Understanding the Dynamics of Causal Factors related to Excessive Speeding Behavior of the Drivers

Arif Mehmood
United Arab Emirates University
P.O. Box 17555
College of Engineering
Al Ain, U.A.E.
Tel: ++ 97150-2330396
Email: amehmood73@gmail.com

Abstract

Excessive speeding behavior of the drivers is one of the challenges in the area of transportation around the world. Excessive speeding is defined as driving faster than the posted speed limit or driving too fast for the prevailing traffic and environment conditions. This paper provides a modeling framework that integrates the dynamic interaction between causal factors responsible for motivating drivers to adopt excessive speeding behavior. This modeling framework is developed based on information gathered through extensive literature review on speed choice behavior of the drivers, interviews of officials from police department, and interviews of a group of drivers. The modeling framework has been translated into a formal simulation model. The development of simulation model includes heuristic relationships that need refinements based on empirical evidence. It is expected that end product of this research would be a fully integrated decision-support tool that would help in understanding the resistance to achieving a sustainable reduction in the number of excessive speeding drivers.

Background Information

Excessive speeding behavior of the drivers is one of the challenges in the area of transportation around the world. Excessive speeding is defined as driving faster than the posted speed limit or driving too fast for the prevailing traffic and environment conditions. A large percentage of drivers in many countries such as Netherlands, Sweden, UK, and USA consider the excessive speeding as a common driving offence (Wegman et al., 2006). Van Schagen et al., (2004) reports on average 40–45% of the Dutch drivers exceed the posted speed limits. A study carried out in Britain reports that 70% of drivers exceed the urban speed limits, and 30% to 55% exceed the speed limits on motorways and dual carriageways (DETR, 2000). Harkey et al. (1990) found that 70 percent of the vehicles exceeded the speed limit on a representative sample of low and moderate speed roads in four States of the USA. Similar results are reported by the European Transport Safety Council (1995) and in Canada by Knowles et al. (1997).

This paper focus on understanding the dynamics of causal factors that motives drivers for adopting excessive speeding behavior in the United Arab Emirates (UAE). In the UAE traffic violations and aggressive behavior while driving are usual phenomena; incidents often occur such as, excessive speeding, sudden lane change, violating traffic regulations, tailgating, and even sometimes disrespecting other drivers. The culture of excessive speeding is so embedded that speed violation is perceived as a normal offense. Recently, field observations are carried out on major arterials of the main cities of the UAE including Dubai, Abu Dhabi, and Al Ain. These filed observations indicate that a large percentage of drivers (60 to 90 %) drive faster than the speed limits. The previous research on road safety in the UAE supports the results of these field observations (Abdalla, 2002). Based on road crash statistics excessive speeding is considered as a major cause for a substantial number of road crashes in the UAE. Police reports indicate excessive speeding contributed almost 60 percent of the total road crashes occurred during 200 to 2006.

It has been observed that the number of road crashes in the UAE has been declined during the period from 1981 to 2006 (Figure 1). But unfortunately, reduction in the number of road crashes could not control the number of deaths due to road crashes. As shown in the Figure 2 number of deaths due to road crashes in the UAE has been increasing exponentially since 1981. During the interviews with police officers, it is

found that increase in the number of road crash fatalities is mostly due to increase in the severity of road crashes. There are a substantial number of road crashes in which drivers and passengers both died on spot (Police reports, 1990-2002). One possible major cause of sever road crashes in the UAE is the excessive speeding behavior.

