

**NIGHT-TIME ROAD CONSTRUCTION OPERATIONS
SYNTHESIS OF PRACTICE**

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Executive Summary

The Transportation Research & Development Bureau (TRDB) performed a literature search on issues related to night time construction. This report synthesizes existing literature on nighttime construction operations, recognizes gaps in the current state of knowledge, and identifies research in progress.

This literature review and synthesis found the following:

- There is no statistically significant difference between night and day time operations in terms of **safety**, i.e., severity and types of accidents experienced.
- There is no difference in **productivity** levels between night and day time operations. Higher productivity levels at night may be experienced because of less interference from traffic and longer working hours.
- **Quality** of work does not seem to be affected by performing work at night.
- **User cost** decreases when work is performed at night because of the elimination of delays-Businesses experience less disruptions as well.
- There is no consensus on whether **construction cost** increase or decrease as a result of performing work at night.
- Some evidence indicates that nighttime work affects **worker health** negatively. However, nighttime construction work is not different from any other night shift work. Some individuals are more tolerant than others to night shifts.
- Nighttime operations significantly reduce or eliminate traffic **congestion** and delays associated with day time operations.
- Elimination of traffic delays and idling lead to **air quality** improvement and lower fuel consumption.
- **Noise pollution** as well as vibrations can be of concern to neighboring community when conducting work at night or during day time.
- New technologies seem to be effectively addressing concerns over **light pollution** during nighttime operations.

PURPOSE

The purpose of this report is to increase knowledge about issues related to nighttime road operations. Specifically, this report will:

- Examine the implications of conducting road operations at night versus day time.
- Identify gaps in knowledge about night versus daytime road operations.
- Track research in progress and identify existing gaps in research.
- Compile a bibliography of the research and practice literature on night time operations;

APPROACH

This report synthesizes the research and practice literature on night time road construction operations. A literature search of several databases was conducted. The search revealed a large number of relevant articles and reports on the topic. A number of those articles and reports were reviewed and synthesized to meet the objectives of this report.

FINDINGS, SYNTHESIS OF EXISTING LITERATURE, AND DISCUSSION

A number of studies have researched the implications of conducting night versus day time road operations: The following is a synopsis of these studies' findings.

Safety – Studies recorded that the rate of traffic accidents at night on a per mile basis is three times higher than day time accidents.¹ This is believed to be caused by reduced visibility at night, driver drowsiness and alcohol use. Data indicates that alcohol use causes three times more fatal accidents at night than during the day.² Also drowsiness cause more accidents at night than during the day.³

A study conducted in 1989 found that accidents per mvm (million-vehicle-miles of travel) during night work activities were 87% higher than during night periods when the work zone was inactive. Crashes on a per work hour, per lane per mile basis were 68% higher during nights of work than during nights where there was no work.

However, significant changes have occurred in the way night work is conducted since these studies. These changes include new sheeting materials for signs and channeling devises that provide higher retro reflectivity, increased use of portable message signs, and improved guidance on lighting.

¹Driver Night Visibility Needs. Accessible at http://safety.fhwa.dot.gov/roadway_dept/retro/gen/back_needs.htm. Updated by Carl K. Andersen, FHWA Research and Development, June 2007.

²*Alcohol-Related Fatalities and Alcohol Involvement among Drivers and Motorcycle Operators in 2005*. Report No. OT HS 810 644, National Center for Statistics and Analysis, Washington, D.C., August 2006.

³Stutts, J.C., J.W. Wilkins, J.S. Osberg, and B.V. Vaughn. Driver Risk Factors for Sleep-Related Crashes. In *Accident Analysis and Prevention*, Vol. 35, 2003, pp. 321–331.

