Integrating Human Panic Factor in Intelligent Driver Model

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***Abstract*— This study aims to explore the effects of human panic factor on drivers' driving behavior. Most of the car following models focus on idealistic situations aiming for perfection, traffic psychology, however, suggests that emotions do play a significant role in drivers' behavior which in result effect their driving and decision making. Therefore, it is necessary to incorporate human factors in car following models for better realistic results in driving situations where external task demand increases (for example, poor weather conditions like fog, or making up to a meeting in time). Despite the fact that car following models have sublime appreciation in literature, none of them has focused on incorporating human panic factor in these models. Although some work is being done on understanding panic factor in drivers which helps us to understand their driving behaviors and effect on acceleration under panic situations, but this work is limited to statistical approach. This study is intended to fill this void by reviewing literature and making latest advancements by integrating human panic factor in Intelligent Driver Model (IDM). We attempted to integrate human panic factor in IDM, and simulation-based results verified our assumptions for the enhanced version of IDM. The enhanced version of model namely P-IDM models the acceleration behavior of drivers under panic condition, and reproduces acceleration as intended.**

Keywords—car-following, acceleration, driving behavior, human factor, speed choice, panic

I. Introduction

By 21st century, the advent of mobility has led the researchers to a huge number of challenges [1]. Efficient techniques are required to cater traffic related problems. Last decade marked an immense progress in traffic engineering with the help of agent technology. Keeping in mind the complexity of transportation system, not only new techniques, but driver's individual choices are also to be taken into consideration to make advancements in traffic system. Since driving is a self-taught task, we need to determine which factors affect the drivers' behavior towards external task demands [2]. Several models have been formulated that focuses on drivers' behavior towards his own goals which he set in his daily life routine, and try to pursue these goals [3]. Some of those goals urge drivers for fast driving, for example, reaching scheduled meeting in time. In contrast to it, the goals of cautious driving urges for slower driving rate. Most of the models make assumption that these internal factors are related to uncertain situations leading to fear and panic in driver. Interestingly, these internal factors are very frequent during driving [4].

Computational transportation Science (CTS) is considered to be the science behind Intelligent Transportation Systems (ITS) [5]. Transportation science covers a wide range of discussion. Traditional mathematical models were not capable enough to deal with real world problems, hence, it led to the use to computational models and simulation, which in result provided solutions to many real-world problems [6]. Computational transportation uses modelling and simulation as a method to study different aspects of transportation which includes traffic demand modelling, individual driver's behavior, traffic optimization, signals optimization, infrastructure optimization, policy testing [7]. One of these tasks include modelling and simulation of driver's individual behavior.

In order to study driver's individual behavior and to model it, generally, lane-changing and car-following models are dealt separately. If we have a bird eye view in car following models, a great deal of work has been done in it. Researchers are now considering to study humanistic aspects of a driver that exert influence on acceleration. The car-following models consists of mechanical and psychological aspects [8]. In our point of view, some situations during driving can induce panic in a driver. These are basically the external task demands that causes distraction to the driver. In general, it is considered that panic cause distraction in driver's work and the driver is not able to perform desired tasks efficiently [9].

Fig.1 provides an overview of the important features of a driver influencing his driving behavior. We have attempted to reproduce the concept given in [10] about these important influencing factors on a driver. We can understand Fig.1 by breaking it down in a horizontal or vertical division.

A driver's behavior is affected by many factors, some of them are external factors while others are his internal factors. A driver's behavior has different levels. Some decisions are long term; also known as the overall goal, it is called the strategy of the driver while others are the spontaneous actions needed to control a particular situation in order to implement his strategy; these are called the operations.

Similarly, if we see behavior in another direction, which we are representing vertically; some of the decisions are internal, which cannot be measured in external world. For example, a driver's reaction time is internal to him. In order, to gauge his reaction time, the only way is to pass the driver through an experiment and then compare it. On the other hand, external factors can be measured easily such as road conditions, a vehicle's limitations etc.

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We can comprehend behavior in a way where we have a main strategy, and in order to implement it, we have to perform some steps at operational level.

It is also important to note in the Fig. 1 that overlapping of two colours is actually the overlapping of two characteristics of vehicle-driver agent. In other words, if you have a strategy, some external and some internal factors will be affecting it.

