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Toward a Comprehensive Policy of Nighttime Construction Work

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A first approximation toward a comprehensive policy of nighttime construction work based on the explicit consideration of the following three main aspects is presented: (*a*) the travel time savings produced by nighttime construction work, (*b*) the impact that nighttime work has on workers' human factors (e.g., sleep deprivation and disruption of family and social lives), and (*c*) the impact that pay differentials for nighttime workers would have on project costs. Other aspects such as quality of work and inspection were not studied because of project constraints. The travel time and economic savings of nighttime work were estimated by means of traffic simulations for a typical case. The human factor analyses relied on field surveys and interviews with workers. This research found ample evidence that indicates that nighttime work produces (*a*) negative impacts on the workers' sleep patterns, body rhythms, and social and family lives and (*b*) significant economic savings in terms of travel time to motorists. A set of policy recommendations is discussed and analyzed.

The last half of the 20th century and the beginning of the 21st century have witnessed an unparalleled increase in urban congestion. Despite the advances that have been made in intelligent transportation systems, real-time traffic control, and transportation planning, urban traffic congestion is still on the rise. Recent statistics indicate that the period of peak congestion increased from 1 h in 1970 to 3 h in 2001 (*1*). It is safe to conclude that the continuous growth of congestion represents a serious threat to the productivity and competitiveness of the nation's economy, the environment, and quality of life.

In a context of increasing congestion, daytime highway construction work—already a major source of nonrecurrent congestion—is bound to produce significant traffic disruptions. This has prompted departments of transportation to increase the frequency of nighttime construction work to reduce the congestion impacts of highway projects. This trend has been clearly observed in the state of New Jersey where, according to the local construction industry representatives interviewed for this project, the frequency of nighttime work has increased in the last 5 years. The estimates produced by the research team on the basis of these interviews indicate that approximately 25% of the highway projects are completely conducted at night, while approximately 80% of the daytime highway projects have some sporadic nighttime work component. If it is assumed that the average duration per highway project is equal to 60 days and that the amount of sporadic nighttime work is 5 days, the figures cited above translate into 30% of project work being conducted during the night.

Nighttime construction operations do have significant advantages: minimal impact to the traveling public, less environmental pollution, longer working periods, ease of material delivery, and lower working temperatures during the hot summer months. On the other hand, nighttime work produces negative impacts on the workers. Sleep deprivation, exhaustion, and difficulties in balancing the conflicting pressures of family life and nighttime work are some of the negative impacts that have been documented in the literature (*2*). Moreover, according to the National Work Zone Safety Information Clearinghouse, in 2000 a significant portion of all fatal work zone crashes, approximately 50%, occurred during the night, despite the lower levels of traffic (*3*). These statistics raise additional safety concerns not only for the motorists involved in these fatal crashes but also for nighttime workers who are likely to be present at the crash site during the nighttime work hours.

The findings presented above illustrate the trade-offs between the collective benefits of nighttime work and its negative impacts on the workers. Despite its evident importance, the literature review conducted as part of this project found no evidence of previous research that could shed light on the complex trade-offs that take place. In this context, enhanced knowledge of the various facets of this important activity will support the definition of a consistent and comprehensive policy of nighttime construction work that takes into account the conflicting needs and expectations of the different stakeholders. This research provides a window into a problem of increasing national importance.

The main objective of the paper is to contribute to the definition of a comprehensive policy of nighttime construction work. This is accomplished by focusing on three key aspects: (*a*) the traffic impacts associated with nighttime work, (*b*) the impact of nighttime work on workers, and (*c*) the impact of pay differentials to nighttime workers on total project costs. Other components, such as ease (and lower costs) of materials delivery, construction quality, and productivity, could not be quantified because of project constraints. These topics should remain the subject of further research.

The remainder of this paper describes the results of human factor analyses, in which the impacts of nighttime work on workers were evaluated. The results of traffic simulations conducted to assess the travel time savings incurred by doing highway work at night instead of during the daytime are then described. A set of policy measures aimed at mitigating the negative impacts of nighttime works on workers is also provided. Finally, a summary of the main findings of this investigation is presented.