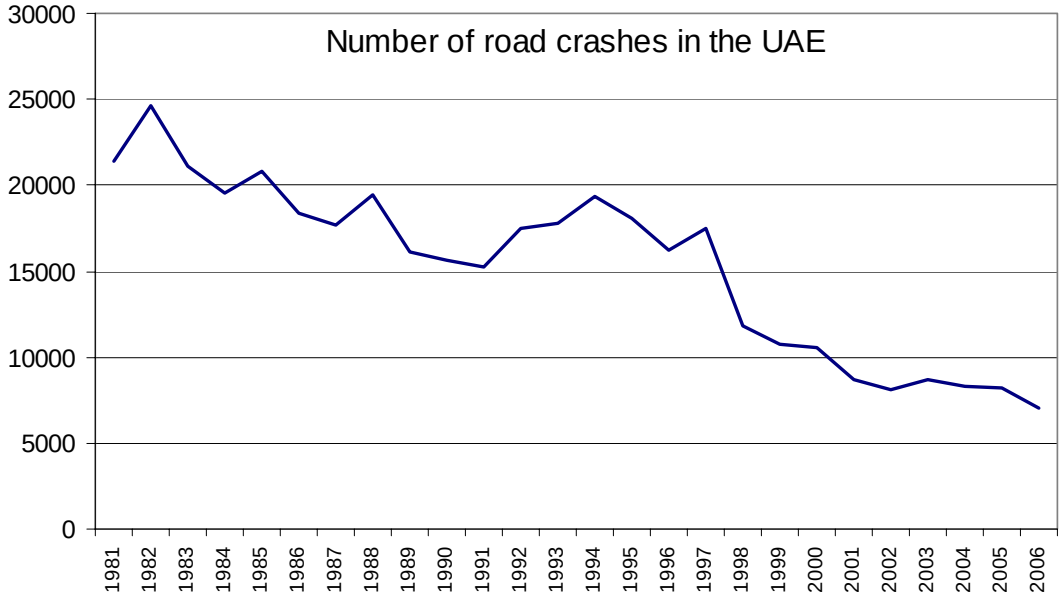

Figure 1: Number of road crashes in the UAE from 1981 to 2006

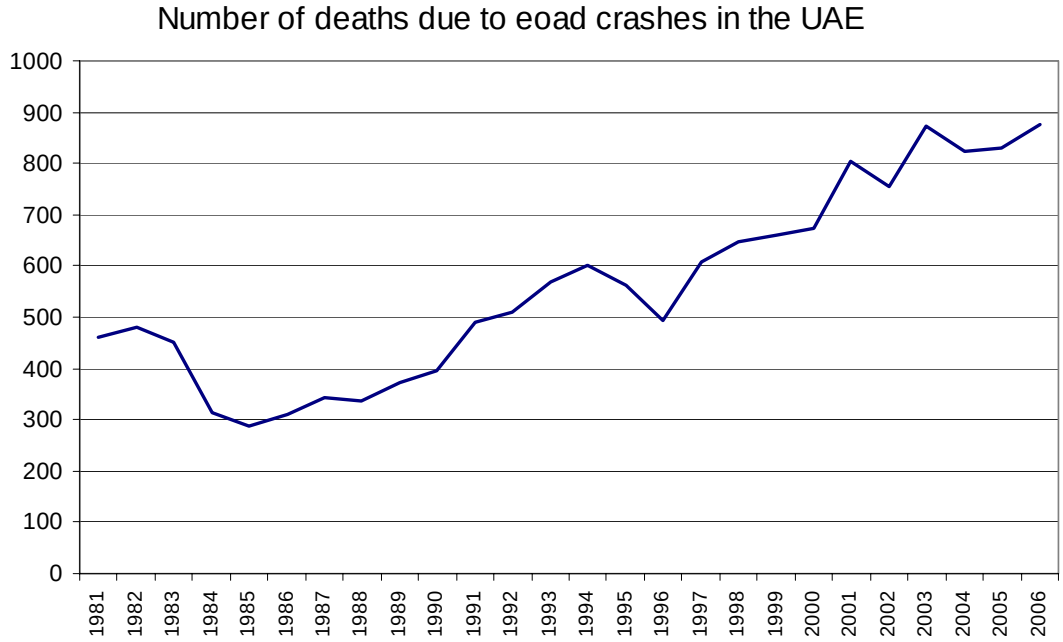

Figure 2: Number of deaths due to road crashes in the UAE from 1981 to 2006

Objectives of the research

The objective of this research is to develop a simulation model to understand the dynamics of causal factors that motives drivers for adopting excessive driving behavior in the UAE. Without developing fully understanding about the actual causes that motivate drivers for excessive speeding, strategies designed to control the number of excessive speeding drivers are likely to fail. The model will assist in understanding how different factors interact over time to influence the speed choice behavior of the drivers.

Dynamic hypothesis of the model

The speed choice behavior of the drivers represents the outcome of a decision process which incorporates interaction among multiple factors. A number of researchers (for example, Salmon, 1964; NHTS, 1995; Warren, 1982; Hauer et al., 1982; Raub, 1985; Shinar and Stiebel, 1986; Tignor and Warren, 1990; Benekohal et al. 1992; Vaa, 1997; Rietveld and Shefer, 1998; Silcock et al., 2000) have identified these multiple factors that influence the speed choice behavior of drivers. These factors include driver age, gender, vehicle type and performance, road classification, perceived risk of law enforcement, perceived risk of having a road crash, travel time costs, and driver's awareness level. Some situational factors such as traffic conditions, weather conditions, traveling alone, time of travel, and long traveling also influence the speed at which a driver chooses to drive (Fildes et al 1991; Rietveld and Shefer, 1998).

The magnitude of these factors change over time, for example, perceived risk of law enforcement might change in response to changes in the law enforcement interventions or driver's awareness level might increase due to increase in the age and experience of the drivers. It is required to investigate how factors influencing the speed choice dynamically change to understand the process of speed choice behavior of the drivers (Brindle, 1980; Jennings & Demetsky, 1983; Westerman, 1990).

For the purpose of this research author considers the factors influencing the speed choice into two types, internal and external. Internal factors are those which change within the dynamic process of the excessive speeding behavior of the drivers and directly influence the motivation of drivers for excessive speeding behavior. Examples of internal factors

include perceived risk of law enforcement, perception about excessive speeding drivers, and driver's awareness level.

