Modelling of Ergonomic Risks Factors as predictors to work related fatigue near miss accidents experienced among Malaysian express bus drivers:

Partial Least Squares (PLS) Approach.

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Abstract. Public, stake holders and authorities of Malaysian government show great concern towards high numbers of passenger's injuries and fatalities in express bus accidents. This paper studies the underlying factors involved in determining the ergonomics risk factors as predictors towards work fatigue related near miss accident. A questionnaire survey was carried out at random among 278 Malaysian express bus drivers at four major cities in peninsular west Malaysia. The result was analyzed by using variance-based Structural Equation Modeling-Partial Least Squares (SEM-PLS): Path-analysis approach. The ergonomics risks factors predictors are; socio-demographic, occupation, organizational safety climate, work place environment and occupational stress are empirically tested for the correlation with work related fatigue, musculoskeletal health and near miss accidents. The finding shows that there are significant correlations (socio-demographic, t =7.70; work place environment, t=3.72; occupational, t=2.10) between ergonomics risks factors predictors and work related fatigue. Significant correlations are also observed between work related fatigue and musculoskeletal health (t=10.72) and near miss accident (t=2.09) at significance level, p= 0.1 The study shows that the ergonomic risks factors are significant predictors inducing work related fatigue near miss accident which may influence errors in making critical decision as causation factors on near miss accidents

Keywords: Ergonomic risk factors, Partial Least Squares, driving fatigue, musculoskeletal disorders and near misses accidents

1. INTRODUCTION

Among Southeast Asia countries (ASEAN), Malaysia has among the highest fatality rate of road accidents with over 6000 deaths per year (WHO, 2009). Accidents involving express buses have become a major issue in Malaysia as express buses are the main public transport especially during the festive seasons. An online survey by the Malaysian Unite for Road Safety shows that 61.6% of the respondent believe accidents are due to human error and only 15.6% due to road conditions.

2. LITRATURE REVIEW

Many studies worldwide have identified fatigue and sleepiness as one of the major causes of road accidents (Akerstedt and Kecklund, 2001: Perez-Chads et al., 2005). Indeed, it is estimated that between 15% and 20% of commercial vehicle fatalities can be attributed to fatigue and sleepiness (MacLean et al., 2003). According to Gawron, French and Funke (2001), socio demographic factors such as age, work experience and occupational factors such as work schedule, work-rest periods and total time driving will influence driving fatigue. Dobbie (2002) determined that prolonged driving without rest can increase the fatigue level and deteriorate the driving performance. Campbell (2002) concludes that the relative risk of fatigue in a fatal accident "gradually increases during the first eight hours, doubles after the ninth hour and is higher by a factor of six by the 12th hour." In Malaysia, it was found that 50% of the drivers would experience fatigue as early as 6.2 hours of driving if they work for 12 hours (Norlen et al. 2008). Organizational safety climate factors base on combination of safety climate and psychosocial factors, also produce negative impacts on the health of workers. (De Raeve et al., 2007). Another contributing factor to workplace stress is the fact that bus drivers usually have no say over the scheduling of routes, choice of equipment (buses), shifts or routes (these are usually dependent on levels of seniority).

In recent years, research projects on the ergonomically optimal driver's workstation were conducted in Canada, Sweden, Germany and the Netherlands (Canadian Urban Transit Association 1992; Peters et al. 1992). The ergonomic design of the driver's workstation is a necessary component of driver safety and health protection.

However there has been very little research done on Asian drivers, especially bus drivers. Therefore the aim of this study is to determine empirically the correlation between ergonomic risks factors as the underlying factors or the determinants that contribute to driving fatigue related to musculoskeletal health and near misses accident among the bus drivers.

From literature review, a path diagram model of ergonomic risks factors related to near misses accident was developed as shown in Figure 1. This path diagram model is then analyzed by the Smart PLS method.