For example, if our strategy is to reach some venue A, we will have to perform operations like using accelerator, brake, moving steering, and while performing these operations; some external factors (road conditions, visibility conditions) and internal factors (speed, reaction time) will be affecting it.

We aim to build a model in which a driver's acceleration behavior can be expressed under panic, so we can study a driver's individual behavior in panic condition, and specifically his acceleration.

We attempted to enhance Intelligent Driver Model (IDM) by integrating human panic factor in it. The simulation-based verification has confirmed our assumptions for the enhanced model, and so it models the acceleration behavior of drivers in panic condition.

The rest of the paper is structured as: Section II provides Literature Review, Section III is about Methodology, Section IV presents Model Evaluation, while Section V and VI provides Conclusion and Future Work respectively.

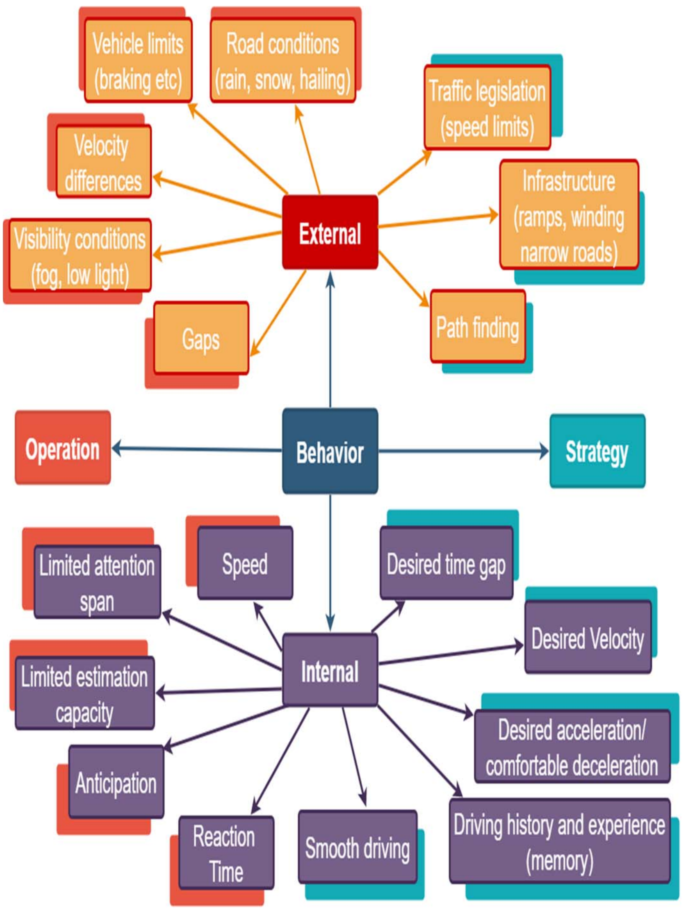

Fig. 1. Characteristics of a driver-vehicle agent.

II. Literature Review

A. Traffic Flow Models

Traffic flow models can be categorized into two types: (1) Macroscopic models (2) Microscopic models. The first type of models is generally used to describe the traffic flow in terms of liquid and gases in motion. For example, it can be used to determine the traffic waves velocity. It does not consider lane-changing and other driver-vehicle aspects like acceleration. The latter type of model including car-following models describe the driver-vehicle aspects of an individual driver. These models describe the driver's reaction in different aspects like lane-changing, speed choice, braking and headway distance depending on their nearby traffic [11].

Car-following models describe the best of Microscopic models. They consider driver's individual behavior according to the traffic. A driver's desired acceleration, braking phenomenon, desired distance from the leading vehicle, switching between lanes; in short, it includes every decision of an individual driver [12]. Car-following models are further categorized as acceleration models, lane-changing models and decision models such as near-intersection maneuvering.

Car-following models based on driving strategies are of our interest. These are assumed to be depicting real driver behavior, because they maintain a safe distance from the vehicle ahead it, prefer a desired acceleration, comfortable speed and braking strategy. These types of models include Gipps Model and IDM.

