



UNIVERSITI PUTRA MALAYSIA

***DEVELOPMENT AND EVALUATION OF NEW PROTOTYPE
SEAT FOR COMMERCIAL STAGE BUS DRIVERS***

WAN CHIK ZAHARAH BT. WAN HASSAN

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SEAT FOR COMMERCIAL STAGE BUS DRIVERS**

By

WAN CHIK ZAHARAH BT. WAN HASSAN

**Thesis Submitted to the School of Graduates Studies, Universiti
Putra Malaysia, in Fulfilment of the Requirements for the degree of
Master of Science**

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Abstract of thesis presented to the Senate of University Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

**DEVELOPMENT AND EVALUATION OF NEW PROTOTYPE SEAT FOR
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Chairman: Shamsul Bahri Hj. Mohd Tamrin, PhD

Faculty: Medicine & Health Sciences

As a developing country, Malaysia has experiencing rapid development in public transport due to the process of urbanization, economic development and population growth. This rapid increase in the total number of vehicles on roads created traffic congestion. Previous study had reported that bus drivers were highly exposed to ergonomic hazards due to poor seat design. Prolong exposure resulted in the incidence of having low back pain. Thus, a cross sectional study was carried out among Malaysian male bus drivers from July 2004 to January 2006 with the main objective of developing a new bus driver's seat design based on anthropometric measurements of Malaysian males. A total of 669 respondents were selected using a stratified random sampling from central, eastern, northern and southern regions of Peninsular Malaysia. Modified Nordic questionnaires were used to determine demographic information, prevalence of low back pain and risk factors associated with low back pain (LBP) among the bus drivers. Martyn Type Anthropometer was used to measure anthropometrics parameters namely sitting eye height, sitting shoulder height, elbow rest height, popliteal height with shoes, popliteal height without shoes,

knee height with shoes, knee height without shoes, elbow breadth, hip breadth, buttock to popliteal length, buttock to knee length and lumbar support height. Measurements for current bus seat taken were backrest height, backrest width, seat pan depth, seat pan width and seat height. Rapid Upper Limb Assessment (RULA) was used to simulate the RULA score of the proposed seat design. The result showed a high prevalence of life time low back pain (59.5%) among Malaysian male bus drivers in Peninsular Malaysia. Logistic regression analysis showed that low back pain was significantly associated ($p>0.05$) with exposure to vibration (2.285, 95% CI 1.610 - 3.243), prolonged sitting (2.729, 95% CI 1.525 - 4.886), hard cushion (2.586, 95% CI 1.396 - 4.788), uncomfortable seat (2.256, 95% CI 1.346 - 3.782), bending (3.928, 95% CI 0.854 - 6.076) and lifting load while working (1.087, 95% CI 0.603 - 1.959). Anthropometric measurements obtained from this study were used as a guide in designing a new seat. The current seat measurements were significantly different ($p<0.05$). RULA simulation showed that the new proposed seat had an acceptable score of 2 while for the current seat score 3. The current seat contributed to the LBP and newly improved seat can be designed and developed using the anthropometric as well the RULA analysis method.

Key words: *bus drivers, low back pain, anthropometry, seat design, RULA, Malaysia*

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

PEMBANGUNAN DAN PENILAIAN PROTOTAIP BARU KERUSI UNTUK

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Malaysia sebagai sebuah negara membangun telah menunjukkan perkembangan yang pesat dalam industri pengangkutan awam. Kesan pertumbuhan kepadatan penduduk yang tinggi, pembangunan ekonomi dan urbanisasi secara tak langsung telah meningkatkan pertambahan jumlah kenderaan pengangkutan awam. Peningkatan ini menyebabkan pemandu kenderaan komersil terdedah kepada pelbagai masalah kesihatan pekerjaan. Kerusi bas yang tidak ergonomik dan akibat duduk terlalu lama akan meningkatkan lagi risiko untuk mendapat masalah sakit belakang. Justeru itu satu kajian analitikal keratan rentas telah dijalankan di kalangan pemandu bas Malaysia pada Julai 2004 sehingga Januari 2006 bertujuan untuk merekabentuk kerusi baru bagi pemandu bas berdasarkan pengukuran anthropometrik pemandu bas lelaki Malaysia. Seramai 669 orang responden telah dipilih secara persampelan rawak tersusun dari bahagian wilayah tengah, timur, utara dan selatan Semenanjung Malaysia. Data demografi, prevalens sakit belakang bawah dan perhubungan faktor risiko dengan sakit belakang bawah telah diperolehi melalui soal-selidik Nordic yang telah diubahsuai. Alat Martyn Type Anthropometer digunakan untuk memperolehi