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HUMAN FACTORS ANALYSES

The first task was the creation of an advisory group comprising representatives of the construction industry and the New Jersey Department of Transportation (NJDOT). The main responsibility of the advisory group was to provide guidance and stakeholder input to the research team.

On the basis of the literature review, a survey instrument was designed to gather data on the most significant human factors. Next, a focus group meeting with 13 union leaders and workers was organized before the fieldwork to refine the survey instrument. The meeting provided a useful platform for the workers to discuss their concerns about nighttime construction operations. In addition to providing feedback about the survey instrument, the participants provided the research team with the following list of issues and suggestions:

- Safety. The workers indicated that their key concerns are motorists traveling at high speeds and that, for that reason, police enforcement must be a priority. An interesting suggestion was to include police enforcement costs as a line item in the budgets of nighttime construction projects to ensure that the police have the resources to do a good job of enforcement.
- Working conditions. There was agreement that nighttime work involves challenging conditions with not enough work space for proper equipment movement and inadequate lighting. Workers do not receive appropriate financial compensation for nighttime work.
- Human factors. There was consensus that nighttime work results in workers not having adequate quality family time, not being able to meet their social responsibilities, working excessive hours (12 to 14 h per day), and not having adequate quality sleep.

The data collection process took place during field visits to four projects selected by the advisory group to provide as wide a spectrum of job conditions as permitted by project resources. A total of 30 workers were interviewed. Brief descriptions of the projects follow.

Project 1: Rural Milling and Resurfacing Project

Project 1 consisted of several miles of milling and asphalt paving on a rural Interstate highway. It is a divided highway with a total of six travel lanes, a 50-ft-wide median, and 12-ft-wide shoulders. Average annual daily traffic (AADT) on the highway was estimated to be approximately 83,000 vehicles.

Project 2: Suburban Bridge Rehabilitation Project

Project 2 consisted of removal and replacement of an existing concrete bridge deck. The bridge was located on an urban freeway/expressway. It has five travel lanes with a 3-ft-wide median and 10-ft-wide shoulders. AADT across the bridge was approximately 75,000 vehicles.

Project 3: Fiber Optics Project

Project 3 consisted of laying a fiber optic cable in a deep trench along an urban highway. The highway has a total of six lanes with a 3-ft-wide median and 12-ft-wide shoulders. AADT on this highway was estimated to be approximately 82,000 vehicles.

Project 4: Suburban Resurfacing Project

Project 4 consisted of maintenance resurfacing of sections of an urban principal arterial. It had six travel lanes, a 12-ft-wide median, and 12-ft-wide shoulders. AADT was estimated to be approximately 64,000 vehicles.

Project Site Visits and Interviews

The research team visited the selected project sites during the night to interview the workers, who were not identified by name for confidentiality reasons. For the most part, the interviews took place on Mondays (once), Tuesdays (once), and Wednesdays (four times) at the beginning of the work period, usually before 9 p.m. The interviews were conducted by using notepads and a digital camera to document the overall site conditions and were tape recorded with the consent of the workers. The interviews took the form of informal conversations with the workers, which provided an environment in which most workers felt confident that they could provide honest answers, although it had the downside that it did not ensure that responses were provided to all questions. The recordings were subsequently transcribed to enable the analyses. The next section provides a summary of the key results.

SURVEY RESULTS

Of the 30 workers interviewed for the study, the vast majority were male workers (only one female was included in the sample). The sample contained a broad spectrum of job types: project engineers ($n = 3$), construction technicians ($n = 3$), a safety officer ($n = 1$), inspectors ($n = 3$), operating engineers ($n = 5$), mechanics ($n = 2$), equipment operators ($n = 3$), truck drivers ($n = 2$), and laborers ($n = 8$).

Although the survey instrument included a wide range of questions about human factors, working conditions, family life, and the like, the number of responses was not always high enough to enable statistical analysis. For that reason, only the questions listed below were analyzed (the numbers of responses are given in parentheses).

