



A comprehension-based ergonomic redesign of Philippine road warning signs

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ABSTRACT

Safety in the road environment is dictated by the effectiveness of road warning signs in terms of comprehensibility. Due to prevalent road accidents associated with human error and confusions with road warning signs, there is a need for signs that are not well-comprehended by drivers to be investigated and further revised. This paper aims to measure the comprehension level of road warning signs in the Philippines and propose redesigned alternative road warning signs with reference to the ergonomic principles of display design. In selecting the most suitable alternative design, an analytic hierarchy process (AHP) method is employed. It is found that more than half of the assessed signs fall below the standards set by the American National Standard Institute (ANSI), thus, leading to the proposal of alternative sign designs. To validate the significant improvement between the prior and new designs, a Mann-Whitney rank sum test is performed. The redesigned alternatives exhibited substantial improvement on the comprehension level of drivers. This implies that the application of ergonomic principles significantly increases driver comprehension level.

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1. Introduction

In the system of general land transportation, the use of road warning signs as an instrument to regulate, warn, and inform road users has become a widely-accepted notion to maintain highway safety (Shinar et al., 2003; Bazire and Tijus, 2009). It is designed to prompt road users, particularly drivers, to practice extra caution to minimize the occurrence of crashes due to human error. When road signs command attention, convey a clear and simple meaning, and give adequate time for proper response, these are believed to be effective (United States Department of Transportation-Federal Highway Administration, 2016). Moreover, it also suggests the compliance of road warning signs with ergonomic sign design principles in terms of spatial compatibility, physical compatibility, conceptual compatibility, standardization, and familiarity (Sanders and McCormick, 1993). In literature, various works have used these ergonomic principles as aid to evaluate the comprehensibility level

of road warning signs (Dewar, 1988; Hawkins, 1993; Sanders and McCormick, 1993; Ben-Bassat and Shinar, 2006; Ng and Chan, 2007; Philippine Department of Public Works and Highways, 2012; Sodikin et al., 2013; Brucal et al., 2015). By definition, spatial compatibility refers to the physical arrangement in space, relative to the position of information and directions. Conceptual compatibility, on the other hand, defines the extent to which symbols and codes conform to people's associations. Physical representation describes the similarity between the content of the sign and the reality it represents while familiarity measures the extent to which the driver is familiar with the sign from his driving experience. Lastly, standardization defines the extent to which the codes used for different dimensions, such as color and shape, are consistent with all signs.

To have a uniform design of road warning signs, the Vienna Convention on Road Signs and Signals is promulgated among contracting countries to establish standard traffic rules on November 8, 1968. This convention is agreed upon by the United Nations Economic and Social Council (UNESCO) (UNESCO, 1968). In the field of international road signs, there are two different systems subject for implementation – the American system with traffic rules and policies documented in the Manual on Uniform Traffic

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Control Devices (MUTCD) and the European system from the Vienna convention. As for the case in the Philippines, road signage practice closely follows the Vienna convention with local adaptations and some minor influences from the United States MUTCD. The standardization convention has been formally ratified in 1973 under Presidential Decree No. 207. The Philippine Department of Public Works and Highways (DPWH) provides and manages quality infrastructure facilities and services on road highways. This department released two manuals on Road Safety Design and Road Signs and Pavement Markings. Road warning signs are standardized in the latter manual.

In the field of traffic engineering and cognitive ergonomics, one definite measure of the effectiveness of road warning signs is through drivers' comprehension (Makinde and Oluwasegunfunmi, 2014). A high comprehension level signifies that road warning signs are sufficiently reliable as designed. Otherwise, issues such as overall safety of the roadway environment may be evident as a consequence. Unfortunately, symbolic signs are often misunderstood by drivers (Al-Madani and Al-Janahi, 2002; Shinar et al., 2003; Kirmiziloglu and Yaman, 2011; Yuan et al., 2014) and is found to be far from satisfactory (Zhang and Chan, 2013), even those that have already been standardized and used throughout the world (Charlton and Baas, 2006). This further proves that these road warning signs are poorly designed as there is no assurance for drivers to notice, understand, and comply with the information presented. With this, road signs become a mere display rather than an informative tool to control traffic flow as well as to warn motorists of hazards. Therefore, comprehension level in terms of individual differences in performance on comprehension test should be evaluated.

