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Studying the Effect of Fatigue and Sleepiness of Long-Haul Truck Drivers on Road Accidents by Adopting Structural Equation Models Analysis

Zhaleh Shams[a], Hamed Khani Sanij[a], Alireza Afshani[a], Ehsan Ramezani-Khansari[c*], Fereidoon Moghadas Nejad[c] & Martin Olazar[d]

[a] Department of Civil Engineering, Yazd University, Yazd, Iran
[b]Department of Social Sciences, Yazd University, Yazd, Iran
[c] Department of Civil Engineering, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran,
[d] Department of Chemical Engineering, University of the Basque Country, Bilbao, Spain

**Corresponding author: E.R.Khansari@aut.ac.ir*

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ABSTRACT

The significant increase in transportation and heavy vehicle traffic has caused freeway routes with heavy traffic to face a decrease in safety levels. Furthermore, fatigue and sleepiness are proven to be two of the main reasons of road accidents, and therefore focus on these issues is crucial. Factors such as "use of engineering (safety) technology for road transport", "informing the drivers on various educational methods", "controlling the drivers' work hours", "use of different routes (alignment inconsistency)" and "observing the drivers' mental health" should be approached to reduce the accidents caused by fatigue and sleepiness. Given the complex interrelationships between these variables and the number of road accidents, structural equation modelling has been used in this study to estimate the effect and relationships between multiple variables. Data were collected during a 5-month period by interviewing heavy vehicle drivers (2765 filled-out questionnaires). The Confirmatory Factor Analysis (CFA) has also been used to ascertain the validity of the questionnaires. The mentioned factors affecting the drivers' fatigue were analyzed using SPSS 24.0 package, which allowed ascertaining that the drivers' mental health is the factor of greater influence on road accidents caused by fatigue and drowsiness. Therefore, actions to improve the drivers' mental and emotional health (by improving the currently used engineering (safety) technology and alignment inconsistency) should be enhanced rather than excessive controls on the drivers' work hours by using GPS, work papers and inspections.

Keywords: Road accidents; fatigue; sleepiness; heavy-vehicle drivers; structural equation modelling

INTRODUCTION

Road accidents are one of the leading causes of death each year and, furthermore, they also cause personal and financial damage to people and society. The significance of such damages is much more relevant in developing countries than in developed ones. Thus, according to the statistics published by WHO, 24896 people lost their lives in road accidents in Iran for the years 2013 and 2014 (WHO 2015). As a result, many studies have been conducted in the field of road accidents in order to ascertain their main causes (PIARC et al. 2004; Oh et al. 2010; Bourdeau, 2014). Motorized vehicles are a major part of our daily lives, and their number is still increasing, which is one of the causes responsible for the increase in the number of accidents (Zhanga et al. 2016). In various researches conducted in this field (Mannering & Bhat 2014; Gregoriades & Mouskos 2013; Lee et al. 2015), driver's drowsiness has been considered one of the most significant facts causing the accidents (Aidman et al. 2015; Zhang & Chan 2014). They weaken the drivers' ability to control the vehicle and cause a delay in their reaction time, increasing the probability of road accidents (Wang & Pei 2014). Although this phenomenon is one of the main factors leading to accidents (in fact it is called the "silent killer), most people are not aware of its possible harms (Guangnan et al. 2016). Thus, the connection between drivers' fatigue and road accidents has been analyzed in many studies (Pizza et al. 2010; Komada et al. 2013; Bunn et al 2017). Thus, long trips on uniform roads, such as expressways, because more fatigue, which applies especially to heavy-vehicle drivers due to their long drives (Philip 2005; Howard et al. 2004). One of these problems is sleep deprivation, which results in more fatigue and a decrease in drivers' safety-relevant performance (Ingre et al. 2006; Otmani et al. 2005), thereby causing drowsiness-related road accidents. In general, the possibility of accidents leading to death is 7% higher for long-haul truck drivers (Smith 2015). From the previous researches, factors such as "use of engineering (safety) technology for road transport" (Anund 2008; Nagadarshan Rao 2017), "informing the drivers on various educational methods" (Elvik et al. 2009), "controlling the drivers' work hours (Elvik et al. 2009) and "use of different routes (alignment inconsistency)" (Liu & Wu 2009) can be related to accidents caused by fatigue and sleepiness. However, the relationships between these variables are not easily identified. Therefore, structural equation modeling (SEM) is used in this study to find these relationships. SEM is a confirmatory technique that allows the analyst to examine dependences between observed and latent variables simultaneously (Golob 2003). Therefore, the variables of greater influence on the accidents caused by drivers' fatigue and sleepiness are ascertained

