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RISK PERCEPTION AND ITS CORRELATES: IMPLICATIONS FOR RESEARCH AND PRACTICE IN THE ROAD TRANSPORT INDUSTRY

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SUMMARY: Global statistics on road transport industry suggest that road traffic crashes are a major public health issue that requires concerted international and national effort given that they are a major global killer. These statistics also imply that urgent attention is required to promote an understanding of and enhancing of safety on roads globally. More recently, evidence has accumulated to the effect that risk perceptions are found to relate to accident through its effect on risk-taking behavior and operator decision-making. Owing to this, author conducted a narrative review to explore whether risk perception relate to operator decision-making, comprehension of safety signs, risk exposure, operator risk-taking behavior, and accident in the road transport industry. One noticeable gap is that many of the studies have been conducted in Western, Educated, Industrialized, Rich, and Democratic (WEIRD) societies. Other findings and the implications for research and practice were also discussed.

Key words: *risk perceptions, decision-making, safety signs, risk exposure, risk-taking, accident*

INTRODUCTION

Global estimate of accident suggest that occupational accidents are high and rising annually. For instance, Tampere University of Technology (TUT), Singaporean Workplace Safety and Health Institute (WSHI) and VTT Technical Research Centre of Finland (VTT) reported that the global estimates of accidents (including work-related traffic accident) of an average of 313,206,348 non-fatal and 352,769 fatal accidents occur annually *(TUT, WSHI & VTT, 2014)*. Similarly, Hämäläinen et al. *(2006)* estimated that 263,838,111 non-fatal and 345,719 fatal accidents occur annually. In the specific case of traffic-related accidents, the World Health Organization *(WHO, 2009)* has documented that road traffic accidents were the ninth (9th) leading cause of death worldwide in 2004 and projects it to be the fifth (5th) leading cause of death globally by 2030. It is expected that this rise will amount to nearly 2.4 million fatalities annually. It is estimated that over 1.25 million deaths occur as a result of road traffic accidents each year while between 20 and 50 million non-fatal road traffic injuries occur annually worldwide *(WHO, 2009, 2013a, 2015)*. Road traffic fatalities were estimated to be 1.27 million in 2009, 1.24 million in 2013 and 1.25 million in 2015. Thus, the number of deaths resulting from road traffic crashes (RTCs) annually reported by WHO has remained relatively stable when compared to the 2007 statistics, though it remains disturbingly high at around 1.20 million deaths each year.

Indeed, it is against this background that RTC has been captured among the targets for *Sustainable Development Goal 3 (Osborn et al., 2015, Stepping & Rippin, 2015)*. Two of the targets are relevant here, namely: Goals 3.6 and 3.4. Goal 3.6 requires that governments around the world

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to halve deaths and injuries from RTCs by 2020 whereas the Goal 3.4 enjoins governments to reduce by one-third pre-mature mortality from non-communicable diseases through prevention and treatment, and promote mental health and well-being *(Osborn et al., 2015, Stepping & Rippin, 2015)*.

The ongoing discussion clearly indicates that road traffic safety is a serious problem worldwide. For instance, using dataset from 1993 to 2007 involving 80 million Japanese drivers, Nishidaall *(2009)* reported nearly 11 million road traffic accidents and 130 million road traffic violations. Again, Nishidall *(2009)* documented approximately 0.83 million injury traffic accidents and 8.5 million traffic violations in Japan in 2007 alone. Similarly, nearly 95,000 people are reported to have been injured due to road traffic accidents in Turkey in 2005 alone while, in India, nearly 2 million people have been disabled as a result of road traffic accidents *(Nishidall, 2009)*. Odero et al. *(1997)* reported that road traffic accident-related injuries accounted for between 30% and 86% of all trauma admissions in a comprehensive review of several epidemiological studies of road traffic accidents in countries in Africa, Asia, Middle East, Latin America and the Caribbean. Thus, Odero et al.'s *(1997)* data provide an estimate of the problem in developing counties.

Notwithstanding the worldwide pervasiveness of road traffic accidents, WHO *(2009)* reports that over 90% of global deaths due to road traffic accidents occur mostly in low- and middle-income countries (LMICs) even though these countries tend to have less than half of world's registered vehicles. However, recent estimates suggest that LMICs now account for nearly 80% of world's road traffic deaths in 2013 and approximately 74% in of world's road traffic deaths in 2015 *(WHO, 2013a, 2015)*. It has also been documented that nearly 62% of world's road traffic accidents occur in ten (10) countries, namely (in descending order): India, China, the United States of America, the Russian Federation, Brazil, Iran, Mexico, Indonesia, South Africa and Egypt. On the other hand, the top ten (10) for fatal road traffic accidents include China, India, Nigeria, the United States of America, Pakistan, Indonesia, the Russian Federation, Brazil, Egypt and Ethiopia. In addition, considering all continents, Africa is reported to have the highest fatality due to road traffic accidents *(WHO, 2013a, 2015)*. In their joint study, Tampere University of Technology, Singaporean Workplace Safety and Health Institute and VTT Technical Research Centre of Finland *(2014)* reported similar pattern for Africa; Hämäläinen et al. *(2006)* also documented similar results in relation to work-related accidents including transport-related accidents in Africa.

