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The Necessities of Effective Adaptive Driving Modification Guidelines for the Independent Disabled Driver Vehicle

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Abstract: The purpose of this study is to gain a deeper understanding of how implementing a guideline for vehicle modification would help to produce safer driving, particularly for a person with disabilities. A total of 29 participants consisting of 8 licensing officers, 12 automotive engineering officers, 11 NGO representatives from Persatuan Orang-orang Cacat Anggota Malaysia (POCAM), Pertubuhan Kebangsaan Orang Kerdil Malaysia (PKOKM) and 6 disabled vehicle manufacturers were gathered and interviewed for this study. This study emphasises the important aspects to ensure that a modified vehicle is safe and suitable for driving purposes. The interview also looks at the respondent's views of how they act and what they find when they assess or conduct modifications to a vehicle, particularly for the use of the disabled community. The results of this interview were analysed using the Nvivo software. The results of this study show that there is no special provision on the aspect of safety, installation, assembly to assure whether a modified vehicle for the disabled person is safe to be driven on road. Almost all of these aspects depend on the suitability and comfort of the consumer as a result of differing disability conditions. This situation has led to difficulties in having appropriate modification to assist a person with disabilities ability to drive.

Key words: Disabled vehicle modification, effective modification usability requirement, design, installation, safety, modification

INTRODUCTION

The ability of assistive driving modification and products to allow a disabled person to use and drive a vehicle independently is important. Advancement and development of vehicle usage accessibility, particularly for a person with disabilities has begun to move forward. This can be seen through the development of intelligence and easy to access assistive technology. Examples of this include the automotive power seat for the disabled person (Shi *et al*., 2009), Advance Departure Assistive System or ADAS (Cades *et al*., 2017), joystick car drive system (Wada and Kameda, 2009) and detachable car control for acceleration and braking function (Boyce *et al*., 2013).

Adhering to regulations and specifications enacted by the responsible bodies for any assistive technology is a must. In addition, applying the proper specifications required by responsible bodies such as Americans Disabilities Act (ADA) ISO9999 (Anonymous, 2007), Automotive Adaptive Driver Manual Control (Anonymous, 2010), AS3954.2-1991 (Anonymous, 1991a, b) and Adaptive Control Safety for the Disabled Person (Anonymous, 2010a) will ensure safety and effective usage.

Table 1: ADA requirement on mobility and accessibility part 38:38.23 (Anonymous, 1991)

Part 38: 38.23	Requirement
General	Equipment must allow appropriate clearance: Wheelchair and other assistive aids (minimum of 2 secure locations) Device (minimum of 1 secure location/22 feet in total length)
Controls (i)	Must be interlocked with the brake pedal or transmission
Power equipment failure	Equipment must able to operate with emergency technique if it fails to receive power

Based on the ADA requirements displayed in Table 1, any changes or modification to a vehicle must allow clearance for the equipment, must be attached to the braking system and must also be able to be operated using another technique if uses electricity as a power source.

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MATERIALS AND METHODS

A sample of 29 participants comprising of 20 officers from Jabatan Pengangkutan Jalan (JPJ), 3 representatives from the disabled persons community and 6 manufacturers of disabled vehicle fabricators were recruited. All of the participants are based within Peninsular Malaysia. Of the 20 officers, 8 (27.58%) are licensing officers while 12 (41.37%) are automotive engineering officers. A different situation was recorded for the 3 community representative respondents whereby 2 (10.34%) represented POCAM (Persatuan Orang-orang Cacat Anggota Malaysia) society and 1 (3.44%) represent PKOKM (Pertubuhan Kebangsaan Orang Kerdil Malaysia) Society. The 6 (20.68%) participants working with disabled person vehicle were recruited from Selangor, Perak, Kuala Lumpur and also Malacca.

The interviews took place office of the respective participants. The duration of the interviews were between 25-30 min and they were recorded and transcribed with the permission of the respondent. In efforts to make the environment more comfortable, the sessions began with questions on demographics and a brief explanation on the interview process. The interviews were conducted by the first researcher.

Qualitative content analysis was used for this study to compare and analyse the similarities between the interviews conducted on the respondent. Moreover, the use of qualitative content analysis allows a combined inductive and deductive approach (Elo and Kyngas, 2008).

The data from the interviews were then analysed using the Nvivo software and coded according to the scope of the study. Although, the categories (codes) were identical after several interviews, analysis continued on several respondents. This is to ensure the precision of the categories obtained.

