Driver Attention Demand and Adaptive Information Management

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ABSTRACT

The road system has seen a recent influx in Intelligent Road Information Systems (IRIS) in terms of Intelligent Infrastructure and Intelligent Vehicles. Although these devices are intended for the safe and efficient operation of the road system, there is increased concern that they may lead to high driver workloads and driving errors. Road safety practitioners have been striving to develop a driver interface, which could schedule information from the various devices for presentation to the driver so that driver capacity is not exceeded. This requires knowledge about the driver's workload limit, and the level of workload from all sources.

Generally, the assessment of workload has been a problem in many workload applications, mainly as a result of the multifaceted nature of the workload concept. Using a driver workload model that combines road complexity with operating speed, this research proposes a driver interface that is more in line with the way the driver adapts the driving task with speed management strategies.

With knowledge about driver workload determinants, the proposed interface gives speed management instructions to the driver in order the keep workload within the driver's limit. Vital operational and safety information no longer have to be postponed as it is normally done in interface design. The driver can be instructed to reduce speed to receive vital information from one of the sources (e.g., a cell phone) of the system.

The proposal is theoretical. The process needs further experimentation and verification.

BACKGROUND

Road mishaps can be attributed to deficiencies in the three components of the road system, vice avis: the road, the driver, and the vehicle. Studies (1,2) have shown that more than 90 percent of these mishaps are caused by driver error related to higher demands on the human information processing system. A close look at the driving task explains how this relates to what happens on the road. In order to move from one point to another, the driver collects information on the path ahead, makes decisions on the safe path to be followed, and takes control actions in a feedback manner (FIGURE 1). Complex road situations, arising from the way the road is designed would therefore present higher intensity information to the driver. This leads to higher demands on the information processing capability of the driver, hence higher driver mental workloads and driving errors. A fundamental aspect of human information processing theory is that there is a limit to the amount of information that the human operator can process at any one time.

Apart from complex road designs, the information content from other traffic, traffic control devices, and computer-based driver information systems might sometimes present information processing problems to drivers, leading to increased driver workload. The latter has become a major road safety concern.

A quick review of Intelligent Transportation Systems (ITS) products which communicate with the driver would seem to suggest that the road system is inundated with information sources. From the road infrastructure (Intelligent Infrastructure), the driver receives information from sources such as Arterial Management Systems, Freeway Management Systems, Traveller Information Systems, Crash Prevention and Safety Systems, just to name a few. Within the vehicle (Intelligent Vehicles), the driver may receive information from in-vehicle devices such as Navigation and Route Guidance Systems, Collision Avoidance Systems, and Intelligent Cruise Control. According to recent estimates (3, 4), vehicle manufacturers are expected to derive a large proportion of their profits from the sale of in-vehicle information systems in the near future.

Whilst most of these devices are intended to aid the driver in the safe and efficient operation of the vehicle, there has been concern that they may lead to excessive driver mental workload or to driver deactivation. With all these devices installed in the vehicle and on the road system, it is possible that at any one time, a couple of them may demand the attention of the driver. A driver could be traversing an intersection or a difficult horizontal curve when information about the weather or the traffic ahead becomes available and is presented to the driver. To prevent the workload (/distraction) that this influx of information might bring, a central monitoring/coordinating interface, which regulates the quantum and timing of information to be presented to the driver has been a subject of research projects like the GIDS (Generic Intelligent Driver Support) (5), and ARIADNE (Application of a Real-Time Intelligent Aid for Driving and Navigation Enhancement) projects in Europe. Such an interface must be able to estimate the demand from the road as well as the demand from each of the devices in order to adequately schedule information. The interface must also be able to estimate the limits of information processing within which the driver can operate if the scheduled information is not to overload the driver.

ASSESSMENT OF DRIVER WORKLOAD

Analysis of the driver workload problem clearly indicates that it requires a two dimensional approach; one dealing with off-line design and the other dealing with on-line design. For off-line design, the designer is concerned with the way road design features affect the safety performance of the driver as a result of the workload induced by the configuration of these features. On-line design deals with the scheduling of Intelligent Road Information System source (IRIS) comprising the Intelligent Infrastructure and the Intelligent Vehicle, so that the driver is not overloaded with the extra information. This requires knowledge regarding the extent to which the driver is already burdened by the task of driving as well as the information processing limits of the driver.

To achieve both designs requires a proper knowledge of driver workload, its theory and measurement, and the development of a predictive model that can give absolute measures of driver workload. Accordingly, this has been a difficult task in many workload applications as a result of the multifaceted nature of the workload concept. Because of the multi-faceted nature of workload, the likelihood of concentrating on certain aspects whilst ignoring other important aspects cannot be ruled out. It is believed that a model of a higher predictive power can be developed by combining all the aspects of workload in a theory that supports the workload concept (6, 7). Generally, the principal dimensions of workload are load intensity, time constraint and psycho/physiological aspects, and they should be considered in any model of operator workload (7, 8, 9, 10). Their combined effect to produce workload is finally dependent on the intervening strategies of the operator, so that the final workload experienced by the operator is determined by the strategy adopted. The proper assessment of driver workload should therefore start with an investigation of the various components that contribute to it, as well as strategies employed by the driver to manage workload.