External factors are those factors which are not influenced by the internal dynamic process of the excessive speeding behavior of the drivers. For example, these factors include age of the drivers, high performance of vehicles, attributes of roads, traffic and environmental conditions. These factors are not static, they also change over time. As age of the drivers increase with time, performance of vehicles is improving every year, characteristics of the roads, traffic and environmental conditions also change over time. However, change in these factors is not directly influenced by the excessive speeding behavior of the drivers. On the other hand these external factors could influence the motivation of drivers for excessive speeding behavior.

Internal factors influencing excessive speeding behavior of drivers

Perceived behavior of the excessive speeding drivers

A number of researchers have found that perceived behavior of the excessive speeding drivers motivates other drivers to adopt excessive speeding (Milgram, 1965; Shinar & McKnight, 1985**;** Zaidel (1992; Connolly & Åberg, 1993; Kimura (1993; Yinon and Levian, 1995). These researchers reported that drivers perceive speed of the other drivers on the road and considers as a source of information about an appropriate speed for the driving. Nishiyama (1988) has reported that speed choice of drivers is partly dependent on the speed of other cars around them. In addition, Connolly & Åberg (1993) and Van Houghton et al. (1985) found that most of the time vehicles traveling close to one another tend to drive at similar speeds. Similarly, Beillinson et al. (1994) described that speed choice of the drivers is positively related to the perceived normal speed of other drivers along a road segment.

Based on findings of the researchers about perceived behavior of excessive speeding as stated above, a dynamics hypothesis is developed (shown in Figure 3). Figure 3 illustrates that excessive speeding drivers create a process of strengthening the motivation for excessive speeding over time. As shown in Figure 3, starting from variable "Percentage of excessive speeding drivers" as it increases, so does the "perception about excessive

speeding drivers" that would increase the motivation index for excessive speeding and in turn, over time number of excessive speeding drivers might rise.

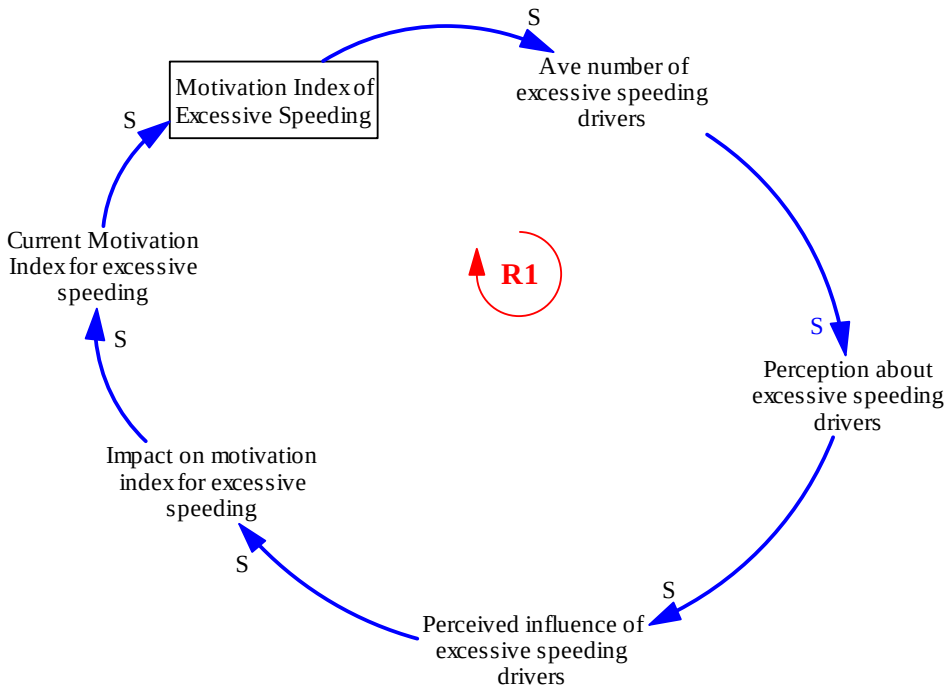

Figure 3: Impact of excessive speeding drivers on motivation index

Effect of law enforcement on speed choice behavior

Hauer et al, 1982; DeWaard & Rooijers, 1994; Rothengatter, 1990, and Corbett , 1997 reported that deterrence influence in response to the law enforcement could impact on the speed choice behavior of the drivers. Deterrence influence refers to the likelihood of being caught and fear of the penalty for excessive speeding. The deterrence influence generally depends on the law enforcement that includes police patrol, presence of speed enforcement detection devices such as speed cameras, radar and laser devices, and magnitude of penalties for speed violations. Cameron, et al, 1992; Rogerson et al, 1994; Bourne and Cooke, 1993 reported that intensive use of automated speed enforcement in Victoria has had a beneficial road safety effect. For example, the introduction of speed cameras in Victoria helped to reduce road crashes by more than 25%, injuries by 40% and fatalities by more than 45%. Similar results have been found in other countries. A report by the OECD (2003) pointed to a 50% reduction in road crash fatalities at camera locations across Europe and reductions of 22% in New South Wales, 30%

in all crashes on urban arterials in Victoria and 35%reduction in serious road crash injuries at camera sites in the UK.

