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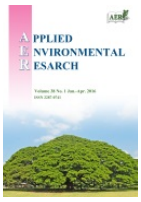

Development of Work-Rest Model for Reducing Fatigue in a Long Distance among Chemical Truck Drivers: Case Study in an Industrial Gas

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Abstract

This study examined the impact of rest breaks on driver fatigue. The study developed and tested a work-rest model to reduce fatigue for chemical truck drivers, following International Labor Organization (ILO) guidelines. The model was tested on a small sample of workers driving from a gas filling plant in Sattahip district, Chonburi province to Muang district, Samut Sakorn province. To test the model, data on driver fatigue was assessed using an interview questionnaire and a flicker fusion instrument, and the Z-test was used to compare fatigue among three work-rest patterns. The results showed 24% of working time (173 minutes) for the drivers sampled was allocated for relaxation, based on a mean driving time of 12 hours. Two work-rest models were developed, considering driving distance, time and levels of fatigue. The findings indicated that the regular schedule pattern resulted in the highest levels of fatigue, both as measured by subjective questionnaire and objectively by the critical flicker frequency value (CFF). Model II, with two 26-minute rest breaks, offers a more effective model to reduce fatigue, using less driving time than model I, with four 13-minute rest breaks. However, this resulted in other new challenges, for example, the need for extended shifts, an increase in production costs and personal costs. Transportation business owners should prepare meals and drinks for chemical transport drivers on the Sattahip to Samutsakorn route (and other cross-province routes) in order to make it more convenient for them to follow safety practices.

Keywords: Chemical truck driver; Critical flicker frequency; Fatigue; Industrial gas; Work-rest model

Introduction

While driving involves very little physical activity, a high degree of vigilance and mental alertness is required. Long-distance drivers exhibit poorer driving performance compared with ordinary drivers, and are more susceptible to fatigue [1-2]. Driving when fatigued can severely impair performance and can ultimately result in the driver falling asleep at the wheel. Fatigue means the inability to function at the desired level due to incomplete recovery from the demands of prior work and other waking activities [3]. Fatigue is a construct that links factors such as time of day, time since waking, task duration and monotony, with safety-related outcomes [4-5]. The effects of fatigue can vary but are best viewed as a continuum, ranging from mild, infrequent complaints to severe, disabling manifestations including burnout, overstrain, or chronic fatigue syndrome [6]. Driving while fatigued has been acknowledged as a major risk factor in road accidents. A comparison of how long distance drivers had slept before an accident and the time of the accident showed that they had slept less than usual. In addition, the risk of a critical event increases with drivers who received significantly less sleep than usual, suggesting fatigue as a major contributing factor [7]. In many countries including South Africa and Thailand, fatigue is not fully defined as an offence under traffic legislation, and hence remains a form of driver behavior that cannot be effectively targeted [8].

Rest break or work-rest means the off duty time that setting during driving to pull driver to get rest [9]. It has an important restorative function and is of fundamental importance in avoiding driver fatigue [10]. Dahlgren et al. [11] found that 12-hr day shifts, which are common in Thailand, were linked to higher levels of fatigue. Vigilance performance recovers with rest [12], and rest breaks have a significant effect on delaying the onset time of a work-related injury, which may have significant safety implications [13]. However, they are not known to restore performance levels after about 9 hours of work [14]. Several studies suggested that the inclusion of rest breaks within a shift and time-off between shifts resulted in significant reductions in fatigue and increased productivity [9, 15-16] with different types of breaks demonstrating different effects [12]. Breaks from driving without sleep temporarily ameliorate time-on-task fatigue [17]. Such findings have led to the restriction of driving hours to a maximum of 9-10 hours per day by the International Labor Organization (ILO). Relaxation allowances should be determined to allow the worker to recover from fatigue and to attend to personal needs, and also break up the monotony of the day [17]. Regulation 29 CFR Part 525 of the United States Department of Labor states that when determining work rates, appropriate time shall be allowed for personal time, fatigue, and unavoidable delays [18]. In the United States, the Department of Transportation sets two period breaks for driving long distances: for example if driving 4 and a half hours, a 15 minute first break and 30 minutes second break is mandated. In EU the rest periods are 30 minutes after 6 hours of driving or, alternatively, two 15-minute breaks [19]. According to the Thailand Transport Law B.E. 2522 Section 103, a driver must not drive more than four consecutive hours. Drivers need to break for 60 minutes in order to drive further, but not more than four additional hours after this break. The Labor Protection Act B.E. 2541 (Regulation No. 12) stipulates that drivers can normally not drive for more than 8 hours per day. However, they are permitted to work overtime for 2 hours per day. Drivers must have a rest period of 60 consecutive minutes to drive further, but cannot drive more than an additional four hours. If a driver will drive against the next day, he must rest for at least 10 consecutive hours [20].