Intelligent Driver Model (IDM) is of our interest in this study as it fills the gaps of Gipps Model giving more realistic approach towards acceleration.

B. Incorprating Human Factors

Very few studies have attempted to incorporate human factors in car-following models. Human factors are highly ignored and are not taken into consideration despite their critical position in transport. In order to enhance traffic safety and to better understand the complex traffic system, we need to integrate human factors as it will be a better realistic approach to understand those models [13].

Fig. 2 on the next page shows some important human factors that affect a driver's driving behavior. Human factors have been classified into six basic classes which are comprised of human factors affecting a driver's driving skills. These classes include socio-economic factors, physiological factors, personality traits, imperfect driving, driving skills, and driving desires. [14]

Furthermore, socio-economic factors include age, gender, income, education, family structure. Physiological factor includes reaction time and vision. Personality traits include aggressiveness or cautious behavior of a driver. Imperfect driving includes driving errors. Driving skills include his driving capability. Lastly, Driving desires include speed choice, desired time-headway, desired acceleration/deceleration [14]. These factors affect the driver in numerous ways.

Researchers are working on different human factors which are affecting daily driving skills. Work is being done on factors like anger, fear, happiness, handling external task demands during driving. However, driver's reaction time is the most commonly incorporated human factor in car-following models [14]. Reaction time is the time duration in which a driver first senses a stimulus, then perceives it, makes a decision, and eventually performs an action in response to that stimulus [15].

A recent study has been performed to determine anxiety state and driving behavior depending on heart-rate, and this experiment concluded anxiety with increased high-rate and cautious driving [16].

Another study examined the emotional impact of drivers on their driving speed. It summarizes that if the external task demands increases, for example, in certain road or weather conditions; fear is aroused in the driver depending on his driving capabilities, and it results in speed decrease [17]. This study proved to be baseline for our enhancement in car-following model, IDM.

Not only in traffic, panic is being studied in pedestrian evacuation models as well. These models show the evacuation behavior in panic condition under natural hazard [18].

Literature suggests panic is considered to be an important human factor. Panic, in general, can be defined as the sudden fear or anxiety that can lead to uncontrollable situations [19].

Till date, panic is studied in different aspects, still this important factor is needed to be incorporated in car-following models. In the light of its huge importance, and to fill this gap, we have attempted to integrate panic in Intelligent Driver Model (IDM) which is considered to be a de-facto car-following model.

III. Methodology

This section starts with the description and mathematical formulation of Intelligent Driver Model (IDM), followed by Integration of human panic factor in IDM, its mathematical formulation and description.

A. *Intelligent Driver Model*

Intelligent Driver Model (IDM) is a microscopic model to observe time-continuous intelligent driving. Each parameter is controlled in such a way that your desired acceleration is met and you can observe the detailed changes in acceleration and deacceleration. It gives the realistic approach towards acceleration in single-lane traffic [20]. Mathematical formulation of Intelligent Driver Model (IDM) is presented in equation (1)

$$a_\alpha = a_0\left[1-\left(\frac{V_\alpha}{V_0}\right)^\delta - \left(\frac{S^*(V_\alpha,\Delta V_\alpha)}{S_\alpha}\right)^2\right] \qquad (1)$$

$$S^*(V_\alpha,\Delta V_\alpha) = S_0 + V_\alpha * T + \frac{V_\alpha * \Delta V_\alpha}{2\sqrt{ab}} \qquad (2)$$

Here in (1) and (2) a_α is the current acceleration of the subjective vehicle, a_o is the desired acceleration, V_α is the current velocity of the subjective vehicle while V_0 is its desired velocity, and ΔV_α is the difference of velocity between subjective vehicle and its leading vehicle. δ is the acceleration exponent which controls the decrease in acceleration when desired velocity is met by the driver, and it is usually set as $\delta = 4$