The burden of road traffic accidents borne by LMICs is not only in the loss of lives and properties but also in losses to their respective gross domestic product (GDP). WHO *(2009)* estimates the global losses due to road traffic accidents to be around US$ 518 billion and/or between 1% and 3% of GDP annually. This impact is likely to be greater on the economies of LMICs which are struggling to engineer economic growth. However, the trend of road traffic accident rates is not necessarily the same for both urban and rural settings. For instance, Nishida *(2009)* documented differences in road traffic accidents rate for Hokkaido and Tokyo in Japan with the latter recording higher road traffic accident rate relative to the former. Hokkaido is the northernmost island of Japan with the lowest population density as well as being more rural; Tokyo is an urban city with the highest population density in Japan.

What are the implications of these statistics in general and with reference to this study? First, road traffic accidents are a major public health issue that requires concerted international and national effort given that more and more people die from road traffic accidents and such accidents are a major global killer. Second, urgent attention is needed to be focused on understanding and promoting safety on roads globally. Recently, it has been demonstrated that risk perceptions relate to accident *(Mazzetti et al., 2020, Oppong, 2021, 2015)*. As a result, the purpose of this narrative review is to explore how risk perception relate to operator decision-making, comprehension of safety signs, risk exposure, operator risk-taking behavior, and accident in the road transport industry. Therefore, the goal of this article is to provide a comprehensive review of the research connecting the perception of risk to operator decision-making, comprehension of safety signs, risk exposure, operator risk-taking behaviour, and accident in the road transport industry. This article will focus on presenting the research about the correlation between: 1) risk perception and risk-taking behaviour; 2) risk perception, decision-making, and comprehension of safety signs; 3) risk exposure and accident; 4) decision-making and risk exposure; and 5) risk-taking behaviour and risk exposure.

To conduct this narrative review, PubMed and Google Scholar were searched for studies on the following thematic areas: risk perception and risk-taking behavior, risk perception, decision-making, and comprehension of safety signs; risk exposure and accident; decision-making and risk exposure; and risk-taking behavior and risk exposure. The reference lists of all identified studies were also searched as well for additional studies. In addition, the following were observed: 1) most recent studies (but also older studies were included where necessary), 2) English Language articles, and 3) articles from any geographic region were included in this review. Results of this narrative review are discussed in the ensuing paragraphs.

RISK PERCEPTIONS AND RISK-TAKING BEHAVIOR

Studies have also been done to examine the relationship that exists between risk perception and risk-taking behavior. Risk perception refers to people's subjective evaluations about the likelihood of occurrence of negative events or possibility of a loss *(Darker, 2013, Paek & Hove, 2017)* while risk-taking behavior may be considered as violations of safety standards that expose people to the dangerous conditions or situations. Thus, risk-taking behavior is similar to unsafe acts or actions that violate safety standards and potentially harm people or cause damage to property *(Oppong, 2011)*. Notably, unsafe acts and, therefore, risk-taking behavior may either create unsafe conditions or expose the individual to the danger. Moreover, it takes a combination of unsafe acts and unsafe conditions for an accident to occur *(Oppong, 2011)*. Consequently, an accident is usually a low-frequency event as not every unsafe act or risk-taking behavior would result in the accident. The overwhelming conclusion has been that risk perception influences risk-taking behavior as there is a high tendency that when people accurately perceive risk, they are less likely to engage in behaviors that can potentially harm them.

Rundmo et al. *(2007)* found that risk perception is significantly related to risk-taking behavior. However, Rundmo et al. *(2007)* contend that the relationship between risk perception and risk-taking behavior may be due primarily to the fact that a common set of antecedent variables influence both perception and behavior. They added that, if one partials out the effect of these predictor variables, the relationship between the two factors ceases to exist. Methodologically speaking Rundmo et al. *(2007)* erred as one can only partial out the effect of intervening variables (mediators and moderators) rather than predictor variables *(see Baron & Kenny, 1986)*.

Again, when considered in terms of partial correlation a similar conclusion would be reached. Howell *(1997, p. 526)* defined partial correlation as:

"the correlation between two variables with one or more variables partialled out of both X and Y. More specifically, it is the correlation between the two sets of residuals formed from the prediction of the original variables by one or more other variables".

Prior to being partialled out, the effect of the third variable functions as a predictor. Nevertheless, when its effects are partialled out, it no longer functions as a predictor but rather as either a moderator or mediator.

Thus, it is more likely that those predictor variables Rundmo et al. *(2007)* identified were either mediators or moderators. As a result, in this study, it is conceptualized that risk perception directly influences risk-taking behavior and has an influence through its effect on driver decision-making.

Another outstanding finding by Rundmo et al. *(2007)* was the fact that there is a positive relationship between driver risk-taking behavior (or in-traffic risk behavior) and work-related risk-taking behavior. Similarly, they reported a positive association between non-work-related risk-taking (or risk behavior during the leisure time) and work-related risk-taking behavior (on-the-job risk behavior). Palamara et al. *(2012)* reported similar relationships between risky driving behaviors and other health risk behaviors among young adults. These findings imply that inferences about driver risk-taking behavior can be drawn from studies on both work-related and non-work-related risk-taking behavior.

In their study among individual investors in Malaysia, Hamid et al. *(2013)* reported that risk propensity was positively related to risk-taking behavior whereas risk perception was negatively associated with risk-taking behavior. The implication of this finding is that individuals who perceive higher levels of risk tend to associate the situation with negative outcomes and consequently would make less risky decisions. Indeed, Hamid et al.'s *(2013)* study provides additional evidence that risk perception can influence risk-taking behavior. Given that risk-taking behavior shows a uniform pattern across different settings, it can be inferred from Hamid et al.'s *(2013)* study that driver risk perception would be predictive of driver risk-taking behavior.

