Transactions on Engineering and Computing Sciences - Vol. 11, No. 3
Publication Date: June 25, 2023
DOI:10.14738/tecs.113.14796.
Etika, A. A., Adeke, P. T., & Ubana, G. O. (2023). An Assessment of the Relationship Between Speed and Road Safety. Transactions on Engineering and Computing Sciences, 11(3).98-107.

SERVICES FOR SCIENCE AND EDUCATION

An Assessment of the Relationship Between Speed and Road Safety

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ABSTRACT

Despite research showing a connection between vehicle speed and crash severity and risk, the leading cause of traffic crashes and fatalities worldwide continues to be driving at speeds that are illegal or unsuitable. An overview of the relationship between vehicle speed and road safety in relation to crash involvement and crash severity is given in this study. Additionally, it examines and emphasizes the Power Model's applicability and effectiveness in projecting safety gains from speed increases. According to the paper's summary, there is still a significant association between speed and road safety. Yet, because of the moderating effects of several factors, it is difficult to quantify the exact relationship between speed and crash rate and injury severity. But it is generally acknowledged that speed both directly and indirectly affects crash rates and raises the severity of damage or fatality.

Keywords: Speed, Crash, Fatalities, Severity, Road Safety, Crash frequency, injury.

INTRODUCTION

The terms "excessive speed" (driving over the speed limit) and "inappropriate speed" (driving too fast for the circumstances but within the restrictions) have both been used to describe speeding [1-2]. It is one of the most researched topics in road safety because it is regarded as one of the most significant variables in the combination of safety and mobility [3-5]. According to reports, speeding is currently the most common traffic infraction, with an average of 40–50% of cars exceeding the posted speed limit [1].

According to research, speeding increases the severity of all road crashes and is a contributory factor in about one-third of fatal crashes in Europe [6]. In the UK in 2019, 24% of crashes that resulted in a death were speed-related, and over 50% of reported crashes in Nigeria were found to have excessive speed and speed limit infractions [7-8].

Speeding has been consistently identified as the leading cause of fatal crashes and injuries in traffic over time [4, 9]. Similar studies have also shown a link between travel speed and the likelihood of crashes (crash involvement) and the seriousness of the injuries they cause (crash consequences) (10-13). The distance travelled during the driver's reaction time and stopping distance increase as speed rises, raising the chance of driver error [2].

The relationship between speed and crash severity is positive (i.e., an increase in speed results in a much greater percentage increase in crash severity), whereas the relationship between speed and the risk of involvement in a crash is more convoluted and unclear [14, 1, 15]. This is because road traffic crashes can be caused by a variety of factors, including road/environmental, vehicular, and human factors. Primary safety (involvement in the crash) and secondary safety (crash consequences/severity) were distinguished by Fildes & Lee [10]. Secondary safety deals with guarding the person engaged in a crash, while primary safety deals with what causes crashes and the preventive steps to be taken to avoid them. Speed interventions will have various effects due to the very diverse relationships between crash involvement and accident severity and travel speed [10].

To develop better interventions to decrease fatalities and increase compliance with speed limits, it is crucial to understand the relationship between vehicle speed and its effects on road safety.

SPEED AND CRASH INVOLVEMENT

Speeding and crash frequency have not always been directly correlated, as shown by the lack of unanimity in previous studies. In addition to the fact that crashes are complicated events that are rarely caused by a single factor [6,10, 16], there is also a dearth of data on annual average speed that may be used to estimate crash speeds [17].

Indeed, speed plays a part in crash risks because it shortens drivers' stopping distances, which are the sum of their response times and braking distance [18]. The stopping distance, for instance, is the entire distance travelled before using the brakes (response time) plus the distance travelled after applying the brakes when a motorist traveling at high speed unexpectedly encounters an impediment. The distance travelled before applying the brakes (reaction time) and while the vehicle is being slowed down by the brakes are combined to form the stopping distance (braking distance). The choice of speed by the driver will determine whether they have the necessary response time to evaluate the information at hand and make sensible decisions and actions. This indicates that at higher speeds, there is a greater chance of a car running into an obstruction in the road. Figure 1 demonstrates that slower-moving vehicles can stop more quickly than faster-moving ones.