data pengukuran anthropometrik dengan mengukur ketinggian aras mata-pinggul, ketinggian aras bahu-duduk, ketinggian aras siku-duduk, ketinggian aras popliteal dengan kasut, ketinggian aras popliteal tanpa kasut, ketinggian aras lutut dengan kasut, ketinggian aras lutut tanpa kasut, lebar siku-siku, lebar pinggul, panjang pinggul-popliteal, panjang pinggul –lutut dan ketinggian aras penyokong lumbar. Bagi pengukuran kerusi pemandu sekarang yang diukur adalah ketinggian penyandar belakang, lebar penyandar belakang, kedalaman tempat duduk, lebar tempat duduk dan ketinggian kerusi. Kaedah simulasi dengan menggunakan perisian *Rapid Upper Limb Assessment* (RULA) digunakan untuk memperolehi scor postur badan yang betul bagi merekabentuk kerusi pemandu bas baru. Hasil kajian menunjukkan prevalens sakit belakang bawah yang pernah dialami sekali sepanjang hidup dikalangan pemandu bas Semenanjung Malaysia adalah tinggi iaitu 59.5%. Melalui ujian statistik analisis persamaan *linear* menunjukkan sakit belakang bawah mempunyai perhubungan yang signifikan dengan faktor-faktor risiko iaitu pendedahan getaran (2.285, 95% CI 1.610 - 3.243), duduk terlalu lama (2.729, 95% CI 1.525 - 4.886), kusyen terlalu keras (2.586, 95% CI 1.396 - 4.788), kerusi tidak selesa (2.256, 95% CI 1.346 - 3.782), membongkok ketika memandu (3.928, 95% CI 0.854 - 6.076) dan mengangkat beban ketika bekerja (1.087, 95% CI 0.603 - 1.959). Data pengukuran anthropometrik yang diperolehi melalui kajian ini digunakan sebagai rujukan dalam merekabentuk kerusi baru. Analisi ujian t mendapati bahawa terdapat perhubungan yang signifikan bagi pengukuran parameter antara kerusi baru dan kerusi sekarang ($p < 0.05$). Hasil daripada simulasi yang dijalankan dengan menggunakan kaedah analisis RULA menunjukkan bahawa rekabentuk kerusi baru adalah diterima dan sesuai dengan scor postur badan 2 manakala rekabentuk kerusi pemandu bas sekarang adalah tidak bersesuaian dan tidak memenuhi keperluan populasi

pemandu bas Malaysia dengan skor 3. Kerusi pemandu bas sekarang adalah merupakan faktor penyumbang kepada sakit belakang bawah dan kerusi pemandu bas baru boleh direkabentuk dan dibangunkan menggunakan kaedah anthropometrik serta kaedah analisis RULA.

Kata kunci: pemandu bas, sakit belakang bawah, anthropometri, rekabentuk kerusi, RULA, Malaysia