A 2008 analysis of accident data found that crash rates per 100 hours of road work per mile were much higher during the day than at night. The study also found that a slightly greater percentage of severe night time crashes before night work and during night work as compared to day time crashes. However, lower traffic demand at night can result in fewer crashes over the duration of the project.⁴

Analysis of alcohol related crashes suggest that night time road work does not experience a significantly greater percentage of alcohol related accidents than would normally occur if the work was not present.⁵ Additionally, examination of accident data revealed that the percentages of drowsy driving involved in accidents were almost identical between day-time and night-time periods. The slightly higher accident percentages associated with the night time construction are not statistically significant.⁶

Workers often perceive travel speed to be higher at night and to feel that their safety is more compromised during night shifts. The limited data on crashes at night and day time negate this perception. The National Institute of Occupational Safety and Health confirm this assessment based on examination of fatal occupational injuries and conclude that “*working at night is not responsible for the overall increase on highway worker deaths.*”⁷

The New York State Work Zone Accident database reports that 89% of total road construction accidents occur during the day time, while 11% occur during night time.⁸ There was no statistically significant difference between night time and day time operations in terms of severity and type of accidents experienced. Examination of this data is not conclusive and does not confirm that issues of concerns associated with night work including less sleep, less visibility and longer hours, impact worker safety negatively. There is a need for more data and more research to look in more depth at these issues.

Productivity - Several studies conclude that there is no difference in night time versus day time production rates. Studies by Ellis et.al (1993), Dunston et. Al. (2000) and Colbert (2003) on pavement milling and asphalt paving recorded no difference between day and night time shifts in productivity rates.⁹ Douglas and Park’s (2003) study on

⁴ FHWA, Nighttime Road Construction Impacts Report to Congress- Report to The Senate Committee on Environment and Public Works The House Committee on Transportation and Infrastructure, Office of Safety Washington, DC., 2007

⁵ Ibid.

⁶ Ibid.

⁷Pratt, S. Roadway Worker Deaths during Night Operations: What Do the Data Show? Undated presentation, National Institute of Occupational Safety and Health, Center for Disease Control.

⁸*Traffic Safety Evaluation of Night-time and Day-time Work Zones.* National Cooperative Highway Research Program Report Project 17-30, Transportation Research Board, National Research Council, Washington, D.C. Accessible at <http://www.trb.org/trbnet/projectdisplay.asp?projectid=456>.

⁹ Ellis, R.D., Z.J. Herbsman, P.N. Chheda, W.C. Epstein, and A. Kumar. *Developing Procedures for Night Operations of Transportation Construction Projects.* Report No. UTC-UF-326-93-1, Transportation Research Center, University of Florida, Gainesville, Florida, January 1993.

Lee, C.D. Night-time Construction Work on Urban Freeways. In *Traffic Engineering*, Vol. 39, No. 3, March 1969, pp. 26–29.

Colbert, D.A. *Productivity and Safety Implications of Night-Time Construction Operations.* Independent Research Study Report, Purdue University, West Lafayette, Indiana, May 2003.

Asphalt paving, however, found 23% more tonnage placed per hour at night than during the day.¹⁰ Lee's study (1969) on concrete paving reported a productivity increase of 1.5 lane-mile per night. Higher productivity levels are attributed to longer working hours and less interference of traffic at night.¹¹ These studies do not confirm the perception that productivity levels decrease at night because of loss of sleep.

Quality - Studies on the quality of work produced at night versus during the day do not confirm the perception that the quality of night time work decreases. Price (1985) concludes that the quality of work does not experience significant degradation if the work was performed at night versus day time.¹² Hacher and Taylor (2001) and Al-Kaisy and Nassar (2002) conclude that cooler temperatures at night and longer working hours can actually increase night-time work quality.¹³ Par et. Al (2001) reported that the International Roughness Index Score for paving operations were only 3% less at night than during the day.¹⁴

Economic Impacts - There is no doubt that road user costs decrease when road work is performed at night. Neighboring businesses also avoid potential disruptions due to work operations during the day time.

As for work costs, the literature does not provide consensus on whether costs increase or decrease when night time work is performed. Hinze and Carlisle (1990) found that the contract cost was 9% higher at night because of increased costs associated with increased traffic control requirements, lighting and worker overtime costs.¹⁵ Ellis et. Al. (1993), however, confirm that there was either no change in cost or even a cost saving resulting from performing work at night.¹⁶ The savings were attributed to higher productivity due to less interference by traffic and quicker material deliveries.