However, evidence from Kuwait (Ali et al, reported in Webster, 2000) described that cameras had no effect on the "undisciplined driving environment of the oil rich nations of the Middle East". Reliance on automatic cameras alone to reduce the traffic violations in an environment characterized by poor driving behavior, low level of driver's awareness about road safety and inadequate law enforcement capacity is unlikely to be effective.

Some of the researches have supported the effectiveness of the use of speed cameras in many countries to control the excessive speeding. There is also a clear evidence that speed camera effects in particular (and enforcement effects in general) may be specific to the location and time of enforcement, and temporary (for example, Hauer, Ahlin & Bowser, 1982; Zaal, 1994). It seems that while use of speed cameras have indeed been effective at reducing speeding behavior but there is no evidence of associated long-term changes in drivers' attitudes to this behavior (DeWaard and Rooijers, 1994). For example, whilst speed humps reduce speed locally, drivers are then free to increase their speed (Pau & Angius, 2001); similar effect has also been observed with speed cameras (Keenan, 2004). Similarly Shinar and Stiebel (1986) found that compliance with speed limits is higher in the vicinity of police vehicles or speed cameras and diminish as drivers move away from such vicinities.

Based on above literature review related to effect of law enforcement on speed choice behavior of the drivers, a dynamic hypothesis is developed (shown in Figure 4). It is assumed that all other things being equal, number of drivers caught for speeding violations would increase with an increase in the law enforcement capacity. An increase in the relative number of drivers caught for excessive speeding would increase the deterrence influence, and in turn, motivation for excessive speeding will decrease that might reduce the number excessive speeders. The relative number of drivers caught for speeding violations depends on the likelihood of being caught, whereas the likelihood of being caught is influenced by the law enforcement capacity and its effectiveness. As shown in figure 4, it is hypothesized that number of excessive speeders set the need for increasing the effectiveness of law enforcement and capacity of the law enforcement.

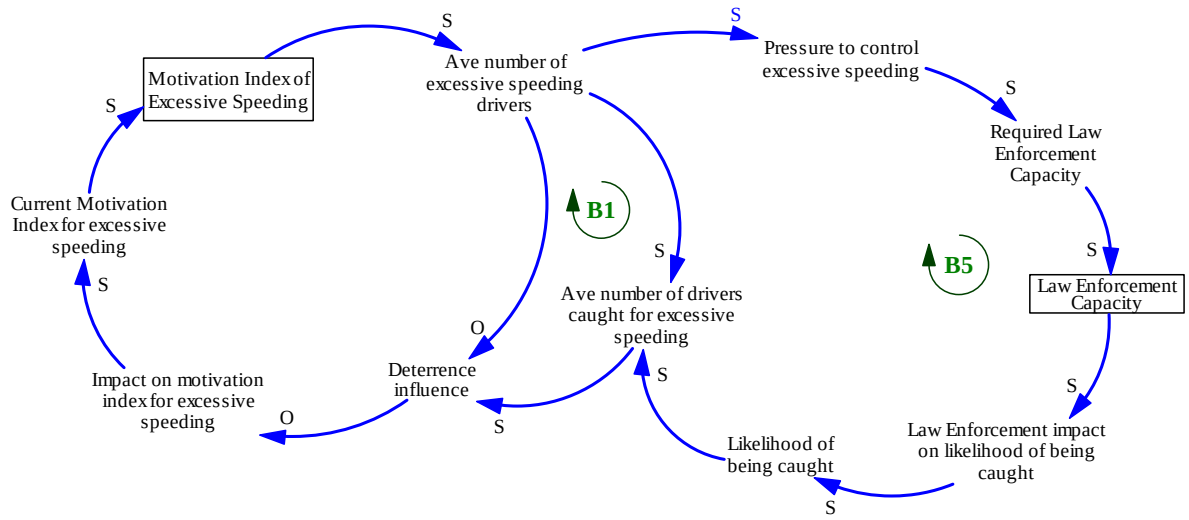

Figure 4: Impact of Law Enforcement on motivation index

Effect of education campaigns on excessive speeding behavior

While continuous efforts of the education campaigns for driver awareness can also help in changing the excessive speeding behavior of the drivers (Elliott, 1993). As awareness level of the drivers regarding implications of excessive speeding behavior increases, it might be possible that drivers progressively develop sense of responsibility and avoid violating the speed limits. However, developing sense of responsibility to comply with the speed limits takes time and does not depend only on the awareness level of the drivers. For example, in the UAE it has been observed through interviews with a group of drivers that excessive speeders have awareness about consequences of violating speed limits but their awareness is not effective to comply the law. Here, it is assumed that the reason for awareness level not being effective could be presence of relatively a high number of speeding drivers. If in a system many drivers are violating the speed limits then effectiveness of awareness may be reduced to overcome the excessive speeding behavior.