Determinants of Driver Workload

What is apparent from most experiments conducted to study driver workload is that driver workload depends on load intensity as presented by the road layout (design) or IRIS devices. Various experiments have studied the effect of radius of curvature, lane width, or the layout of the road on driver workload (11, 12, 13, 3) and the consensus is that as road complexity increases, driver workload also increases.

With the increase in the use of IRIS devices and the consequent concern for driver safety, various research efforts have lead to the setting up of guidelines for the manufacture and use of IRIS devices in the vehicle (14). With approximately 5 million vehicles equipped with in-vehicle navigation systems, Japanese police records showed at least 59 crashes between August 1997 and May 1998 associated with the use of navigation systems (15). Whilst there may not be enough statistical evidence to associate crashes with the use of these devices in North America and Europe (mainly as a result of low usage), it was estimated that at the present pace, US roads will record 21 deaths and 2100 injuries in the year 2007 due to the use of navigation systems (15). These estimates are based on the visual demand (workload) that the devices will impose on drivers; since time spent collecting information from in-vehicle devices will be time spent with eyes off the road (the main task of driving). The effect on older drivers is even more profound since these drivers tend to exhibit lower processing abilities compared to younger drivers (3).

Another contributing factor to driver workload that has been recognized by researchers but not often used in the determination of driver workload is the operating speed the driver adopts. Senders et al. (16), (later confirmed by McDonald et al. (12)) have shown that as the operating speed increases, the attention demand of the road also increases. Van der Horst & Godthelp (17) reported an experiment in which subjects drove on a tangent section at different speeds with voluntary visual occlusion (a measure of visual demand). The results showed that as speed increased, drivers' visual occlusion time decreased. In other words, drivers paid more attention to the road, an indication of a higher visual demand from the road. Cnossen et al. (18) made subjects drive a simulator at a slow speed (accurate), a fast speed, and when following a lead car, with or without a memory task. The effect of the speed scenarios and the memory task on driver workload was estimated using different workload measures (performance, subjective, and physiological measures). The conclusion was that as speed increases, driver workload increases.

Despite the evidence about the relationship between driver workload and operating speed, some measures and applications of driver workload have used complexity of the roadway as the only determinant of workload (11, 13). Where driving speed is considered, it is mostly kept constant in field or simulated driving tests (13). In experiments to determine appropriate measures of driver workload, de Waard (11) observed decreased workloads in complex road situations, and attributed it to the ability of the driver to adjust speed in order to keep overall workload within capacity. It would therefore be very difficult to determine absolute measures of driver workload without speed considerations.

The general workload literature has identified psycho/physiological factors, load intensity and time constraint as the main determinants of operator workload (7). In the case of driver workload, the time constraint aspect is induced with the operating speed. The information utilized by the driver to make driving decisions may be concentrated at one spot (as for a narrow bridge or a lone intersection), but road design information sources are mostly distributed on a per kilometre basis and are therefore expressed as such. For example, curvature is measured in degrees per kilometre and we can measure intersection effect in terms of the number of intersections per kilometre. Hilliness and bendiness are measured on a per kilometre basis as well as is the roughness of the road surface.

The information due to these various complexities of the road can therefore be normalized in one unit such as bits of information per kilometre. Therefore, if a road segment has for instance, H bits of information per kilometre and two drivers traverse this road segment at 50km/hr and 80km/hr respectively, it is obvious that the time available to the slower driver to process the information imbedded in one kilometre is more, and will therefore involve less time pressure. The first step towards the development of any predictive model of driver workload should be the incorporation of at least time constraint (speed) and road complexity.

Driver speed behaviour also seems to suggest that the driver may use speed to regulate experienced workload. If this controlling ability of the driver is not considered in workload assessment, then association between road design elements and workload cannot be established. This controlling ability is known as adaptation in the workload literature and its influence in driver workload assessment is more direct, making driving to be termed as a self-paced task.

From the above assessment, driver workload may be driven by the following factors:

a. Driver state: affected by fatigue, drugs (including alcohol), age, experience
b. Road environmental factors: including road layout (design), surface conditions, traffic, etc.
c. Intelligent Road Information Systems, and
d. Adaptive strategies: including speed and its management.

It may not be easy to quantify the effects of all of the above; especially driver state factors in a model, which may result in some aspects of generalization. However, a large proportion of road factors, speed and its adaptive control are quantifiable to some extent and should be considered in any model of driver workload.