¹⁰Dunston, P.S., B.M. Savage, and F.L. Mannering. Weekend Closure for Construction of Asphalt Overlay on Urban Highway. In *ASCE Journal of Construction Engineering and Management*, Vol. 126, No. 4, July/August 2000, pp. 313–319.

¹¹Douglas, K.D., and S.B. Park. *Selection Criteria for Using Night-time Construction and Maintenance Operations*. Report SPR 322, Oregon State University, Corvallis, Oregon, May 2003.

¹²Price, D.S. *Night-time Paving*. Report No. CDOH-DTP-R-85-2, Colorado Department of Transportation, Denver, Colorado, 1985.

¹³Hancher, D.E., and R. Taylor. Night-time Construction Issues. In *Transportation Research Record 1761*. Transportation Research Board, National Research Council, Washington, D.C., 2001, pp. 107–115.

Al-Kaisy, A., and K. Nassar. Night-time Construction Issues Revisited. *CD-ROM Proceedings*, 82nd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2002.

¹⁴Park, S., K.D. Douglas, A.S. Griffith, and K.J. Haas. Factors of Importance for Determining Day-time versus Night-time Operations in Oregon. *CD-ROM Proceedings*, 81st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2001.

¹⁵Hinze, J., and D. Carlisle. Variables Affecting Night-time Construction Projects. In *Transportation Research Record 1282*. Transportation Research Board, National Research Council, Washington, D.C., 1990, pp. 95–103.

¹⁶Ellis, R.D., Z.J. Herbsman, P.N. Chheda, W.C. Epstein, and A. Kumar. *Developing Procedures for Night Operations of Transportation Construction Projects*. Report No. UTC-UF-326-93-1, Transportation Research Center, University of Florida, Gainesville, Florida, January 1993.

Social Impacts - Disruptions of the biological sleep cycle can cause various physiological and psychological stresses.¹⁷ 20% of workers engaged in night shift activities report sleep-related disorders.¹⁸ Older workers seem to be less tolerant of the effects of sleep disruptions than younger workers.¹⁹ Several studies pointed to an association between night shift work and physical problems such as heart disease and greater frequency of injuries.²⁰ Negative impacts on marital, parental and community activities were also believed to be associated with night time work.²¹ In a study of night time work operations, workers reported that challenges associated with night work included the sporadic nature of night time work which make it difficult to adjust to a night time schedule and the fact that workers often have to perform double shifts of night and day time work.²²

Environmental Impacts - Concerns over **noise pollution** are intensified when work is performed during night time. However, the same concerns also exist during day time especially when construction occurs in proximity to schools or hospitals. Existing Literature does not address the issue of noise for night time construction. However, Evans and Maxwell (1997) examined the detrimental effects of noise related to day time construction work activities on the classroom environment and learning abilities.²³

There are several noise mitigating strategies that can be used to bring the noise levels down by 10 decibels. Noise mitigating strategies include use of temporary sound shields around the work site, establishing truck and equipment clean up areas away from residential areas, use of less offensive back up alarms, disengaging the alarms and using manual spotters, and lining truck beds with rubber to reduce sounds when materials are loaded. These strategies will translate to increased costs to the contractor

¹⁷Carpentier, J., and P. Cazamian. *Night Work: Its Effect on the Health and the Welfare of the Worker*. Report No. ISBN-92-101676-5, International Labor Office, Geneva, Switzerland, 1977.

¹⁸Holguin-Veras, J., R. Baker, A. Medina, and D. Sackey. *An Analysis of Human Factors at Night-time Work Zones*. Report FHWA/NJ-2001-025, City College of New York, New York, New York, November 2001.

¹⁹Reid, K., and D. Dawson. Comparing Performance on a Simulated 12-Hour Shift Rotation in Young and Older Subjects. In *Occupational Environmental Medicine*, Vol. 58, No. 10, October 2001, pp. 58–62.

²⁰Carpentier, J., and P. Cazamian. *Night Work: Its Effect on the Health and the Welfare of the Worker*. Report No. ISBN-92-101676-5, International Labor Office, Geneva, Switzerland, 1977.

