INSA AI Assisted Driving Usage Based Liability Insurance

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Abstract

The following discussion addresses Levels 1 -3 of Autonomous Driving that are currently posed as entry levels to Autonomous Driving. We delve into their current attributes showing that these Levels as currently specified are a non-deterministic statement of functionality and hence not a suitable statistical quantum for usability-based liability rate setting.

We proceed then from an INSA perspective by defining corresponding to Levels 1 – 3 functionality the nomenclature of AI Assisted Driving. (pages 2 – 7)

AI Assisted Driving will incrementally evolve from competing Autonomous Navigation Solution Providers and will, over-time, functionally span the facilities current outlined in Autonomous Levels 1-3.
AI Assisted Driving also is deterministic to the degree that for each Solution Provider's package as installed by subject insured vehicle, we can use statistical methods to perform usability-based liability rate setting.

We then proceed to show how AI Assisted Driving lends itself into being subdivided into four separate liability domains. Each domain is quantifiable via its respective set of INSA Quality Metrics.
(pages 8 –13)

A formula is then derived whereby the appropriate weighted Quality Metrics of each domain are respectively assembled into representative Composite Quality Metrics for statistically mapping usage-based liability rates. (pages 13 – 21)

We then show how the AI Assisted Driving Quality Metrics can be used as Crash Forensic Tools to infer whether the driver or the AI package is the most likely cause of the liability issue. (pages 21 -22)

Introduction

In the following discussion we will detail the INSA based methodology for Usage Based liability rate setting for a composite of mileage accrued under **Manual** – human/operator/driver control (Level 0) and **Autonomous Driving Levels** *1 through 3*[1] where "Level" reflects the current scheme for inferring the extent of driver non-direct control of the vehicle. In the vernacular the term "Autonomous" is used to class this deferral of some degree of hands-on driver control to an AI based system.

To focus on the rate setting for what is currently classified as Autonomous Levels 1 – 3, we start with Figure 1, from the Society of Automotive Engineers (SAE). The SAE summarizes functionally the domains of the respective Levels of AI control (Column 3) and shows the corresponding decreasing domains of operator responsibility (Columns 4 - 7) as the Level increases.

Using the SAE table as a starting point however, if one researches the literature, it quickly becomes apparent that no industry-wide agreement exists on the precise specification of respective features of each Level[2]. Hence for the foreseeable future the precise domains by Level of driver versus AI control will tend to differ by navigation solution provider – of which there are currently about half a dozen major players: Waymo/Google, Mobileye/Intel, Tesla/Autopilot, GM/Cruise, Mercedes/Drive Pilot, BMW/Personal-Copilot, etc.

This lack of uniform functional definition is the first complication in simply mapping a vehicle operator's liability or vendor Product Liability to a premium rate based simply on AI Level.

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[1] AI Levels 4 -5 represent fully autonomous operation. These Levels, as currently depicted, do not require a priori that the operator maintain an on-demand fallback role to intervene and re-assert vehicle control.

Level 4 differs from Level 5 AI navigational control in that on occasion from the outset of a transit to a destination, the System will specify well in advance part(s) of the route as requiring driver/operator intervention because of core AI issues such as limited data communication, insufficient map database resolution or weather. However, when under AI Level 4 -5 control, accidents would reflect "product liability" where INSA Usage Based Product Liability Insurance. http://www.imageautomationltd.com/insa/documents/Autonomous_Vehicle_Useage_Based_Product_Liability_Insurance.pdf uniquely provides a usage-based rate setting model.

[2] A good example of the current lack of industry accepted standards is the Level 1 feature of "self- parking". Current systems, e.g., Volvo, Mercedes, Cadillac etc. -- differs in how they handle right vs left side parallel street parking, 60 degree parking and responsibility for breaking during parking.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Figure 1: Levels 1 - 5 of Autonomous Control by Definition and by Specification Domains of System and Driver Control
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Secondly, since no such precise industry specification or certification of AI Levels exists or is likely to exist in the foreseeable future, AI Level as a parameter in rate setting is "non-deterministic."[3] At every AI Level, a vehicle`s operational handling as it navigates traffic/road realities will differ by navigation solution provider vendor and, as we will explain, actually on a day-by-day basis!

The propensity for such AI based vehicle control to subtly change even daily stems from the operational reality that all AI Levels represent a massive technology and computational challenge.