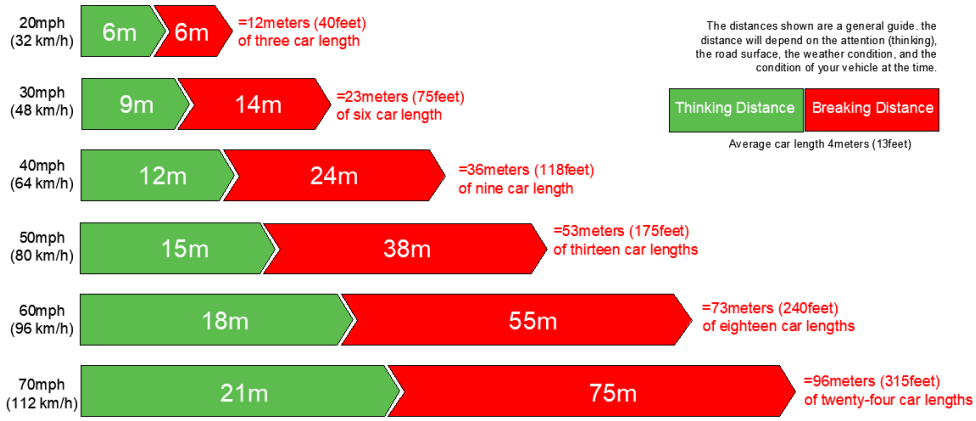


Figure 1: Typical stopping sight distances. Data Source: [19].

According to Forbes.... as vehicle speed increases, the amount of visual information the driver can comprehend grows as the visual picture changes more quickly. To control the flow, the driver obliquely narrows the visual field to obviate part of this information [20]. Because there is less time to distribute one's attention across a wider field of view at greater speeds, the driver's visual field shrinks, making it harder for them to judge whether something might be dangerous [1, 6]. For instance, a driver may see potential road obstructions clearly at a speed of 40 km/h since their visual field span is roughly 100 degrees, but at 100 km/h, their field of vision is only less than 30 degrees. (See Figure 2).

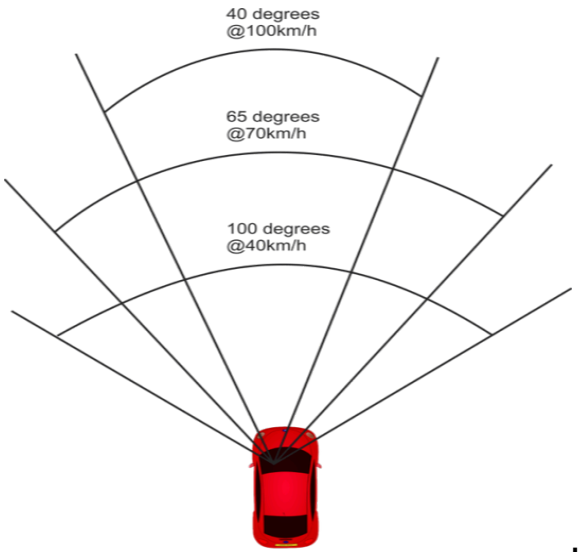


Figure 2: Speed and driver's field of vision. Data Source: [20].

However, other elements including a road's geometry and usage, the complexity of the surrounding traffic, and vehicle characteristics can all increase the chance of an accident. On motorways with higher speed restrictions having lower crash rates compared to urban roads with lower speed limits, the intricacy of speed-crash frequency can be further explained. Consequently, it can be claimed that there is an inverse relationship between crash frequency and speed.

A driver is more likely to be engaged in a collision if their vehicle is traveling faster than the average speed of traffic, according to one of the early studies on the connection between speed and crash involvement by Solomon and Cirillo [21–22]. These studies compared measured speeds from traffic not involved in crashes with pre-crash traveling speeds for vehicles involved in crashes on designated rural and interstate routes. The studies demonstrate a U-shaped link between speed and crashes, with crash risk increasing at both relatively low and high speeds (See Figure 3).

Given that driving at a reasonably high speed is safer than driving at a low speed on major country roads, the probability of a crash occurring is more closely connected to the speed variance than the mean travel speed [21–22]. According to the studies, the crash involvement rate is highest at very low and very high speeds, and it is lowest when traffic is moving at a pace that is close to its average speed [21–22].