At present, road transport is the predominant form of chemical transportation in Thailand. There are many research studies on risk management among drivers but there are fewer studies specifically investigating chemical transport drivers. In addition, there are currently no official guidelines on the working hours and work-rest periods of chemical transport drivers.

From this perspective, this study focused on developing a work-rest model for reducing fatigue among long-distance drivers in the hazardous chemical transport industry. The research outcomes provide beneficial results for the enterprise as a guideline to set driving schedules to include appropriate rest breaks for drivers. This also carries important public health benefits by reducing the incidence of traffic accidents involving dangerous chemicals.

Materials and methods

1) Sampling sites and study population

Selection criteria for sampling locations were based on industry location, type of industry and other factors including consent of the plant manager and workers to conduct the research. Sampling sites were high-risk chemical Industries as defined in the attachment to the notification of the Ministry of Industry No.3/2542 under the Hazardous Substances Act B.E. 2535. By considering incidents during chemical transportation, one of the industries encountering frequent accidents- namely, the liquid gas industry, was selected as the sampling location for our study [21]. All participants were chemical truck drivers driving a long distance (480 kilometers per trip) from Sattahip district, Chonburi province to Muang district, Samut Sakorn province. Due to the small population of drivers working on this route (n=5), data were collected from all drivers. Inclusion criteria were having experience for driving truck chemical in the industry for at least 4 months, willingness to give written informed consent and no diseases affecting their levels of fatigue (such as gout, osteoarthritis). Participants who changed in the driving route while data collection were excluded from the study. A consent form was signed before completing a questionnaire and other tests. This study was approved by the Ethics Review Committees for Research on human subjects, Burapha University.

2) Study design and tool

A quasi-experimental design was performed during May-July, 2016 in an industrial flammable gas factory located in Sattahip, Chonburi. The study route of chemical transportation was between the gas filling plant at Sattahip and the gas station at Samut Sakorn. A relaxation allowance is an addition to the basic time intended to provide the worker with the opportunity to recover from the physiological and psychological effects of specified work and to allow attention to personal needs [17]. The relaxation allowance was calculated using the semi-quantitative assessment fatigue scale following ILO guidelines. Subjects were interviewed using questionnaires comprising four parts: sociodemographic profile (age, BMI), work history (in terms of work experience, driving hours and distance, safety training), worker's health status (i.e., congenital diseases, visual abnormality, sleeping hours, smoking and alcohol drinking habits) and subjective fatigue questions. The drivers' objective fatigue levels were also assessed using a flicker fusion instrument (Flicker fusion model 12021A). The questionnaire was sent to 3 experts to verify its structural and content validity with Index of item Objective Congruence ($IOC \geq 0.6$). Consistency was examined using Cronbach alpha coefficient, which was calculated to be 0.788. Global positioning system (GPS) was used to measure the drivers' actual speed and to monitor their routes.

3) Assessment of driver fatigue

Measurements of the critical flicker frequency threshold were undertaken by intrafoveal stimulation with a luminous diode. It was measured in a quiet, semi-darkened room. When the eyes are not fatigued, they would be perceived to blink well at high frequency; critical flicker frequency values (CFF) will be high. The results of testing showed decreased CFF values when visual fatigue occurred. Critical flicker frequencies were measured before and after driving for three times each and the mean value was then calculated. The unit of critical flicker frequency was reported in Hertz. Fatigue symptoms were observed when the value of CFF_{after}-CFF_{before} were less than 1. With a high variability between individual scores, we assessed objective fatigue by using the standard deviation for each person.