[3] Deterministic as used in this paper refers to the mathematical and statistical property of a system whereby ". A deterministic model will thus always produce the same output from a given starting condition or initial state".

Current estimates size the AI autonomous control code base, just the part that resides in the vehicle,[4] (exclusive of the Server) covering the mission critical control functions:

- AI dynamic control logic,
- map database management,
- sensor data management,
- man/machine interface
- communication,

as exceeding *400 million lines* of executable code with an embedded coding error totaling likely in the tens of thousands.

Such a mass of complex functionality will be constantly evolving almost daily with algorithm tuning, design changes, and the continuous fixing of code errors[5]. This background maintenance process makes each vehicle's AI control characteristics, independent of Level, a moving target[6]; even on a day to day basis and hence adds another dimension, making AI Level as presently posed by the industry, non-deterministic and not in itself a suitable quantum to statistical use for rate setting – either operator/driver liability or product liability.

Lastly, Levels 1-3 are distinct from the truly autonomous vehicle control of Levels 4 – 5 by requiring integral to their operation a mode of operator/driver re-engagement when their AI and sensor input indicates they can no longer maintain safe vehicle control. This handover of control and "the events directly before and after" the system senses control issues, is the nexus of key Level 1-3 autonomous driving man versus AI/machine liability issues.

Each autonomous driving solution provider's "control algorithms" have different instantaneous criteria for defaulting back to the operator/driver control as well as different methodology for "signaling" to get

[4] https://techcrunch.com/2017/07/25/artificial-intelligence-is-not-as-smart-as-you-or-elon-musk-think/

[5] Daily updates will be required to avoid legal liability that could result from having deferred computer code error corrections updates and/or algorithm enhancements from entering service on the earliest occasion.

[6] There is also no assurance that every vehicle has update its AI driving package to the manufacturer specified code release level. This apples and oranges diversity of software update status in the field is analogous to that presently affecting PC operating systems.

operator attention that a hand-over of control is required.

Integral to this train of AI generated awareness that a control problem exists, liability has to contend with the nexus of receding AI control and the “characteristics displayed” during the simultaneous default to the operator/driver. The characteristics of these events will be totally unique by vehicle, road conditions and driver -- reflecting human traits of driver awareness, skill and mental acuity involved in handling an unanticipated set of dynamic events.

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In summary, the factors above combine to erode any objective meaning of AI Level 1 -3 and make any released Autonomous navigation package, capability-wise, a moving target -- not a defined quantum for statistically inferring liability rates.

Since Autonomous Driving Level 1 through 3 do not lend themselves to deterministic liability rate inference based on AI Level, we will now proceed to detail the **INSA AI Assisted Driving (AAD)** liability model and from the AAD model the **INSA Usage Based AI Assisted Driving Insurance (UBADI).**

Note: We will no longer refer to Levels 1 – 3 but rather we will mean in the AAD and UBADI the *then current* AI Assisted Driving package in an insured vehicle[7].

INSA AI Assisted Driving Liability Model from an AAD Liability Model we begin by conceptualizing each period of AAD, from start of AI assuming vehicle control, through resumption of driver control as an INSA UBADI event. The driving safety of each INSA UBADI event is characterized in a usage-based framework using INSA Quality Metrics[8].

Each UBADI event is also subdivided – Quality Metric data reduction-wise - into the period before and after the “AI default signaling” to the operator/driver to assume control.
(Figure 2)

[7] AI Levels 1 – 3 will of course continue to be used in the literature but cannot be used in deterministically as we have outlined above

[8] Pages 15 – 41 http://www.imageautomationltd.com/insa/documents/INSA UBI Privacy and Driving Quality Metrics.pdf