In a cross-national study of drivers in Ghana and Norway, Lund *(2006)* found that attitudes towards traffic safety influenced driver behavior among the Norwegians more so than among Ghanaians. Lund *(2006, p. 92)* explained this observation in terms of the following:

"One explanation may be that attitudes are not as successful at predicting driver behavior in Ghana compared to Norway. Attitude's ability at predicting driver behavior may be culturally conditioned. Westerners look to peoples' attitudes to explain their behavior, whereas individuals of other cultures may emphasize situational contexts and the surroundings to explain behavior".

In a study that explored the relationship between traffic safety attitude and driver behavior, one would expect that all the respondents would have been drivers. However, Lund *(2006)* reported that the participants were selected at markets, workplaces, University areas (namely, University of Ghana and the University of Cape Coast) and bus terminals/lorry stations. Lund (2006) also reported that 101 (34%) of the Ghanaian sample held a driver license and that about 100 of them were Geography and Psychology students at the University of Ghana, Legon. The sample description leaves one wondering if all the respondents had driving experience or were drivers. If only 34% of the respondents were drivers, then their scores on driver behavior would introduce error variance. Thus, with this doubt in mind, it is likely that, if not every participant was a driver, traffic safety attitude would not be predictive of driver behavior.

Besides, Shaddish et al. *(2002)* contended that it is easier to identify a causal relationship between two variables in a homogenous group than in a heterogeneous group because heterogeneity increases error variance in the analysis. Indeed, heterogeneity is said to obscure systematic covariation between two variables. Nonetheless, no details were presented regarding the Norwegian sample in Lund's study. Despite this gap, it can be concluded that the non-significant relationship between traffic safety attitude and driver behavior largely reflects a methodological problem rather than an actual lack of relationship.

Similarly, Ivers et al. *(2009)* also reported poorer risk perceptions were linked to risky driving and increased crash risk among novice drivers. Rankin et al. *(2021)*, in a study among operators who have involved in motorcycle collisions (MCC) and motor vehicle collisions (MVC), reported that operators involved in MVC tend to engage in higher risky behaviors and multiple risk behaviors. Simons-Morton et al. *(2011)* even reported that the presence of risky friends can lead to higher risky driving and increased risk of crash among novice drivers. Similarly, Machin and Sankey *(2008)* have also documented evidence that risk perception is linked to risky driving among young drivers. This further lends support to the fact that risk perceptions may be linked to operator risk-taking behavior. However, Bohm and Harris *(2010)* have documented evidence that operator risk perception is linked to the perceived fear of a crash, instead of the likelihood of a crash occurring. They also reported that risk-taking behavior was often also related to situational factors (such as site safety rules or the behavior of other people at the site, and organizational culture that values production over safety). This may imply that risk perception does not translate into behaviors. Indeed, Wolf et al. *(2019)* recently drew our attention to the fact that perceived risk differs from the following closely related concepts: worry or feelings of fear and perceived probability. Despite this, more recent evidence seems to support the link between risk perceptions and risk-taking behavior *(Mazzetti et al., 2020, Oppong, 2021b)*. Notwithstanding, further research is needed to isolate perceived danger and likelihood of a crash occurring in the measurement of risk-taking behavior so that we can determine its relationship with risk perception. There is a need for further studies focusing on such research agenda.

RISK PERCEPTION, DECISION-MAKING, AND COMPREHENSION OF SAFETY SIGNS

In the driving situation, risk perception is also expected to influence the quality of decision or accuracy of decision-making. Decision-making involves selecting an option or a set of options out of several alternatives *(Markman & Medin, 2002, Oppong, 2019)*. In the driving situation, accurate recognition of risk should serve as a valuable input when one must choose among behavioral options in responding to the risk. Thus, accurate recognition of risk in each situation should make the individual to select behavioral options that enable him or her to avoid the inherent harm. However, it is acknowledged that risk perception is not the only factor that can influence the accuracy of decision-making. For instance, the protection motivation theory of risk suggests that people will avoid harm if they have both the motivation and capability to avoid it *(Sheeran et al., 2013)* while the situated rationality theory suggests that individuals would choose a risky option because it serves a rational purpose known to them alone *(Cafri et al., 2009)*. Notwithstanding, it is argued here that risk perception is positively related to accuracy of decision-making.

Some studies have explored the relationship between decision-making and driver behavior. However, these studies tend to focus on decision-making styles rather than the accuracy of the decisions. For instance, it has been found that lack of thoroughness in decision-making is associated with accident risk *(West et al., 1993)*. Thoroughness is defined as the degree to which an individual plans, approaches decision-making in a logical and systematic fashion and the likelihood of considering the costs and benefits of the alternative course of action before making a decision *(Diamant, 2000)*.

In a related experimental study, Diamant *(2000)* utilized two scenarios for situational decision-making. He showed the participants (1) a first picture in which a vehicle was approaching an intersection with the green traffic light blinking and (2) another in which a vehicle was approaching a roundabout without a traffic light. In both scenarios, the participants had to decide whether to stop or to continue. Building on West et al.'s *(1993)* study, Diamant *(2000)* found that risk perception was negatively related to driver decision. This meant that drivers who were able to recognize the scenarios as hazardous were less likely to make a "go" decision. Thus, correct recognition of risk would result in accurate decisions such that the behavioral option selected would lead to the avoidance of the harm.