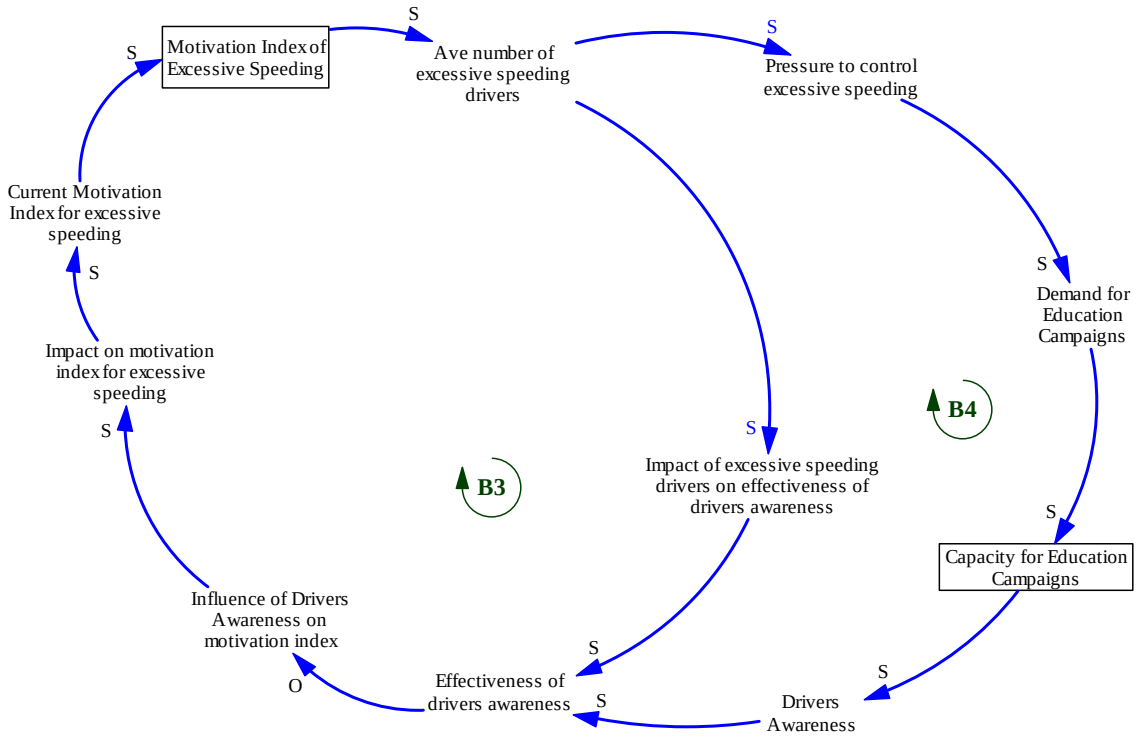

Figure 5: Effect of Education Campaigns on motivation index

Effect of Advanced Driver Assistance Systems on excessive speeding drivers

Advanced Driver Assistance Systems (ADAS) such as adaptive cruise controls and collision warning systems in the vehicles are relatively new technologies that expected to control the excessive speeding drivers. These technologies has a wide range features varying from systems supporting the driver in one specific driving task (for example, proper distance keeping, blind spot obstacle warning, lane keeping) up to highly advanced systems where the drivers' steering, throttling and braking tasks are fully automated like the auto-pilot (Van der Heijden and Wietho, 1999; Giannopoulos, 2004). Another example of these systems is the application of Intelligent Speed Adaptation (ISA). The ISA systems takes into account the local speed restrictions and warns the driver in case of speeding or even automatically adjust the maximum driving speed to the posted maximum speed (Varhelyi and Makinen, 2001).

Figure 6 shows dynamic hypothesis that attempts to incorporate the effect of ADAS on excessive speeding drivers. It is assumed that need for developing and introducing ADAS depends on the averaged number of excessive speeding drivers. As number of excessive speeding drivers increases pressure to develop new system to control them would rise.

The development and implementation of ADAS in response to increase in the pressure may have twofold affect, one in the short term and the other in the long term. The short term affect would be usage of ADAS might reduce the number of excessive speeders as ADAS directly controls the vehicle not the driver behavior. The long term impact of ADAS might be reduction in the effectiveness of driver awareness. It is assumed that usage of ADAS can have negative affect on driver behavior, as drivers can relay more on the system rather than developing inherent ability to avoid speed violations.