Subjective fatigue was assessed using the Piper fatigue scale [22]. This is a 22-item scale used to measure the following four subscales: behavior (6 items), affect (5 items), sensory (5 items) and cognition/mood (6 items). Each item has 11 response categories on a 0-10 metric scale with verbal descriptors anchoring the endpoints. Each subscale is scored individually and then aggregated together for an overall score, with higher scores reflecting greater fatigue. The subjective fatigue scores were then classified into a 2-category response scale (0.00-4.00 = no fatigue; 4.01-10.00 = fatigue).

4) Research procedure

This study procedure comprised six steps including: (1) contacting chemical industrial sites to explain the study aims and methodlogy; (2) survey of the chemical truck driving route and the usual driving style; (3) studying the rest-break time according to the ILO; and (4) taking the calculated rest-break times to propose to the factory in order to determine the optimal rest-break model, as well as to administrative and safety committees for considering the possibility of introducing these rest-break models; (5) testing all rest-break patterns, spacing them one week apart; and (6) conducting a meeting to present the results, including the model that resulted in the greatest reduction of fatigue.

5) Calculation of relaxation allowance by following ILO guidelines

The instrument used for calculation of relaxation allowance comprised 3 basic groups of factors including personal, work and environmental factors. The instrument was developed under the guidelines of the International Labor Organization [23] using the semi-quantitative assessment fatigue method. Three experts in industrial hygiene and safety (IHS), as well as a logistics engineer, assessed the scores and percent level of relaxation allowance. After that the scores for each factor were added together and converted into percentage of relaxation allowance time and thence into rest-break times in hours and minutes. The researcher then proposed the calculated rest-break times to administrative and safety committees of the factory in order to establish a practical model for rest-breaks and to consider adopting this rest-break model for chemical transportation drivers.

6) Statistical analysis

All general data including socio-demographic profiles, work history and health status were analyzed by descriptive statistics including number, percentage, mean, standard deviation (SD), median, minimum and maximum values. Analysis of CFF value change pattern for each time period was presented using linear graph plotting between driving time and CFF value, based on personal driving and work-rest patterns. The Z-test for proportional difference was also used to compare fatigue among three work-rest patterns in chemical truck transport driving. The statistically significant criterion was set at p=0.05.

Results and discussion

For regular *(existing)* pattern on the study route, between Sattahip gas filling plant and Samut Sakorn gas station, the distance per trip was approximately 480 kilometers, which took the drivers a mean 13.55 hours to traverse (SD=1.02). Work rest was flexible in timing and there were no fixed places for rest breaks and no fixed route among the sample of drivers. The average number of work-rest was 2.8 breaks/ trip (range of 2-4 breaks); however, drivers had rest breaks on the roadside which is not considered safe for activities such as smoking or other personal activities. The roads most regularly used were Sukhumvit Road, Bangna Trad Road, Bangna Expressway (Burapha Withi), Motorway No.7 Road and Kanjanapisek Road, depending on traffic conditions and driver familiarity with each routes. The average driving time was 788 minutes (range 720-900). The mean speed measured using GPS was 40.2 km/hr (range 28.7-45.0).

Normally, the driver might take time out for personal needs, fatigue allowance and contingency allowance [24-25]. In our study, based on 1 month of observations on the route, the mean number of driving hours was about 12 hours or 720 minutes. Therefore, the rest break time was about 173 minutes (24% of 720 minutes), in other words, 24% of working time of the drivers was allocated for relaxation (the so-called “relaxation allowance”). The reasons for the rest break were reported according to be (1) personal factors, defined as personal and basic fatigue allowance, which comprised 9% of working time, (2) physical strain, defined as relief from posture and vibration, and mental strain, i.e. related to concentration, monotony, visual fatigue resulting from work factors (15% of working time), and (3) working environment factors which were reported none of working time (0%) (Table 1). However, optimum rest schedules are likely to be specific to the nature of the work activity being under taken (e.g. driving route) as well as difference in both the individual’s state (e.g. ability, motivation, sleep debt) and trait (e.g. circadian type) [26].