ADAPTATIVE CONTROL IN DRIVING

Mental workload may be related to external task demands and operator abilities, but it is also mediated by the operator in order to counteract the stressful effects of tasks. Mediation can be by way of mobilizing additional resources to match task demands, or choosing processing structures which place fewer demands on the operator's processing capabilities, or direct physical intervention of the operator as in air traffic control (operators can redirect aircrafts to other operators to reduce workload). This mediating capability of humans in human-machine systems has generally been termed "adaptation" (19, 7, 20).

Driving has long been considered a self-paced task (21, 22, and 23), making it one of those areas of human activity where there is a high possibility for adaptation. It starts from planning the journey right up to arrival at the destination. To some extent, the driver can choose the time of day the journey can be made in order to avoid being in heavy traffic and can make a choice among available routes in order to make the journey easier. In addition, the choice of mode of transport is also available, all adding together to determine how convenient the journey can be.

The adaptive capabilities available to the driver have been explained in many theories ranging from car-following models (24), to the risk models of Naatanen & Summala (21, 22), and Wilde (23). The driver generally reacts to situations on the road, whether due to traffic or road layout, by adjusting behaviour either in terms of speed or steering action.

In most cases, the driver is able to adapt efficiently and can complete the journey without any incidents despite the numerous possibilities. There are however times or situations when the driver will fail to adapt adequately, and accidents may result. Some design situations may cause the driver to adopt speeds that result in workloads far in excess of the driver's information processing capacity. The problem for design is to understand how drivers adapt, and how they sometimes fail in adaptation, so that design can be tailored to aid the driver to adapt adequately. A model of driver workload, which considers all the determinants and also includes adaptation, could be the key to the solution of this complex problem.

A Driver Workload Model Development

Assuming that driver workload depends on road complexity and the time constraint function of driving speed, Navin et al. (25) developed a driver workload model combining these components. The concept is based on human information processing theory, which assumes that the human has a limited information processing capacity (or capacities from Wickens' (26) multiple channel theory).

Since most road complexity measures are defined on a per kilometre basis (e.g., curvature, bendiness, roughness, hilliness, etc), a road section having an information content of B_r bits/km was assumed (16). Taking Hendy et al.'s (7) time pressure approach to workload; and assuming a limiting driver information processing capacity of C bits/sec, the time T_r, required to process the road information is given by

$$T_r = \frac{B_r \text{ bits/km}}{C \text{ bits/sec}} = \frac{B_r}{C} \text{ sec/km} \quad \ldots\ldots (1)$$

That is, the shortest time for the driver to traverse 1km of the road is $\frac{B_r}{C}$ seconds.

Therefore,

$$T_r = \frac{1}{V_r} \text{ sec/km} \quad \ldots\ldots (1a)$$

V_r is the required maximum speed.

If for any reason the driver traverses the road at a speed of V_a km/sec, then the time available, T_a, to process the information is given by

$$T_a = \frac{1}{V_a} \text{ sec/km} \quad \ldots\ldots (2)$$

The information processing load or time pressure (TP) is given by (7)

$$TP = \frac{T_r}{T_a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3)$$

From Equations 1 and 2

$$TP = \frac{1}{V_r} \div \frac{1}{V_a} = \frac{V_a}{V_r} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3a)$$

TP can also be expressed alternatively in terms of relative demand for processing resources. The rate of information processing demand (RID) can be expressed as the ratio of the total information and the time available to process it.

$$RID = \frac{B_r}{T_a} = B_r * V_a \text{ (bits/km * km/sec)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots(4)$$

$$TP = \frac{T_r}{T_a} = \left(\frac{1}{C}\right) \frac{B_r}{T_a} = \frac{B_r * V_a}{C} = \frac{RID}{C} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (5)$$

For a curved section having a curvature of D degrees/100ft, the information load B_r bits/km can be expressed as a function of D, that is, $B_r = f(D)$. Then TP will be given by

$$TP = \frac{T_r}{T_a} = \left(\frac{1}{C}\right) \frac{B_r}{T_a} = \frac{f(D) * V_a}{C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... (6)$$

or

$$TP = \frac{f(D * V_a)}{C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots... (6a)$$

Equations 5 and 6 define workload, i.e., the proportion of the operator's information processing capacity that is used to perform a particular task. Assuming capacity, C to be constant for a particular driver, the equations suggest that driver workload is a function of road complexity (degree of curve in this case) and operating speed.

Channel overload occurs when TP>1. Operators are known to adopt various strategies when TP>1. The theory of adaptation suggests that drivers adapt operating speeds to deal with high task demand situations, or to adapt workload to some convenient level, which can be determined by modeling driver speed behaviour with respect to workload.

A theoretical approach is presented below with regards to driver speed behaviour with respect to horizontal curvature. Equation 7 is the general form of driver speed behaviour with respect to curvature normally used in design consistency studies (27). Other mathematical models (28) have been used but the general trend is, as curvature increases, speed reduces.

$$V = A - b^*D \qquad (7)$$

where $V = 85^{th}$ percentile operating speed,

D = degree of curve in degrees/100ft

A = a function representing the maximum speed attainable on tangents

B = constant.