As suggested earlier, evidence exists that individuals show similar patterns of risk-taking across different settings *(Palamara et al., 2012, Rundmo et al., 2007)* with the implication that inferences about driver risk-taking behavior can be drawn from studies on both work-related and non-work-related risk-taking behavior. It is against this backdrop that inferences are drawn from the study by Chen et al. *(2015)* in the Chinese construction industry. They examined the influence of risk perception and risk propensity on bid/no-bid decisions taken by decision-makers in the Chinese construction industry. Using binary logistic regression, Chen et al. *(2015)* found that risk perception was negatively related to decision-making whereas risk propensity was positively associated with decision-making. Decision-makers who perceive higher levels of risk are more likely to choose low-risk projects. On the other hand, decision-makers who tend to take risks are expected to probably choose high-risk projects. Chen et al.'s *(2015)* findings suggest that accurate recognition of risk will result in more accurate decisions. In a more recent study, Castro et al. *(2021)* reported that a negative significant relationship between risky decision-making and hazard prediction such that as hazard prediction becomes more accurate, risky decision-making reduces.

Another insightful study was carried out by Bazire et al. *(2006)*. They explored driver decision-making in response to road signs. Bazire et al. *(2006)* ran an experiment in which less experienced drivers and experienced drivers were shown a stimulus comprising 40 road signs. The stimuli were of two kinds: (1) stimulus 1: the road sign is presented alone and (2) stimulus 2: the road sign is presented in a context. In that experiment, 50% of the participants were shown 20 road signs in the form of stimulus 1 followed by those in the form of stimulus 2. The other 50% of the participants were presented with the stimulus in the reverse other. In each, the participants were asked to indicate the correct action to perform in response to the given road sign and the meaning of the sign. They reported that there is an inverse relationship between the number of years of practice and the understanding of the intended meaning of road signs. Thus, the more one drives, the less likely that he or she is able to correctly respond to the meaning of road signs, implying that there is an inverse relationship between driving experience and comprehension of road signs. Again, they found that in the real road situation, most of the participants knew what to do in response to a particular road sign.

Another relevant finding, not originally investigated by Bazire et al., *(2006)* but that can be deduced from their study is the relationship between comprehension of road signs and decision-making. When a Pearson product-moment correlation is performed on the data presented by Bazire et al. *(2006)*, a significant positive relationship is found (see Table 1). This can be taken to also mean that risk perception influences decisions owing to the fact that understanding of the road sign also implies accurate recognition of the inherent hazard. Thus, he who understands the message being communicated by the sign also knows the hazardous conditions involved. However, it is one thing being aware of the risk and another appreciating the magnitude of the risk.

Given the small sample size used in this reanalysis, no conclusion is being drawn on this as small sample sizes leave parameter estimates unstable *(Hollenbeck et al., 2006)*. Nonetheless, Hollenbeck et al. *(2006, p. 2)* also forcefully make the argument that small sample sizes "should not and do not limit researchers' ability to conduct exploratory research and search for insights that would be interesting to explore with other techniques and larger sample sizes." This implies that comprehension of road signs is more likely to improve the accuracy of decisions. The reanalysis performed should be considered only as exploratory.

Kirmizioglu and Tuydes-Yaman *(2011)* investigated the level of comprehension of traffic signs among urban drivers in Turkey and argued that risk perception would improve when signs are made more meaningful. This does not directly assess the link between risk perception and comprehension of safety signs, but it gives some indication that risk perception and comprehension of traffic signals may be related. Similarly, Kay et al. (2014) found that driver behavior (and therefore the decision) during bicycle passing maneuvers tend to change in response to nature of traffic signals. Related to this is the finding that road signs have the potential to improve perception of serve bends on a stretch of road *(Milleville-Pennel et al., 2007)*.

Table 1. Percentage of Correct Responses on Comprehension and Decision Tests

Tablica 1. Postotak točnih odgovora na testovima razumijevanja i odlučivanja

	Do not drive	Less than 2	2 to 5	5 to 10	More than 10
Road sign alone/what does it mean?	0.66	0.89	0.76	0.71	0.68
Road sign alone/what to do?	0.65	0.94	0.74	0.67	0.47
Road sign in context/what does it mean?	0.83	1.00	0.73	0.50	0.43
Road sign in context/what to do?	1.00	1.00	0.90	1.00	0.86

$r = 0.89$, $p = 0.044$. This r is based on the data on road sign alone.

Source: Author's own computations based on Bazire et al. *(2006, p. 2589)*.

Lenné et al. *(2011)* also documented evidence in support of the fact that traffic signals at rail level crossings have no safety benefits over flashing red lights. Thus, drivers tend to respond to both in the same manner. Oppong *(2021b)* has also shown that risk perceptions predict decision-making and comprehension of road warning signs. However, Oppong *(2021b)* did not find evidence in support of comprehension of safety signs predicting risk perceptions.

In sum, there have been fewer studies examining the relationship between risk perception and driver decision making. As a result, inferences are largely drawn from related studies rather than studies that have directly investigated the link. Similarly, most of the studies reviewed have not directly explored the relationship between risk perception and comprehension of safety signs as well as comprehension of safety signs and driver decision making. This makes it difficult to draw any conclusion about the exact nature of the relationships among risk perception, driver decision making, and comprehension of safety signs. This shows that there is a need to pay empirical attention to the link between risk perception and decision making.

