of such situations. A maintenance system is required for cost justification and control and is a useful adjunct in the defense of tort liability.

- [Yamanaka83] Yamanaka H.M. Social and Environmental Impacts: Edens Project. *Journal of Transportation Engineering/ASCE* 108, 721-732. 1983.

Abstract: The Edens Expressway project, one of the largest reconstruction projects involving an urban, high volume, Interstate freeway, required an in-depth assessment of the various socioeconomic and environmental impacts from the construction and measures that could be taken to reduce any harm to the communities involved. The measures can be categorized into six basic areas: (1) Beneficial development from the freeway construction; (2) effective and meaningful public communication; (3) reduction of harm during construction; (4) conservation of energy and material resources; (5) improvements to the visual quality of the freeway; and (6) social and economic benefits. Many of the benefits and costs are intangible and indirect so that a tabulation in finite terms is difficult. The success of the Edens Expressway rehabilitation can be attributed to the time, detail, and planning that went into those problems affecting the communities directly impacted by the construction.

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Lee83 19 Leisch83 20 Levine84 20 Lutz84a 21 Lutz84b 21

Maslin83 22 McCann85 21 Memmott84 22 Meyer81 23 Meyer83 23

Nemeth83 24 Nemeth85 25 Neveu85 24 Nickerson 26

OBrien85 26

Pool83 27

Richards85a 28 Richards85b 28 Richards85c 29 Robson84n 29 Roupail85 29

Shober83 30 Sicking85 30

TRR85 31

USDOT84 33

Vecellio84 31 Viljoen81 3 2

Weed85 33 Willenbrock76 34 Woltman84 35

Yamanaka83 35