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I certify that a Thesis Examination Committee has met on 14 July 2009 to conduct the final examination of Wan Chik Zaharah Bt. Wan Hassan on her thesis entitled “Development and Evaluation of New Prototype Seat for Commercial Stage Bus Drivers” in accordance with Universities and University Colleges Act 1971 and the Constitution of the Universiti Pertanian Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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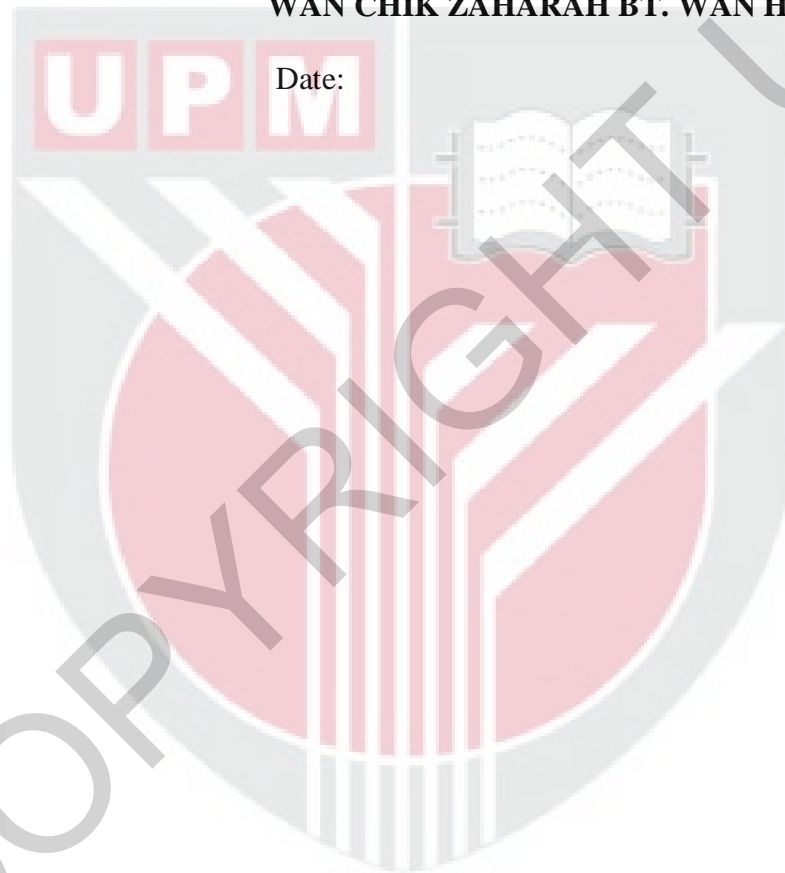


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LIST OF ABBREVIATION

WHO	World Health Organization
LBP	low back pain
MOH	Ministry of Health
et al.	and others
No.	number
OR	odds ratio
WBV	whole-body vibration
NIOSH	National Institute of Occupational Safety and Health
MSD	musculoskeletal disorders
BMI	body mass index
m	meter
cm	centimetre
mm	milimeter
kg	kilogram
CI	confidence interval
SD	standard deviation
N	total of sample
%	percentage
>	more than
<	less than
=	equals to
IRPA	Intensification of Research in Prioritised Area
H⁺	Hydrogen
Na⁺	Natrium

Ka⁺ Kalium

ISO International Standard Organisation

ACGIH American Conference of Government Industrial Hygienist

EMG electromyography

RULA Rapid Upper Limb Assessment

◦ degree

e.g. example

E scaling factor



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CHAPTER 1

PREFACE

1.1 Introduction

As a developing country, Malaysia has experiencing rapid development in the field of road transport due to the process of urbanization, economic development and population growth. This rapidity experiencing has increased the total number of vehicles on roads. The increased traffic volumes on roads can create traffic problems among drivers.

According to Road and Transport Department (2007), there were about 959 714 new registered motor vehicles in Malaysia including motorcycle, motorcar, public transport, taxi, hire and drive car, good vehicles and other vehicles. Hence from that grand total it was about 62 308 registered public transport which were stage bus, express bus, mini bus, school bus, employee bus, excursion bus and chartered bus. In

2007 there were about 99 683 public service drivers registered with Road and Transport Department in Malaysia.

Buses are one of the commercial vehicles chosen by many people as a mode of transportation to go anywhere as it is the cheapest and easy to get. Bus driving is characterized by psychological and physical stresses. Most severe are the stresses of traffic in big cities, because of the heavy traffic and frequent stops (Alfons & Andreas, 1998).

Bus drivers have big responsibilities and risks because they carry many passengers every day to anywhere. In most transit companies, the drivers must handle tasks such as selling tickets, observing passenger loading and unloading and providing information to passengers (Alfons & Andreas, 1998). Thus means, the bus drivers most probably expose to occupational safety and health hazard during their work.

The World Health Organization (WHO, 1998) reported that there were more than a million cases of neck and back disorders worldwide and they ranked second after iron deficiency anemia. There were about 250 000 cases of neck and back disorders were due to occupational injury as reported by WHO (1998). While in Malaysia, it was reported that 18 027 cases of all musculoskeletal disorders (MSDs) (Ministry of Health, 1996).

Many studies have investigated back pain among professional drivers. Low back pain (LBP) is a significant health problem for professional drivers compared to the general population with higher incidence of low back pain (Troup, 1978). LBP is also considered as one of the most common health problems around the world and one of the most difficult health problems to treat. It is often associated with functional disabilities and therefore has economic, social, industry and health care system implicating (Khalil et al., 1993).