RISK EXPOSURE AND ROAD TRAFFIC CRASHES

Wolfe *(1982, p. 337)* defines the concept of traffic risk exposure as "simply be being in a situation which has some risk of involvement in a road traffic accident." However, he provides another insightful operational definition of risk exposure as follows:

> "A measure of the frequency of being in a given traffic situation, which number can be used as the denominator in a fraction with the number of accidents which take place in that situation as the numerator, thus producing an accident rate or risk of being in an accident when in that situation" *(Wolfe, 1982, p. 338).*

Thus, risk exposure may be defined as the degree to which a driver's unsafe behavior or risky behavior leaves him or her vulnerable to hazards in unsafe or dangerous traffic situations. Hakkert and Braimaister *(2002)* provide similar insightful arguments that are consistent with Wolfe's *(1982)* contention. For instance, they report that:

> "…exposure is meant as exposure to risk. To what extent are certain segments of the population likely to be involved in an accident? The measure of exposure is generally defined as some form of the amount of travel, either by vehicle or on foot. Once the amount of travel is known for certain activities, or road users, and if we know the number of crashes that are associated with that activity or population, the associated risk can be calculated" *(p. 8)*.

Wolfe *(1982)* intimated that risk exposure is a better outcome measure for safety studies than accident frequencies. Rather than use it as an outcome variable, Kweon and Kockelman *(2003)* controlled for the risk exposure on road crash involvement. Generally, risk exposure is measured as some form of distances travelled. This implies that measurement of risk exposure requires the availability of objective data rather than subjective data. However, when risk exposure is measured at the individual level, respondents are required to remember the distance travelled. Wolfe *(1982)* has questioned this manner of measuring risk exposure. For instance, Wolfe *(1982)* questioned whether respondents would be able to provide accurate data for the calculation of risk exposure. It is noteworthy that such a criticism is like the criticism levelled against the use of subjective measures. Similarly, Hakkert and Braimaister *(2002)* have challenged the basic assumption that it is advantageous to ensure equal risk to various categories of road users while asking if it is valuable to ensure equal risk levels for citizens in a variety of occupations. These criticisms deal with the possibility that individual differences in risk exposure exist *(Hakkert & Braimaister, 2002).*

The above claims by Hakkert and Braimaister *(2002)* and Wolfe *(1982)* suggest that individual differences would exist in the magnitude of risk to which people are exposed. It is logical to expect that every driver on the road has a generally similar risk exposure as everyone else. But it is also reasonable to argue that there are individual differences in the level of risk-taking behavior or unsafe acts. It is also known that unsafe acts create unsafe conditions or predispose people to existing unsafe conditions *(Oppong, 2011)*. This would then imply that varying levels of individual driver risk-taking would also result in varying levels of unsafe conditions. This means that risk exposure would also vary from one driver to the other.

Similarly, Paefgen et al. *(2014, p. 30)* defined risk exposure "as the quantified potential for loss that might occur as the result of some activity… A common interpretation of exposure … is the accumulated mileage of a vehicle" or the driving duration of a vehicle. Interestingly, Paefgen et al. *(2014, p. 38)* conceptualized mileage as "a measure of the 'extent' of exposure" in their study and reported a relationship between mileage and accident involvement. In addition, af Wåhlberg *(2011)* also documented evidence that a linear relationship exists between risk exposure and road traffic accident. However, af Wåhlberg *(2011)* found that the relationship between risk exposure and road traffic accident ceases when road traffic accident was measured as self-reported collision as opposed to recorded or 'objective' measure of collision. What is interesting about af Wåhlberg's *(2011)* study is that risk exposure was conceptualized and measured as mileage. In other words, self-reported data were correlated with objective measure of risk exposure (as mileage).

Martínez-Ruiz et al. *(2013)* have provided evidence in support of the idea that risk exposure is related to different types of road traffic crashes as well as that there are individual differences. For instance, they reported that those aged between 10 and 19 years, being male, use of alcohol or drug and non-helmet use were associated with increased risk of crash among cyclists. On the other hand, being aged more than 60 years, use of alcohol, not using safety devices and being a nonprofessional driver increased the risk of crash among vehicle drivers. Again, Martínez-Ruiz et al. *(2015)* reported that risk exposure contributed to increases in fatality rates after estimating the mortality rate ratios for different age categories and gender. Jiménez-Mejías et al. *(2013)* collected data on prior driving exposure (measured a year before measuring the road traffic crashes), risk-related factors and road traffic crashes among a sample of 1114 car drivers in a cross-sectional survey. They reported that prior risk exposure is related to risk of road traffic crash and that this relationship is also mediated by risky driving *(Jiménez-Mejías et al., 2013)*. However, the measure of risk exposure was mileage per year. These studies seem to suggest that risk exposure is related to road traffic crashes but did not do so directly, on one hand and did not account for variability in risk exposure, on the other hand.

More recently, Rolison and Moutari *(2018)* have shown that mileage-based assessments can produce biased measures of risk exposure. They introduced risk-exposure density as a measure of risk exposure that comprises mileage, frequency of travel, and travel duration. Risk-exposure density was estimated as travel duration divided by mileage and the quotient multiplied by frequency of travel *(Rolison, Moutari, 2018)*. After estimating the risk-exposure density, they compared different age groups as well as fatal crash risk and concluded that risk-exposure density that incorporates multiple components of travel (mileage, frequency of travel, and travel duration) reduces bias caused by any single indicator of risk exposure.