Two models of rest break schedules and route were proposed by the research team based on the theories of safety and fatigue management system [3, 17, 27]. Driving performance (e.g. ability to control, navigate, and guide the vehicle) decreased significantly after about 8 hours of driving with regular schedules, and after just 4-5 hours of driving with irregular schedules. For long distance driving, it was determined that the driver should rest after 2 hours of driving for at least 15 minutes [22, 28-29]. For the rest area, the research team investigated safe parking spaces for chemical trucks which must have facilities for the drivers, such as toilets. The proposed safe route for chemical transportation was Motorway No.7 Road, continung along Kanjanapisek Road. Both proposed models provided 53 minutes of break time by setting 120 minutes for loading gas time at Samut Sakorn gas station .Loading gas time varied between 1.5-2 hours .However, at the time of loading gas, driver had rest time of approximately 1 hour. In the first experimental rest break model (Model I), workers were given four 13-minute breaks evenly distributed over the driving distance (a 13 minutes break for every 2 driving hours by average. In the second rest break model (Model II), workers were given two 26-minute breaks evenly distributed over the driving distance (26-minute break about every 120 km of distance as shown in Figure 1. The proposed 4 rest break areas for Model I were on the Motorway No.7 Road, km.79, car park after Kanjanapisek Tollway gate, Samaedam Rama II Road, km.11, and Motorway No.7 Road, km.49 (Motorway Service Center). For Model II, the proposed 2 rest break points were both on the Motorway Service center as shown in Figure 2.

Table 1 Calculation of relaxation allowances for chemical truck driving

Items	Relaxation allowance	Percent level (%)	Data description
1	Personal allowance	5	ILO guideline
2	Basic fatigue allowance	4	ILO guideline
3	Posture	2	Fixed sitting posture in truck cabin
4	Vibration	1	Whole body vibration, only on the rough road
5	Concentration	5	High concentration
6	Monotony	3	Constant in motion
7	Visual	4	Eye strain from focusing and contending with distractions i.e., sun glare, headlights
8	Working environment condition	0	Close cabin with air conditioner, temp.77F and humidity 55%
	Total	24	

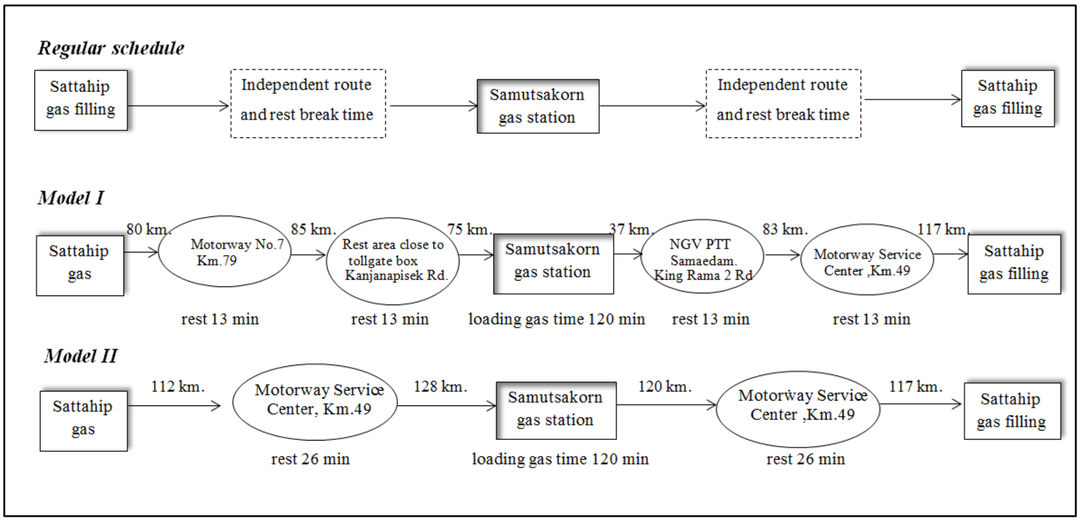

Figure 1 Driving route, regular schedule and proposed work-rest model.