The validity of the findings and their interpretation in relation to the rise in danger at the low-speed zone have been evaluated, though. Studies have demonstrated, for instance, that the crash probability at the high-speed end appears to be unaffected by bias and can be used as a guide, at least for that location and time. The likelihood of a car being engaged in a serious crash increased exponentially for each speed beyond the average speed of travel, according to several studies that looked at the relationship between vehicle absolute speed and crash frequency [11, 13]. For instance, increasing your speed by 5 km/h doubles your probability of being involved in a crash.

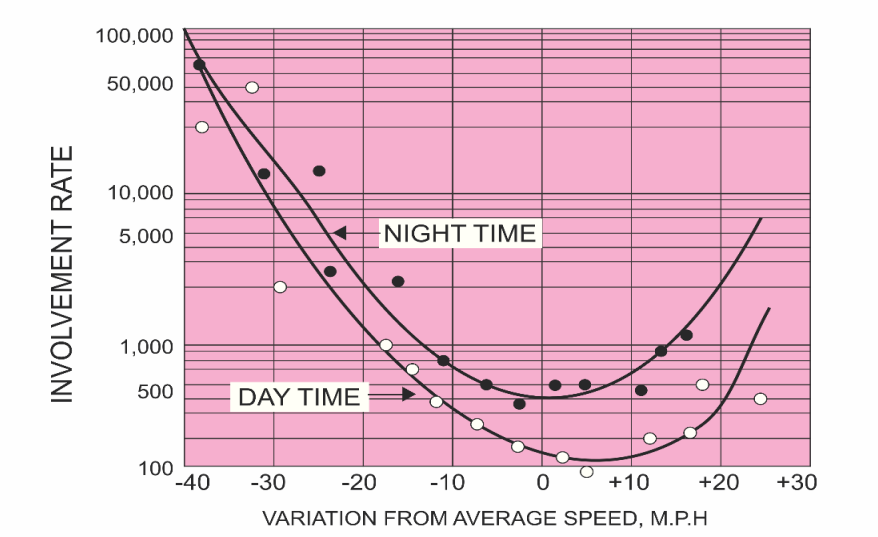


Figure 3: Crash risk by variation from average speed on study section day and night. Data Source: [21]

It was found that the incidence of reported injury crashes grows disproportionately with increasing speed in sections of urban (speed limit of 30MPH or 40MPH) and rural (50MPH or 60MPH) areas [12]. If the ratio of the standard deviation to the mean is constant, the likelihood of an accident is roughly proportional to the square root of the average traffic speed. Hence,

there is an 11% likelihood of a crash occurring on urban roads for every 5% rise in mean speed, with speed decreases likely to reduce the frequency of casualties.

The literature that is currently available tends to imply that the probability of crashes increases with speed and on routes where the variation of speed is high.

According to the body of existing research, crash risk increases with speed and is higher on routes with more speed variation. Unfortunately, evidence on the relationship between vehicle speed and crash risks can only be obtained through data from actual collisions [11].

SPEED AND CRASH SEVERITY

The extent of damage is therefore influenced by the physical forces present during collisions because the human body has a limited ability to absorb the impact of a collision [23]. Given that the severity of the injuries received by those engaged increases as vehicle speed, the association between speed and injury severity at impact is both well-known and convincing [10]. Although the link is not linear, a given increase in vehicle speed results in a proportionately higher rise in injury severity [11]. This relationship follows the rules of physics, according to which the amount of kinetic energy absorbed after a collision equals the square of the velocity times the mass, showing that the impact's impact is significantly amplified as velocity rises [2]. For instance, a 10% increase in speed will cause a 22% increase in the amount of kinetic energy lost.

By providing passengers with some amount of protection through the absorption of some of the energy lost during collisions, safety measures like airbags and seatbelts are beneficial in preventing catastrophic head injuries [20, 24]. Yet, there is still a larger danger of serious injury for flimsy road users including motorcyclists, cyclists, and pedestrians. Children (those under the age of 10) and elderly adults (those 65 and beyond) are more susceptible to serious injury or death in collisions due to their physical frailty [25–26]. This group can't absorb a lot of energy during crashes because their soft tissues are less elastic, and their bones are more brittle. Moreover, most pedestrians frequently have no protection at all or very minimal protection from motorcyclists [27]. As a result, speed continues to contribute to the severity of crashes for this group. The Power Model [28–29], which is an adaption of the kinetic energy formula (Ek= 1/2mv2), has been used in several studies to show this relationship but is still the most popular and well-respected.