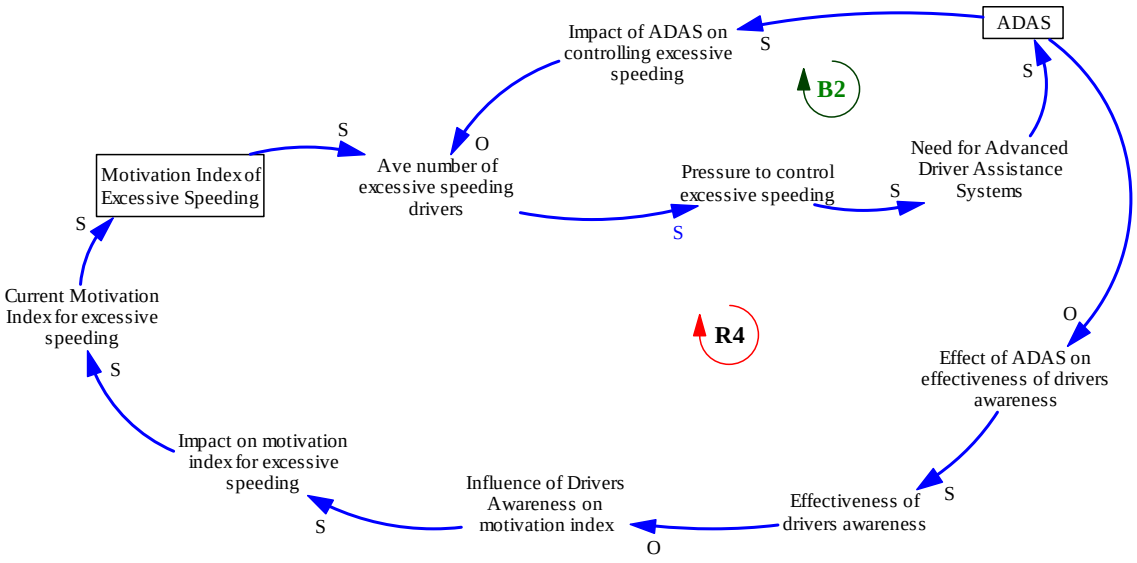

Figure 6: Effect of Advanced Driver Assistance System on number of excessive speeding drivers

External factors influencing excessive speeding behavior of drivers

Figure 6 depicts external factors that influence motivation index for excessive speeding behavior. These external factors include age of the driver, high performance vehicle, characteristics of road, traffic and environment conditions.

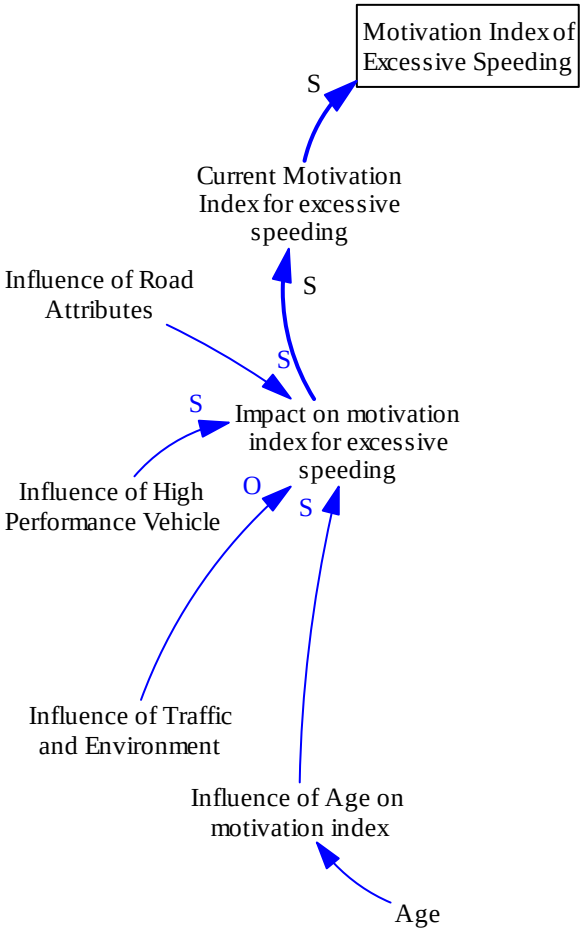

Figure 7: External factors influencing motivation index for excessive speeding

Age

Fildes et al. (1991) reported that young male drivers of age less than 25 years are most likely exceed the speed limit. Similarly other researchers such as (Krug & Cattell, 1980; Baxter et al, 1990; Anon, 1991, and Corbett & Simon, 1992) found that younger drivers tend to drive faster than older drivers and tend to violate traffic laws more often than any other group. Studies in California have found that the rate of speeding violations per mile traveled is at least three times as high for drivers 16-19 years old as it is for drivers age 30 and older (hwysafety.org). Of all the drivers involved in fatal crashes due to excessive speeding in the UAE are young males under the age of 25 (Police reports UAE).

High performance of vehicles

Silcock et al. 2000 reported that high performance vehicles equipped with advanced systems motivate drivers to drive fast because drivers feel they can stop faster enough to avoid the road crash. During the interviews with police officials in the UAE, it is found that percentage of high performance vehicles in the UAE has been increased. And also during interviews with a group of drivers 60 percent of respondents agreed that high performance vehicles is one motivation factor for high speeding in the UAE.

Road attributes

Researchers such as (Warren, 1982; Jennings and Demetsky, 1983; Fildes et al., 1987) found that attributes of the road environment could influence the drivers speed choice. For example, classification of the road, horizontal and vertical alignment, lane width, grade, length of grade, number of lanes, surface condition, sight distance, lateral clearance, number of intersections, and built-up areas near the roadway.