When drivers adapt speed with respect to curvature, they are also adapting the rate of information processing demand (RID). So, by studying RID with respect to speed adaptation, we should know what it is being adapted to.
From Equations 5 and 6, RID is given by

$$RID = f(D^*V_a) \qquad (8)$$

$$RID = D^*V_a/c \qquad (8a)$$

where c is a constant that must be determined.

For a successful speed management strategy, $V_a = V$ (the 85th percentile speed), and combining Equations 7 and 8 gives

$$RID = \frac{(aV_{max} - bD)D}{c}$$

or

$$RID = \frac{aV_{max}}{c}\left(D - \frac{D^2}{D_{max}}\right) \qquad (9)$$

Similarly, by substituting for D

$$RID = \frac{D_{max}}{c}\left(V - \frac{V^2}{aV_{max}}\right) \qquad (10)$$

Equations 9 and 10 are expressions of the demands on the driver due to the speed adaptation in Equation 7. The equations suggest some maximum value of RID, RID_{max} (FIGURE 2) which the idealised driver is striving to maintain with the speed management strategy. Design should therefore be tuned so that RID_{max} is not exceeded with any combination of road complexity and operating speed.

Determination of RID_{max}

In order to set workload criteria for design, the value of RID_{max} must be determined in addition to estimates of driver workload. Navin et al. (25) investigated driver workload for various combinations of curvature and operating speed, and for possible speed management strategies adopted by drivers. In a test track experiment, they instructed drivers to drive at speeds ranging from 30km/hr to 100km/hr, and speed scenarios that would normally be adopted by “late” and “leisure” drivers. The late driver scenario was replicated by instructing subject drivers to drive as if late for an important interview whilst considering safety. For the leisure-driving scenario, the instruction was to drive as if they were having a Sunday afternoon leisure drive.

RID was measured in terms of attention demand (workload), that is, the attention the road was demanding from drivers for various combinations of speed and road curvature. A full description of the experiment is reported elsewhere (25).

The attention demand (AD) was measured using the secondary task performance measure of random number repetition. Subjects drove the test track whilst repeating random numbers generated from a mini computer. The percentage of numbers repeated whilst driving the test track was compared with the percentage repeated whilst the vehicle was stationary. The attention demand was estimated as follows:

Let the percentage of numbers repeated correctly when the vehicle is stationary be C%, and for a particular speed/curvature combination on the track, let the percentage be X%.

The attention demand, AD is given by:

$$AD = \frac{C - X}{C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(12)}$$

For X = 0, AD = 100% and for X = C, AD = 0%

The results of the experimental evaluation of the Navin et al. (25) study are reproduced in FIGURE 3 and 4. FIGURE 3 can be used to determine driver workload for various combinations of curvature and speed. FIGURE 4 agrees with the theoretical derivation shown in FIGURE 2. FIGURE 4 indicates that, on the average, the late driver accepts a peak attention demand (workload) of about 75% when tracking horizontal curves of various radii. The peak attention demands for the leisure driver and the 85th percentile driver on the road are about 45% and 50% respectively. From a further analysis of the raw data, the study reported that when familiar with the road, late drivers would accept attention demand levels of about 80%, whilst unfamiliar late drivers accept about 65% demand on their attention.

The Navin et al (25) analysis shows the levels of workload to which drivers (under different driving situations) would normally pace themselves. The fact that the different peak values of workload prevail for different driving scenarios supports the suggestion that operating speed should be considered when workload is assessed. The workload experienced on the road can no longer be estimated as a static phenomenon that is based on design complexity alone.

Traffic on the road comprises of drivers with several motives. At the extreme end, drivers could be late for any one of numerous human activities, and would therefore adopt higher speeds. They would however manage this speed relative to the complexity of the road so that the workload generated by the speed/road complexity combination does not exceed the effort they are prepared to invest. At the lower end of the spectrum, leisure drivers would seem to have spare capacity most of the time and may therefore present little cause for concern. Design normally provides for the 85th percentile driver so that a majority of the driver population is covered. The aspired limit of the 85th percentile driver may therefore be taken as the design value. The upper limit may seem to be set by the limit of the late driver, and since the unfamiliar driver would normally experience higher workload than the familiar driver for the same road situation (25), the unfamiliar late driver may determine the upper limit.

The above analysis shows that at some points along the road, the driver may have some spare processing capacity as indicated by the shaded area. The apparent spare capacity for the high curvature sections of the road could be as a result of more cautious speed behaviour in the face of high load intensities. This is however the region where mishaps are high, because more often than not, driver speed management strategy fails when driver expectancies are violated. The resulting inappropriate speeds combine with the high curvature to cause very high workloads. The presence of spare capacity in this region represents the situation where driver speed management strategy is working, and cannot therefore be used for design purposes.