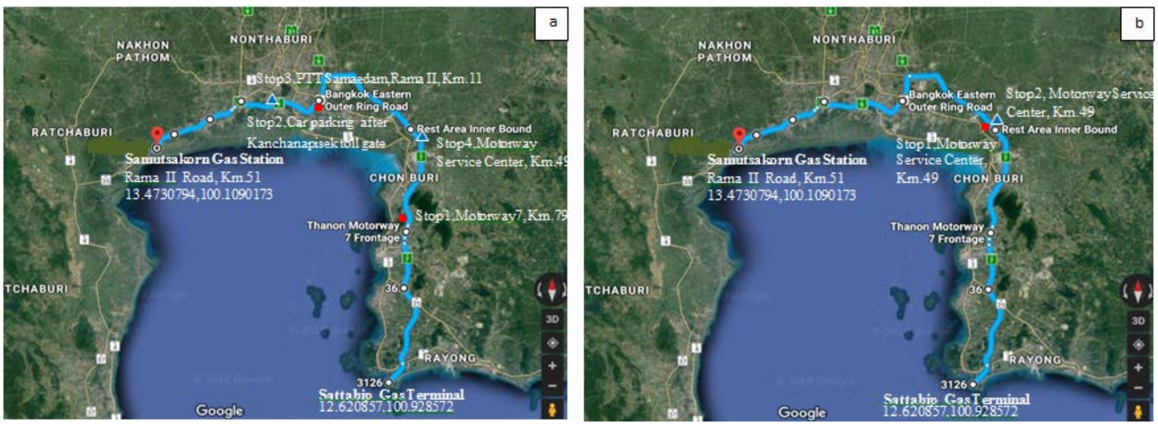

Figure 2 Rest break model I (a) and model II (b)

Break point from Sattahip gas filling plant to Samutsakorn gas station

Break point from Samutsakorn gas station to Sattahip gas terminal.

Five chemical truck drivers participated in this study. All were male and had driving experience in the range of 1-17 years. Their mean age was 37.8 years and mean BMI of 27.44 kg/m^2. 80% of the drivers were overweight as indicated by their BMI (BMI $\geq$ 23). All drivers had been trained in chemical and road safety. Of all participating drivers, one (20%) had a history of visual abnormality and had an accident affecting bone and muscle within the past year. Sixty percent (3 out of 5) of participants were daily smokers and occasionally drank alcohol. The general characteristics of drivers are summarized in Table 2. IN regard to sleepiness, although we controlled sleep hour before starting the experiment, about 10 % of trial drivers slept not less than 6 hours per night. Model testing results showed that both of the two experimental rest break models had a negative effect on production, and the 26-minute breaks model showed the least percentage of fatigued drivers (20%). The regular (existing) schedule pattern resulted in the highest levels of fatigue, as measured both by CFF and by psycho-physiological questionnaire. There was no subjective fatigue among the participating drivers both in either proposed model (I & II, Table 3). However, subjective fatigue might not reflect the objective physiological status of the fatigued person because of bias in motivation and personal factors such as experience, training, and so on [30]. The individual objective fatigue values (CFF) in each pattern are shown in Figure 3. For regular pattern, B had the most frequent breaks (4 times/trip), while D had at least one rest break per trip. There were 2 out of 12 (16.67%) rest breaks that increased fatigue. For model I, 15% (3 out of 20 break times) of 13-min rest breaks showed higher levels of fatigue. For model II, we found that all drivers had decreased fatigue after a 26-minute rest.

Table 2 Basic characteristics of drivers expressed as means (SD) (n =5)

Variable	Mean (SD)
Age (year)	37.80 (3.06)
BMI (kg/m^3)	27.44 (4.65)
Driving experience (year)	6.40 (6.22)
Driving distance (km/day)	479.46 (13.57)
Driving hour (hour/day)	13.55 (1.02)
	n (%)
Smoking / Alcohol drinking	
Yes	3 (60)
No	2 (40)
Vision	
Normal	4 (80)
Abnormal	1 (20)
Accident affecting bone and muscle 1 year past	
Yes	1 (20)
No	4 (80)
Chemical and road safety training	5 (100)

BMI, body mass index; SD, standard deviation

Table 3 Number (percentage) of fatigue drivers from flicker fusion test and questionnaire

Work-rest patterns	Flicker fusion test		Subjective fatigue questionnaire	
	n	**%**	**n**	**%**
Total (n = 15)	6	40	1	6.67
• Regular break schedule (n=5)	3	60	1	20
• Model I: four 13-minute breaks (n=5)	2	40	0	0
• Model II: two 26-minute breaks (n=5)	1	20	0	0