The European Transport Safety Council (1995) reported that width, gradient, alignment, and layout, and the consistency of these variables, are the determinants of speed choice on a particular stretch of road. The attributes of the road are usually designed to provide a comfort and smooth riding surface to the drivers. However, it has been observed that road characteristics influence motivation of drivers for driving fast. For example, Cooper et al. (1980) found that average vehicle speeds increased by 1.6 mi/h (2 km/h) after resurfacing major roads in the United Kingdom; no change in traffic speed was found in locations where surface unevenness remained the same after resurfacing. Parker (1997) found no change in speeds on two rural highways and a 3 mi/h (5 km/h) increase on two urban streets that were resurfaced and had the speed limit raised.

Traffic and environment conditions

Mustyn and Sheppard (1980) found more than 75 percent of drivers claiming they drive at a speed that traffic and weather conditions permit, regardless of the posted speed limit. Weather conditions influence the vehicle speed selected by

most drivers. For example, reduced visibility due to fog caused a 6 mi/h (10 km/h) decline in mean speeds on a freeway in Minnesota (CRC, 1995). Greater reductions in speed can be observed under extreme conditions (Schwab, 1992).

Although wet road surfaces will affect traction when attempting to stop, pass, or negotiate a curve or turn, most drivers do not reduce their speeds very much when traveling on wet roads. Olson et al. (1984) compared speed data collected during daylight hours on wet and dry days at 22 sites in Illinois and found no practical differences. The maximum difference in speed was less than 2.5 mi/h (4km/h). Similarly, Lamm et al. (1990) found no differences in operating speeds on dry and wet pavements for 11 curves studied on two-lane rural roads in New York. Although light rain had little effect on speeds, Ibrahim and Hall (1994) observed 3 to 6 mi/h (5 to 10 km/h) reductions during periods of heavy rain.

Simulation model

Following the dynamics hypothesis of the model described above, a formal system dynamics simulation model is developed. In the simulation model external and internal factors described above are joined together to form an integrated model as shown in the Figure 8. The mathematical relationships between the variables are defined to transform the dynamic hypothesis into a simulation model. These relationships are *initially* based on an intuitive or heuristic understanding as opposed to having been calibrated on the basis of empirical evidence.

As shown in figure 8, there are four stock variables in the model. These are: 1) Number of Licensed Drivers, 2) Motivation Index for Excessive Speeding, 3) Law Enforcement Capacity, 4) Capacity for Education Campaigns, and 5) Advanced Driver Assistance System (ADAS).

It is assumed stock for the number of licensed drivers would increase due to increase in the population and number of registered vehicles. The increase or decrease of the stock for the Motivation Index of Excessive Speeding is endogenously determined based on net influence of external and internal factors described earlier in this paper. The net influence on motivation index is considered as a product function of the impact of external and internal factors. The impact of internal factors changes during the simulation time, while impact of external factors is considered as constant throughout the simulation duration.