However, Elvik *(2014, p. II)* criticized such summary measures such as vehicle kilometers or mileage as "essentially, a black box and tell us nothing about what happened along any kilometer driven". Therefore, Elvik *(2014, p. I)* defined risk exposure "as any event, limited in time and space, that has the potential of becoming an accident and places demands on road user cognition". Elvik's *(2014)* definition makes it possible to reconceptualize risk exposure that involves human perception as "any event producing the potential for an accident is the result of human behavior and requires action by road users to control it so that it does not become an accident" *(p. II)*. This implies that empirical studies reconceptualizing risk exposure as perception such as perceived risk exposure are both required and possible. Using the recommendation to measure risk exposure as perceived risk exposure, Oppong *(2021b)* has documented evidence in support of the relationship between risk exposure and road traffic crashes, in a study among commercial vehicle drivers in West Africa. It appears, to date, that Oppong *(2021b)* may be the only study that has attempted to measure risk exposure as perceived risk exposure as deduced from Elvik's *(2014)* work. This implies that there is a need for more empirical studies where risk exposure is treated as perceived risk exposure.

DECISION-MAKING AND RISK EXPOSURE

Interestingly, there seems to be little or no direct research attention paid to the relationship between driver decision-making and risk exposure. The approach to the definition and measurement of risk exposure in the extant safety literature would not make it possible to even study its link to decision-making. This is because the unit of analysis for decision studies is the individual *(see Chen et al., 2015)* whereas the one for risk exposure is at the aggregate or group level *(see Hakkert & Braimaister, 2002)*. Any attempt to investigate the relationship between decision-making and risk exposure may prove futile as the latter suffers from restriction of range, which is known to attenuate the relationship between two variables *(Shaddish et al., 2002)*. Though it may be possible to infer from cross-national studies, such studies also suffer from serious threats to internal validity, difficulty in interpretation, and Simpson's paradox (2021c). Notwithstanding, it is theoretically plausible to suggest that inaccurate decisions would result in exposure to risk. This implies that a negative relationship between driver decision-making and risk exposure is to be expected.

Another of such understudied relationships is the one between decision-making and behavior. In and out of the safety literature, attention has been focused on the influence of risk perception on decision *(see Bazire et al., 2006, Chen et al., 2015, Diamant, 2000)*. In the case of the relationship between decision-making and behavior, it is here suggested that its understudied nature may be due to (1) variability in how decisions are defined and measured and (2) the difficulty of observing decisions being translated into behaviors in experiments.

In many of the decision studies, the outcome variable is defined and measured in terms of what one would do in each situation. In some sense, decisions are equivalent to probable behaviors in the experimental situation. Experiments take place within too short a time to observe the fidelity between what research participants say they would do and what they actually do. Nonetheless, it is possible for experimenters to ask participants what they would do and observe what they do. Thus, decisions can be connected to behavior in such studies. But, to address such a challenge would require researchers conducting cross-lagged panel designs or longitudinal studies. In such panel or longitudinal studies, researchers would be required to measure decisions at time 1 and correlate with actual behaviors at time 2. While expensive and time-consuming, this approach is appropriate to studying the link between decision and behaviors.

Alternatively, researchers can measure decisions and behaviors separately but simultaneously. In this alternative approach, there must be a distinction between how both decisions and behaviors are defined and measured. Thus, decisions can be measured in terms of what one is likely to do in a given situation while behaviors are defined in terms of the frequency with which the participants engage in a particular set of actions related to the decision situations. It is worth noting that the measurement of decisions and behaviors in this way should be conducted within the same frame of reference. This is because a decision relating to **problem A** is not to be expected to influence action taken in response to **problem B** if **problems A** and **B** do not share a common denominator.

This problem shall be referred to as the “common denominator problem” (see Figure 1). This would occur in decision-behavior studies when the decision is assessed from a task frame of reference that is different from the task frame of reference from which the behavior is measured, even though the former is theoretically supposed to be predictive of the latter. Put another way, the decision and behavior do not share a common denominator or frame of reference. This arrangement is problematic when, theoretically, the decision is expected to be predictive of the behavior, and it represents a threat to the validity of any statistical conclusion in such studies *(see Shaddish et al., 2000)*.

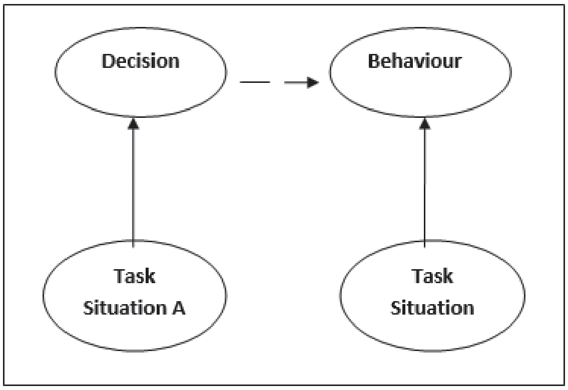

Figure 1. Diagrammatic Representation of the Common Denominator Problem

Slika 1. Dijagramski prikaz problema zajedničkog nazivnika

It is likely that this suggested second approach would also suffer from mono-method bias *(see Shaddish et al., 2002)*. Though such a criticism is not unexpected and not unjustified, mono-method (common method) bias unfortunately undermines the construct validity in most survey studies in which a single method for measurement (such as measuring all variables using questionnaires) is employed. Shadish et al. *(2002, p. 76)* recommends that researchers should consider (1) "using methods of recording other than paper and pencil" and (2) "varying whether statements are positively or negatively worded". It has also been recommended that in place of panel or longitudinal studies, statistical models of causal explanation such as structural equation modelling or path analysis be used *(Shaddish et al., 2002)*. Using the recommendation by Shaddish et al. *(2002)* to address this common denominator problem, Oppong *(2021b)* found evidence that operator decision-making predicts risk exposure. Related to the above is the study by Rahimdel and Mirzaei *(2020)*. They attempted to investigate whole-body vibration (WBV) exposure of the mining truck drivers and link that to decision making under fuzzy conditions *(Rahimdel & Mirzaei, 2020)*. Even though it was an attempt to study decision making and WBV exposure, Rahimdel and Mirzaei *(2020)* only indirectly examined the link between WBV exposure and decision making as they evaluated decision making under varying conditions of WBV exposure to identify the optimal solutions. They found seat suspension maintenance was on optimal solution to reduce the vibrations and injuries related to the WBV exposure. In addition, driver training, haul road construction and maintenance, lighting and visibility improvement and work organization were documented as potential solutions as well.