MATHEMATICAL FORMULATION

The SEM approach is a very powerful multivariate analysis technique that can explain the relationships between endogenous and exogenous variables by analyzing the structure of their interrelationships expressed through a series of simultaneous equations. Therefore, it is a technique that allows testing a group of hypotheses based on all the available data. The SEM approach consists of two parts: 1) a measurement model to evaluate the relationships between observed and latent variables. 2) a structural model to show the direction and strength of the relationships between endogenous and exogenous variables. The structural model may be written as follows:

$$\eta = B\eta + \Gamma\xi + \zeta \tag{1}$$

where η is the m × 1 vector of the endogenous latent variables, ξ is the n × 1 vector of the exogenous latent variables, B=m×m is the matrix of the coefficients associated with the latent endogenous variables, Γ is the m × n matrix of the coefficients associated with the exogenous latent variables and ζ=m × 1 is the vector of the error terms.
The measurement model can be defined by the following equations (Bollen, 1989):

$$\mathrm{x} = \Lambda_X + \delta \tag{2}$$

$$y = \Lambda_y + \varepsilon \tag{3}$$

in which X is the column of vectors related to the exogenous variables, y is the column of vectors related to the observed endogenous variables, Λ_X = q × n is the structural coefficient matrix for the effects of the exogenous latent variables on the observed variables, Λ_y is the p×m matrix of structural coefficients for the effects of the latent endogenous variables on the observed ones, δ is the q × 1 vector of measurement error terms for observed variables x and ε is the p × 1 vector of the measurement errors for the endogenous indicators.

METHODS AND PRINCIPLES

The information to be analyzed was collected by interviews and 2765 questionnaires gathered from heavy-vehicle drivers in the national rest stops for truck drivers, which are located on the highways in Iran. This study aims at ascertaining the factors affecting drivers' fatigue and sleepiness, which have been analyzed using SEM (AMOS Graphics v.22 and SPSS 24.0 software packages).

Summary of Descriptive Statistics of the Questionnaires

Concerning the age of the people, 1121 (40.5%) were aged from 20 to 30, 702 (25%) from 30 to 40, 452 (16%) from 40 to 50, 471 (17%) from 50 to 60 and, finally, 19 (1.5%) were above 60. Their average age was 36.4, and the standard deviation 11.748. A total of 545 drivers had elementary school degree, whereas 2106 were high school graduates, and only 114 had a college degree. A total of 1635 (59.1%) had 1-10 years of driving experience, 515 (18.6%) 10-20 years, 379 (13.7%) 20-30 years, 132 (4.8%) 30 to 40 years, and only 104 person (3.8%) had 40-50 years of experience. Approximately 21.5% of these drivers considered the hours from 12 to 3 a.m. as those they felt most tired and drowsy, while 69% considered the hours from 3 to 6 a.m. as the most tiring. In addition, 56% of the drivers used to sleep less than 6 hours a day, whereas 36% of the whole group were driving for 9 to 11 hours a day, and 32.5% for more than 11 hours a day.

As observed above, 68% of the drivers, were driving for 9 to 11 hours or even more every day (Table 1). Table 1 shows the vehicle they drive and the places they choose for resting when tired. According to these statistical reports, it is clear that the drivers mostly choose heavy-vehicle rest stops, in which they sleep in the cabins inside trucks and roadside rests. Therefore, they take a low-quality rest, as these rest stops contain a high amount of air and noise pollution (e.g., vehicle smoke), which can interrupt the drivers' sleep (Lekme et al. 2016). As a result, long-haul truck drivers usually spend considerable time on the road, which can cause mental and emotional stress. Hence, proper rest stops and service areas, safety engineering for road transport and informing the drivers about the dangers of non-stop driving, particularly at the final hours in the nigh or at the first hours in the morning (Vivoli et al. 2013), are essential facts.