RESULTS AND DISCUSSION

The necessities of having appropriate guideline when making modification onto a vehicle for a person with disabilities is always a priority in ensuring safe and effective on road driving. One of the major aspects is the design of the driving aid. This component will help the user counterbalance their strengths and weaknesses when steering or accelerating when steering or accelerating with a vehicle.

One such example is the low volume vehicle transport Association's requirement for assistive driving modification 45-30 (03) (Anonymous, 2010) displayed in Table 2. As to add more the standards clearly feature the appropriate design requirement when building or making a hand control as assistive driving.

Table 2: Adaptive hand control design requirement by LVVTA New Zealand

Components	Design requirement
System	Properly construct for longer usage time Must be push and pull or radial control type
Support bar	Material must be equal or greater than the size of 25×5×3 mm hollow rectangle steel
Lever	12 mm round steel bar or 20×6 mm flat steel bar
Pivot pins	Tensile strength equal or greater than 8.8 metric 6mm for Clevis fork design with double- sheer pivot pin 8 mm for other design
Brake rods	High tensile or stainless steel with a diameter of 10 mm
Imported modifications	Must comply with the LVVTA regulation Must obey and follow the international standards such as ADA/SAE/NHTSA

Even, so, the practice of having and applying any design guidelines was found to be displeasing. From the interview, the participant identified the design for assistive driving modification as not available.

> We don't have any specific design standard here in Malaysia (Automotive Engineer Officer 2, Selangor Malaysia)

> I'm not sure about the design standard here in Malaysia as there is no specific code on colour, shape or dimension stated in any regulation. Most of the decisions were made by the authorities during vehicle inspection (Disabled vehicle fabricator 3, Selangor Malaysia)

The insignificance on design, particularly for assistive driving modification products result in the use of unsuitable material and uncomfortable product usage. Images a and b below shows this situation. The arm holder was found to be unsuitable for a person suffering from Phocomelia (Osadsky, 2011) arm. He was diagnosed with Phocomelia arm disabilities since birth and he has since, lived with permanent deformities (Fig. 1). Furthermore, the user was unable to adapt to the suggested modification to assist his steering limitations (Fig. 1 and 2). The arm holder requires him to move his chest forward and forces him to spin the steering using the deformed arm. As a result, the respondent took the initiative to use his right foot to steer the vehicle in and right foot to change gear in order to counter the uncomfortable posture and visual limitation (Fig. 1b). Standard J2388-201110 developed by the Society of the Automotive Engineers (SAE) clearly addresses three aspects for effective assistive driving products for persons with disabilities (Anonymous, 2010). These aspects include.

The assistive driving product must able to be operated by a non-disabled person. Product must able to be accessed and suits the correct disability category. The assistive driving product should not cause problems when used on the road.

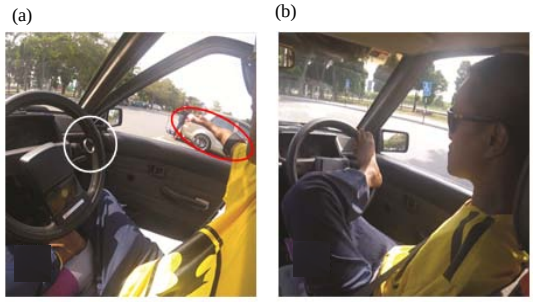

Fig. 1: Image a displays the failure of the arm holder as a modification to assist the user's car steering abilities. The situation has led the driver to steer the vehicle using his foot (image b)

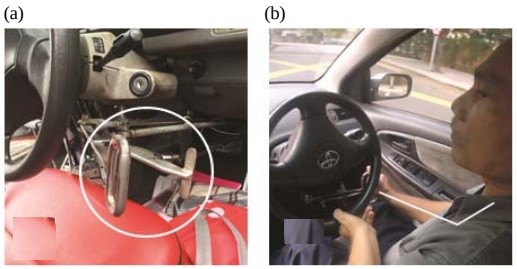

Fig. 2: The user must hold the toggle in a static position, causing him to suffer muscle aches. Most users were also unable to drive during hot weather due to the heat absorbed by the chrome steel toggle (image d)

Most of the assistive driving modifications that are available and used were found to be unsatisfactory, particularly in terms of design. One of the paraplegic drivers as displayed in Fig. 2 often suffered muscle swelling on their forearm and pain on their palm due to the static position when using the push and pull modifications during long drives.