This shows that there is scarcity of studies directly examining the relationship between risk exposure and decision making among drivers. Therefore, this gap in the empirical literature needs to be addressed through further studies that focus on direct relationships among risk exposure, driver decision-making, and behavior.

RISK-TAKING BEHAVIOR AND RISK EXPOSURE

Risk-taking behavior is also expected to be predictive of risk exposure. Fewer studies reviewed have directly analyzed the association between the risk-taking behavior and risk exposure. For instance, Jun et al. *(2007)* investigated the relationship between risk exposure (measured as mileage) and speeding among older drivers. Jun et al. *(2007)* reported that older drivers involved in road traffic accident tended to travel longer distances and at higher speed than their counterparts who were not involved in crashes. This finding is quite interesting given that af Wåhlberg *(2011)* found that the relationship between risk exposure and road traffic crashes was moderated by the type of measure (self-reported versus recorded) of road traffic crash used. Specifically, he reported that self-report measure weakens the relationship. However, Kamaluddin et al. *(2018)* identified 134 studies have used self-reports of involvement in road traffic crashes worldwide.

Pérez-Núñez et at. *(2020)* investigated the variation in exposure to this risky behavior by city and other characteristics. They reported that exposure varied by city. However, their study did not even directly investigate the relationship between risk exposure and risk-taking behavior but it can be implied from how risk exposure was measured. Similarly, Scott-Parker et al. *(2013)* reported that high risk 'problem young drivers' were characterized by, among other factors, risky driving exposure and involvement in road traffic crash. This seems to imply that higher risky driving is associated with higher risk exposure.

Moreover, inferences may also be drawn from studies that explored the relationship between risk-taking behavior and involvement in road traffic crashes. In a meta-analytic study, de Winter and Dodou *(2010)* investigated the impact of errors and violations sub-components of the Manchester Driver Behavior Questionnaire (DBQ) on accident involvement. They found that risk-taking behavior influenced the frequency of involvement in road traffic crashes. Similarly, they reported a positive relationship between DBQ scores and exposure (measured as mileage). Using the Manchester Driver Behavior Questionnaire (DBQ), af Wåhlberg et al. *(2011)* found small but significant effect of driver behavior on involvement in road traffic crashes. The findings from these studies suggest that risk-taking behavior has the potential to influence risk exposure if the latter is sometimes conceived of as accident involvement. These findings make a lot of sense when viewed in terms of Elvik's *(2014, p. I)* definition of risk exposure "as any event, limited in time and space, that has the potential of becoming an accident and places demands on road user cognition" and that "any event producing the potential for an accident is the result of human behavior and requires action by road users to control it so that it does not become an accident" *(p. II)*. This is because one can expect risk-taking behavior to result in a situation becoming an accident.

Again, risk-taking behavior is also likely to be related to risk exposure given that indulging in risky behaviors is more likely to leave someone exposed or vulnerable to dangerous situations on the road. However, what we do not know is whether perceived risk exposure measured at the individual level would be related to risk-taking behavior. Rupp et al. *(2016)* also found, among college-aged adults, that risk-seeking traits influenced engagement in distracted driving. Even though they did not directly investigate the relationship between risk-taking and distracted driving, we can infer that risk-seeking traits will increase the exposure to risk-taking behavior *(Breivik et al., 2019)*, hence the relationship. However, Oppong *(2021b)* has directly measured the relationship between risk-taking and risk exposure [measured in line with the recommendation by Elvik *(2014)*]. He found evidence that operator risk-taking is predictive of risk exposure. The implication is that there is a need for further studies that directly investigate the relationship between risk-taking behavior and risk exposure among drivers.

IMPLICATIONS FOR RESEARCH AND PRACTICE

Most of the studies have been conducted in Europe, Australasia, and North America *(Kamaluddin et al., 2018)*. Asia, Africa, South America, and Middle East have received little research attention. This means that the studies so far tend to paint a picture of risk perception and its correlates in WEIRD (Western, Educated, Industrialized, Rich, and Democratic) societies *(Henrich et al., 2010)*. Again, recommendations for improving safety will more likely be relevant to the WEIRD contexts rather than in non-Western settings. Thus, cross-cultural differences are expected as the types and patterns of on-the-road risk-taking behaviors and crash involvement as well as risk perception among drivers are more likely to be situated in particular contexts. As an example, Dun and Ali *(2018)* investigated wearing of seatbelts among Arab men within the context of a collectivist and masculine culture and recommended that behavior change communication should be culturally responsive and tailored to avoid triggering reactance. Again, Ranjit et al. *(2017)* also explored reckless driving in urban Nepal (another collectivist culture) and reported that the nature of behavioral change communication responsive to a collectivist culture affected the adoption of recommended behaviors. Specifically, they documented evidence that "directive" messages (as opposed to than "autonomy support" messages) predicted the likelihood that an individual would see value in the recommended behavior. Similarly, Oppong *(2021a)* documented evidence that supports cultural differences in comprehension of road hazard communication designs and co-designed, with a participants of commercial vehicle drivers, some road warning signs as possible replacements for those they did not comprehend. This means that there is a need for more research in non-Western settings to increase the body of knowledge on road safety. Besides, there are still limited number of studies that have directly investigated the relationships among the variables under discussion in this article, even in WEIRD settings. Therefore, there is an urgent need for psychologists and other behavioral safety scientists to 1) directly study the relationships among the variables and 2) extend the research attention to non-Western settings to produce a complete picture of safety issues across the world.