1. What is your job title? ($n = 30$)
2. At what time does your work shift start and end? ($n = 20$)
3. How do you get to work? ($n = 13$)
4. How long is your commute to the work site? ($n = 14$)
5. How many hours per day do you work (on average)? ($n = 20$)
6. How many days do you work per week? ($n = 26$)
7. Do you like to work during the night? ($n = 25$)
8. If the answer to Question 7 is yes: Why do you like night work? ($n = 4$)
9. Are you in a permanent night schedule or in a rotation? ($n = 18$)
10. How many consecutive weeks have you spent in night work? ($n = 18$)
11. Do you receive additional financial compensation for nighttime work? ($n = 30$)
12. Do you get enough sleep? ($n = 19$)
13. How many hours of sleep do you have? ($n = 19$)
14. How does night work affect your body rhythms? ($n = 20$)

15. How does night work affect your family and social life? ($n = 29$)
16. How does your family react toward you working at night? ($n = 19$)
17. Are you married? ($n = 25$)
18. Do you have any children? ($n = 25$)

Summary of Responses for Work Categories

Table 1 shows the responses for typical individuals representing each of the different categories of workers. As the responses indicate, there was agreement among the workers that nighttime work (*a*) has a detrimental effect on their family lives, (*b*) leads to sleep deprivation, and (*c*) produces significant stress in their lives. A significant number of the workers agreed that Mondays and Fridays are the worst days of the week because of the changes in the sleep patterns. The mechanics and operators noted additional stress from extra preparation and maintenance of equipment. They sometimes had to rely on trucks' headlights to get enough light to do maintenance work. The truck drivers were generally dissatisfied and felt tired and overworked. A significant number of drivers admitted driving trucks both in the daytime and the nighttime, with very little sleep. A few of them noted that they routinely fall asleep in their trucks while waiting for work to resume.

The NJDOT field engineers were concerned about the challenging conditions for quality control and inspection of work on nighttime projects. They indicated that despite their very best efforts, it is very difficult to ensure that quality control and inspection for nighttime projects are of the same quality as those for daytime projects. In their opinion, proper lighting is an issue because, even in those cases in which lighting strictly adheres to specifications, "it is not the same as during the day."

All engineers from both the construction companies and NJDOT indicated that, more often than not, they must go to the office during the day to do administrative work. These additional daytime duties increase their working hours, imposing additional stress on them. The contractors' representatives noted additional stress arising out of work scheduling, lane closure restrictions, and starting and ending times that are too restrictive. In their opinion, the period of maximum stress is just before the lanes are opened to the traveling public.

Summary of Responses for Entire Sample

This section discusses the results for the entire sample. Since the participants did not always provide responses to the questions asked, the number of observations is usually less than the number of participants in this investigation.

The distribution of the workers by marital status (26 respondents) indicated that approximately 85% were married (91% of them had children) and 15% were single (25% of them had children). Those workers who were married with children expressed serious concerns about the adverse impact of nighttime work on their family lives.

TABLE 1 Typical Responses from Various Categories of Workers

Project engineer	**Mechanic/welder**	**Laborer**
On night work for 7 weeks	On night work for 7 weeks	On night work for 4 months
Works from 7:00 PM to 5:30 AM	Works from 6:00 PM to 6:00 AM	Works from 7:00 PM to 6:30 AM
Married, no children	Married with children	Married with children
Has no social life	Has no social life	Sees family only on weekends
1 hour commute each way	1 hour, 45 minutes commute each way	Commutes 30 minutes each way
Worst day: Monday	Worst days: Mondays and Fridays	Worst days: Mondays and Fridays
Sleeps 3 to 5 hours a day	Inadequate sleep: 5 hours of sleep	No sleep problem, sleeps 6 hours
Has no regular eating hour	Eats a lot less	Irregular eating routine
Still trying to adjust to night work	Not really used to working at night	Has not adjusted to work at night
Frequently has day duties		
Equipment operator/driver	**Operating engineer**	**Project supervisor**
On night work for 6 months	On night work for 6 months	On night work for 6 months
Works from 7:00 PM to 8:00 AM	Works from 6:00 PM to 8:00 AM	Works from 5:00 PM to 9:00 AM
Has a family with four children	Single, has no children	Married, has no young children
Has no social life	Has no social life	Has no quality time with family
Has 1-hour commute each way	Has 1-hour commute each way	Commutes 15 minutes each way
Worst days: Mondays and Friday	Worst days: Mondays and Fridays	Worst days: Mondays and Fridays
Biggest problem: inadequate sleep	Sleep deprived, 4 hours of sleep	Sleeps only 4 hours a day
Irregular eating routines	Irregular eating routines	Not able to eat regularly
Difficulties adjusting to night work	Difficulties adjusting to night work	Would not work at night
		Frequently has day duties
Laborer	**Truck driver**	**Construction technician**
On night work for 3 months	(Did not respond)	On night work for 6 months
Works from 8:00 PM to 6:00 AM	Works from 7:00 PM to 6:30 AM	Works from 7:00 PM to 5:30 AM
Single with no children	Married with children	Single father
Has no problems with social life	Has no social life problems	Has no social life
Commutes 45 minutes each way	Commutes half-hour each way	Commutes 15 minutes each way
Best day: Friday	(Did not respond)	(Did not respond)
Has no problems sleeping	Sleeps four-and-one-half hours a day	Has problems sleeping
Has no eating problems	Irregular eating habits	(Did not respond)
Likes night work (keeps him out of trouble)	Likes to work at night	Does not like to work at night
	Sometimes works during the day	