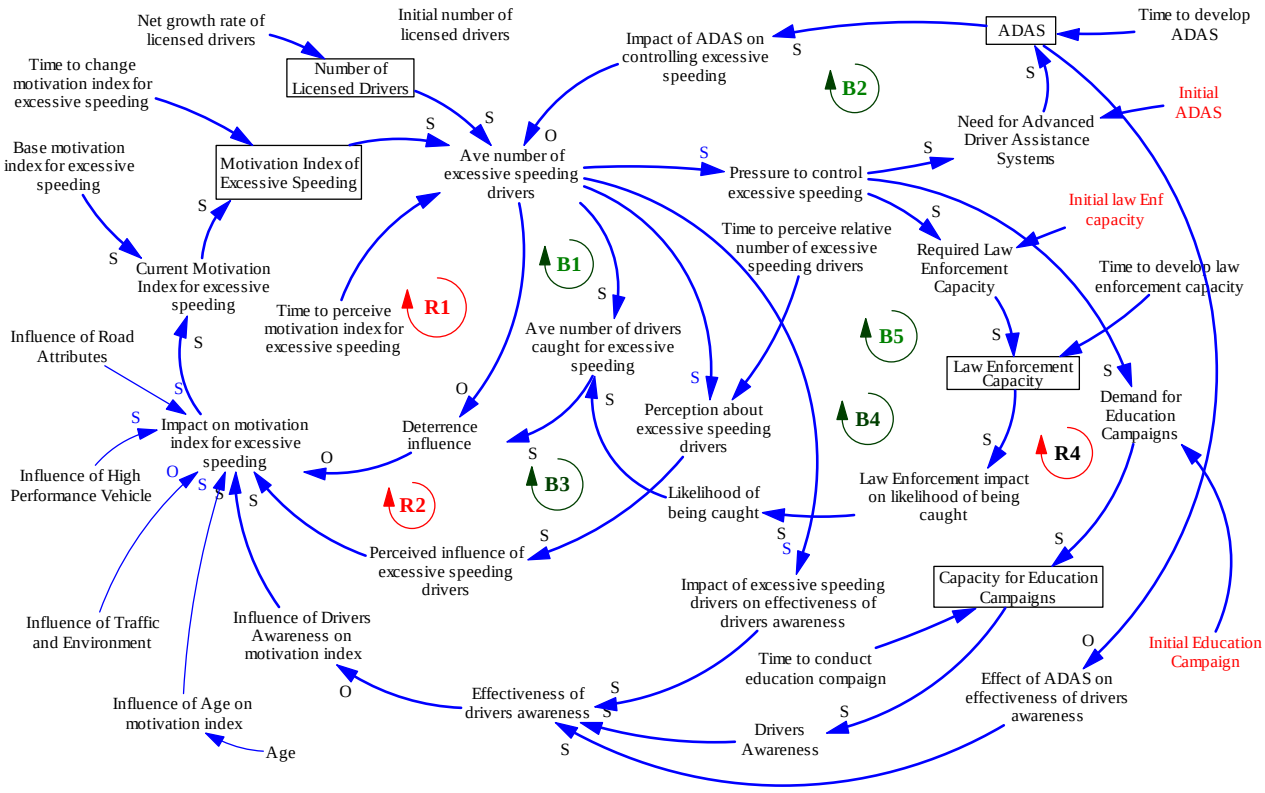

Figure 8: Integrated simulation model for drivers' speed choice behavior

Model experimentations

Initially the model is parameterized in a way that equilibrium exists in all stocks. To test the dynamic hypothesis articulated in this paper, the model is driven from equilibrium state and an exogenous disturbance is introduced. The step input, a sudden one-shot disruption of the system's equilibrium state, is a very simple and uncomplicated, yet informative, disturbance (Lynies, 1988). Such a test is important for understanding any tendency internal to the system (Saeed, 1987). The equilibrium of the model is disturbed by a four percent step increase in the net growth of the licensed drivers. This increase in would represent the increase in the population and number of registered vehicles. All other parameters and nonlinear graphical functions remain unchanged during the base run of the model. Followed to base run, policies related to Law Enforcement, Education, and introduction of ADAS are tested.

Figure 12 shows simulation results of these tests over a hypothetical period from 2000 to 2050 for a variable, “Motivation Index of Excessive Speeding”. The simulation results shown in figure 12 indicate none of the policy run provides sustainable reduction in the motivation index. The output of each simulation run provides a temporary reduction in the motivation index and in the long run motivation index stabilizes almost at the level of base run output, except the law enforcement strategy.

As described earlier the relationships between variables in the existing model are based on heuristic understanding. These relationships need to be investigated based on scientific evidence.

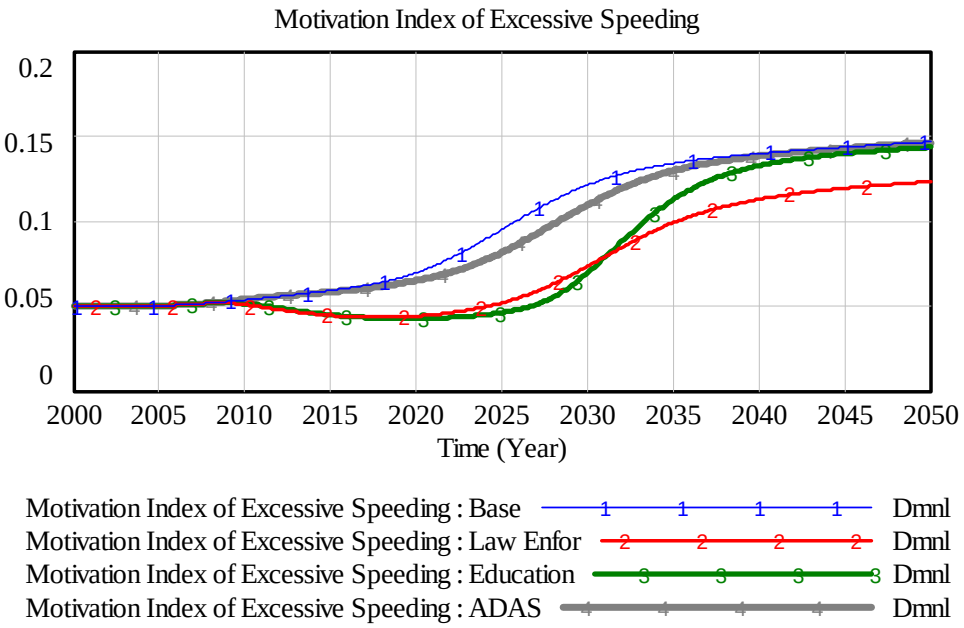

Figure 9: External factors influencing motivation index for excessive speeding

This paper provides a modeling framework that integrates the dynamic interaction between causal factors responsible for motivating drivers to adopt excessive speeding behavior. The development of simulation model needs substantial work to refine the model relationships. It is expected that end product of this research would be a fully integrated decision-support tool that would help in understanding the resistance to achieving a sustainable reduction in the excessive speeding drivers.

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