As reported by Bovenzi & Zadini (1992) and Troup (1978), factors such as frequent awkward postures, muscular effort, vibration, shock and whole-body vibration (WBV) exposure and finally prolonged sitting in a constrained position contribute to overwork of the lumbar spine and its supportive structures, causing LBP.

Olanrewaju et al. (2007) studied on the exposure to posture demands, manual materials handling (MMH) and WBV as risks for LBP among 80 city bus drivers for three models of bus (a mini-bus, a single-decker bus, a double-decker bus). The results showed that city bus drivers spend about 60% of the daily work time actually driving, often with the torso straight or unsupported, perform occasional and light MMH, and experience discomforting jerking vibration events. Transient and mild LBP (not likely to interfere with work or customary levels of activity) was found to be prevalent among the drivers and a need for ergonomic evaluation of the drivers' seat was suggested.

The findings were supported by NIOSH (US) (1997), there was strong evidence of an association between MSDs with workplace physical factors, and non-work related characteristics. Non-work related characteristics include physical fitness, anthropometric measures, lumbar mobility, physical strength, medical history and structural abnormalities of the individuals. Workplace physical factors include heavy physical work, lifting and forceful movements, awkward postures, WBV and static working postures. Static work postures of prolonged standing, sitting and sedentary work are isometric positions where very little movement took place.

The driver's workstation in buses was designed in the form of a half - open cabin. Alfons & Andreas (1998) suggested that ergonomic design of the driver's workstation was a necessary component of driver safety and health protection. Technical measure was the ergonomically optimal design of the driver's workstation.

Not many studies have been done by researchers in Malaysia to identify risk factors of occupational safety and health problem among commercial vehicle drivers. Lack of awareness and preliminary data of MSDs among commercial vehicle drivers in Malaysia will lead to reduced productivity due to pain, discomfort and illness in a worker. Detection and intervention at an early stage could possibly affect workers physically and mentally. Therefore it is a necessary to carry out a new study among commercial vehicle driver in Malaysia that focuses on their work environment that relate to risk factors of occupational safety and health problem that would eventually improve work tasks and eliminate or reduce the MSDs problems.

1.2 Problem Statements

MSD is considered a major problem among commercial vehicle drivers not only in Malaysia but also worldwide. A higher incidence of musculoskeletal problems was reported among transit bus drivers compared to the general population (as high as 3 times greater) (Courtney & Evans, 1987).

Many studies have reported a higher percentage of bus drivers having musculoskeletal complaints. Maciulyte et al. (2000) reported that many vehicle drivers experienced problems on their skeletal muscles, cardio vascular and digestive systems. In United States, Magnusson et al. (1996) examined a group of professional drivers, and found that 50% of the subjects' complained of neck, shoulder and back pain.

A study conducted by Maciulyte et al. (2000) found that 57% drivers experienced skeletal muscle symptoms such as cramps, aches and discomfort on their back, legs and hands. Gilmore et al. (1997) reported that, the primary interest in the bus driver's workstation was the relationship between the driver's seat, steering column and wheel and pedals. Bus drivers were required to interact and maintain constant with each of these components. It was the use and combination of these components that influence the bus driver's posture.

The prevention of MSDs can be achieved by interventions which reduce the probability and severity of injuries. It is estimated that through ergonomics design, up to one-third of compensable LBP in industry can be reduced (Levy & Wegman, 1995). More than 70% of workers in developed countries have sedentary jobs (Reinecke et al. 1994) and concern about musculoskeletal problems have led to the increasing application of ergonomics in changing the workplaces to provide good sitting postures (Alfons & Andreas, 1998).

As LBP is considered a major problem among commercial vehicle drivers and the most of the risk factors had been identified, there is an urgent need for us to study the current seat used by Malaysian bus operators, proposed a new seat design and eventually reduce the high prevalence of LBP. Many bus manufacturers view the bus driver's seat as an add-on or afterthought. Typically, the bus interior is designed to optimize the number of passenger seats. The workstation is cramped with instrumentation and a fare box. The bus driver's seat is fitted within this space. The design of the bus driver's workstation must not just take into consideration the tasks performed by the bus driver. The design must also consider the physical characteristics of the driver and the accommodations required that permit the full range of seat adjustments (Alfons & Andreas, 1998 and Saporta, 2000).