They receive persistent negative reactions from spouses and children about working at night. They noted that nighttime work is a real threat to their married lives and that they would never work at night if they had a choice. Those who were single without children seemed to be indifferent about working at night.

One of the most striking findings of this research pertains to the number of hours that the workers spent each day working at night. As shown in Figure 1, the number of daily work hours ranged from 10 to 16 h. More than 77% of the workers worked more 12 h and more per day, including 17% that worked 13 h or more per day. The workers expressed concern about the stress imposed on them by these long working hours.

The long work hours described above were made worse by the commute times to work. The data collected indicated that 17% of the workers had total commute times of more than 3.5 h, 7% had total commute times of 3 h, 25% had total commute times of 2 h, and 50% had total commute times of less than an hour. The long commutes increase the duration of the workday and take away time that might have been spent with the family or participating in other social activities. The long commutes contribute to the total stress of the worker.

As a consequence of the combined effects of long working hours, commute times, stress, and family obligations, the workers experienced significant reductions in the number of hours of sleep (Figure 2). The average number of hours of sleep for the various categories of workers ranged from a minimum of 3 h to a maximum of 6 h. As shown in Figure 2, 32% had 4 h of sleep or less a day, 36% had 5 h, and 32% had 6 h. None of the workers had a normal period of sleep of 8 h. These figures are significantly higher than the statistics for night-shift workers that indicate that 20% of them suffer from sleep-related problems, sleeping 1 to 4 h less than normal (*2, 4*). This implies that the nighttime construction workers sleep 2 to 5 h less than the normal 8 h. As a result, the vast majority of them considered a lack of sleep to be a serious problem. The workers attributed this to the difficulty in sleeping during the daytime because this is the period during which, under normal conditions, the human body is in a state of activation. Others also attributed it to noise and disruptive activities in their neighborhoods during the day.

The amount of time spent on night work is shown in Figure 3. Although about 50% of the workers interviewed had spent more than 10 weeks working at night, they indicated that they have not been able to completely adjust to nighttime work and that it is very difficult for them to fully adjust to working at night. They attributed this difficulty to the switch to normal day–night schedules on weekends.

The data indicate that the overwhelming majority of workers (87%) preferred to work during the daytime, while 13% of them preferred to work at night. The four workers that like nighttime work indicated they like it because it (*a*) enables him to earn extra money (one worker), (*b*) it gives him free daytimes (one worker), and (*c*) "keeps him out of trouble" (one worker); one of the workers did not volunteer a reason. Three of the four workers who liked nighttime work were middle-aged or married and did not have young children.

All workers on one project complained about the excessive speed of the traffic. They noted that a police presence slows down the traffic and helps them feel safer. It should be noted that although the researchers did not measure the traffic speeds, the speeds did appear to be excessive. This finding is consistent with the opinions expressed during the focus group.

An interesting finding was related to the role of motivation. Although this research was not intended to investigate the role of the manager–worker relationship, the conversations with workers seemed to reveal that workers who felt "abandoned" by project supervisors were more likely to feel negatively affected by nighttime work. On the other hand, workers who felt "part of a team" seemed to have a much better attitude toward nighttime work. This suggests that managers should try to provide adequate motivation and working conditions and ensure that the nighttime workload is equitably spread among all involved.