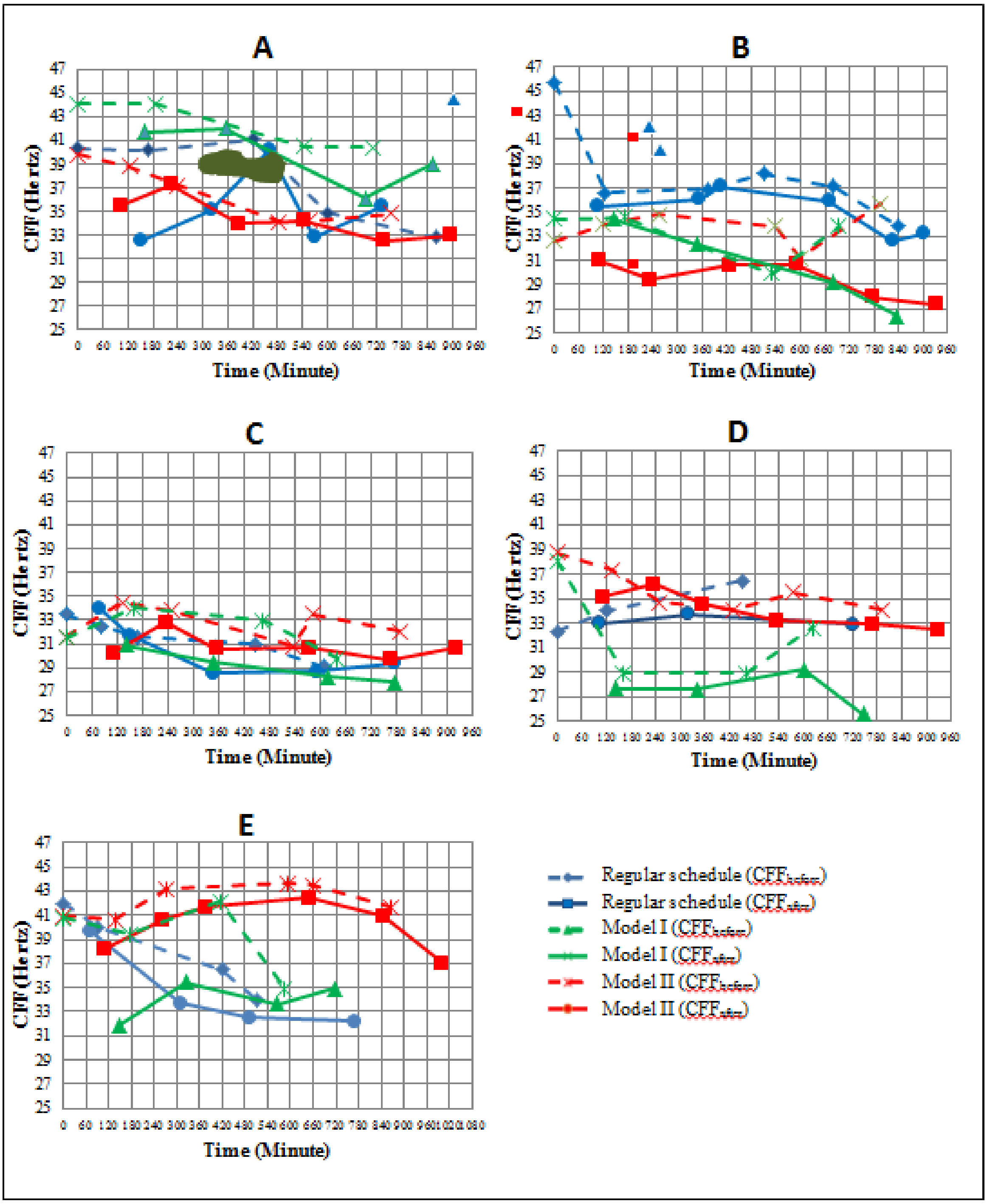

Figure 3 Individual fatigue (A-E) reported in CFF value for Regular schedule and Model I&II.

From this research, it was found that model II with two 26-minute rest break showed the lowest level of objective fatigue (CFF) followed by model I with four 13-minute rest breaks and a regular driving schedule, respectively (Table 4). Results of the statistical analysis with the Z-test for proportional difference showed no significant differences between the CFF values in the three rest break patterns as shown in Table 5. However, the satisfaction survey revealed that the drivers were more satisfied with Model I (41.33%) and Model II (24%), respectively, due to reasons of cheap food (at Motorway No.7 Road, km.79) and smoking. Approximately 35% of drivers were still satisfied with the regular schedule pattern (data not shown).