TABLE 1. Summary of descriptive statistics of the questionnaires

Data	Number	%	Mean	SD
Age			11.748	36.40
40 and younger	1823	65.9		
41 and older	942	34.1		
Education				
Elementary school	545 2106	19.7		
High school or less	114	76.1		
College degree		4.12		
Type of vehicle				
Trailer	2115	76.5		
Truck	650	23.5		
Driving experience				
10 or less years	1635	59.1		
More than 10 years	1130	40.9		
Drivers resorts				
gas station	276	10		
Mosques along the road	387	14		
Heavy vehicles stations	651	23.5		
Police stations	1175	42.5		
Inside the truck	276	10		
Sleepiness peak hours				
24 to 3 AM	594	21.5		
3 to 6 AM	1908	69		
6 to 10 AM	124	4.5		
10 to 13 AM	42	1.5		
13 to 16 PM	69	2.5		
16 to 24 PM	28	1		
Daily work hours				
Less than 5 hours	69	2.5		
5 to 7 hours	235	8.5		
7 to 9 hours	567	20.5		
9 to 11 hours	995	36		
More than 11	899	32.5		
Sleep duration (workdays)				
Less than 6 hours	1548	56		
6 to 7.15 hours	885	32		
7.15 to 8.15 hours	263	9.5		
More than 8.5	69	2.5		

With this aim, the goodness-of-fit parameters of the structural model were analyzed following Hooper (Hooper et al. 2008). Thus, different kinds of indices are used to determine the model fit, and acceptable threshold levels for each one are suggested. The following goodness-of-fit indices were used in this research:

1. Absolute fit indices: Chi-squared test, goodness of fit index (GFI), adjusted goodness of fit index (AGFI), root mean square error of the approximation (RMSEA) and root mean square residual (RMR).
2. Incremental fit indices: Normed fit index (NFI) and comparative fit index (CFI).
3. Parsimony fit indices: Parsimony goodness-of-fit index (PGFI) and parsimonious normed fit index (PNFI)

CONCEPTUAL FRAMEWORK OF MODEL AND VARIABLES

In the study, twenty variables of accidents caused by fatigue and sleepiness are set as ‘x observed variables’, which could be split into several groups having similar characteristics (i.e., exogenous latent variables in SEM). Four variables are set as ‘y observed variables’, which would make endogenous latent variables representing ‘accidents caused by sleepiness’ in the SEM, and six variables are latent variables. In our initial model, 22 observed variables are used and they are split into the six groups (latent variables) shown in Table 2: 1) Engineering (safety) technology, 2) Informing the drivers, 3) Controlling the drivers’ work hours, 4) Alignment inconsistency, 5) Observing the drivers’ mental health, 6) Accidents caused by fatigue and sleepiness. Table 2 shows the definitions of latent and observed variables and the codes used for them.

TABLE 2. Definitions of latent and observed variables and their codes

Latent variables	Observed variables	Observed variable coding	Levels for variable quantification
Engineering (safty) technology	Appropriate road lighting	V1	Very little: 1
	Increasing the safety of the roads by installing rolling barriers instead of W-beam guardrail	V2	Little: 2
	Using shoulder rumble strips	V3	Average: 3
	Using rumble strips	V4	A lot: 4
	Repairing the incline on the side of the road	V5	A great deal: 5
Informing the drivers	Holding classes for road safety education	V6	
	Handing out educational booklets and CDs to the drivers	V7	
	Informing them through mass media such as TV or radio	V8	
	Installing warning signs and posters along the roadside	V9	
Controlling work hours	Installing GPS on the vehicles	V10	
	Checking the work papers and inspecting the drivers	V11	
Alignment inconsistency	Having curves on the road and avoiding long straight forward roads	V12	
	landscaping the road (e.g., roadside planting)	V13	
	Glowing lines and signs	V14	
	Free tea stations with sport programs	V15	
	Police patrolling	V16	
	Building appropriate rest stops and service areas	V17	
Drivers’ mental health	Inappropriate police behavior	V18	
	Changing rumble strips to improper bumps	V19	
	Low quality asphalt	V20	
Accidents caused by fatigue and sleepiness	The number of damaged vehicles	V21	
	The number of injured person	V22	

RESULTS

FACTOR ANALYSIS

The main aim of factor analysis is to summarize the obtained data. It is based on the hypothesis that all variables correlate to some extent with each other. As a result, those variables that specify a common hidden dimension should have a high correlation with each other, whereas they have a low correlation with those variables that specify another dimension. In this study, the main aim is to distinguish clusters or classes of correlated variables that are independent factors (Ho 2006), for which the value of the test statistic may vary between 0 and 1. If the value of this statistic is greater than 0.4, the data will be appropriate for doing the factor analysis (Brons et al. 2009). The results of the factor analysis with orthogonal rotation are shown in Tables 3 and 4.