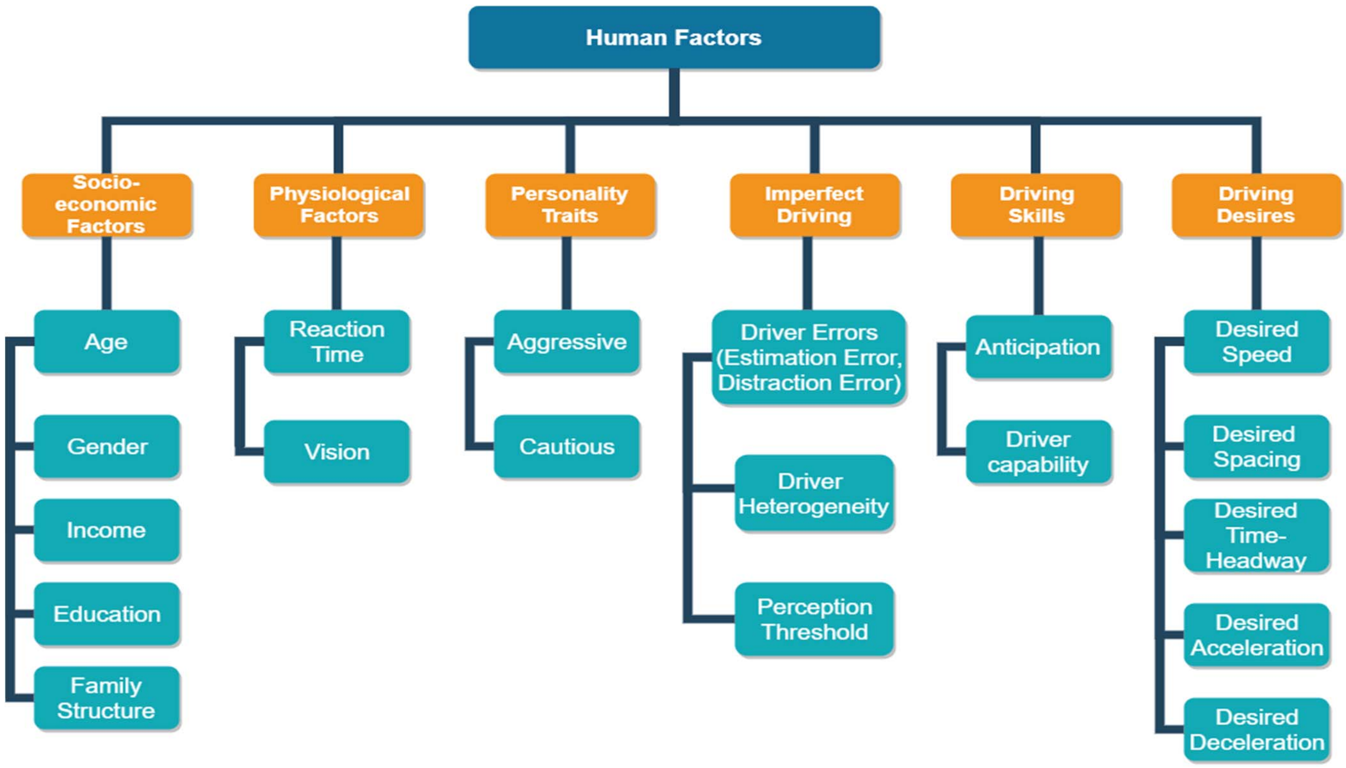

Fig. 2. Human factors affecting traffic flow dynamics. [14]

Equation (2) controls the free flow. It gives the desired distance of the vehicle. Here T is the time headway, that is how much distance should a vehicle maintain from its leading vehicle in terms of time, furthermore, a is the maximum acceleration while b is the desired deceleration. $(S_0 + V_\alpha * T)$ in equation (2) gives the safety distance. The safety distance is calculated by the time headway T along with the desired distance S_0. The second term $\frac{V_\alpha * \Delta V_\alpha}{2\sqrt{ab}}$ in equation (2) gives the Intelligent Braking Strategy which determines the dynamic behavior of the vehicle while it advance towards the leading vehicle.

Each parameter is luminously balanced in IDM. Different driving aspects can be easily modelled by merely changing the desired speed. Sample parameters for the Intelligent Driver Model are shown in Table I [20].