3. METHODOLOGY

3.1 Participant

A questionnaire interview survey was carried out at random among n= 278 express bus drivers; Terminal Central Kuantan, Pahang (n=110), express bus terminal Kuala Terengganu, Terengganu (n= 45) express bus terminal, Kota Bharu (n=55) and Hentian Pudu Raya Kuala Lumpur (n= 68). The express bus routes covers all the major towns in the peninsular of west Malaysia.

The interview sessions were carried out early in the morning at the bus depots before the drivers scheduled departure to other respective towns and during the drivers lunch time at the bus depots upon their arrival from others towns. Each volunteer participant was given a questionnaire to be answered. On average the participant took about are 15 to 20 minutes to complete the 5 pages questionnaire. During the answering session, the researcher is present to give any assistance in completing the questionnaire. When the questionnaire is returned, the researcher checked for any missing data.

3.2 Questionnaire

The questionnaire is made up of 8 constructs with 278 cases and 92 items. The eight constructs are: Socio-demographic factors adapted from Di Milia et al., (2011) consists of appropriate items on age, ethnic, education level, job status, express bus driver experience and years of employed with the organization. Occupational factors adapted from (Campbell, 2002 and Norlen et al. 2008) consists of appropriate choice Likert Scale items on work shift schedule, driving hours per shift, working hours per shift, time-out break per driving shift, location provided during the driving shift break, working days per week. Work place environment adapted from Parent-Thirion, A. (2007); Canadian Centre for Occupational Health and Safety (CCOHS), 2009 consists of appropriate Likert Scale choice items on the adjustability of driver's seat, the adjustments of the steering wheel, the size of the steering wheel, forwards and rear visibility, accessibility of the instruments panel, body weight and height should also be taken into account (Clarke, 2006), and the feeling of vibration and noise level. The items on the organational safety climate comprises of communication and procedures; work pressure (management commitment; relationships; driver training, safety rules and psychosocial factors adapted from Hackman, J. R., & Oldham, G. R. (1975). Driving fatigue is often referred to as a feeling of tiredness and reduced alertness that is associated with drowsiness, which impairs both capability and willingness to perform driving task adapted from (Craig, Tran, Wijesuriya, & Boord,2006; Lal & Craig, 2001). Powell et. al., (2007) studied the after effect of drowsiness when the express bus drivers were on off duties comprises of Likert scaled items on the feeling of drowsiness on different circumstances like; reading while sitting, watching television, sitting alone in public, as passengers of public transport on long distance journey, lying at rest when situation is permissible, chatting with some while sitting, sitting alone after dinner without smoking and fall asleep while the car at traffic light. The effect of occupational stress result from the work environment adapted from Cartwright, Cooper, & Barron (1996) comprises of Likert Scale items measured on poor job/position designed (low paid, less work perks, poor job support from supervisor and teammates, work pressure due to high workload are predictors towards occupational stress and been linked to work-related drivers fatigue. Self- reported, fatigue-related near misses accident are reported to have a close association with actual accidents adapted from (Powell, Schechtman, & Riley, 2007). The questionnaire items asked the participants if they had experienced a near misses accident that they thought was attributed to driving while fatigue in the past 3 years. The description of the near misses was provided: types of road, times of near miss, environment factors or others circumstances. MSDs symptoms adapted from a modified Standardized Nordic Questionnaire (SNQ) by Kuorinka, I.(1987) consists general questionnaire showed a body map of nine-anatomical body regions and asking about ache, pain, and discomfort for the last 12 months in each of the body regions. Respondents were ask to indicate on a Likert scale of 0-4 (0 = no fatigue feeling, 4 = numbness and tingling pain) on how severity is the musculoskeletal disorders symptoms.