At low levels of curvature (or road complexity), higher speeds are required in order to attain capacity. Drivers may however be limited by the capability of the vehicle, speed limits or caution. Drivers have been known to attend to other non-tracking tasks in this region, implying that this region could be used in a more controlled manner for the introduction of in-vehicle information systems. Some countries are legislating a total ban on the use of cell phones in the vehicle. This may not be the case when used in a controlled manner in conjunction with a user interface.

APPLICATION TO THE DESIGN OF USER INTERFACE FOR IN-VEHICLE INFORMATION SYSTEMS

The effective utilization of in-vehicle information systems has long been linked to the development of a central coordinating interface. The interface estimates workload from the road, as well as from the various sources of information (5, 29, 30), and then schedules the information both spatially and temporally so that driver workload is not exceeded. The main obstacle to this has been the lack of proper methods for the estimation of workload coming from the primary task of driving as well as from the information systems. After workload is estimated, the need still exists to determine the extent to which the driver can be loaded when all the sources of workload (road complexity and information sources) are put together. This might suggest the so-called workload “red-line” (11), but according to the results of the Navin et al (25) and the underlying theory, the driver on the road could be aiming at some workload level less than the red-line value that might be associated with that of a late driver.

Armed with a means of estimating the workload due to road design and an idea of the loading limits of the driver; driver interface design becomes a bit more interesting. Interface design used to be limited to establishing whether there is extra processing capacity to accommodate the information before it is scheduled. If there is limited spare capacity, the information is postponed until spare processing capacity is available. This need not be the case, especially if the role of operating speed as a major contributor to experienced workload as well as its use as an adaptive tool is accepted. For information that is crucial, especially to safety, the driver can instead be instructed to reduce speed in order to accommodate crucial information. The future interface can be designed to be more of a CARING INTERFACE type rather than just a regulator. The modalities for the operation of such an interface are explained below.

MODALITIES FOR THE OPERATION OF A MORE CARING DRIVER INTERFACE FOR IN-VEHICLE INFORMATION SYSTEMS

According to FIGURE 5 the driver interface is in communication with the road, the various in-vehicle information devices, the vehicle, and the driver. From the information on the road regarding design (whether in a sharp curve, built-up area, intersection) and the speed of the vehicle, the ***ESTIMATOR*** makes an estimate of the amount of attention (AD_R) the road is demanding from the driver. This is continuously being compared (by the ***COMPARATOR***) with the processing limit (AD_L) of the driver to see whether there is any information-processing mismatch in this first instance. If there is a mismatch, the ***SCHEDULER*** sends information to the driver, probably by audio, to adopt a speed (the required speed V_r in Equation 1a) appropriate for the complexity of the coming road. Interface design is being employed in this case at points where off-line design fails to make the driver adopt speeds that respect the safe loading limits.

When information is available from the IRIS devices, the ***ESTIMATOR*** prioritizes the information and calculates the attention demand (AD_D) from the device whose information is in line to be presented to the driver. The ***COMPARATOR*** adds the device attention demand to the road attention demand (AD_R) provided the latter is less than the driver's limit in attention demand AD_L, to arrive at the total attention demand (AD_T). AD_L and AD_T are compared to see if there is any mismatch. If there is no mismatch, meaning that the total attention demanded is less than the driver's limit, the information is presented to the driver. If there is any mismatch, the ***SCHEDULAR*** does not immediately postpone the information in case it is very important for safety or operational purposes. If the driver is approaching a curve at a high speed that might cause rollover or skidding, this information cannot wait. Also if the driver is about to miss an exit that may cause serious operational problems (which sometimes leads to safety problems), the information cannot wait. Instead the driver is warned to reduce speed in order to accommodate the crucial information. This way, the interface is acting more like a caring device, that is, it is trying to keep the driver out of critical workload situations.

The information source could also be from a cell phone connected to the interface. The caller is informed about the driver's state and instructed to express priority of call by pressing 1, etc. if the driver is a medical doctor, then depending on the urgency of the call as punched in by the caller, the system would instruct the doctor to reduce speed to receive the vital information.

CONCLUSIONS

The direct link between crash risk and driver speed behaviour has been the subject of many research projects (31, 32). Drivers adopt inappropriate speeds either intentionally or because of driver expectancy violations brought about as a result of faulty design. One source of driver workload, design inconsistency, is directly related to operating speed differentials induced by faulty design.

Design consistency theory provides a direct link between driver workload and the driver's operating speed. It is also obvious that the normal tracking task, which involves receipt of information from the road, processing of this information, and the adoption of control actions becomes more difficult as the operating speed increases. Speed regulation would therefore prove to be an effective remedy for the driver workload problem.

The solution for design inconsistency is the harmonisation of design so that speed differentials between successive road design elements are reduced to a minimum. This off-line design solution is inappropriate with the addition of other sources of driver workload not related to road design, that is, those coming from road system information sources. The current practice of driver interface design which schedules the additional workload sources has however continued to treat the workload coming from the road as a static phenomenon; using look up tables to estimate the workload. The theory of driver workload suggests differently, tying experienced workload to the operating speed of the driver.