TABLE 3. Rotated Component Matrix[a]

Component	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
v1	.945	.011	.068	.025	.103	.158
v2	.978	.032	.046	.046	.093	.130
v3	.949	.032	.058	.027	.103	.122
v4	.961	-.002	.060	.044	.092	.124
v5	.953	.020	.045	.051	.089	.142
v6	-.090	.034	.042	.213	-.093	.327
v7	-.024	.043	.016	.195	-.094	.313
v8	-.089	.031	.055	.225	-.095	.304
v9	-.039	.037	.029	.222	-.098	.324
v10	-.129	.223	.050	.943	-.124	.017
v11	-.116	.218	.042	.947	-.116	.015
v12	-.014	.975	.129	.090	.045	.009
v13	-.037	. 751	.130	.086	.036	.041
v14	-.004	. 862	.137	.105	.052	-.015
v15	-.046	. 969	.131	.084	.035	.043
v16	-.034	. 872	.132	.089	.040	.027
v17	.250	.677	.273	.293	.049	-.335
v18	.052	.213	.909	.066	.215	-.002
v19	-.021	.210	.904	.010	.108	.007
v20	.034	.206	.935	.039	.147	-.007
v21	.209	.079	.325	-.199	.844	-.074
v22	.277	.107	.203	-.084	.886	.040

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization
a: Rotation converged in 6 iterations.

TABLE 4. Rotated Component Matrix[a]

Component	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
v2	0.978					
v4	0.961					
v5	0.953					
v3	0.949					
v1	0.945					
v12		0.975				
v16		0.872				
v15		0.969				
v14		0.862				
v13		0.751				

continue ...

... continued

v17		0.677				
v20			0.935			
v18			0.909			
v19			0.904			
v11				0.947		
v10				0.943		
v22					0.886	
v21					0.844	
v6						0.327
v9						0.324
v7						0.313
v8						0.304

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization
a: Rotation converged in 6 iterations.

According to Tables 3 and 4, Factor 1 is related to 'engineering (safety) technology' because it accounts for a high load of certain observed variables, as are: Rolling barriers, repairing the incline, shoulder rumble strips, rumble strips and appropriate road lighting. Factor 2 is related to 'alignment inconsistency' because the observed variables of highest load are: Free tea stations, building appropriate rest stops, landscaping the road, police patrolling and glowing lines and signs. Factor 3 is related to 'drivers' mental health', as it is associated with the corresponding high load variables, as are: low-quality asphalt, inappropriate police behavior and changing rumble strips to improper bumps. Factor 4 is related to 'controlling work hours' because variables of significant load are: Checking the work papers and installing GPS on the vehicles. Factor 5, related to 'accidents caused by fatigue and sleepiness', is associated with the number of damaged vehicles and the number of injured people. Factor 6 is related to 'informing the drivers' because the variables of highest significance accounting for it are as follows: Classes for safety education, education by booklets and CDs, warning sign along the roadside and informing drives by TV or radio. Therefore, five factors are used as exogenous latent variables in the model. Twenty-two observed variables (twenty X observed variables and two Y observed variables) are grouped into six latent variables (five exogenous and one endogenous) for use in SEM, based on the result of factor analysis. Exogenous latent variables are Factors one 1 to 4 and the endogenous latent variable is Factor 5.

As observed in Tables 3 and 4, the values for Factor 6, which refer to the latent variable 'driver training', are below 0.4, and should therefore be removed. Although previous studies report that driver training has a positive effect on reducing accidents (Elvik et al. 2009; Alvaro et al. 2018), this is difficult to apply in developing countries, such as Iran. Thus, according to the reports analyzed, about 68% of the population drive on average from 9 to 11 hours and, frequently, even more than 11 hours every a day. Therefore, due to lack of sufficient time and job pressure, they have no favorable opinion on educational programs. It should also be mentioned that, in these countries, due to the low level of education quality and the lack of proper training programs by the relevant organizations, the driver training factor has virtually no effect on the reduction of such accidents. Maybe, this is why the drivers have been evaluating its impact at a low level.