The results discussed in this section also suggest the existence of confounding effects that must be taken into account when analyzing the results. The first such effect is related to the fact that some groups of workers (i.e., truck drivers and engineers) frequently perform other duties during the day. A second effect is related to the seemingly longer working hours during nighttime work. These confounding effects make it difficult to separate the effects of nighttime

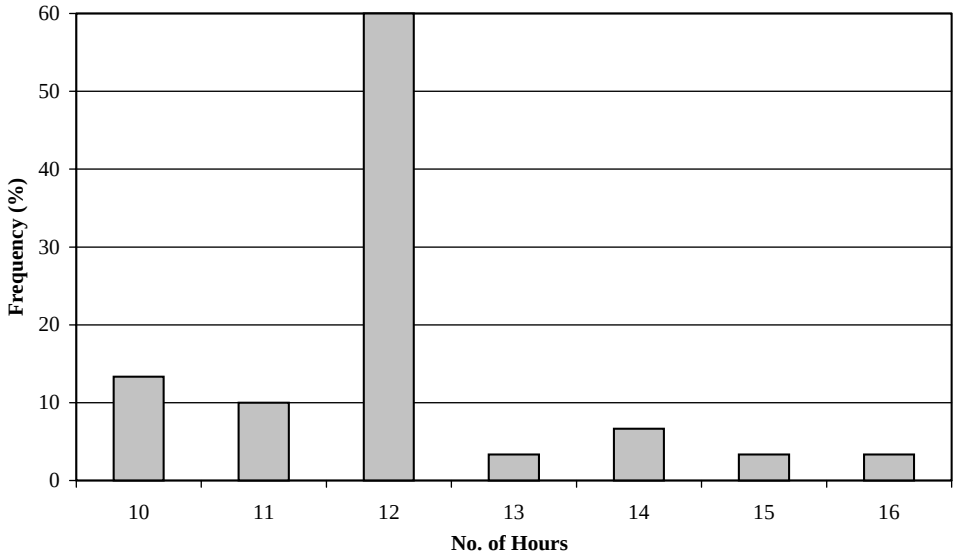

FIGURE 1 Number of work hours per day.

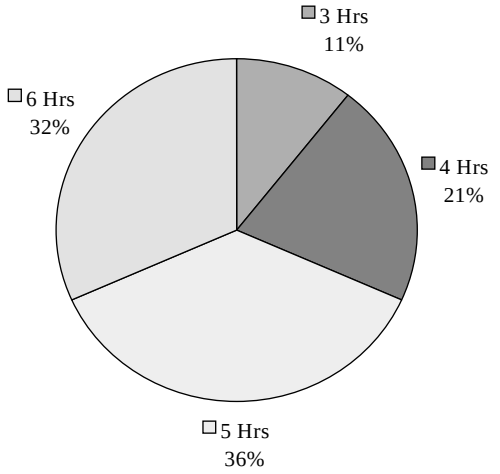

FIGURE 2 Average number of hours of sleep.

work per se from those produced by daytime duties or the long work hours, or both. Regardless of the cause, it is clear that the impact of nighttime work on workers is a problem of significant and growing importance that deserves close attention from policy makers and regulators.

The information gathered in this investigation reveals that, in general, workers do not like nighttime work because it (*a*) upsets their personal lives, (*b*) forces them to alternate their sleep patterns and eating routines, (*c*) disrupts their personal lives, (*d*) reduces their family time, (*e*) is more difficult because of a lack of appropriate lighting, and (*f*) is less safe than working during the day. This was a common theme throughout all of the interviews. The overall impact of these factors is to significantly diminish the quality of life of the workers (*2*). The concerns noted above are consistent with previous research on circadian rhythms, human performance, the impact of sleep disorders on productivity, and safety during nighttime work (*2, 5–8*).