The driver interface design proposed in this paper also relates the solution to the regulation of the driver's operating speed. When in operation, it will prove to be a more superior tool as it covers both off-line and on-line design solutions. Another advantage is that it provides a more CARING SYSTEM. It is sensitive to vital, life saving information whilst still considering overall safety.

Enforcement of the appropriate speed has mostly been through legislation and road design measures, but it is slowly moving into the realm of information technology. Truck rollover warning systems and the active accelerator pedal are good examples. The application to the driver workload problem however needs further research related to the relationship between driver workload, operating speed and other road design elements.
The determination of the driver workload from road system information system sources also needs further investigation.

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FIGURES

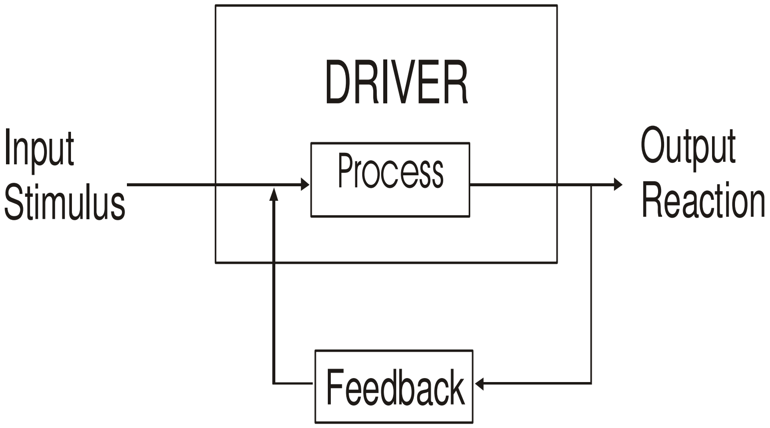

FIGURE 1 Driver Model as a Single Processing Unit

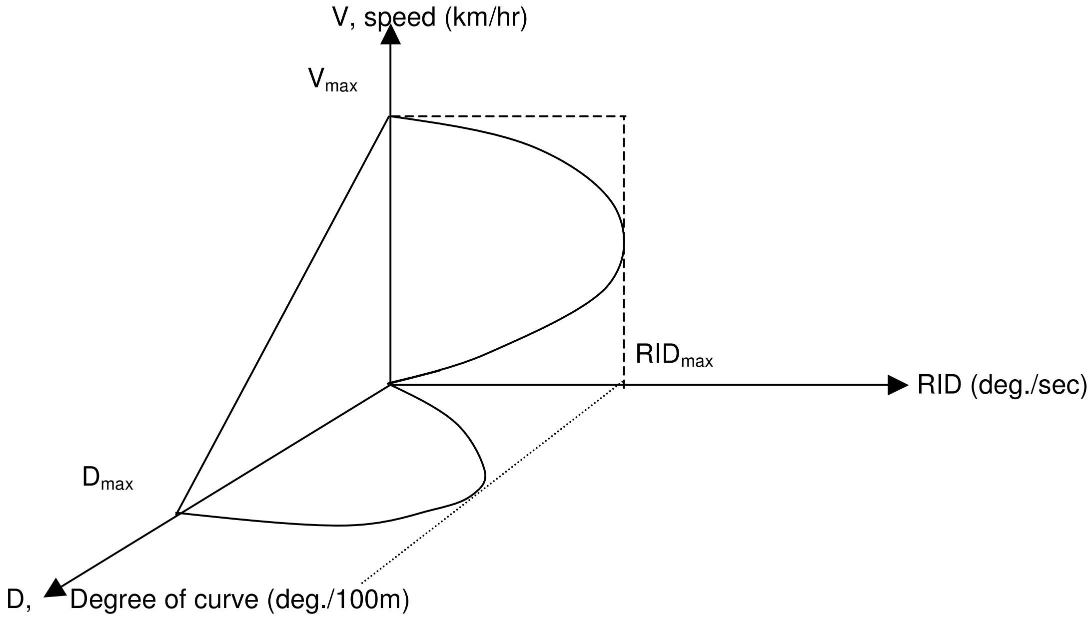

FIGURE 2 Graphical Representation of the Relationship amongst Curvature, Speed and Rate of Information Demand (RID).