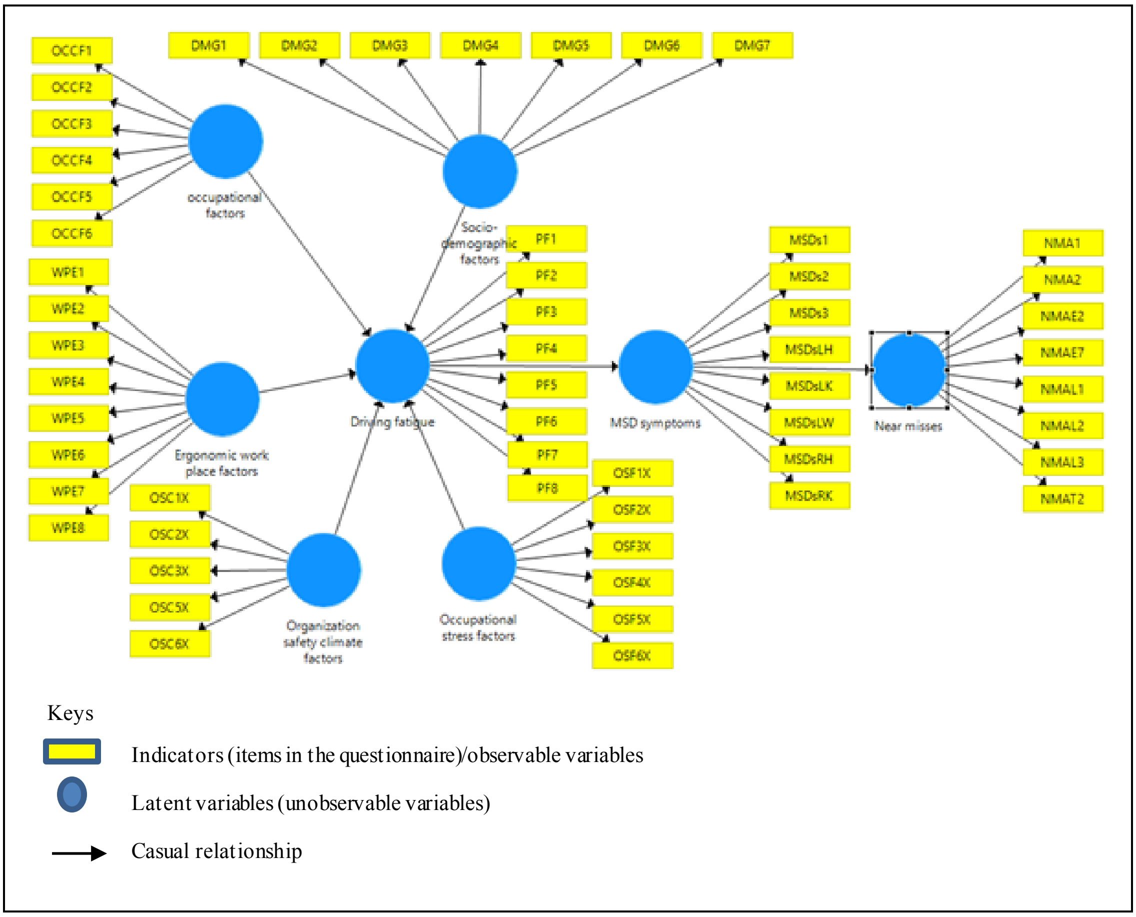

Figure 1: Path diagram of conceptual model ergonomic risks factors as predictors on driving fatigue related to near misses accidents

In the context of PLS-SEM, the path model diagram is made up of two elements; the measurement model (the outer model) and the structural model (the inner model). The measurement model display the relationship between the constructs (latent variable) and the indicators (items in the questionnaire). The indicators or the items in the questionnaire are the independent variables (observed variables or raw data) and are represented by the yellow rectangles. The arrows pointing from the constructs towards the indicator variables, indicating the assumption that the constructs causes the measurement (covariation). The estimation procedure for PLS-SEM is an ordinary least squares (OLS) regression based method.

The second element in the path model is the structural model or the inner model. The structural model display the relationship between the constructs (latent variables). The constructs are dependent variables (unobserved variables) and are represented by blue circles. The arrows pointing from one construct to another constructs indicating the assumption the relationship between the construct is of causal effect.