ESTIMATION OF TRAFFIC IMPACTS

This section describes the microscopic simulation used to quantify the economic impacts, in terms of travel time savings, produced by nighttime work. This was accomplished by conducting traffic simulations for two traffic conditions (morning peak and nighttime) under two sets of operational situations (all lanes operational and one lane blocked because of highway work). Two of the scenarios represent normal traffic conditions with five fully operational lanes during the peak period and the nighttime off-peak period, respectively. Two other scenarios were developed to test the hypothetical conditions when the most interior lane is closed because of roadwork during the peak period and the nighttime off-peak period, respectively. The analyses were conducted by using traffic simulation with the Paramics software. The scenarios considered are described below:

- Scenario 1: morning peak period (total, 4 h), five lanes open
- Scenario 2: morning peak period (total, 4 h), one of the five lanes closed
- Scenario 3: nighttime (off-peak period) (total 4 h), five lanes open
- Scenario 4: nighttime (off-peak period) (total, 4 h), one of the five lanes closed

The case selected for illustration purposes is the I-880 freeway described previously (*9*), which was selected because its peak volume, on a per-lane basis, correlates nicely with the peak traffic per lane in the projects studied here. The origin–destination patterns and other parameters are based on data and previous calibrations (*10*). In this simulation, the speed limit is taken as 60 mph, the capacity is 1,800 vehicles per hour per lane for a 5-mi length of the freeway section with five lanes in each direction. For the off-peak period the total traffic is 1,375 vehicles per hour for five lanes, and for the peak period the total traffic is 6,381 vehicles per hour for five lanes. Although the estimates of the economic savings produced here are approximations, they provide an idea about the order of magnitude of the savings produced by nighttime work in real-life conditions.

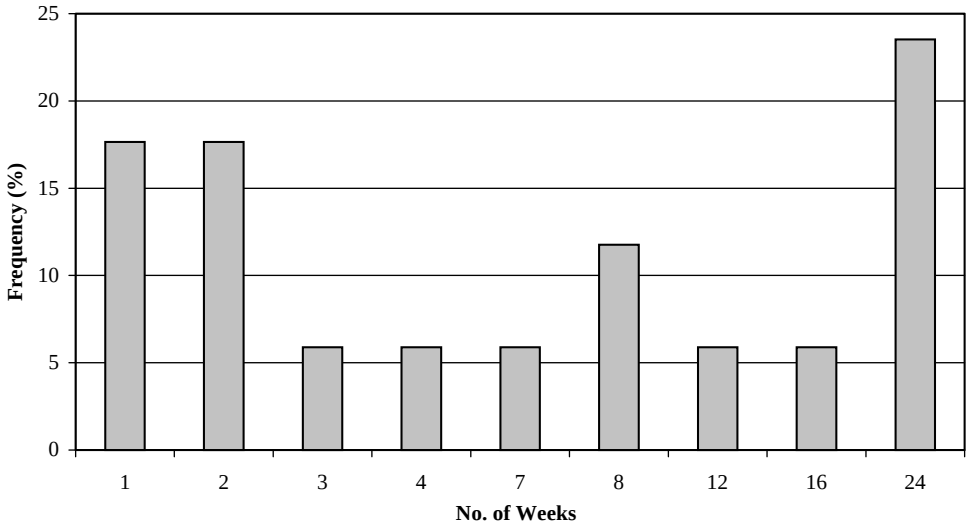

FIGURE 3 Number of consecutive weeks spent working at night.

Table 2 presents a summary of the simulation results for three different runs. Table 2 shows that if the lane is closed during the peak period, the average speed decreases by 24.81%, while the average travel time increases by 17 min. However, if the same lane is closed during the nighttime off-peak period, the speed and travel time remain almost the same as those in the normal situation. These results clearly show that nighttime work saves a significant amount of time for highway users.

The total travel time savings produced by nighttime work are also significant. While closure of one lane during the peak period increases the total delay by 247%, the same closure during the night creates hardly any additional delays. As highlighted in Table 2, nighttime work has great advantages in terms of traffic delays, especially if it is done on relatively busy roads similar to the ones considered in this paper.

The economic value of these savings is significant. By assuming travel time values (in 2002 dollars) of $20/h (for passenger cars) and $45.00/h (for trucks), the economic savings were calculated as the difference between the total costs for daytime and nighttime work. Thus, the travel time savings attributed to nighttime work in this example amount to $22,000/day if the construction work affects the traffic in only one direction and $44,000/day if the work affects the traffic in both directions.