In regard to driving time, we found that model I resulted in the longest driving time of 865 minutes (≈14.5 hours) while the others used travel time of approximately 13 hours. Therefore, Model II was preferred over Model I due to the time saving of about 1.5 hours, which further reduced fatigue. This was in agreement with the findings of Campbell [5] who reported that increased driving time was associated with a higher relative risk of fatigue-involved crashes for truck drivers. To classify by person, D took the least amount of time and B took the longest time on average. However, the driving hours of each work-rest pattern and each driver were not significantly different (p=0.07 and 0.55, respectively) (data not shown). In regard to driving distance, Model II had the longest distance (487 km) while the regular pattern had the shortest distance (466 km). Most drivers used Sukhumvit Road and Bangna Trad Road for the schedule pattern due to the shorter distance and/or to avoid driving into the sun. If loading gas time was less than 2 hours, we proposed drivers to prolong their rest break to 15 minutes (Model I) and to 30 minutes (Model II). These were consistent with previous reports, indicating that a 15-minute rest allowed drivers to recover from a two-hour driving task [1, 19].

Table 4 Driving fatigue assessed by using flicker fusion test among three work-rest patterns

Work-rest patterns	**Number (%) of objective fatigue drivers***		
	Sattahip to Samutsakorn gas station	**Samutsakorn to Sattahip gas filling plant**	**All driving distance**
Regular break schedule	2 (40)	2 (40)	3 (60)
Model I: four 13-minute breaks	3 (60)	1 (20)	2 (40)
Model II: two 26-minute breaks	2 (20)	0	1 (20)

Table 5 Comparison of objective fatigue by using critical flicker frequency value among three work-rest patterns in all driving distance

	Work-rest patterns	**Objective fatigue drivers**		**Z**	**p-value**
		n	%		
1	Regular break schedule	3	60	0.63	0.527
	Model I: four 13-minute breaks	2	40		
2	Regular break schedule	3	60	1.29	0.197
	Model II: two 26-minute breaks	1	20		
3	Model I: four 13-minute breaks	2	40	0.69	0.490
	Model II: two 26-minute breaks	1	20		

The study's limitations included the small sample size, which may be one of the reasons why no significant differences were found in the analytical statistics. Another limitation was difference in driving start time at Sattahip gas terminal which was in the range of 4.00-10.30 a.m., depending on the customer's order. This meant the time for returning to the depot in Sattahip also varied from 6.00-11.00 p.m. This time difference could also affect sleepiness and driver fatigue and confound the findings .Sleep deprivation and wake-up time are major risk factors for fatigue [18, 31]. In addition, truck driver's irregular working schedule is a contributing factor to truck-related crashes [27, 32]. Other potential sources of study bias might be caffeinated beverages (i.e. energy drink, coffee, tea) which could reduce fatigue and return driving performance to baseline (pre-sleep deprivation) levels [33-34]. In future, the study design should be improved to emphasize the need for careful and accurate fatigue monitoring such as increased number of study trips for each work-rest pattern, and controlling caffeinated beverages.

Conclusions

This research suggested the optimized break period for chemical truck drivers of long distances is 173 minutes and proposed rest break areas for chemical trucks leading to more effective work performance and higher safety. Model II, with two 26-minute rest breaks was proposed as the optimal model of chemical transport drivers due to its higher effectiveness in reducing fatigue, as well as using less driving time than Model I which had four 13-minute rest breaks. However, the models generated scheduling issues such as the extended shifts, increase in production cost for toll fees, and an increase in personal cost for foods and drinks. The business firms should prepare toll fees, meals and refreshments for chemical transport drivers on the Samut Sakorn route (and other cross-provincial routes) in order to make them convenient and following prescribed safety practices. In addition, employers should pre-determine designated rest areas or safety points on other chemical transport routes.

Rest breaks were not effective to reduce fatigue if there are no relaxing activities while resting. Further study is needed on the efficiency of an intervention program for reducing fatigue during rest breaks (i.e., taking a nap, drinking coffee or tea, eating snacks between or instead of main meals), and may contribute further to reducing fatigue and accidents among chemical truck drivers.

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