The ability to sustain the equipment handling momentum also reduces due to the wheelchair loading activities (Fig. 3 and 4). This discovery was in line with the studies on car transfer and wheelchair loading activities (Haubert *et al*., 2015). According to him, the 3 h rest will help reduce muscle strain faster. The situation was found to be in line with the findings of studies conducted on forearm and shoulder activities using variable computer mouse (Chen and Leung, 2007). In addition, an increase in activities which require the muscle to slant forces the forearm muscle to perform large wrist extension. This has the potential to cause Carpal Tunnel Syndrome (CTS) to the muscle involved. As a result, he often stops from driving activities for 3 h. Some of respondents display their disappointment by describing the disadvantages of their modifications.

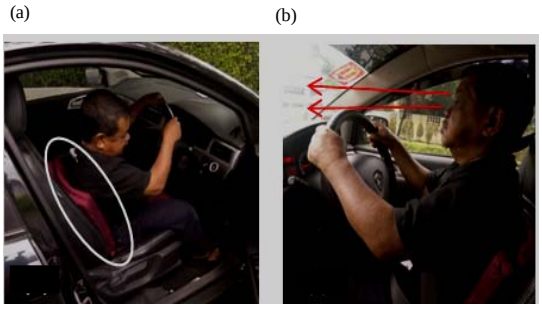

Fig. 3: Self-made upholstery to increase the seating height. The self-made modification causes a shorter driver to face difficulty reaching the pedal as well as poses visual limitations

Fig. 4: Paraplegic driver facing difficulties accessing and storing the wheelchair into the vehicle. This is due to the unavailability of modification options and inability to adjust the seating

> I usually wrap the accelerator toggle with cloth if the weather is too hot. This situation also happens to my colleagues (POCAM member 2, Kuala Lumpur Malaysia)

> I am okay with it but some of my colleagues do not like it because their arm positions need to be static. It causes them pain (Disabled Vehicle Fabricator 1, Selangor Malaysia)

A modification should have the ability to assist and address the limitation based on the category of the disabled driver. Guidelines provided by the road and traffic authority as displayed in Table 3 clearly state several parameters of suitable modifications as requirements to address the driving limitations of a person with disabilities (Anonymous, 2007). It is important not only for the vehicle manufacturer but also for the user as well, so as to identify the appropriate assistive modifications. The right assistive driving modifications can prevent dangerous circumstances when using the vehicle on the highway or congested route.

Table 3: Guidelines on appropriate vehicle modification according to disability categories by road and traffic authorities australia

Disability category	Suitable modification
Parameters	Leg Left foot accelerator for right leg disabilities
	Hand control if both legs cannot be used
Arm	Spinner Knob
	Extension to reach the control
Neck or head	External Mirror
Wheelchair occupant	Wheelchair restraint system, added with fire extinguisher and visible hazard light

Assembly and installation: It was found that less attention was given to the assembly and installation of driving modification for vehicles for the disabled. Most respondents reported that implementing strict guidelines was difficult due to a disabled person's physical differences. Respondents representing the authorities reported that they are unable to be stringent on this aspect, apart from the jointing and finishing of an installed product. Besides, this situation occurs because of the income level of a majority of the disabled persons in Malaysia. Among the responses given in terms of installation and assembly are:

> We will only look at several components such as the assembly, weld finishing and locking system of the installed modification. We can't be too strict on other components as a majority of Malaysia's disabled drivers are not rich (Automotive Engineer Officer 2, Perak)

> I ordered my modification online from Singapore. My modified car passed the PUSPAKOM installation inspection without problem (POCAM member 2, Kuala Lumpur Malaysia)

> Some disabled drivers prefer the products of unapproved manufacturers due to cheaper prices. In the end, they avoid inspection due to improper welding (POCAM Member 1, Kuala Lumpur Malaysia)

This aspect is said to be the most crucial component in producing safe and effective vehicles for a disabled person to drive on the road. Apart from that, LVVTA (Low Volume Vehicle Technical Association) in their guidelines clearly describe the best method for welding and installation of driving modification. Furthermore, the suitable rod dimensions for modification and welding criteria are also highlighted to ensure the modification's effectiveness when in use. Such guidelines can be a helpful reference when developing a suitable guideline for vehicles driven by disabled persons. In addition, detailed content will help users to be clear and careful when selecting a manufacturer that is approved by the authorities (JPJ).

It is very important for any assistive driving product or modification to be securely installed in a vehicle as the response of a person with disabilities is much slower than that of a normal person (Pauley *et al*., 2013).