Fynn, P. The Effects of Shift Work on the Lives of Employees. In *Monthly Labor Review*, Vol. 104, No. 10, October 1981, pp. 31–35.

Coburn, E. Shiftworker Fatigue: The \$77 Billion Problem. In *Cost Engineering*, Vol. 39, No. 4, April 1997, pp. 26–28.

Forston, K.N. The Diurnal Pattern of On-the-Job Injuries. In *Monthly Labor Review*, Vol. 127, No. 9, September 2004, pp. 18–25.

²¹Ellis, R.D., Z.J. Herbsman, P.N. Chheda, W.C. Epstein, and A. Kumar. *Developing Procedures for Night Operations of Transportation Construction Projects*. Report No. UTC-UF-326-93-1, Transportation Research Center, University of Florida, Gainesville, Florida, January 1993.

²²Holguin-Veras, J., R. Baker, A. Medina, and D. Sackey. *An Analysis of Human Factors at Night-time Work Zones*. Report FHWA/NJ-2001-025, City College of New York, New York, New York, November 2001.

²³Evans, G.W., and L. Maxwell. Chronic Noise Exposure and Reading Deficits: The Mediating Effects of Language Acquisition. In *Environment and Behavior*, Vol. 29, No. 5, May 1997, pp. 638–656.

especially if the contractor does not conduct regular night time work to achieve economies of scale and offset costs.²⁴

Concerns over construction caused **vibrations** intensify when work is performed at night. Vibrations that exceed 0.12 inches per second will likely generate complaints by residents.²⁵

Lighting is critical to night time operations but complaints of **light pollution** and glare from adjacent neighborhoods are often heard. This is exacerbated since lighting technologies that produce sufficient light for the worker while avoiding harsh effects on workers' and drivers' eyes is often produced by high towers which can increase glare to neighboring residents. Improvement in lighting technologies will eventually overcome this problem. A promising new technology, the light balloons, tends to avoid the glare problems and produce sufficient light that is not harsh to the eyes.

Improvements in **air quality** and lower fuel consumption can be gained from conducting work at night because of the elimination of idling cars and traffic delays. There is consensus in the literature that night time operations significantly reduce or eliminate **congestion** and delays associated with day-time work activities. The impact of night time work on reducing motorist delays and traffic congestions has been the focus of several studies. Krammes et al estimate that the loss of one travel lane in a three lane freeway results in a 49% reduction in traffic capacity.²⁶ The decision to conduct work at night on the Woodrow Wilson Bridge in Washington led to reducing traffic congestion to acceptable levels and the completion of the project in 2 months rather than 6 months.²⁷

²⁴Knauer, H. S. Pederson, C. Reherman, J. Rochat, E. Thalheimer, M. Lau, G. Fleming, M. Ferroni, and C. Corbisier. *FHWA Highway Construction Noise Handbook*. Report No. DOT-VNTSC-FHWA-06-02. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., August 2006.

²⁵New, Barry M. Ground Vibration Caused by Construction Work. In *Tunneling and Underground Space Technology*, Vol. 5, No. 3, Great Britain, 1990.

²⁶Krammes, R.A., G.L. Ullman, J.L. Memmott, and C.L. Dudek. *User's Manual for QUEWZ-92*. Report No. FHWA/TX-92/1108-7, Texas Transportation Institute, College Station, Texas, January 1993.

²⁷Case Study Snapshot #2, I-95 Operational Analysis for Lane Closures at Night. Accessible at <http://www.tfhrc.gov/its/pubs/05143/snapshot.htm>.