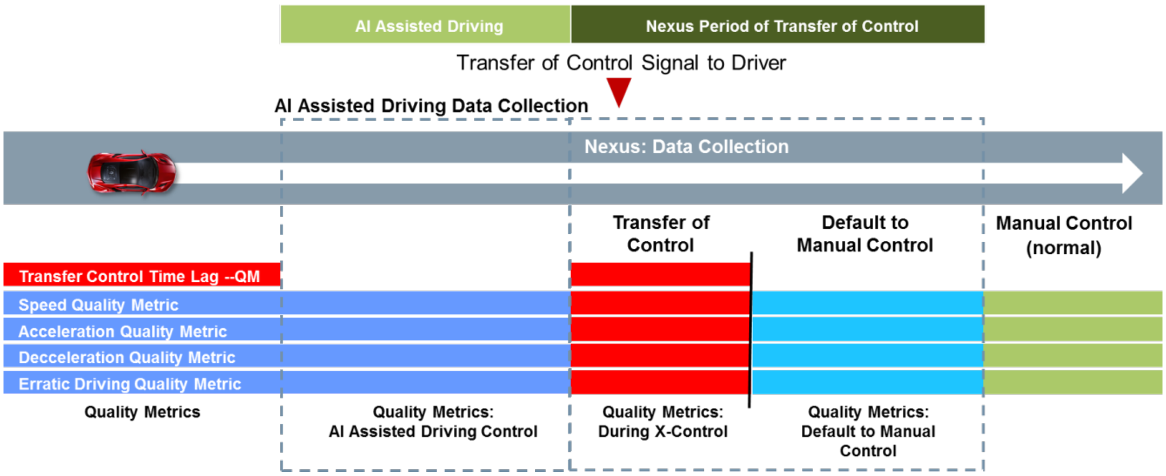

Figure 2: Quality Metrics of Each Risk Dynamics Surrounding Autonomous DEFAULT

An important Open Issue

In proceeding to detail the INSA methodology for mapping AI Assisted Driving to liability rates, two approaches will be detailed because legal jurisprudence and legislative rule making concerning how to treat assisted and autonomous driving liability are still in flux.

Levels 4 -5 control are clearly moving toward being designated Product Liability[9].
Some pivotal states like California[10] however also appear to be shifting the liability focus of even current AI Assisted Driving toward "product liability" even where a driver is mandated by the solution provider as still having a role integral to safe driving.

[9] https://www.axios.com/ai-liability-1529450898-ad632716-0618-472e-a6f6-932a1f9cb2c9.html

[10] https://arstechnica.com/tech-policy/2017/10/heres-how-california-plans-to-regulate-driverless-cars/?amp=1

California's vision for autonomous vehicles

If the car has no driver, then the driver can't be held responsible for accidents, so liability is likely to fall to the manufacturer of the self-driving car. So the new rules require companies deploying self-driving cars to demonstrate they have the ability—either through insurance or their own financial resources—to pay out judgments of up to $5 million in case of a crash involving their vehicles.

Driverless cars need to comply with state and local driving laws, and the new regulations require automakers to certify that they will be able to promptly update car software as those laws change. If the car is sold to a customer, the car company has to make the updates available. But the customer is responsible for making sure the updates are applied.

For vehicles that are sold to customers, manufacturers must explain how they plan to train customers on the safe operation of the vehicle.

Most experts expect early self-driving software to only operate in certain environments, *e.g.*, on pre-mapped roads and only when there's no snow on the road. Fully self-driving cars—defined as "level 3" or higher in industry jargon—will need to either hand control back to the human driver or pull over to the side of the road and stop in unapproved environments or situations. California's laws require manufacturers to describe how their cars will handle these kinds of situations.

Source:https://arstechnica.com/tech-policy/2017/10/heres-how-california-plans-to-regulate-driverless-cars/?amp=1

California axes self-driving car rule that would limit product liability in crashes

Sub-par maintenance won't let automakers off the product liability hook

California has been happy to tweak the rules to get more self-driving cars on the road, but it still has its limits. The state's DMV has eliminated a planned rule (suggested by GM) that would have let companies avoid liability for an autonomous vehicle crash if the machine hadn't been maintained to manufacturer specs. In other words, they could have been let off the hook if your car's sensors were muddy, even if an accident was really due to bad code. The DMV ditched the idea after reading comments objecting to the potential rule. The comment period ends December 15th, and the completed regulations should take effect sometime in early 2018. California's change of heart doesn't amount to a sudden crackdown on self-driving cars, but it does reflect an evolving approach where it's not quite so willing to give brands everything they want. This might also help settle the ongoing questions about liability in driverless car crashes. If owners are less likely to be blamed for accidents, automakers may be more cautious with development in order to avoid paying for costly mistakes.

Source: Associated Press via www.engadget.com

Figure 3: Possible legislation whose scope may include AI Assisted Driving

If this view prevails and AI Assisted Driving is treated as product liability, INSA UBPLI[11] can be directly extended to cover AI Driving Assist liabilities. The details will follow later in this paper.