Product affordability: A problem can be seen in the ability of disabled drivers to afford a modification or a product that could to address their driving limitation. The situation depicted from the responses gathered during the interviews was that there is no standard price offered by distributors and manufacturers. The lack of price standardisation has led to differences in cost between the types of vehicle used by the person. Most companies implement a system where by the modification is carried out and the price is discussed later. This phenomenon has yet, to change and is a burden to customers who plan on making modifications to their vehicles. As the result, some disabled drivers end up driving a non-modified vehicle and risk getting into an accident. According to statements made by the respondents.

> The cost of a modification is unknown because it is set by the vehicle manufacturer. You may ask them for prices in detail (Driver License Officer 2, Putrajaya Malaysia)

> The price for a modification differs according to the type of car. The modification in my car for example, cost RM 2000. The price is higher if the modification is installed in a luxury or big size car (POCAM Member 2, Kuala Lumpur Malaysia)

Stating an average price for each type of modification would be ideal for the user. Such approaches can be seen in the guideline drawn up by RICA (Research Institute of Consumer Association) in the UK. The guideline offer a list of a wide range of products together with its price for easier decision making (Holmes, 2012). Knowing the average price of each product helps the user to prepare financially (Anonymous, 2015).

Product function and suitability of use: In terms of product function there is no specific measure or assessment to evaluate usage effectiveness. According to Automotive Engineer officer 1, the suitability of a modification will be assessed and evaluated through an assessment conducted by a physical therapist. The assessment is carried out based on a checklist prepared

by the Ministry of Health Malaysia (Anonymous, 2012). At the end of the assessment, the physical therapist will then issue an approval letter for disabled driving license and suitable modification for assistive driving. This practice was found to be similar to the driving assessment procedure conducted by the association of driver rehabilitation specialist and also the national mobility dealer association (Boyce *et al*., 2013).

As for product effectiveness no practices or assessment were found available in Malaysia. According to the interview, most of the assistive driving products used in Malaysia do not require any specific testing or in-lab evaluation. According to some of the respondents.

> We do not conduct any special task before allowing it to be installed and be used legally in Malaysia (Vehicle Licensing officer 4, Selangor Malaysia)

> I was never requested by any authorities or bodies to send my products for testing at any special facilities like SIRIM or MIROS (Disabled vehicle manufacturer 2, Selangor Malaysia)

Similar issues were found on the aspect of product suitability, particularly for assistive driving purposes. Some of the respondents mentioned that the owner of the modified vehicle must drive it themselves. This is to ensure that the vehicle owner is able familiarise with and use the modifications effectively. The situation becomes even more crucial when only the vehicle owner will be familiar with the installed modification. Some of the respondents stated.

> The disabled driver will practice to use the installed modification with an appointed assistant at any driving centre (Vehicle licensing officer 8, Perak Malaysia)

> Here, in Putrajaya, we test the function by asking the vehicle owner to perform several driving tasks such as at traffic light junction, accelerating, decelerating and several others. The approval letter for on road use will be issued if the user is able to perform the entire task without causing any problem (Automotive engineer officer 1, Putrajaya Malaysia)

As a result, any improvement on the assistive driving product, particularly those that are locally built, would be impossible. The situation results to disabled drivers to have no license and to drive a car that has not has been modified.

Adding virtual simulations such as the STISIM drive 3 programme used in the drive by wire system (Kim and Kim, 2016) could be an effective approach. The approach will not only be able to identify product weaknesses but also allow the vehicle owner to identify the appropriate modification they prefer. The effectiveness of virtual simulation for driving rehabilitation was proven in a study of two detachable hand controls (PHC-3 and TNT). As a result, weaknesses such as the toggle position on the PHC-3 and the advantages of using the thumb to control the accelerator on TNT was discovered (Boyce *et al*., 2013). Apart from that the approach will also able to help the disabled driver to practice fuel efficiency and safe driving distance (Marumo *et al*., 2015).

CONCLUSION

The necessities of having an effective adaptive driving modification guideline for the independent disabled driver vehicle have been discussed. There is a lack in guideline for assistive driving modification, especially in Malaysia. Insufficient components for an effective modification guideline is not only puzzling but also worrying. Product flaws such as design, installation of the modification, affordability and also suitability has yet, to meet the required standards. Proper modification for vehicles for disabled persons is a must, despite the fact that a majority of the disabled community are from the low income group. This is to ensure the suitability, safety and effective usage of assistive driving modification.