A study by Al-Madani and Al-Janahi (2002) investigated a total of 28 symbolic warning and regulatory signs in five Middle East countries in reference to comprehension factors in terms of the role of age, marital status, gender, nationality, educational background, and monthly income. These factors are investigated according to its effects on the understanding of drivers with regards to road warning signs. The overall results revealed that drivers' comprehensibility level of regulatory and warning road signs is 55.00% and 56.00%, respectively, representing that drivers comprehend only half of the symbolic signs posted along the roadways. Specifically, Ben-Bassat and Shinar (2015) looked into the effect of context and drivers' age on 28 highway traffic signs comprehension and concluded that indeed young drivers are more likely to correctly comprehend the meaning of the signs than older drivers. This is attributed to the fact that young drivers learned the meaning of signs much more recently while preparing for the driver license examinations while older drivers have more driving experience, therefore, more familiar with traffic signs (also see Al-Madani, 2000; Key et al., 2016). These scenarios clearly pose a serious problem in a one-way communication system between road signs and drivers. Similarly, in separate studies conducted by Makinde and Opeyemi (2012) and Makinde and Oluwasegunfunmi (2014) which investigated the understanding of road warning signs in Nigerian cities, a low comprehension level of 63.00% is found on the evaluated road warning signs. The results are relatively close to that of a study conducted in Indonesia which obtained a 67.00% comprehension level among drivers (Sodikin et al., 2013). Recently, Chocharukula and Sriroongvikrai (2017) examined the comprehension level of international road users in Thailand and found that 56.00% of the posted signs are correctly comprehended by the respondents as influenced by significant travel characteristics such as trip duration, trip objective, mode of transportation, and frequency of visit. International road users are also taken as respondents in the study of Yoh et al. (2017) to extract the effect of sense of priority, speed and comprehension rules to traffic violations. The results

pertaining to comprehension revealed that foreign drivers are more prone to violate traffic regulations in the context of Japanese traffic situation.

While prior studies conduct an assessment of comprehension based on individual differences in a performance involving user characteristics such as age, gender, driving experience, and educational background, to name a few, another aspect of comprehension evaluation, that is sign design characteristics, is looked into in the context of this paper. Although user characteristics also dictate comprehension level, sign design in term of cognitive features (e.g., familiarity, concreteness, meaningfulness, and semantic closeness for various road signs) affects the comprehension level of users as well (Ng and Chan, 2007; Zang and Chan, 2013). It is also important to note that the drivers' poor reading performance, and at its extreme, dyslexia, is negatively associated with road sign comprehension scores and road sign processing (Taylor et al., 2016). Therefore, as a user characteristic pertaining to reading performance, it does not appear to affect the comprehension of road warning signs at a general level (although it is recently argued by Roca et al. (2018) that despite the potential deployment of compensatory strategies, adults with dyslexia may still find it difficult to read and understand visual messages). The same can also be inferred for multidimensional driving style inventory (MDSI) that assesses four broad driving styles (i.e., reckless and careless, anxious, angry and hostile, and patient and careful) which may vary across generations (Skvirsky et al., 2017). Additionally, sign design characteristics are more flexible to probable modifications compared to user characteristics which may entail psychological shifting and alterations.

1.1. Measuring and increasing comprehension level

Correct understanding is a major factor in determining the effectiveness of road warning signs. Lack of understanding may reduce its intended purpose and may lead to road accidents including errors in making predictions about other road users' actions (Lee and Sheppard, 2016; Crundall, 2016). To aid in the evaluation of the comprehensibility of road warning signs, a standard has been set by the American National Standard Institute (ANSI) and the Organization for International Standardization (ISO). According to ISO 3864, signs are considered acceptable when a level of at least 67.00% accuracy is obtained in a comprehension test (Brucal et al., 2015). A higher comprehension level of 85.00% is later set by ANSI Z535.3 (2002). In outstanding studies, the comprehension level standard set by ISO 3864 is widely adopted as such can be found in studies of Al-Madani and Al-Janahi (2002), Shinar et al. (2003), Żakowska (2004), Ben-Bassat and Shinar (2006), and Brucal et al. (2015), to name a few. When the comprehension level of road warning signs is known to be below the standard set, the goal to accordingly increase such level then follows. Additionally, it is imperative to recognize that a strong relationship between a sign's compliance to each of the ergonomic principle to the sign's comprehensibility exists (Ben-Bassat and Shinar, 2006). Therefore, designing road warning signs according to ergonomic guidelines results to a more understandable sign which further improves comprehension.

Several methodologies facilitated the redesign process of poorly comprehensible road warning signs. Two common parts are observed to be able to carry out the redesigning process structurally: (1) procedure for determining critical and specific factors on sign design and (2) the procedure for generating a final or best design among the set of redesigned alternatives. To date, there are limited studies which pursue the redesign phase of road signs involving comprehension criteria level that can be related to safe driving performance. One of the few papers is that of Pietrucha

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