POLICY RECOMMENDATIONS

On consideration of the different facets of the problem described here, the project team selected a set of policy initiatives to mitigate the negative impacts of nighttime work on the workers. These initiatives were the subject of extensive discussions involving representatives of the construction industry and NJDOT. Four policy measures are discussed in this section: (*a*) a 4-day workweek, (*b*) pay differentials, (*c*) itemization of traffic enforcement costs, and (*d*) temporary accommodations for nighttime workers.

Four-Day Workweek

As discussed earlier in the paper, a lack of sleep and the resulting exhaustion are major problems among construction workers. It is clear that further action is needed to reduce the amount of time that construction workers spend at nighttime projects. This has been accomplished in other industries by having multiple shifts. However, the unique conditions in nighttime construction projects, in which dividing a 12-h period of work into two shifts may translate into significant downtime and inefficiencies, seem to suggest that shortening of the workweek may be a better vehicle with which to accomplish the same objectives. Implementation of a shorter workweek may translate into workers who are more rested and who endure fewer disruptions to their social and family lives. However, it is important to keep in mind that a shorter workweek may have a negative effect on the workers if adequate pay differentials are not implemented, because workers may have to look for additional work to compensate for the lost income.

Pay Differentials

The economic value of the congestion avoided by nighttime work is considerable. A portion of these savings should be transferred, in the form of a pay differential, to the people who make it possible. Although pay differentials would not reduce the negative impacts on the workers, they would be a significant morale booster that would translate into a more responsive worker.

Furthermore, the use of pay differentials in combination with a shorter workweek could ameliorate the negative impacts of nighttime work on human factors and translate into the workers who have additional time to rest and stay with their families. The estimates produced by the research team, shown in Table 3, indicate that the implementation of pay differentials has only a modest impact on project costs. The pay differentials considered (15% and 20% increases in total labor costs) increase the daily labor costs for the projects up to a maximum of $9,333, which represents a fraction of the economic benefits produced by nighttime work. Assuming that labor costs are 40% of total costs, which is considered typical for projects in New Jersey, the pay differentials considered here translate into project cost increases of 6% and 8%, respectively.

Itemization of Traffic Enforcement Costs

The safety of nighttime construction zones is a major issue for nighttime workers that could be mitigated by appropriate police enforcement. However, because a police presence at nighttime construction zones involves additional costs that further strain the finances of local police departments, it seems appropriate to include a line item in the project costs for traffic enforcement. Among other things, the itemization of traffic enforcement costs would (*a*) ensure adequate resources for traffic enforcement and (*b*) avoid overwhelming police departments' resources with the additional strain of patrolling nighttime construction zones.

An alternative to a police presence may involve technological solutions. For that reason, more research is needed to assess the

TABLE 2 Simulation Results

	Peak hour			Off peak		
	Normal	One lane closed	% Change	Normal	One lane closed	% Change
Speed (mph)	32.04	24.09	–24.81	58.26	57.18	-1.85
Travel time (min:sec)	6:36	23:20	253.48	5:07	5:08	0.20
Total delay for 4 hours	398.3	1382.12	47.00	302.2	303.3	0.36
Average total delay for one hour	99.63	45.52	47.00	75.6	75.8	0.36

TABLE 3 Impacts of 15% and 20% Pay Differentials on Labor Costs

Labor Costs	Duration (days)	Increases in Daily Cost of Labor of: 15%	20%
$800,000	30	$4,000	$5,333
$900,000	30	$4,500	$6,000
$1,000,000	30	$5,000	$6,667
$1,200,000	30	$6,000	$8,000
$1,400,000	30	$7,000	$9,333

cost-effectiveness of technological solutions that may contribute to reducing traffic speeds and therefore increase traffic safety, even though they do not provide the full benefits of police presence. Examples of such technologies are (*a*) automatic speed sensors that display the speeds of individual vehicles and (*b*) red-light cameras, or variations thereof, which could be used or modified to take photos of the license plates of speeding vehicles.

Temporary Accommodations

As shown in this paper, the combination of long working hours, long commute times, changes in body rhythms, and stress inexorably lead to sleep deprivation. This is particularly acute for those workers whose commute times are significant. To mitigate this issue, the research team suggests that workers be provided accommodations in nearby hotels. This will reduce the commute time and increase the productivity of the worker.