However, given that solution providers and OEM vehicle manufacturers themselves are starting to push back by referring to their entry-level AI Assisted Driving features as extension of current vehicle accessories like:

- "Adaptive" Cruise Control
- "Camera-based" Cruise Control,
- "Lane-Centred" Steering
- Active Lane Keeping Assist

at least the first wave of AI Assisted Driving, like those that the SAE in Figure 1 are quantified as: Assisted Driving and Partial Automation -- will remain part of operator/driver liability and require a seamless way of combining with the vehicle/driver's INSA Usage-Based Liability Insurance. On this premise we proceed to elaborate on the INSA Usage-based Assisted Driver Insurance.

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[11] http://www.imageautomationltd.com/insa/documents/Autonomous_Vehicle_Useage_Based_Product_Liability_Insurance.pdf

Overview of the INSA AI Assisted Driving Model and its Functional Constituents

We now return to the **INSA AI Assisted Driving (AAD) Model** to explain the data collection that underlies our final formulation of **INSA Usage-Based Assisted Driving Insurance (UBADI)** from which we can map combined Manual and AI Assisted Driving to vehicle/driver specific usage-based liability rates

Returning to Figure 2 we see that we can delineate each episode of AI Assisted Driving into three distinct domains:

1. AI Assisted Driving: Vehicle dynamics are substantially under AI control with no unanticipated issues The Quality Metrics related to vehicle dynamics under AI Assisted Driving are compiled with episode of AI Assisted Driving conceptualized and attributed as a *"Pseudo Driver #1"*:

- Speed,
- Acceleration,
- Deceleration,
- Erratic Driving

Onset: *Nexus of Transfer of Control Issues*

2. Transfer of Control: AI "realizes" it is encountering driving conditions beyond it design limits and "signals" for "Operator Intervention".

The duration between signal and Operator Intervention is measured and for this progressive control *hiatus* we compile and compute

- Quality Metrics for *Transfer of Control Time Lag*
- Quality Metrics for dynamic measures *as above for AI Assisted Driving*

Quality Metrics are attributed to *"Pseudo Driver #2"*.

As can be noted from Figure 2 the time interval for Transfer of Control encompasses a time period before the Signal for Transfer of control. How and why we go back-in-time will be explained when we detail Transfer of Control Quality Metrics in the next section.

3. Insured Driver Reassumes Vehicle Control

A short period of time, e.g. 60 seconds, is designated after the driver reassumes control and for that period we compute Quality Metrics: dynamic measures *as above*

In the preceding three dynamic data snaps shots of AI Assisted Driving spanning normative operation and abrupt transfer back to manual control, we have put a slightly different spin on Quality Metrics: Speed, Acceleration, Deceleration, Erratic Driving and have also introduced a new Quality Metric: *Transfer of Control Time Lag.*

Before we detail how each is combined to achieve a Usage-based liability premium rate by insured vehicle/driver, it is important we explain the role each of the above dynamic snapshots plays in capturing usage-based attributes to usage-based characterize AI Assisted Driving.

Handover Time Lag Quality Metric

Referencing Figure 4: Handover Time Lag Quality Metric, we see a schematic of the process flow. Via this Quality Metric, we are able to quantify the driver's degree of attentiveness as well as effectiveness in design for the critical man-machine aspects of a given AI Assisted Driving package particularly with respect to alerting the driver for imminent transfer of control.