The following table lists the Advantages and Disadvantages of night time construction;

Night Time Operations: Advantages & Disadvantages		
Traffic-Related Parameters		
	Advantages	Disadvantages
Congestion	Significantly reduces or avoid altogether the impacts of roadwork on traffic congestion and motorist delays.	
Safety	Lower traffic demand at night lead to reduced overall crashes. Workers may be more aware of the dangers and more conscious of safety practices.	Risk of crashes may increase due to low visibility and less alert workers and drivers. Lighting can cause glare to the traveling public.
Traffic Control	Increased flexibility in work zone due to less traffic interference and improved level of service.	Need enhanced traffic control which can increase project cost and duration. Set up and removal are complex and can make night operations unfeasible if they cannot be removed by day time. Potentially lower levels of speed limit enforcement in work zones.
Construction-Related Parameters		
	Advantages	Disadvantages
Quality	Quality can be achieved when sufficient level of lighting is provided. Cooler temperatures can enhance the quality of the concrete set at night.	Work quality may be affected negatively. In some cases, work products were less aesthetically pleasing than products done during the day.
Productivity	Less traffic interference and longer work shifts can positively affect productivity and efficiency. Allow more lanes to be temporarily closed to accommodate work activities. Increase the duration during which lanes can be closed at one time improving efficiency and reducing completion time.	Reduced visibility and worker conditions may lead to lower productivity levels. Surveys indicate that some agency personnel believe there is an association between night work and lower productivity levels. Longer set up and removal time of traffic control and lighting. Greater difficulty communicating with supervisor and technical support staff.
Equipment Repair	Breakdown of equipment can be mitigated through the use of contingency plans.	Equipment repair may be hampered during night time.
Work Operations	Possibility of decreased completion time through double shift work.	Personnel scheduling may be more difficult. Local ordinance may restrict work at night. Restrictions may also be imposed by unions, material suppliers on night time work.

Social Parameters		
	Advantages	Disadvantages
Driver Condition	No evidence to suggest that alcohol involvement or drowsy driving conditions result in significant increase in crashes. Driver anger and frustration as a result of traffic delays may be reduced.	Concerns over driver fatigue, drowsiness and effects of alcohol increase at night.
Worker Health	Although the research literature is very limited, data does not point to a dramatic difference in the type of degree of severity between day and night time traffic or work accidents. Health of workers can be affected positively by less exposure to automotive emissions caused by decreased congestion.	Concerns over loss of sleep, biological clock factors, increased chance of sleep disorders and various physiological and mental stresses that can result from lack of sleep. Workers often perceive that their level of safety decreases at night and that speed are higher. Employee satisfaction may be negatively affected. Normal social and family life of workers may be disrupted.
Economic Parameters		
	Advantages	Disadvantages
Business Cost	Losses incurred by surrounding business as a result of operations may go down as a result of eliminating work during day time.	Trucking and shipping industries which rely extensively on night time operations may be impacted.
Driver Cost	Delays to drivers as a result of work operations will go down. Driver costs will decrease because of lower vehicle operating cost and time savings.	
Construction Cost	Reduced traffic interference and improved flexibility design can drive cost of night time operations down compared to day time operations.	Costs of delivering materials may be slightly higher for night time than day time. Night operations may be more expensive because of overtime, night premium pay, lighting expense and enhanced traffic control costs.
Environmental Parameters		
	Advantages	Disadvantages
Light Pollution	Excessive lighting can be controlled by using new technologies.	Excessive illumination can be caused by excessive lighting of the work zone.
Noise	Disturbances can be mitigated by using technologies, and proper planning and administration of work zone.	Can cause noise, vibration, light and other disturbances to neighboring communities.
Fuel Consumption	Less fuel is burned through idling cars in congested work zones.	
Air quality	Pollution from automotive exhaust emissions decreases from reduced congestion levels.	

EXISTING GAPS IN KNOWLEDGE

There are several gaps in our knowledge of the impacts of night time construction.

- More research is needed to more accurately quantify the cost of night time work versus day time. There is currently no consensus in the literature on whether cost of conducting night time work actually increase or decrease.
- Research also needs to develop better tools of quantifying environmental benefits of conducting night time work, including decrease in fuel consumption and improvement in air quality.
- There is little information available on the impacts of night time construction outside of the immediate project site. Impacts on the supply chain, i.e., hot mix asphalt and ready-mix concrete plants, have not been well documented and reported.
- Data and literature available regarding the specific impacts of night-time road construction on highway worker health and fatigue is limited at this time.