Given the weight of the evidence now, it is quite possible to suggest some interventions for safety improvements. For instance, there appears to be sufficient evidence, regardless of the indirect measurements, in support of the link between risk perceptions and risk-taking behavior *(Bohm & Harris, 2010, Ivers et al., 2009, Machin & Sankey, 2008, Mazzetti et al., 2020, Oppong, 2021b, Rankin et al., 2021, Simons-Morton et al., 2011)*. To recommend an intervention will require knowledge of the antecedents of risk perception. There is also sufficient evidence that risk perception is influenced by safety climate *(Mazzetti et al., 2020, Oppong, 2021b, Rasmussen & Tharaldsen, 2012, Wills et al., 2009)*. According to Lehmann et al. (2009), employers set limits to risk tolerance which partly define risk boundaries for the workers. Risk tolerance is defined as the amount of risk an individual is willing to take on *(Oppong, 2011)*. Risk tolerance is induced in the workplace by the employer's safety policies, procedures, and practices, all of which are elements of the workplace safety climate. Thus, safety climate affects risk tolerance which in turn influences risk perception.

Lehmann et al. *(2009)* have already intimated that risk judgment is influenced by risk tolerance. Thus, a high safety climate would lead to better recognition of risk and, therefore, more accurate risk perceptions. Given that management and supervisor's attitude and commitment towards safety largely establishes the safety climate *(He et al., 2019, Griffin & Curcuruto, 2016, Luo, 2020, Mosly, 2019, Zohar, 2010)*. It is imperative for management and owners of transport businesses (private vehicle owners, managers of private transport businesses, driver unions, public bus systems, etc.) to devote resources and attention to safety. Measures such as having (1) a mission statement that includes safety of employees, (2) frequent public declarations by management to promote safety, (3) a key performance indicator for safety at both the organizational and individual levels, (4) creation of a managerial and a board-level role responsible for safety, (5) periodic management team training on safety (6) hiring of professionally trained drivers are some of the interventions that can be instituted to improve management commitment to safety. Other general interventions include the use of culturally appropriate road signs, periodic culturally appropriate safety training for drivers, and a balanced focus on meeting commercial targets (e.g., timeliness, sales, etc.) and safety concerns by vehicle owners and managers of transport businesses. Once these interventions are implemented, the risk tolerance of drivers may become lower which would improve risk perceptions. In sum, improved risk perceptions would also enhance safety behavior and operator decision-making, and this has the potential to reduce risk exposure and occupational accidents in the road transport industry.

CONCLUSION

In this narrative review, it was found that fewer studies have been carried out in non-Western societies. This tends to produce evidence-based practices in road safety that are more meaningful to the WEIRD societies and their people. This means that safety improvement solutions developed in the WEIRD settings may not necessarily be applicable to the non-Western settings. Thus, behavioral safety scientists are being called upon to address this gaping gap. Besides, many of the relationships among the variables under discussion in this article have not been directly assessed, leaving readers to infer the relationships from the results of related studies. This situation needs to be corrected where researchers, particularly, psychologists and other social scientists begin to show interest in measuring these variables in behavioral terms and investigating the relationships. Therefore, I call on safety researchers to begin to pay more attention to these research gaps to improve theory, research, and applications in the domain of road transport safety.

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PERCEPCIJA RIZIKA I NJEZINE KORELACIJE: IMPLIKACIJE NA ISTRAŽIVANJE I PRAKSU U CESTOVNOJ PROMETNOJ INDUSTRIJI

SAŽETAK: Globalne statistike o industriji cestovnog prometa sugeriraju da su prometne nesreće veliki problem javnog zdravlja koje zahtijeva usklađene međunarodne i nacionalne napore s obzirom na to da su glavni globalni ubojica. Ove statistike također impliciraju da je potrebna hitna pozornost kako bi se promicalo razumijevanje i poboljšanje sigurnosti na cestama na globalnoj razini. Nedavno su se nakupili dokazi da se percepcija rizika povezuje s nesrećom kroz njezin učinak na ponašanje u preuzimanju rizika i donošenje odluka operatera. Zbog toga je autor proveo narativni pregled kako bi istražio je li percepcija rizika povezana s donošenjem odluka operatera, razumijevanjem sigurnosnih znakova, izloženošću riziku, ponašanjem operatera u preuzimanju rizika i nesrećama u industriji cestovnog prometa. Jedna uočljiva praznina je da su mnoga istraživanja provedena u zapadnim, obrazovanim, industrijaliziranim, bogatim i demokratskim (WEIRD) društvima. Također se raspravljalo o drugim nalazima i implikacijama istraživanja i prakse.

Ključne riječi: *percepcije rizika, odlučivanje, znakovi sigurnosti, izloženost riziku, preuzimanje rizika, nesreća*

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