Power Model

According to the Power Model [28], a collection of Power functions can be used to assess how changes in speed affect the quantity of crashes and the seriousness of injuries. This function's exponent value fluctuates according to the severity of the crash. According to the model, the second, third, and fourth powers of the relative change in mean speed, respectively, are directly proportional to the number of all injury crashes, serious injury crashes, and fatal injury crashes. The general form of the Power Model is represented in Equation (1).

$$\left(\frac{Crashes\ after}{Crashes\ before}\right)=\left(\frac{Speed\ after}{Speed\ before}\right)^{\text{Exponent}} \qquad \text{Equation 1.}$$

According to the Power Model, a 5% increase in mean traffic speed causes an increase in all fatal cases of around 22% and an increase in all injury cases of about 10%, respectively. Similar to this, a 5% decrease in mean speed reduces the number of cases by 10% for all injury cases and about 19% for fatal cases. For vulnerable road users, the effects of higher speed are much more severe and striking. For instance, the likelihood of a pedestrian dying in a collision with a vehicle traveling at 30 km/h is 5%. It is 45% at 50 km/h, and it increases to 85% at 65 km/h.

Six equations were produced by a revised version of the Power model for fatalities, severe injuries (including fatal and serious injuries), and all injuries. Moreover, there are formulae for fatal wrecks, accidents involving fatal and serious injuries, and accidents involving all injuries [29]. The Power Model's safety relationship is shown in Figure 4.

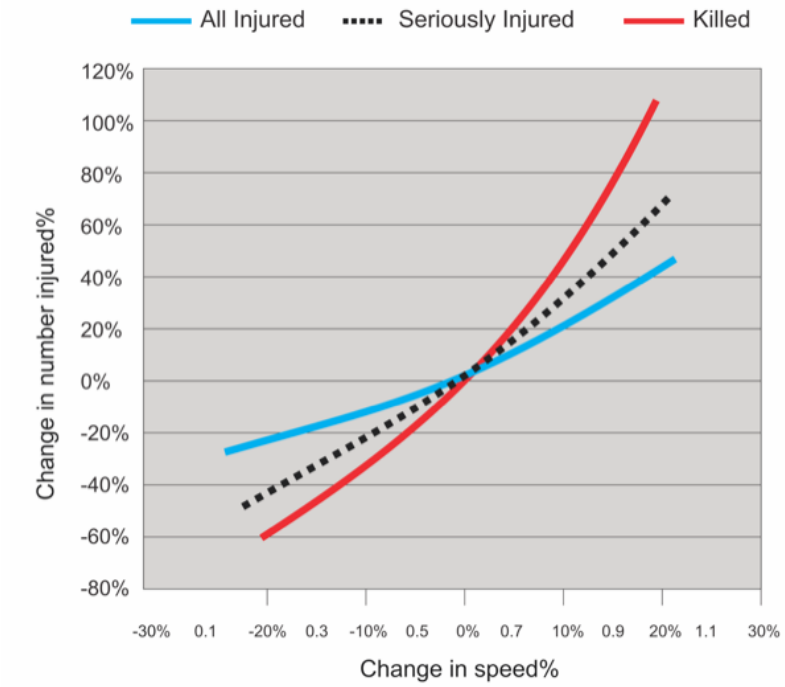


Figure 4: Illustration of the Power model relationship between change in speed and change in the number killed and seriously injured. Data Source: [29]

There is a substantial causal link between changes in traffic speed and changes in road safety, according to the results of the meta-analysis evaluation of the Power Model's association with speed and crashes [4]. Results from a modified version of the model indicate that the traffic environment and initial speed both have an influence on how much speed has an impact on crashes. It was suggested that the Power Model's exponential values be reduced, with values on residential and urban roadways being far lower than those on rural and interstate roads [30]. Although speed is still a significant risk factor for collisions and injury severity, it appears that its impact is waning. Improvements in vehicle safety (seatbelts, collision zones, and airbags), more "forgiving roads," fewer vulnerable road users (pedestrianization), and more safety-conscious people are the most plausible explanations for the minor decline over time. For the Power Model's revised values, see Table 1.