Evidence by Courtney & Evan (1987) among Chinese bus driver, reported that bus seat built with European anthropometry did not match with the anthropometry of Chinese bus drivers in Hong Kong. This resulted in an improper add on such as brick

or a piece of wood for foot rest and padding of rags or rubber shoe bottoms on the pedals to fit their size. The inappropriate anthropometric data used resulted in poor design, with the workforce modifying the workstation to accommodate their needs. It can be observed that workplace design should concentrate on the need for operators to vary their sitting behavior according to job requirements rather than on finding a single, so-called optimal position (Grieco 1986).

Alfons & Andreas (1998) and Harrison et al. (2000) suggest that modification of the bus seat itself will reduce the prevalence of MSDs. These modifications include seat adjustment such as (1) backrest inclination, (2) lumbar support (up/down translation), (3) seat height adjustment, (4) seat bottom, (5) seat back (forward/backward), (6) armrest, (7) headrest and (8) shock absorbers to dampen WBV (Harrison et al., 2000). Bovenzi et al. (1992) reported that these modifications will reduce LBP up to 86% reduction of time off per injury and 78% reduction in the frequency of workstation related injuries.

Currently, Malaysian bus operators only considering on the driver's workstation and the tasks performed by them but failed to consider the physical characteristics of the driver such as their size and anthropometry. This physical characteristic required a full range of seat adjustments based on Malaysian anthropometry. Evidently, most of Malaysian bus operators tend to buy their bus seat from either European or Korean seat that does not accommodate our Malaysian drivers.

The aim of this study are to determine the prevalence of LBP among Malaysian bus drivers and recommend a new seat design based on anthropometric measurement of Malaysian bus drivers and also to evaluate the effectiveness of the new seat design.

1.3 Study Justification

This study will develop a bus seat prototype based on Malaysian adult male anthropometry. This will be the first time a Malaysian anthropometric data will be used in developing a new bus seat specifically for Malaysian drivers. This seat will be designed with the objective of reducing MSD problem among the bus drivers due to occupational health injury at workplace. Therefore it will eventually increase in workers productivity due to pain and discomfort. It is important to create a healthy working condition and environment at workplace.

It is a necessary to establish the causes of MSDs among drivers and to identify the prevalence of the MSDs among vehicles drivers in Malaysia. Furthermore, this study could generate data to use as baseline for MSDs among Malaysian vehicles drivers. Solution and recommendations may be derived from this study to improve the situations and problems in future.

This study will also benefit both the government and the private sector especially that involved with the Ministry of Transportation such as the Road and Transport

Department, Road Safety Council, Commercial Vehicle Licensing Board in the development of new standard of bus drivers' seats. The owner of public busses such as RAPID KL and TransNasional will also benefit focus the reduce cost of importing seats from other countries such as United Kingdom and South Korea.

1.4 Conceptual Framework

There are 3 main factors shown in Figure 1.1, which contribute to low back pain namely (1) ergonomics factors, (2) environmental factors and (3) social demographic factors. In this study, only the ergonomics factors and environmental factors will be considered.

There are 3 main factors that contribute to ergonomics. They are (1) anthropometry (2) vibration and (3) postures. The anthropometry of bus drivers taken were (1) sitting eye height, (2) sitting shoulder height, (3) popliteal height, (4) hip breadth, (5) buttock to popliteal length (6) elbow to elbow breadth and (7) lumbar height. The unsuitable seat design could result bad postures among bus drivers to prevail, hence create the LBP problems.

WBV is mainly transferred to the bus drivers from the engine and road surface. Vibrations from the engine are transferred via the steering wheel while the road

surface will cause vibration to the bus and this will be transmitted to the bus drivers through the bus floor and seat pan.

The third ergonomics factor is posture of the bus driver, especially in sitting position. When a seat and the work area are not compatible will lead to awkward postures requiring twisting and bending. The duration of driving also plays an important role as prolonged seating will lead to muscle fatigue and eventually LBP.

Therefore based on ergonomics factors, parameters that will be used in proposing a new seat prototype are (1) adjustable sitting height, (2) adjustable seat pan, (3) adjustable backrest and (4) adjustable lumbar support. All these parameters will be used based on adult male Malaysian bus drivers' anthropometry.

The second factor is social demographic factor such as age, body mass index, smoking habit, diseases and injury in the past had been reported as a risk factors influencing MSD especially with regards to LBP.