TABLE I. MODEL IDM PARAMETERS

Parameter	***Typical value Highway***	***Typical value City Traffic***
Desired speed V_0	120 km/h	54 km/h
Time headway T	1.0 s	1.0 s
Desired distance So	2 m	2 m
Acceleration exponenet δ	4	4
Acceleration a	1.0 m/s^2	1.5 m/s^2
Decceleration b	1.5 m/s^2	1.5 m/s^2

B. *Incorporating Human Panic Factor in IDM*

Panic, being a latent variable cannot be measured directly. In order to reduce complexity, we have assumed panic to be scalar quantity varying between 0 and 1. The mathematical model to represent panic incorporation in Intelligent Driver Model (P-IDM) is presented in equation (3).

$$a_\alpha = a_0 \left[1 - \left(\frac{(V_\alpha * (1+p))}{V_o} \right)^\delta - \left(\frac{S^*(V_\alpha, \Delta V_\alpha)}{S_\alpha} \right)^2 \right] \quad (3)$$

Here in (3), p represents panic. We have introduced panic with the velocity term based on our hypotheses that panic is related to speed as discussed earlier. Here, when $p = 0$, meaning panic factor is nil, our enhanced model behaves exactly like IDM as in equation (1), and when $p = 1$, the velocity's penalty will be doubled.

IV. MODEL VERIFICATION

We have performed simulation based verification for our model. Verification has been done in order to evaluate enhanced IDM; we call it P-IDM. We have considered desired initial conditions for normal driver type in Table II. We have introduced five different levels of panic in our model, starting from $p = 0$, which represents the model in absence of panic, and here it behaves exactly like IDM. Then, increasing the value of p shows panic being induced in the driver, and $p = 1$ depicts the actual behavior in extreme panic.

TABLE II. DESIRED IDM PARAMETERS

Panic Level	**Normal Driver Profile**						
	p	***V₀***	***S₀***	***T***	***a***	***b***	***δ***
Nill	0.00	33.33	2	1.5	1.4	2	4
Low	0.25	33.33	2	1.5	1.4	2	4
Average	0.50	33.33	2	1.5	1.4	2	4
High	0.75	33.33	2	1.5	1.4	2	4
Very High	1.00	33.33	2	1.5	1.4	2	4

Five different values of panic were used in order to determine panic level and its effect on acceleration accordingly. For nil panic, our model had same results as that of IDM, and after inducing panic; acceleration began to decrease.

Fig. 3 illustrates the comparative behavior of IDM with our enhanced model P-IDM, where the blue line represents the usual behavior of IDM while the orange line represents the model's behavior after integrating Panic. Acceleration seems to be constant in IDM, that is, because we have set other parameters constant in order to assume that the driver has reached his desired speed so that we can observe panic effect. We took sample values for the model as:

$a_0 = 1.4\, m/s^2, V_\alpha = 23.33\, km/h$, $V_0 = 33.33\, km/h$, $\Delta V_\alpha = 5.56\, km/h$ and $S_\alpha = 159\, m$.

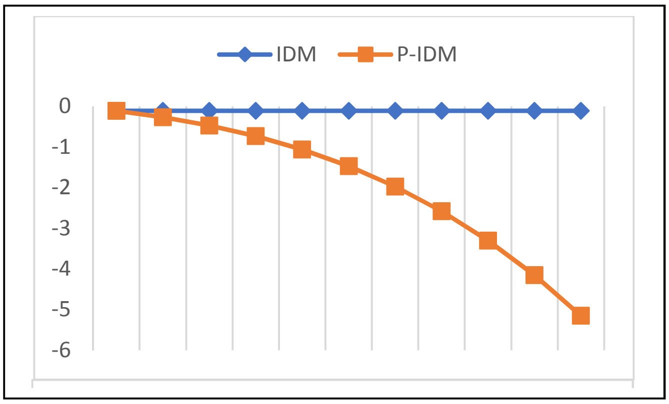

Fig. 3. Effect of panic in P-IDM

We can observe from the Fig.3, initially when panic $p = 0$, P-IDM had the same behavior as that of IDM. Then, by slowly increasing panic $p = 0.25$, showed a slight change and the difference began to increase with the increasing panic factor. As soon as the panic factor begins to increase, driver's speed begins to drop resulting in deceleration.

We also experimented our model for when distance is increasing and decreasing between current vehicle and its leading vehicle.