It is important to highlight that the implementation of the policy measures discussed here would require further research before their implications are fully understood. Nevertheless, there was consensus among the members of the advisory group that these policy measures could go a long way toward mitigating the negative impact of nighttime work on the workers.

On the Decision to Do Nighttime Work

This paper has demonstrated that nighttime work produces significant externalities in terms of safety and the impact on workers' human factors. For that reason, the decision to do nighttime work must take into account both the economic value of these externalities and the travel time savings to motorists. The joint consideration of both elements clearly suggests that nighttime work is an economically feasible alternative from a societal point of view, if and only if the economic benefits in terms of travel time savings clearly exceed the corresponding economic externalities (e.g., the impacts on human factors, safety, productivity, and quality). The definition of guidelines that can be used to identify when nighttime work should be undertaken requires estimation of both the economic values of travel time savings for a variety of traffic conditions and the loss of quality of life for the workers. These topics should be the subject of future research.

CONCLUSIONS

This paper has presented a first approximation toward a comprehensive policy of nighttime construction work that takes into account (*a*) the impacts on the workers, (*b*) the economic benefits that nighttime work produces in terms of reduced congestion, and (*c*) the impact that pay differentials have on construction project costs.

The analyses of human factors conducted here were based on field studies that qualitatively assessed workers' human factors at nighttime construction zones in New Jersey. The sample comprised nine different job categories, ranging from project engineers to truck drivers and laborers.

The study confirmed the findings in the literature that night-shift workers suffer from sleep deprivation and related problems and found that the daytime sleep of nighttime construction workers is 2 to 5 h shorter than the normal nighttime sleep. Furthermore, the study confirms that nighttime work adversely affects individuals' circadian rhythms as well as their social and domestic lives, as noted in the literature.

In general, the workers interviewed agreed almost unanimously that nighttime work has a negative impact on both their health and their social and family lives, although a relatively small group of workers preferred to work at night. Only 17% of those interviewed said they receive extra financial benefits from working at night. However, most of them were willing to forfeit this benefit to be able to work during the daytime.

The workers interviewed for the study worked long hours and had to commute relatively long distances. As a result of this and the physiological strain of working at night, the workers did not have adequate sleep. In terms of working hours, 77% of the workers worked 12 h or more each day. This was compounded by the long commutes to the work site. Half the workers indicated that they drive 2 h or more (round-trip) every day to work. Average sleep times ranged from a minimum of 3 h to a maximum of 6 h: 32% of the workers had 4 h of sleep a day or less, 36% had 5 h of sleep, and 32% had 6 h of sleep. None of the workers interviewed indicated that he or she had slept the normal amount of 8 h.

The situation described above stands in contrast to the significant economic benefits produced by nighttime work. The traffic simulations conducted indicated that the economic value of the travel time savings produced by nighttime work ranges from $22,000/day to $44,000/day.

The paper proposed the implementation of a number of policy measures aimed at mitigating the negative impact of nighttime work on the workers: (*a*) a 4-day workweek for night work, (*b*) pay differentials for night work, (*c*) itemization of traffic enforcement costs, (*d*) provision of temporary accommodations for night workers, and (*e*) a careful evaluation of when to do night work. In the opinion of the advisory group and the research team, these policies would go a long way toward enhancing the quality of life of nighttime workers.

Because the economic value of the congestion avoided by nighttime work is considerable, a portion of these savings should be transferred, in the form of a pay differential, to the people who make it possible. The quantitative estimates of the impact of pay differentials indicated that increases in the range of 15% and 20% lead to increases in total costs that represent a fraction of the economic savings produced by nighttime work and amount to increases in total project costs of 6% and 8%, respectively.

The analyses described here indicate that from a societal point of view, nighttime work should be undertaken if and only if the benefits that it produces in terms of travel time savings to motorists clearly exceeds the externalities generated (e.g., the impact on human factors and a loss of construction quality). More research is needed to produce guidelines that support such a decision-making process.

In all, it is clear that this is a very complex problem that involves complex trade-offs between the societal benefits of doing nighttime work and the impacts on the workers' human factors. Rather than providing a definite set of answers, this paper has highlighted the seriousness of a problem that is affecting the workers at nighttime construction projects. A major challenge is to address these problems while taking into account the needs and expectations of all stakeholders. This research is nothing more than the first step.

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