Table 1: Modified exponents for the Power model. Data Source: [30]

	Rural roads/Freeway		Urban/Residential		All Roads	
Crash or Injury severity	**Best Estimate of Exponent**	**95% Confidence Interval**	**Best Estimate of Exponent**	**95% Confidence Interval**	**Best Estimate of Exponent**	**95% Confidence Interval**
Fatal Crashes	4.1	(2.9,5.3)	2.6	(0.3, 4.9)	3.5	(2.4,4.6)
Fatalities	4.6	(4.0-5.2)	3.0	(-0.5,6.5)	4.3	(3.7, 4.9)
Serious injury crashes	2.6	(-2.7,7.9)	1.5	(0.9,2.1)	2.0	(1.4, 2.6)
Seriously injured road users	3.5	(0.5-5.5)	2.0	(0.8-3.2)	3.0	(2.0, 4.0)
Slight injury crashes	1.1	(0.0.- 2.2)	1.0	(0.6, 1.4)	1.0	(0.7, 1.3)
Slightly injured road user	1.4	(0.5, 2.3)	1.1	(0.9, 1.3)	1.3	(1.1,1.5)
Injury Crashes (All)	1.6	(0.9,2.3)	1.2	(0.7,1.7)	1.5	(1.2,1.8)
Injured road users (All)	2.2	(1.8.2.6)	1.4	(0.4, 2.4)	2.0	(1.6,2.4)
Property-damage-only crashes	1.5	(0.1,2.9)	0.8	(0.1,1.5)	1.0	(0.5, 1.5)

The Power Model has a reasonable chance of success in predicting changes in traffic speed because prior research has amply supported it (31-33). It is important to keep in mind that the Power Model was calibrated for high-income countries (HIC), which have better traffic regulations, more energy-efficient automobiles, and better roads and infrastructure. As a result, its application to LMICs (low- and middle-income countries) may vary. Since LMICs are known to have lower rates of seat belt use, less protected vehicles, a lack of emergency services, fewer road barriers, and inadequate facilities for vulnerable road users, it is likely that the exponents will be higher in these nations. For instance, a crash at a certain speed may be more likely in Nigeria than in the UK to cause significant injuries or fatalities. This is due to factors including the likelihood that Nigerian drivers will buckle up, the likelihood that their cars and roads will adhere to international norms, and more. As a result, the Power Model will assert that a collision at a given speed is more likely to have serious consequences in developing countries than in rich ones.

However, the straight use of speed control measures that have been demonstrated to be effective in industrialized countries does not result in the same safety improvement in developing countries, and this is due to several variables [34]. For instance, most underdeveloped countries lack the necessary infrastructure for enforcement and lack definite road safety plans. These nations frequently employ older or used vehicles that lack contemporary safety features like seatbelts and airbags.

Almost 90% of deaths in developing countries are caused by road traffic crashes, which primarily impact passengers and vulnerable road users including pedestrians and cyclists. Contrast this with industrialized nations, where accidents on the road typically result in injury to drivers [35]. The association between traffic speed and injury crashes is influenced by the condition of the roads. Changes in traffic speed have a bigger impact on poorer-quality roads than on better-quality ones [36]. Most high-income countries have improved their road and traffic infrastructures and regulations over time, which has led to lower exponents in the Power Model. Thus, it may be assumed that in LMIC, the exponents will be smaller. As a result, you would anticipate that any given change in speed in developing countries will have less of an impact on estimates of road safety than in developed nations.

CONCLUSION

In earlier investigations, the link between driving speed and road safety has consistently been demonstrated. It has been shown that the frequency of crashes increases with speed and on routes with high-speed variability. Moreover, crashes at higher speeds are probably to result in injuries that are more severe. Given the moderating impact of multiple roads, traffic, and vehicle features, the precise relationship between speed and crash rate and injury severity is difficult to quantify. There is general agreement, though, that speed raises the severity of damage or fatality and adds directly or indirectly to crash rates. Therefore, it is essential that current speeding initiatives be assessed based on decreases in crashes as well as decreases in the severity of injuries and fatalities.

ACKNOWLEDGMENTS

Appreciation to the Cross River University of Technology, Calabar, Nigeria (through its Tertiary Education Trust Fund intervention), and the Institute for Transport Studies, University of Leeds, the UK for funding my Ph.D. studies of which this paper is part of.

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