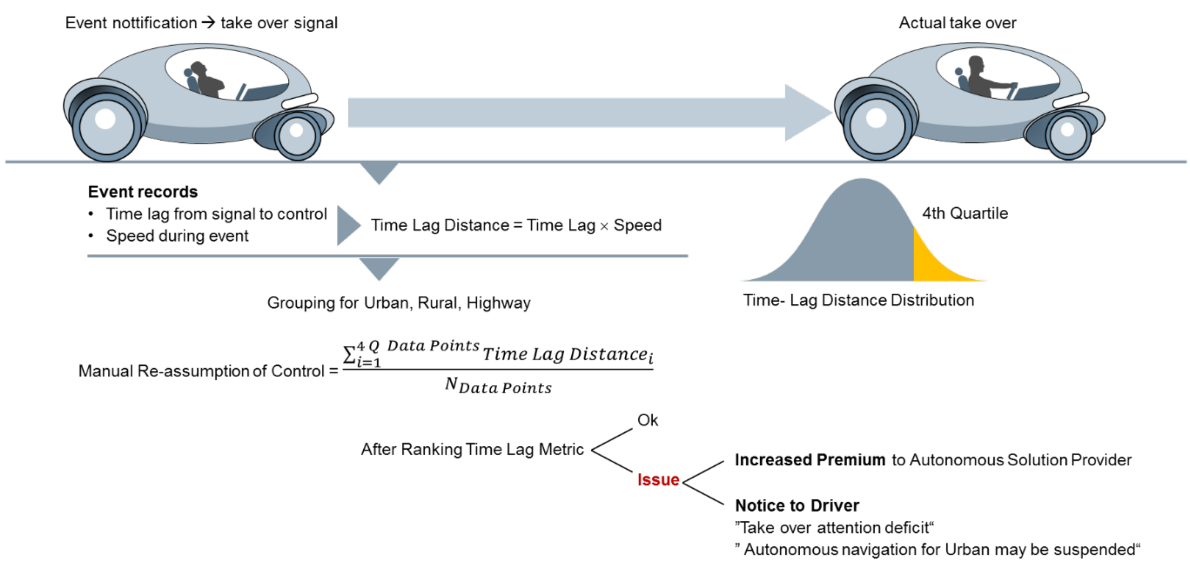

Figure 4: Handover Time Lag Quality Metric

Specifically, Handover Lag Time Quality Metric, reflects the time gap between the driver receiving the signal to intervene and the driver taking actual control of the vehicle. Most importantly, the relevance of each individual event of control handover time lag is relatively weighted by the speed of the vehicle during the time lag. Hence, the magnitude of the handover control time lag has a radically different impact on the eventual INSA usage-based liability rate computation if the *same* time lag takes place at 120 kph versus 20kph.

Like all Quality Metrics, Handover Time Lag events are subdivided by locale: urban, rural or highway. The dynamic that we focus upon capturing with the Handover Time Lag Quality Metric is the intertwined impact of both handover alert design and driver alertness.[12]

In figure 4 we also show that we take only those events that are in the right-hand tail of the curve, for example the 25% worst cases/scores.
The rationale is that we don't expect too many transfers of control and hence we focus on the worst cases which will tend to be the most meaningful in terms of causation of AI Assisted Driving accident event.

AI Assisted Driving Quality Metrics

While the vehicle is under nominal AI Assisted Driving control and no alert has been signalled, we characterize in a usage-based manner the handling of the vehicle by compiling Quality Metrics just as if the vehicle was being driving by a surrogate of the insured driver. The detailed data collection and computation of the respective Quality Metrics is given in the previously cited footnote 11 -- *INSA Usage-Based Liability Insurance using Quality Metrics* and we call the associate surrogate driver: Pseudo Driver #1 Nexus Quality Metrics
Per figure 4, when AI Assisted Driving enters the Nexus of Control Transfer leading to the operator/driver re-assuming control, we generate two separate and dynamically distinct sets of Quality Metrics:

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[12] It is worth noting that the raw time lag and speed data we collect for the Handover Time Lag Quality Metric can also be used separately to assess the relative merit of alternative navigation solution provider techniques for alerting the driver.
This may be a separate area of interest for actuaries and at the moment is beyond the immediate scope of this paper.

a. Transfer of Control

b. Default to Manual

Transfer of Control Quality Metrics

When the AI Assisted Driving control system signals an alert for Transfer of Control, the compilation of the Transfer of Control Quality Metrics begins.

These Quality Metrics are computationally identical to the previously mentioned instances – except that the domain of data collection starts a period of time – e.g., 2 minutes – before the Transfer of Control was signalled and continues until the Operator/Driver reasserts control.

This set of Quality Metrics offers unique insight into the subject vehicle's AI Assisted Driving package's ability to manage the vehicle's dynamics in the indeterminate period until the operator/driver reassumes control. The Transfer of Control Quality Metrics captures how the AI Assisted Driving package proactively senses that the complexity of traffic and/or road etc. is diminishing its horizon of control and how it manages the safety degradation occurring immediately prior to signaling for transfer of control and for the duration until the driver reassumes control.

By capturing the usage-based dynamic events leading up to and transpiring during the AI controlled part of the Nexus Period, these Quality Metric capture critical insight into this highly accident-prone period.