Fig.4 shows the panic effect on acceleration while the current distance between current vehicle and the leading vehicle is increasing. For this we set the values for different parameters as:

$a_0 = 1.4\ m/s^2$, $V_\alpha = 23.33\ km/h$, $V_0 = 33.33\ km/h$, $\Delta V_\alpha = -5.56\ km/h$, however, S_α was initially set to $10\ m$, and we incremented it by 1 till it reached $110\ m$.

It showed the results that the drivers with extreme panic where $p = 1$, had least acceleration as compared to drivers with lower levels of panic.

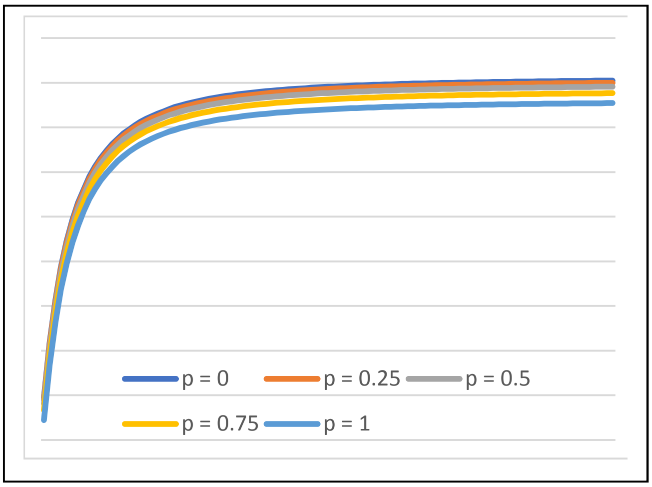

Fig. 4. Effect of panic in context of increasing distance

Next, we examined the acceleration behavior in presence of panic while the distance between the two vehicles is decreasing as shown in Fig.5. For this we set the values for different parameters as:

$a_0 = 1.4\ m/s^2$, $V_\alpha = 23.33\ km/h$, $V_0 = 33.33\ km/h$, $\Delta V_\alpha = 5.56\ km/h$, however, S_α was initially set to $110\ m$, and we decremented it by 1 till it reached $10\ m$. Although, we observed slight changes, but they were clear to demonstrate how panic effects acceleration behavior.

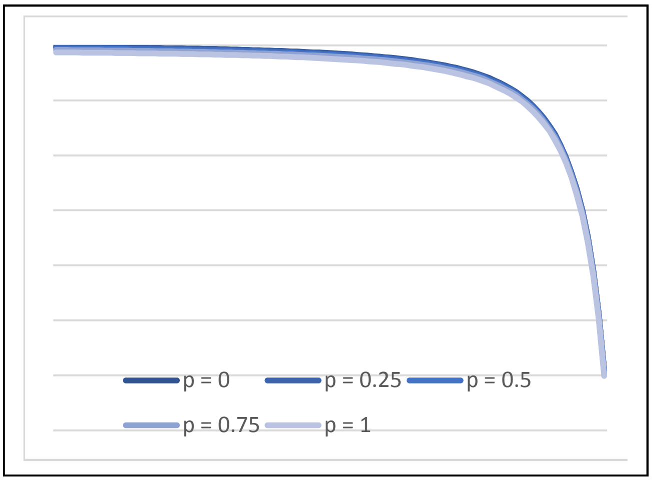

Fig. 5. Effect of panic in context of decreasing distance

V. Conclusion

In the past, most of the car-following models have been designed for idealistic behaviors. They mainly focus on the cognitive driving aspects of a driver and their physical conditions; however, psychological aspects are not taken into consideration. With the advancements in traffic systems, and in order to cope with advance challenges, human factors are also needed to be integrated in car-following models.

We attempted to enhance IDM model with the incorporation of human panic factor in it. The simulation-based verification has confirmed our assumptions for the enhanced IDM. Thus, it is concluded that our enhanced version of IDM; P-IDM models the acceleration behavior of drivers in panic condition.

VI. Future Work

We are intended to validate P-IDM through human-in-the-loop experiments validation by exposing real human beings in panic situation through psychological techniques in a virtual reality traffic environment. It is also intended to perform extended experiments for different contexts.

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