RESEARCH-IN-PROGRESS

The following research studies are planned or underway:

- **Quality and Impact of Nighttime construction on pavement life.** The objective of this study (focused on Airports) is to develop appropriate guidelines to improve the efficiency of nighttime construction and improve the quality of construction. The study will be conducted through NCHRP and is expected to be completed in December 2010.
- **Analysis of Nighttime construction Activities and Impacts on Safety, Quality, and Productivity.** The objective of this research is to identify best practice and recommend strategies for nighttime construction operations from analysis of current practices to improve: a safety and construction faciatalites. This project will be conducted through NCHRP and is expected to be completed in December 2010.
- **Nighttime construction: Evaluation of Lighting Glare for Highway construction in Illinois. This objective of this study is to evaluate and recommend acceptable levels of glare and developing practical tool for measuring and controlling glare in nighttime highway construction.** This study is sponsored by Illinois Department of Transportation and conducted by University of Illinois, Urbana-Champaign. This project is on-going and expected to be completed soon (interim report is available).
- **Illumination guidelines for nighttime construction operations.** The objective of this study will be to design a proper glare free lighting system with uniform visibility for approaching and exiting from nighttime construction zone. This project will also develop the most effective retro reflective delineation and efficient lights needed to identify nighttime construction vehicles, temporary road signs, and equipment... This project was submitted by the Construction Division, in response to the last call for research, currently waiting for funding approval.
- **Several other national research projects related to nighttime construction have been proposed but have not been approved for funding at this time.**

LITERATURE ON NIGHTTIME ROAD OPERATIONS

Krammes, R.A., G.L. Ullman, J.L. Memmott, and C.L. Dudek. *User's Manual for QUEWZ-92*. Report No. FHWA/TX-92/1108-7, Texas Transportation Institute, College Station, Texas, January 1993.

Case Study Snapshot #2, I-95 Operational Analysis for Lane Closures at Night. Accessible at <http://www.tfrc.gov/its/pubs/05143/snapshot.htm>.

Driver Night Visibility Needs. Accessible at http://safety.fhwa.dot.gov/roadway_dept/retro/gen/back_needs.htm. Updated by Carl K. Andersen, FHWA Research and Development, June 2007.

Alcohol-Related Fatalities and Alcohol Involvement among Drivers and Motorcycle Operators in 2005. Report No. OT HS 810 644, National Center for Statistics and Analysis, Washington, D.C., August 2006.

Stutts, J.C., J.W. Wilkins, J.S. Osberg, and B.V. Vaughn. Driver Risk Factors for Sleep-Related Crashes. In *Accident Analysis and Prevention*, Vol. 35, 2003, pp. 321–331.

FHWA, Nighttime Road Construction Impacts Report to Congress- Report to the Senate Committee on Environment and Public Works The House Committee on Transportation and Infrastructure, Office of Safety Washington, DC. 2007

Ellis, R.D., Z.J. Herbsman, P.N. Chheda, W.C. Epstein, and A. Kumar. *Developing Procedures for Night Operations of Transportation Construction Projects*. Report No. UTC-UF-326-93-1, Transportation Research Center, University of Florida, Gainesville, Florida, January 1993.

Lee, C.D. Night-time Construction Work on Urban Freeways. In *Traffic Engineering*, Vol. 39, No. 3, March 1969, pp. 26–29.

Colbert, D.A. *Productivity and Safety Implications of Night-Time Construction Operations*. Independent Research Study Report, Purdue University, West Lafayette, Indiana, May 2003.

Dunston, P.S., B.M. Savage, and F.L. Mannering. Weekend Closure for Construction of Asphalt Overlay on Urban Highway. In *ASCE Journal of Construction Engineering and Management*, Vol. 126, No. 4, July/August 2000, pp. 313–319.

Douglas, K.D., and S.B. Park. *Selection Criteria for Using Night-time Construction and Maintenance Operations*.

Report SPR 322, Oregon State University, Corvallis, Oregon, May 2003.

Price, D.S. *Night-time Paving*. Report No. CDOH-DTP-R-85-2, Colorado Department of Transportation, Denver, Colorado, 1985.

Hancher, D.E., and R. Taylor. Night-time Construction Issues. In *Transportation Research Record 1761*. Transportation Research Board, National Research Council, Washington, D.C., 2001, pp. 107–115.