The structural equations involved in the model are shown in Figure 1 and regression weights in Table (Table 5). They correspond to the situation prior to eliminating the latent variable "driver training".

As observed in Table 5, the p-value for "informing drivers" is 0.082, which is higher than 0.05, corresponding to 95% confidence internal. Therefore, the training of heavy vehicle drivers does not have a significant relationship with the reduction of accidents caused by fatigue and sleepiness. Therefore, once driver training factor has been removed the final model SEM of accidents caused by fatigue and sleepiness can be described as shown in Figure 2.

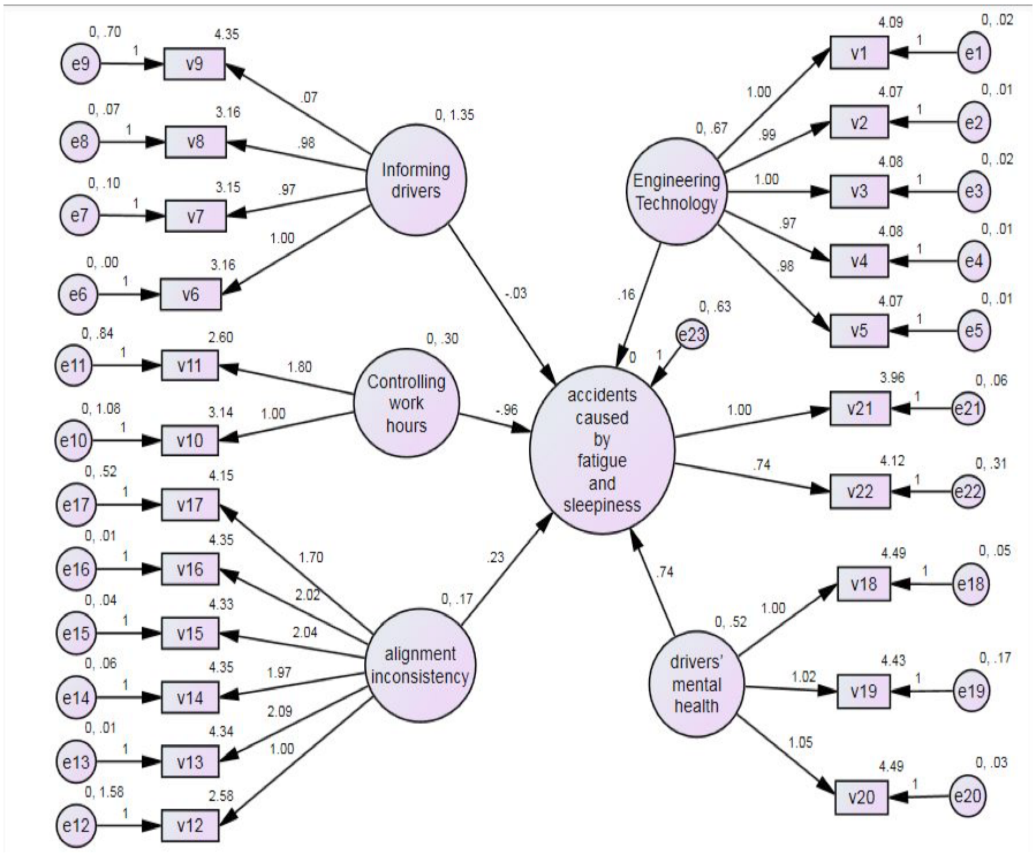

FIGURE 1. SEM of accidents caused by fatigue and sleepiness including all the factors

TABLE 5. Regression weights of measured relationships

			Estimate	S.E	C.R.	P
accidents_caused_by_fatigue_and_sleepiness	<--	Informing_drivers	-.026	.015	-1.740	.082
accidents_caused_by_fatigue_and_sleepiness	<--	Controlling_work_hours	-.964	.062	-15.561	***
accidents_caused_by_fatigue_and_sleepiness	<--	alignment_inconsistency	.227	.044	5.196	***
accidents_caused_by_fatigue_and_sleepiness	<--	drivers' mental health	.743	.024	30.358	***
accidents_caused_by_fatigue_and_sleepiness	<--	Engineering_Technology	.157	.021	7.522	***