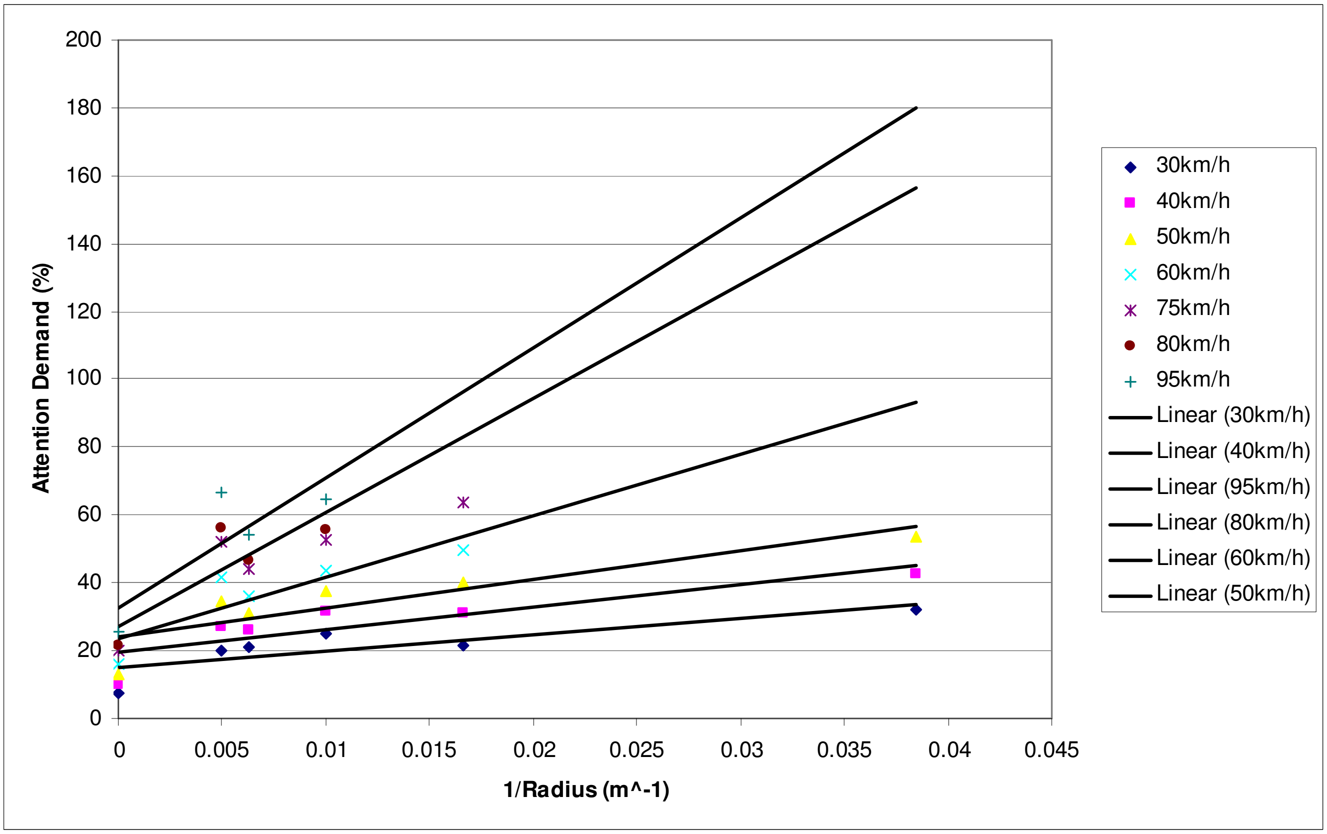

FIGURE 3 A Comparison of the Relationships between Attention Demand and 1/Radius for Various Speeds (25).