Central to this set of Quality Metrics is that we can actually start the Transfer of Control Quality Metric data acquisition *before* the Transfer of Control alert in signaled. This is done using the data buffer, earlier debuted for INSA Data Capture – specifically Crash Data retention.

As shown in Figure 5: INSA FIFO Data Buffer, all key INSA raw data derived from GPS and continuous Accelerometer readings is stored in the INSA Buffer. Being a First In – First Out (FIFO) buffer design, these data stay resident in the INSA Data Buffer for a duration predetermined by the system specification – in our case as shown in Figure 5 -- 10 minutes.

This provides our ability to start the Transfer of Control Quality Metric before the actual AI Driving Assist initiated Signal for request the Transfer of Control.

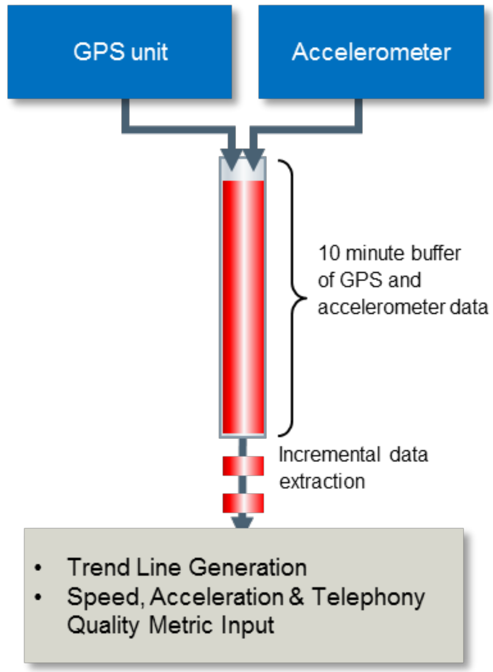

Figure 5: INSA LIFO Data Buffer

Accordingly, the Transfer of Control Quality Metrics captures a unique insight into the vehicle's AI Assisted Driving package.

The Transfer of Control Quality Metrics captures and infers the effect – pro or con – of the degree of proactive sensing early-on that the complexity of traffic and/or road etc. is diminishing its horizon of AI control and how the AI package handles the resulting challenges until the operator/driver re-assumes control. The AI Assisted Driving Quality Metrics can also capture the potential corresponding intensive over-control that may be AI initiated like deceleration or erratic lane changing to manage the vehicle until driver control is re-assumed.

Clearly an AI package's superior proactive determination of need to transfer control and the more effective the signaling approach to alert the driver or the converse of these, will be inferred by the Transfer of Control Quality Metrics. How it factors into liability rate setting will be elaborate upon later in this paper.

Default to Manual Driving Quality Metrics

The Default to Manual Quality Metrics as shown graphically in Figure 4 starts when the operator/driver resumes control of the vehicle[13]. The related Quality Metrics for Manual Resumption are computationally the same as in the prior AI Assisted Driving and Transfer of Control Quality Metrics.

The Manual Re-assumption of Control Quality Metrics captures this important episode of manual control, distinct from Level 0 – traditional Manual control – as the conditions faced by the driver and his response reflect both the sophistication of the AI Assisted Driving algorithm, the effectiveness of the mode of alerting to driver and above all the driver's alertness and skill.

Creating Representative Manual and AI Assist Driving Quality Metric Scores

In this section we assume familiarity with the standard Quality Metrics as detailed in the referenced documentation

http://www.imageautomationltd.com/insa/documents/INSA UBI Privacy and Driving Quality Metrics.pdf

Our objective is to create a set of Composite Quality Metrics for all the Quality Metrics in Table 1 below that will reflect for each Composite both the Manual and AI Assisted Driving done during a usage-based period.

The approach that will follow is one method[14] that reflects, so to speak, the "physics of the problem" and that needs to properly scale and weigh statistical measures before combining them into a Composite.

[13] The assumption is that that like the current OBD port, AI Assisted Driving, will or can be mandated by the insurers to provide an open interface for third party applications. This would provide the cues we need for the Transfer of Control and Manual Re-Assumption of Control Quality Metrics. These are but a few of the many design discussions that must take place between AI Navigation Solution Providers and regulators that insurers need to proactively become engaged with. Also, reluctance of Assisted and Autonomous Navigation Solution Providers to provision their systems with insurer requested access would move the insurance issue for both Assisted Driving and Autonomous Driving to Product Liability as they would preclude individual treatment under the umbrella of vehicle liability.