Al-Kaisy, A., and K. Nassar. Night-time Construction Issues Revisited. *CD-ROM Proceedings, 82nd Annual Meeting of the Transportation Research Board*, Washington, D.C., January 2002.

Park, S., K.D. Douglas, A.S. Griffith, and K.J. Haas. Factors of Importance for Determining Day-time versus Night-time Operations in Oregon. CD-ROM Proceedings, 81st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2001.

Hinze, J., and D. Carlisle. Variables Affecting Night-time Construction Projects. In *Transportation Research Record 1282*. Transportation Research Board, National Research Council, Washington, D.C., 1990, pp. 95–103.

Ellis, R.D., Z.J. Herbsman, P.N. Chheda, W.C. Epstein, and A. Kumar; *Developing Procedures for Night Operations of Transportation Construction Projects*. Report No. UTC-UF-326-93-1, Transportation Research Center, University of Florida, Gainesville, Florida, January 1993.

Carpentier, J., and P. Cazamian. *Night Work: Its Effect on the Health and the Welfare of the Worker*. Report No. ISBN-92-101676-5, International Labor Office, Geneva, Switzerland, 1977.

Holguin-Veras, J., R. Baker, A. Medina, and D. Sackey. *An Analysis of Human Factors at Night-time Work Zones*.

Report FHWA/NJ-2001-025, City College of New York, New York, New York, November 2001.

Reid, K., and D. Dawson. Comparing Performance on a Simulated 12-Hour Shift Rotation in Young and Older Subjects. In *Occupational Environmental Medicine*, Vol. 58, No. 10, October 2001, pp. 58–62.

Carpentier, J., and P. Cazamian. *Night Work: Its Effect on the Health and the Welfare of the Worker*. Report No. ISBN-92-101676-5, International Labor Office, Geneva, Switzerland, 1977.

Fynn, P. The Effects of Shift Work on the Lives of Employees. In *Monthly Labor Review*, Vol. 104, No. 10, October 1981, pp. 31–35.

Coburn, E. Shiftworker Fatigue: The \$77 Billion Problem. In *Cost Engineering*, Vol. 39, No. 4, April 1997, pp. 26–28.

Forston, K.N. The Diurnal Pattern of On-the-Job Injuries. In *Monthly Labor Review*, Vol. 127, No. 9, September 2004, pp. 18–25.

Ellis, R.D., Z.J. Herbsman, P.N. Chheda, W.C. Epstein, and A. Kumar. *Developing Procedures for Night Operations of Transportation Construction Projects*. Report No. UTC-UF-326-93-1, Transportation Research Center, University of Florida, Gainesville, Florida, January 1993.

Holguin-Veras, J., R. Baker, A. Medina, and D. Sackey. *An Analysis of Human Factors at Night-time Work Zones*. Report FHWA/NJ-2001-025, City College of New York, New York, New York, November 2001.

Pratt, S. Roadway Worker Deaths during Night Operations: What Do the Data Show? Undated presentation, National Institute of Occupational Safety and Health, Center for Disease Control.

Traffic Safety Evaluation of Night-time and Day-time Work Zones. National Cooperative Highway Research Program Report Project 17-30, Transportation Research Board, National Research Council, Washington, D.C. Accessible at <http://www.trb.org/trbnet/projectdisplay.asp?projectid=456>.

Evans, G.W., and L. Maxwell. Chronic Noise Exposure and Reading Deficits: The Mediating Effects of Language Acquisition. In *Environment and Behavior*, Vol. 29, No. 5, May 1997, pp. 638–656.

Night-Time Road Construction Operations: Synthesis of Practice

Knauer, H. S. Pederson, C. Reherman, J. Rochat, E. Thalheimer, M. Lau, G. Fleming, M. Ferroni, and C. Corbisier. *FHWA Highway Construction Noise Handbook*. Report No. DOT-VNTSC-FHWA-06-02. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., August 2006.

New, Barry M. Ground Vibration Caused by Construction Work. In *Tunneling and Underground Space Technology*, Vol. 5, No. 3, Great Britain, 1990