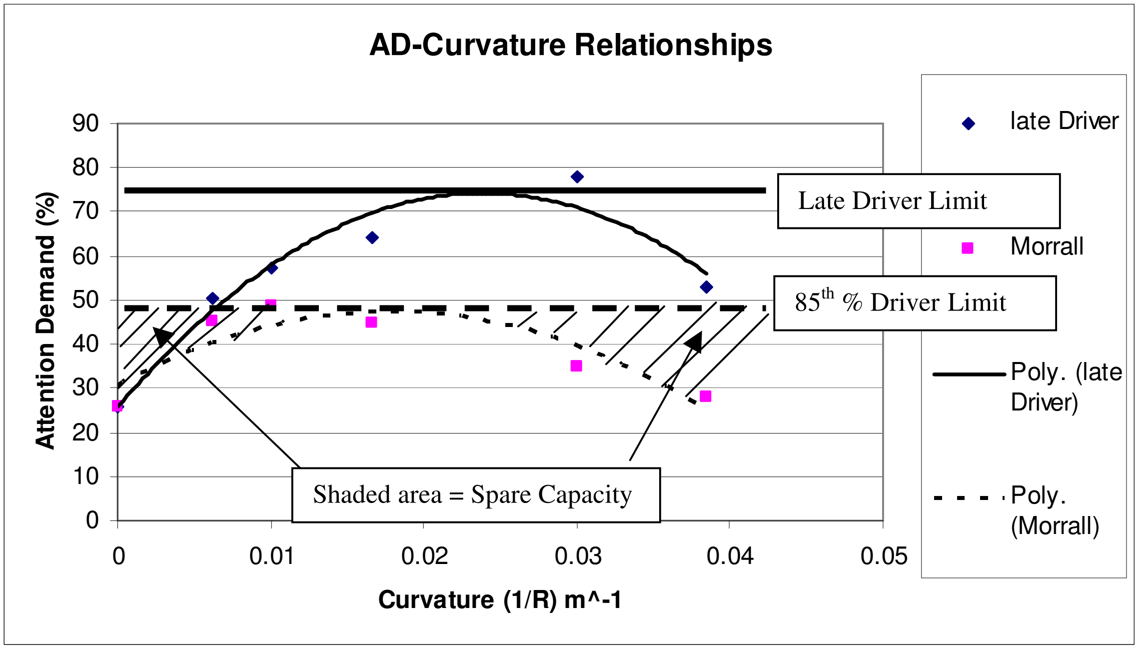

FIGURE 4 Self-Adaptive Driving Limits

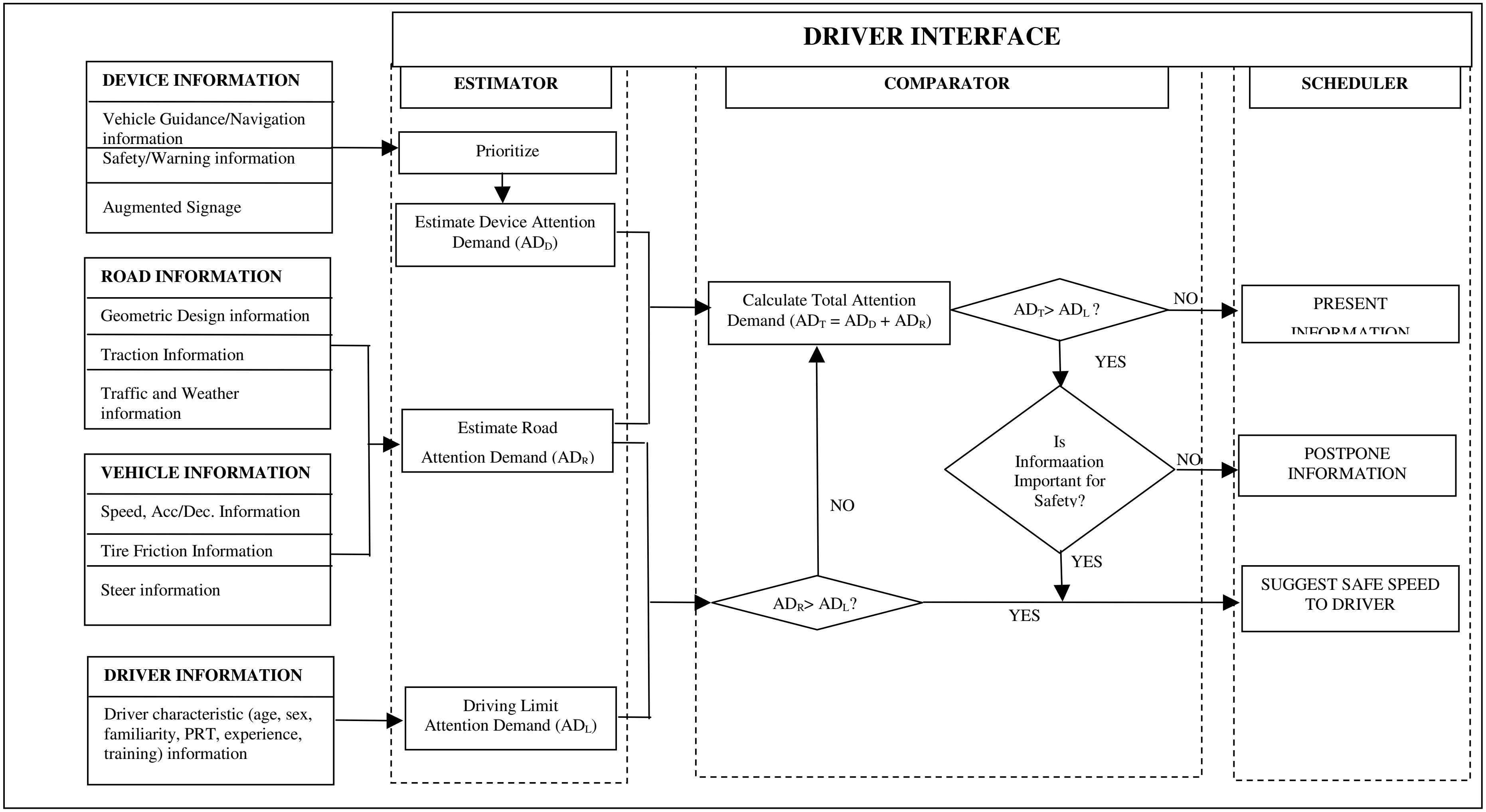

FIGURE 5 A Caring Adaptive Driver Interface