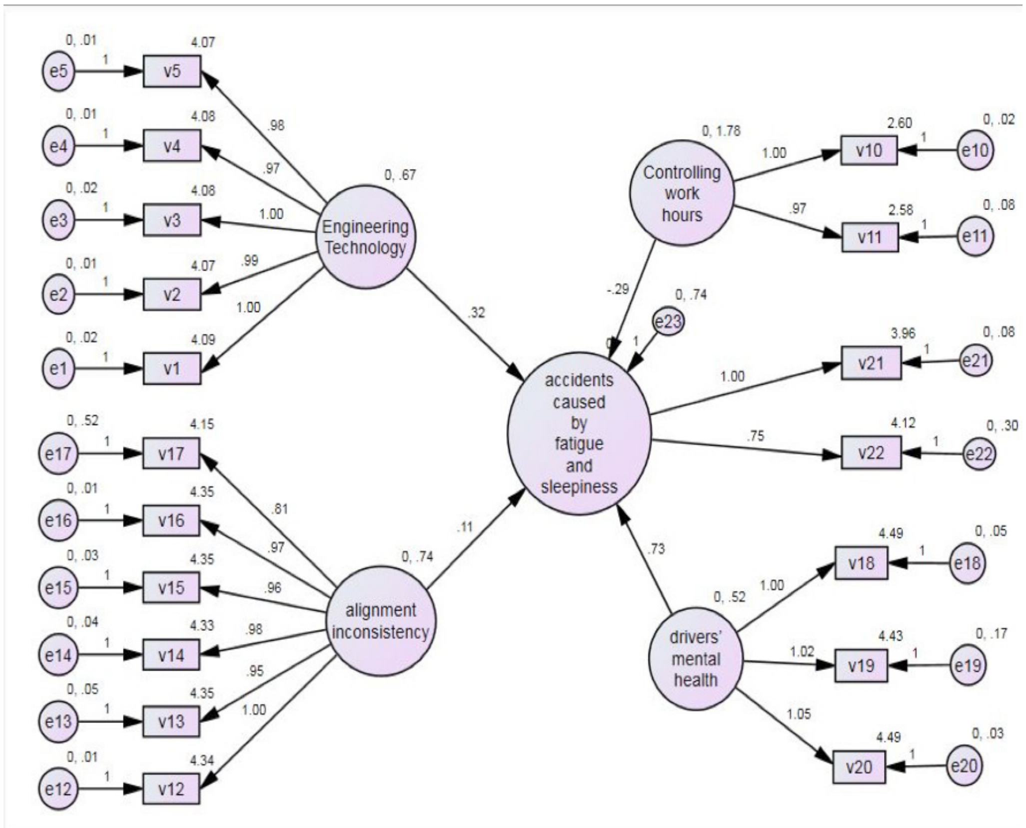

FIGURE 2. SEM of accidents caused by fatigue and sleepiness once factor 6 has been removed

As observed in Figure 2, the model allows deriving, for example, that V20 (low quality asphalt) (1.05) has a stronger influence on the drivers' mental health than V19 (changing rumble strips to improper bumps) and V18 (inappropriate police behavior), as the values of their corresponding coefficients are 1.05, 1.02 and 1.00, respectively. V12 (having curves on the road and avoiding long straight forward roads) has about 1.23 times stronger effect (1/0.81) on the alignment inconsistency than V17 (building appropriate rest stops and service areas). According to the structural model, the parameters estimated for four exogenous latent variables show that "observing the drivers' mental health", "using different routes (alignment inconsistency)" and "using the engineering (safety) technology for road transport" have positive path coefficients and "controlling the drivers' work hours" has a negative path coefficient. In other words, the first three have a positive effect and the fourth one has a negative effect in reducing road accidents caused by fatigue and drowsiness. Moreover, the main factor influencing "accidents caused by fatigue and sleepiness" is "observing the drivers' mental health". Hence, in order to decrease the road accidents caused by fatigue and drowsiness, controlling the drivers' mental health is more effective than any other latent variable in this model.

As already mentioned, the measurement model describes the relationships between the latent and observed variables, and the properties of the observed variables, whereas the structural equation model shows the pattern of relationships between independent and dependent variables, either observed or latent. These results for the SEM model are displayed in Table 6.