The exogenous constructs; socio-demographic factor (DMG), ergonomic work place (WPE), organization safety climate (OSC), occupational factors (OCCF) and occupational stress factors (OSF) as predictors towards endogenous construct; driving fatigue (PF), musculoskeletal disorders symptom (MSDs), and near misses accident (NMA) in the path model. However the construct, PF have dewy characteristics as exogenous and endogenous constructs.

3.3 Path-model analysis by PLS algorithm method

In this study data collected from the questionnaire was validated by using statistical package Structural Equation Modeling (SEM)-Smart Partial Least Square. Path model analysis involves two stages; analysis of the measurement model (outer model) and analysis of the structural model (inner model).

3.3.1 Path analysis of the measurement model.

The outer loading PLS-SEM algorithm's iterative procedure involves 2 stages. In the first stage the construct scores are estimated by PLS regression. PLS regression is the multivariate data analysis i.e., linear relationship between multiple independent variables (indicators/items) and a single or multiple dependent variables (constructs). The estimation for all relationship in the measurement model produce the outer loadings values. The outer loading values are written on the arrows pointing from the construct to the multiple independent variables (indicators/items) as shown in Figure 2. A standardized value of outer loading should be 0.708 or higher. High outer loading on a construct indicate that the associated indicators have much in common, which is captured by the construct. Generally outer loading below 0.40 are eliminated from the scale (Hair, Ringle, &Sarstedt, 2011).

3.3.2 The internal consistency reliability

The assessment of the measurement model will evaluate the reliability and the validity of the constructs measures. The internal consistency reliability, is measured by the composite reliability (ρc) values.

$$\text{Composite reliability } \rho_c = \frac{(\sum_i l_i)^2}{(\sum_i l_i)^2 + \sum_i var(e_i)} \qquad (1)$$

Where: li = standardized outer loading of the indicator I of a specific construct. Ver (e_i) = varieance of the measurement error = 1-li^2.

In assessing internal reliability, higher values indicate higher level of reliability. Values between 0.60 and 0.70 are considered acceptable in exploratory research whereas values between 0.70 and 0.95 are considered "satisfactory to good" (Hair, Hult, et al., 2014). A composite reliability value of greater than 0.95 are not desirable because they indicate that the indicator variables are measuring the same phenomenon and are therefore unlikely to be a valid measure of the construct.

3.3.3 The convergent validity

The validity of the construct is measured by its convergent validity. The common measure to establish convergent validity on the construct level is the average variance extracted (AVE).

$$\text{AVE} = \frac{\sum_i \lambda_i^2}{\sum_i \lambda_i^2 + \sum_i var(\varepsilon_i} \qquad (2)$$

Where: λ_i^2 = squared loading of indicator i of a constructs ver(Ɛi) =squared measurement error of indicator i.

AVE should exceed 0.5 to suggest adequate convergent validity (Bagozzi & Yi, 1988).This criterion is defined as the grand mean value of the squared loading of indicators associated with the construct (i.e., the sum of the squared loading divided by the numbers of indicators). An AVE value of 0.50 or higher indicate that on average, the construct explains more than half of the variance of its indicators. Conversely, an AVE of less than 0.50 indicates that, on average, more error remains in the items than the variance explained by the construct.

3.3.4 Discriminant validity

A discriminant validity is the extent to which a constructs is truly distinct from other construct by empirical standard. Discriminant validity can be determine by examining the cross loading of the indicators. An indicator's outer loading on the associated construct should be greater than all of its loadings on other construct (i.e., construct reliability).

3.4 Path- analysis of the structural model.

3.4.1 Model predictive accuracy (R^2 Value) and model relevancy (Q^2)

The assessment of the structural model involves the model ability to predict the model's capabilities i.e. the significance of the path coefficient, the coefficient of determination (R2values). R2 values ranges from 0 to 1 with higher levels indicating levels of predictive accuracy. R2 values of 0.75, 0.50 or 0.25 for endogenous latent variables can as a rule of thumb be respectively described as substantial, moderate or weak (Hair, Ringles,& Sarsted, 2011;Henseler et al.,2009). All Q2 values above zero indicate predictive relevance of the model.