The content analysis approach for this study has helped the researcher to obtain and extend the findings wider. In addition, the use of content analysis allowed the researcher to be flexible as the approach allows the use of text and visual as data (Schreier, 2012).

Although the interviews managed to discover the issues and shortcomings of disabled vehicle modification requirements, particularly in Malaysia, more studies should be conducted to gather more findings. Further research, perhaps involving input from the end user will help obtain more vital and concrete data.

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REFERENCES

Anonymous, 1991a Motor vehicle controls-adaptive systems for people with disabilities: Part 2 hand comtrols-product requirements. Standards Australia, Sydney, New South Wales.

Anonymous, 1991b Part 38-Americans with Disabilities Act (ADA) accesibiltiy specifications for transportation vehicles: Subpart B-buses, vans and systems 38 C.F.R. U.S. Government Publishing Office (GPO), USA.

Anonymous, 2007. Vehicle standard information. Roads and Transport Authority, Dubai, UAE.

Anonymous, 2010a Automotive adaptive driver controls, manual. SAE International, USA.

Anonymous, 2010b.Disability adaptive control systems. Low Volume Vehicle Technical Association, New Zealand.

Anonymous, 2010c.Secondary control modifications. SAE International, USA.

Anonymous, 2012. Medical examination standards for disabled driving license at Malaysia ministry of health facility. Ministry of National Health Services, Islamabad, Pakistan.

Anonymous, 2015. Adapting motor vehicles for people with disabilities: United State department of transportation. National Highway Traffic Safety Administration, Washington, D.C., USA.

Boyce, M.W., D.K. Fekety and J.A. Smither, 2013. Resource consumption and simulator driving performance using adaptive controls. Assistive Technol., 25: 158-165.

Cades, D.M., C. Crump, B.D. Lester and D. Young, 2017. Driver Distraction and Advanced Vehicle Assistive Systems (ADAS): Investigating Effects on Driver Behavior. In: Advances in Human Aspects of Transportation, Stanton, N., S. Landry, G.D. Bucchianico and A. Vallicelli (Eds.). Springer, Switzerland, ISBN:978-3-319-41681-6, pp: 1015-1022.

Chen, H.M. and C.T. Leung, 2007. The effect on forearm and shoulder muscle activity in using different slanted computer mice. Clin. Biomech., 22: 518-523.

Elo, S. and H. Kyngas, 2008. The qualitative content analysis process. J. Adv. Nurs., 62: 107-115.

Haubert, L.L., S.J. Mulroy, P.E. Hatchett, V.J. Eberly and S. Maneekobkunwong *et al*., 2015. Car transfer and wheelchair loading techniques in independent drivers with paraplegia. Front. Bioeng. Biotechnol., 3: 139-139.

Holmes, J., 2012. Car controls: A guide for older and disabled people. Master Thesis, Rica (Research Institute for Consumer Affairs), London, England.

ISO., 2007. Assistive products for persons with disability classification and terminology. International Organization for Standardization, Geneva, Switzerland.

Kim, Y. and Y. Kim, 2016. Driving performance of adaptive driving controls using drive-by-wire technology for people with disabilities. J. Ergon. Soc. Korea, 35: 11-27.

Marumo, Y., T. Nakano and H. Suzuki, 2015. Driver assistance system to encourage appropriate longitudinal behavior considering pre-preceding vehicle information. Intl. J. Automot. Eng., 6: 113-118.

Osadsky, C.R., 2011. Phocomelia: Case report and differential diagnosis. Radiol. Case Rep., Vol. 6,

Pauley, T., F. Ismail, C. Boulias, M. Devlin and C.P. Phadke, 2013. Comparison of foot pedal reaction time among patients with right or left hemiplegia and able-bodied controls. Top. Stroke Rehabil., 20: 500-508.

Schreier, M., 2012. Qualitative Content Analysis in Practice. Sage Publications, Thousand Oaks, California, ISBN:978-1-84920-592-4, Pages: 272.

Shi, Y., I.T. Lee, A.M. Afsar and J.I. Song, 2009. Development and performance analysis of an automotive power seat for disabled persons. Intl. J. Automot. Technol., 10: 481-488.

Wada, M. and F. Kameda, 2009. A joystick car drive system with seating in a wheelchair. Proceedings of the IEEE 35th Annual Conference on Industrial Electronics (IECON'09), November 3-5, 2009, IEEE, Porto, Portugal, ISBN:978-1-4244-4648-3, pp: 2163-2168.