The final factor includes environmental factors such as road condition, age of buses, type of buses (fully automated or manual buses) and unsuitable current seat. The current seat bus driver's is not designed based on Malaysian anthropometric

measurements. The unsuitable current seat will lead to muscle fatigue due to no blood circulation and movement (prolonged sitting).



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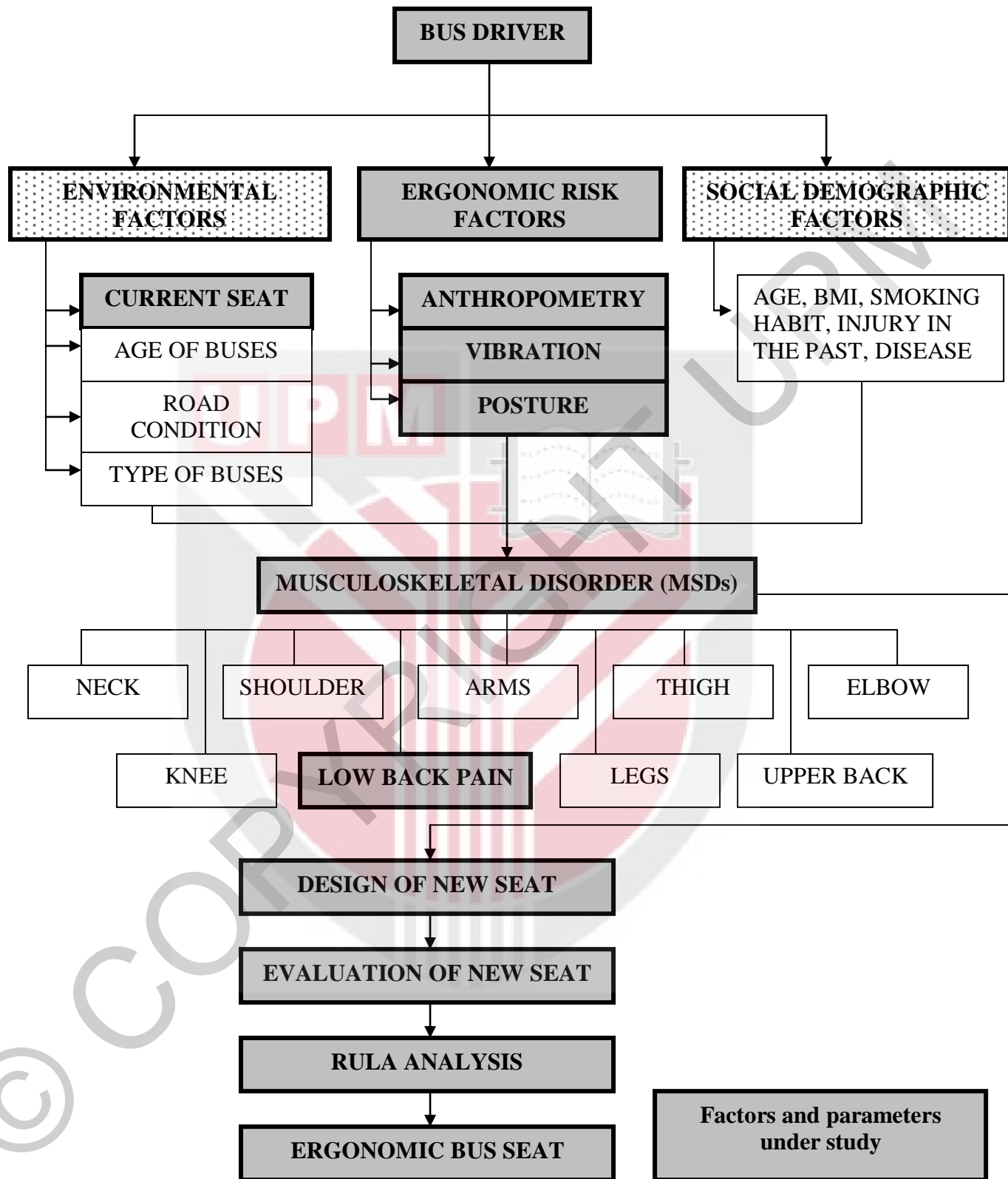


Figure 1.1 Conceptual framework factors contributing to musculoskeletal problem and development of prototype new seat design in reducing low back pain

1.5 Study Objectives

1.5.1 General objective

The aim of the study is to develop an ergonomically designed seat based on the anthropometric measurements to reduce ergonomic risk factors for LBP among bus drivers.