3.4.2 The significance of the path coefficient.

The path coefficients have standardized value between -1 and +1. Estimated path coefficient close to +1 represent positive relationship (and vice versa for negative values) that are almost always statically significant. The closer the estimated coefficient are to 0, the weaker the relationship. Very low values close to 0 are usually nonsignificant.

Whether a coefficient is significant depend on the standard error obtained by means of bootstrapping. Bootstrapping is a resampling technique that draws a large number of subsamples from the original data (with replacement) and estimates models for each subsample. It is used to determine standard errors of coefficient estimates to assess the coefficient's statistical significance without relying on distributional assumptions.

Critical values for the two tailed test are 1.65 (significance level = 10%), 1.96 (significance level =5%) and 2.57 (signifance level =1%).

4. RESULT AND DISCUSSION

4.1 Path model analysis

Table 1 below shows the result of path-model algorithm, the outer loading of each of the exogenous constructs; DMGF, OCCF, WPE, OSCF,OSF and endogenous constructs; DF, MSDs and NMA. All the values of outer loading exceed the standardized value 0.6 (exploratory research).

4.2 Constructs validity assessments on measurement model (outer model)

Construct validity is the extent to which a set of measured items actually reflect the theoretical latent construct they are designed to measure. Construct validity assessments involved the convergent validity (factor loading, internal consistency reliability (Composite Reliability (ρc)) and average variance extracted (AVE) and discriminant validity

4.2.1 Internal consistency reliability

From Table 1, the composite reliability of SDF (0.83), EWP (0.70), OCCF (0.74), OSCF (0.90) and OSF (0.90) demonstrate predictor's constructs to endogenous constructs; PF (0.91), MSDs (0.88) and NMA (0.90) that all five reflective constructs have high level of internal consistency reliability.

4.2.2 Convergent Validity

Table 1 shows AVE values of reflective constructs; DMGF (0.66), OCCF (0.58), WPE (0.54), OSCF (0.64) and OSF (0.75) as predictors construct towards endogenous constructs with AVE values; DF (0.59), MSDs (0.59), NMA (0.67). Thus the measures of the five reflective constructs and the endogenous constructs have high level of convergent validity.

4.2.3 Discriminant Validity

Table 1 shows that all outer loading of the reflective constructs, DMGF, OCCF, WPE, OSCF and OSF, are all well above the indicator reliability. The indicator OCCF1 (outer loading: 0.67) has the smallest indicator reliability with a value of 0.64 (0.672), while the indicator SDF1 and SDF7 (outer loading: 0.97) has the highest indicator reliability with a value of 0.94 (0.992). Thus all of the indicators for the five reflective constructs are all well above the minimum acceptable level of the outer loading.

Table 1: Construct validity assessment

Model Constructs	Measurement Items/indicators	Outer Loading	Indicator Reliability	Discriminant Validity(Outer loading> Indicator Reliability)	Composite Reliability (ρ_c)	Average Variance Extracted (AVE)
Socio-demographic factors (DMGF)	DMGF1	0.97	0.94	YES	0.83	0.66
	DMGF7	0.97	0.94			
Ergonomic Work Place (WPE)	WPE6	0.61	0.38	YES	0.70	0.54
	WPE8	0.84	0.70			
Occupational factors (OCCF)	OCCF3	0.82	0.67	YES	0.74	0.58
	OCCF10	0.70	0.50			
Musculoskeletal Disorders (MSDs)	MSDsLH	0.77	0.60		0.88	0.59
	MSDs1	0.75	0.57			