TABLE 6. Regression Weights of SEM

		Unst	S.E.	St	P
accidents_caused_by_fatigue_and_sleepiness	alignment_inconsistency	.112	.020	.290	***
accidents_caused_by_fatigue_and_sleepiness	Engineering_Technology	.322	.021	.437	***
accidents_caused_by_fatigue_and_sleepiness	drivers' mental health	.727	.025	.471	***
accidents_caused_by_fatigue_and_sleepiness	Controlling_work_hours	-.287	.013	-.445	***
v1	Engineering_Technology	1.000		.887	
v2	Engineering_Technology	.993	.004	.795	***
v3	Engineering_Technology	.995	.004	.888	***
v4	Engineering_Technology	.971	.004	.889	***
v5	Engineering_Technology	.979	.004	.894	***
v10	Controlling_work_hours	1.000		.994	
v11	Controlling_work_hours	.967	.012	.776	***
v12	alignment_inconsistency	1.000		.991	
v13	alignment_inconsistency	.954	.006	.864	***
v14	alignment_inconsistency	.975	.005	.872	***
v15	alignment_inconsistency	.956	.004	.881	***
v16	alignment_inconsistency	.973	.003	.993	***
v17	alignment_inconsistency	.809	.016	.693	***
v18	drivers' mental health	1.000		.855	
v19	drivers' mental health	1.016	.013	.869	***
v20	drivers' mental health	1.053	.009	.772	***
v21	accidents_caused_by_fatigue_and_sleepiness	1.000		.871	
v22	accidents_caused_by_fatigue_and_sleepiness	.750	.016	.835	***

TABLE 7. Direct and total effects on the "accidents caused by fatigue and sleepiness" latent variable

	Alignment Inconsistency	Controlling work hours	Engineering (safty) Technology	Driver's mental health
Direct Effects	0.112	-0.287	0.322	0.727
Total Effects	0.112	-0.287	0.322	0.727
Direct Effects	0.087	-0.345	0.237	0.471
Total Effects	0.087	-0.345	0.237	0.471

Table 7 shows the total and direct effects on the reduction of the accidents caused by fatigue and sleepiness. Given that this model does not have indirect structures, the total effect is equal to the direct one. Considering the standardized total effects shown in Table 5, mental health is the most influential on the reduction of accidents caused by fatigue and sleepiness, and controlling work hours has an adverse effect on the reduction of accidents caused by fatigue and sleepiness.

The goodness of fit statistics for this model are presented in Table 8. The Chi-square of this model is 4241.741 and the degrees of freedom are 231. Some of the measures compare the proposed model to some baseline model. The goodness of fit is generally quantified by using measures, such as GFI, NFI, AGFI, CFI, RMSEA, and RMR. The range of AGFI, CFI, GFI, and NFI is between 0 (no fit) and 1 (perfect fit) (Ho, 2006). The RMSEA for an acceptable model should be less than 0.08 (Browne & Cudeck 1993; MacCallum, Browne, & Sugawara 1996). RMR values below 0.05 mean a well-fitting model. All of the indices are set out in Table 8.

TABLE 8. Goodness of fit statistics

Model Fit Summary		Model Fit Summary	
Chi-square	4241.741	GFI (goodness of fit index)	0.941
Degrees of freedom	231	AGFI (adjusted goodness of fit index)	0.904
NFI (normed fit index)	0.948	RMSEA (root means square error of approximation)	0.057
CFI (comparative fit index)	0.949	RMR (root mean square residual)	0.051

DISCUSSION

So far, many studies conducted show that drowsiness is one of the most important dangers for the drivers (Filtness et al. 2017a; Filtness et al. 2017 b; Bunn et al. 2005; Teff 2012). Furthermore, heavy-vehicle drivers all around the world have admitted to drive long distances for long hours, breaking the work hour rules and continuing to drive even being tired and sleepy (Chen et al. 2015). Thus, it is known that drivers face sleep deprivation to do their job properly (Lemke et al. 2016), and continue to drive even when fatigued (Chen et al. 2015), which in our case accounted for 68% working for 9 to 11 hours, or even more, on a daily basis. Furthermore, more than half of the drivers analyzed (1645) reported that driving when they were tired and sleepy (mainly at night) posed many dangers, which caused considerable harm to them.