1.5.2 Specific objectives

1. To determine the anthropometric measurements of bus drivers.
2. To determine the prevalence of LBP among bus drivers.
3. To determine the ergonomic risk factors of LBP among bus drivers.
4. To determine the association between ergonomic risk factors and LBP among bus drivers.
5. To evaluate the new bus driver seat design using Rapid Upper Limb Assessment (RULA).
6. To compare the new propose seat design based on anthropometric measurement with current seat.

1.6 Study Hypothesis

1. There is a significant association between ergonomic risk factors and LBP among bus drivers.
2. There is a significant difference between current seat design anthropometric with new seat design.

1.7 Terminology

1.7.1 Body Mass Index (BMI)

Conceptual Definition

A value that explains the obesity of an individual without showing the body weight (WHO, 1997).

Operation Definition

Classification of body weight and the height of a person by using the formula below (WHO, 1997):

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m)}^2}$$

The indicators of BMI are as below: -

BMI < 18.5 = Underweight.

BMI 18.5-22.9 = Normal range.

BMI \geq 23 = Overweight.

BMI 23.0 – 27.4 = Pre-obese

BMI 27.5 – 34.9 = Obese I

BMI 35.0 – 39.9 = Obese II

BMI \geq 40.0 = Obese III

1.7.2 Low Back Pain

Conceptual Definition

Pain sensation beginning from muscle attachment at the ribcage down to gluteal fold area (Nachmeson, 1992).

Operational Definition

Low back pain is obtained from the Standard Nordic Questionnaires (SNQ) based on body map diagram. (Kuorinka et al. 1987). Figure 1.2 shows the approximately position parts of the body where the participants had ache, pain or discomfort.



Figure 1.2 Parts of body

(Source: Kuorinka et al. 1987)

1.7.3 Popliteal Height

Conceptual Definition

Vertical distance from the floor to the popliteal angle at the underside of the knee where the tendon of the biceps femoris muscle inserts into lower leg (Pheasant, 1996).

Operational Definition

The height of the underside of the thigh immediately behind the knee with the subject sitting erect, knees and ankles at right angles and looking straight ahead.

1.7.4 Buttock to Popliteal Length

Conceptual Definition

Horizontal distance from the back of the uncompressed buttocks to the popliteal angle, at the back of the knee, where the back of the lower legs meet the underside of the thigh (Pheasant, 1996).

Operational Definition

The horizontal distance from the rearmost surface of the buttock to the back of the lower leg with the subject sitting erect, knees and ankles at right angles and looking straight ahead.

1.7.5 Hip Breadth

Conceptual Definition

Maximum horizontal distance across the hips in the sitting position (Pheasant, 1996).

Operational Definition

The breadth of the body taken laterally across the widest portion of the hips with subject sitting erect, knees and ankles at right angles and looking straight ahead.

1.7.6 Sitting Shoulder Height

Conceptual Definition

Vertical distance from the seat surface to the acromion (i.e the bony point of the shoulder) (Pheasant, 1996).

Operational Definition

The height of the uppermost point of the clavicle above the sitting surface with the subject sitting erect and looking straight ahead.

1.7.7 Elbow to Elbow Breadth (shoulder breadth – bideltoid)

Conceptual Definition

Maximum horizontal breadth across the shoulder, measured to the protrusions of the deltoid muscles (Pheasant, 1996).

Operational Definition

The distance across the lateral surfaces of the elbows with the subject sitting erect, upper arms, vertical and touching the side, forearms held horizontally and looking straight ahead.

1.7.8 Knee Height

Conceptual Definition

Vertical distance from the floor to the upper surface of the knee (usually measured to the quadriceps muscle rather than the kneecaps) (Pheasant, 1996).

Operational Definition

The height of the uppermost point on the knee with the subject sitting erect, knees and ankles are at right angles and looking straight ahead

1.7.9 Sitting Eye Height

Conceptual Definition

Vertical distance from the sitting surface to the inner canthus (corner) of the eye (Pheasant, 1996).

Operational Definition

The height of inner corner of the eye above the sitting surface with the subject sitting erect and looking straight ahead.



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