symptoms	MSDs2	0.72	0.51	YES		
	MSDsLK	0.82	0.67			
	MSDsLW	0.79	0.61			
Near misses accident (NMA)	NMAE2	0.82	0.66	YES	0.84	0.63
	NMAL1	0.79	0.63			
	NMAT2	0.87	0.76			
Driving fatigue (PF)	PF1	0.80	0.61	YES	0.91	0.62
	PF2	0.75	0.67			
	PF3	0.70	0.64			
	PF4	0.81	0.64			
	PF5	0.78	0.63			
	PF6	0.78	0.63			
	PF7	0.73	0.62			
	PF8	0.77	0.62			
Organizational Safety Climate (OSCF) (Safety Climate (OSC) + Psychosocial factors (PSYF)	OSC5	0.71	0.51	YES	0.90	0.64
	OSC6	0.80	0.64			
	PSYF1	0.85	0.72			
	PSYF2	0.85	0.72			
	PSYF3	0.78	0.61			
Occupational Stress (OSF)	OSF1	0.81	0.66	YES	0.90	0.75
	OSF4	0.75	0.56			
	OSF5	0.90	0.81			
	OSF6	0.90	0.81			

Table 2: Significant assessment of constructs in the model.

Constructs	Path-coefficient	Standard error	T value	p-value	Significant(S)/ Non-significant (NS)
DMGF->MSDs	0.21	0.04	5.66	0.00	S
DMGF->NMA	0.04	0.02	2.41	0.02	S
DMGF->PF	0.44	0.05	8.04	0.00	S
MSDs->NMA	0.18	0.07	2.65	0.01	S
OSF->MSDs	0.06	0.03	2.19	0.03	S
OSF->NMS	0.01	0.01	1.52	0.13	NS
OSF->PF	0.12	0.06	2.26	0.02	S
OSCF->MSDs	0.06	0.03	2.03	0.04	S
OSCF->NMA	0.01	0.01	1.41	0.16	NS
OSCF->PF	0.12	0.06	2.08	0.04	S
EWP->MSDs	0.07	0.03	2.65	0.01	S
WPE->NMA	0.01	0.01	1.72	0.09	NS

WPE->PF	0.14	0.05	2.66	0.01	S
PF->MSDs	0.49	0.04	11.02	0.00	S
PF->NMA	0.09	0.03	2.61	0.01	S

Critical value for two-tailed test: t value = 1.96, significance level = 5% (α = 0.05)

4.3 Constructs levels of significant.

. Bootstrapping is a resampling technique that draws a large number of subsamples from the original data (with replacement) and estimates models for each subsample used to determine standard errors of coefficient estimates to assess the coefficient's statical signifance without relying on the distributional assumptions.

The bootstrap standard error allows computing the empirical t value. Commonly value =1.65, signifance level = 10% (α=0.10), t value = 1.96, significance level = 5% (α = 0.05) and t value =2.57, signifance level = 1% (α = 0.01). When the study is exploratory in nature, researchers often assume a signifance level of 10%.

Table 2, displays the path coefficient, t values and their signifance level and p values. The result shows that all the relationship in the structural model are significant, except OSF->NMA, OSCF->NMA, and WPE->NMA. These result suggest that there are significant correlation between socio-demographic factors (DMGF) ->musculoskeletal symptom (MSDs) (t=5.66). DMGF->PF (t= 8.04), PF->MSDs (t= 11.02) among the ergonomic risks factors. Furthermore a substantial significant correlation occur between DMGF->NMA (t= 2.41), MSDs ->NMA (t= 2.65), OSF->MSDs (t= 2.19), OSF->PF (t= 2.08), WPE->MSDs (t=2.65), WPE->NMA (t= 2.66), PF->NMA (t=2.16).