Drivers' drowsiness continues to be a vital concern in the transportation industry. Thus, general studies should be conducted and effective actions should be taken to understand the factors affecting drivers' fatigue and sleepiness on long trips. This study conducted involving the effective and ineffective factors on drivers' fatigue and sleepiness shows that regular checks of the drivers' mental health is the top priority to reduce the number of accidents. In other words, these drivers encounter many physical and emotional problems and mental illnesses, which are directly related to their field of work (Bigelow et al. 2012; Lemke et al. 2015). Furthermore, their mental and physical condition also affects their sleep cycles, causing sleep deprivation or a change in their cycle (Chen et al. 2016). The work environment of heavy-vehicle drivers, their long work hours (up to 14 hours a day), long sitting turns, noise and the vibrations inside their vehicles cause unhealthy living conditions (Bigelow et al. 2014; Lemke et al. 2015; Sieber et al. 2014). Hence, we conclude that switching from rumble strips to improper road bumps, low quality asphalt and, inappropriate police behavior might cause mental and emotional issues for drivers, resulting in more fatigue and sleepiness.

Using engineering (safety) technology for road transport is the second more influential factor. In other words, appropriate road lighting (Wanvik, 2009; Jackett & Frith, 2013), increasing the safety of the roads by using rumble strips (Anund 2008), installing rolling barriers (Nagadarshan Rao 2017) instead of W-beam guardrail and installing warning signs and posters along the roadside can reduce the number of accidents or their damage.

According to the results presented in the tables, alignment inconsistency is the third more influential. Heavy-vehicle drivers are usually inactive when it comes to physical activity, and have unhealthy diet, interfering with the drivers' sleep cycles and so leading to higher stress levels (Angeles et al. 2014; Apostolopoulos 2010; Bigelow et al. 2012; Krueger 2012; Sieber et al. 2014), which increases the mental problems in the drivers compared to the general public (Apostolopoulos et al. 2010; Jones & Switzer-McIntyre 2003). These facts can create a dangerous work environment for the drivers, particularly for the ones with longer work hours, affecting their performance (Crizzle et al. 2017). Hence, police patrols (Lemke et al. 2016) and free tea stations with sport programs during the most dangerous hours (12 to 3 AM & 3 to 6 AM) can reduce the number of accidents caused by fatigue and sleepiness. As mentioned before, most drivers sleep in their vehicles' cabins or rest stops, such as mosques (since they are free of charge), which are low quality places. Thus, building proper and secure free or low-cost rest stops (Fosser 1988) with larger parking areas (Bunn et al. 2017), and providing healthy food (Fitzharris et al. 2017) are directly related to the reduction of accidents.

Regarding Figure 2 and Table 7, controlling the hours of drivers by installing a GPS device on vehicles and controlling the workbook and drivers' check-ups has a adverse effect to reduce accidents caused by fatigue and sleepiness. This is because, based on the obtained reports, drivers admit that they have to violate the labor control laws due to a lot of workloads. As a result, they change the settings of the GPS devices inside the car so that they are not subject to heavy fines of regulatory agencies. Moreover, due to a large number of heavy vehicles in Iran, the relevant organizations do not have adequate oversight on all GPS devices. Accordingly, from the point of view of the drivers from developing countries, working hours control does not reduce fatigue crashes, but, sometimes due to heavy fines, it has an adverse effect on their job concentration, and therefore increase the number of accidents.

CONCLUSION

This study analyses the impact five hidden variables have on the reduction of accidents caused by fatigue and sleepiness of heavy vehicle drivers, based on structural equations. The hidden variables are: a) Using the engineering (safety) technology for road transport, b) informing the drivers using various educational methods, c) controlling the drivers' work hours, d) using different routes (alignment inconsistency) and e) observing the drivers' mental health. Although transport organizations still focus on controlling the drivers hours by installing GPS devices on vehicles and controlling the workbook and inspection, this study shows that other factors are more influential to decrease the accidents caused by drivers' fatigue and sleepiness, which are in a decreasing order as follows: 1) Observing the drivers' mental health, 2) Using the engineering (safety) technology, and 3) Using different routes (alignment inconsistency). Therefore, our suggestion is that the comprehensive and wide-ranging activities to implement engineering techniques, creating spacious and safe parking lots in proper locations, and more attention to motorists' mental health can help to reduce the incidents and accidents caused by fatigue and sleepiness.

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DECLARATION OF COMPETING INTEREST

None

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