4.4 Model predictive accuracy and relevancy

The coefficient of determination (R2 values) are commonly measure to evaluate the model predictive accuracy. It is calculated as the squared correlation between a specific endogenous construct's actual and predicted values. The R2 value ranges from 0 to 1 with higher level indicating higher levels of predictive accuracy. The R2 values for latent variables PF (0.29), MSDs (0.24) and NMA (0.04). The R2 value ranges from 0 to 1 with higher level indicating higher levels of predictive accuracy. The R2 values for latent variables PF (0.29), MSDs (0.24) and NMA (0.04). R2 values of 0.20 is considered high in disciplines such as consumer behavior and in successful drivers studies. However the R2 values of 0.75, 0.50, and 0.25 for endogenous latent variable are described as substantial, moderate or weak (Hair, Ringle, & Sarstedt, 2011; Henseler et al., 2009).

The f2 effect size enable researcher to analyze the relevance of construct in explaining endogenous latent constructs. Table 3 shows the f2 effect size of endogenous construct PF->MSDs (0.31) are comparatively large and MSDs->NMA (0.03) is considered small. Results of 0.02, 0.15 and 0.35 are interpreted as small, medium and large f2 effect size, respectively.

Table 3: R^2, Q^2 and f^2 values

Endogenous latent Variable	R^2 values	Q^2 values	f^2 effect size.	
NMA	0.04	0.01	DMGF->DP	0.26
MSDs	0.24	0.13	MSDs->NMA	0.03
PF	0.29	0.15	OSF->PF	0.02
			OSCF->PF	0.02
			WPE->PF	0.03
			PF->MSDs	0.31

5. CONCLUSION

1. The conceptual model is developed by using PLS path-model diagram showing the ergonomics risks factors as predictors to driving fatigue related near misses accident.
2. The result of analysis on the conceptual model using path model algorithm shows the model developed has convergent validity. This is shown by:

i. All values outer loading of each of the predictors (exogenous) constructs; DMGF, OCCF, WPEF, OSCF, OSF and target (endogenous) constructs; PF, MSDs and NMA exceed the standardized value 0.6 (exploratory research).

ii. The composite reliability of DMGF (0.83), WPEF (0.70), OCCF (0.74), OSCF (0.90) and OSF (0.90) demonstrate predictor's constructs to endogenous constructs; PF (0.91), MSDs (0.88) and NMA (0.90) that all eight reflective constructs exceed the tress hold vales (0.70) have high level of internal consistency reliability.

iii. The AVE values of reflective constructs; DMGF (0.66), OCCF (0.58), WPEF (0.54), OSCF (0.64) and OSF (0.75) as predictors construct towards endogenous constructs with AVE values; PF (0.59), MSDs (0.59), NMA (0.67) exceed the tress hold value of AVE (0.50) Thus the measures of the eight reflective constructs have high level of convergent validity.

3. These result shows that there are significant correlation between socio-demographic factors (DMGF) ->musculoskeletal symptom (MSDs) (t=5.66). DMGF->PF (t= 8.04), PF->MSDs (t= 11.02) among the ergonomic risks factors. Furthermore a substantial significant correlation occur between DMGF->NMA (t= 2.41), MSDs ->NMA (t= 2.65), OSF->MSDs (t= 2.19), OSF->PF (t= 2.08), WPEF->MSDs (t=2.65), EWP->NMA (t= 2.66), PF->NMA (t=2.16) except OSF-> NMA (t=1.52), OSCF->NMA (1.41), and WPEF-> NMA(1.72).
4. The R^2 values for latent variables PF (0.29) and MSDs (0.24) are high level of predictive accuracy and however has low predictive accuracy for NMA (0.03)
5. The Q^2 values which indicate the relevancy of the constructs is given by the endogenous constructs PF (0.15) and MSDs (O.13) are moderately high and relatively low for the endogenous construct NMA (0.03)
6. These findings have strong practical utility as they suggest that organizations should be aware the impact of ergonomic risks factors, practices and procedures enhance profound impact on fatigue-related driver behavior. Therefore the Ministry of Transportation (MOT), the stake holder, the relevance agencies such as MIROS, RTD and the company's management should consider the elements of ergonomic risks factors as works related driver's safety and future safety planning.

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