[14] We assume and welcome trained actuaries either enhancing the formulation to follow or deriving new and novel approaches. The key fundamental though remains the Quality Metric approach to capturing relevant vehicle/driver dynamics for usage-based mapping to liability rates.

Note: As noted in Table 1 Handover Time Lag represents a Quality Metric that only has relevance for Manual operation. Hence it will enter our calculations of a Usage-based Liability Rate only in the last step: http://www.imageautomationltd.com/insa/documents/Monetization of INSA Quality Metrics as Premium Rebates.pdf

Obviously, factors like relative mileage accrued in Manual and AI Assisted Driving modes are key scaling factors and will be directly used in the Composite formulation that follows. However, the focus of the next section is how we proceed to sum up the constituent Quality Metric values for the Domains: Manual, AI Assisted, Transfer of Control and Manual Control Re-assumption for any of the specific Quality Metrics like Speed Metric

Quality Metrics				
Domain	Manual	AI Assisted	Transfer of Control	Manual Default
Speed	Yes	Yes	Yes	Yes
Acceleration	Yes	Yes	Yes	Yes
Deceleration	Yes	Yes	Yes	Yes
Erratic Driving	Yes	Yes	Yes	Yes
Handover of Control Time Lag	Yes	Not Applicable	Not Applicable	Not Applicable

Table 1: Summary of Quality Metric by Driving Domain

In the following explanation we will in fact focus on the Speed Metric and how we would create a single *Composite Speed Metric* that contains the appropriately weighted contribution of both Manual and the respective constituents of AI Assisted Driving. The formulation that follows applies analogously for the remaining Quality Metric: Acceleration, Deceleration and Erratic Driving.

A Composite Quality Metric Formulation

Each of the Quality Metric, with the Speed Metric being our case in point for more detailed discussing, is computed from a large series of separate journey "events" and from the resulting Normal Distribution.

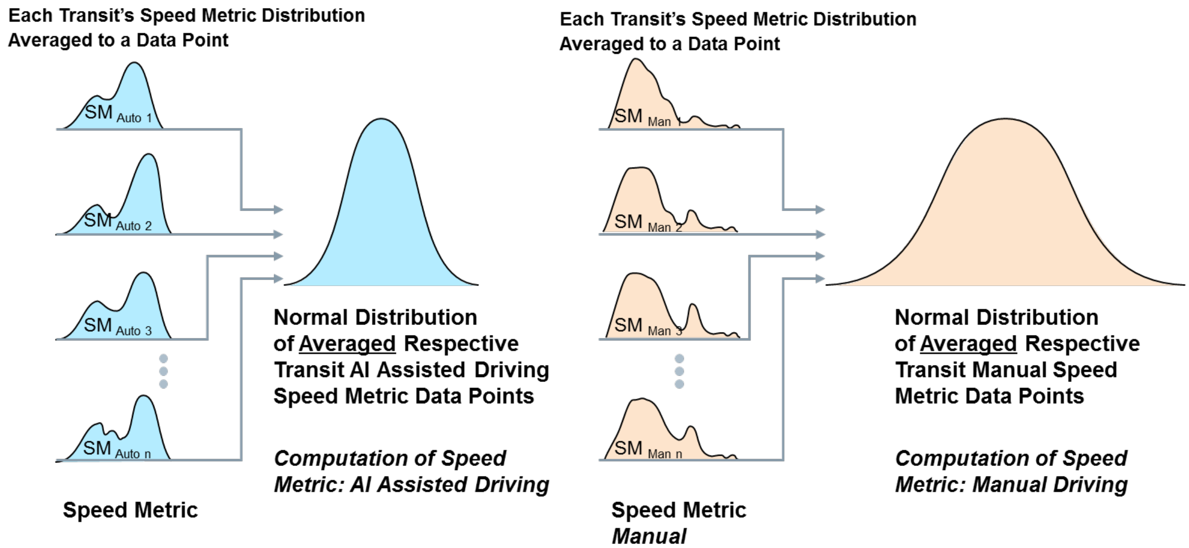

Figure 6: Remapping Transit Quality Metric Events as Normally Distributed Mean Values

The above Normal distributions for AI Assisted Driving and Manual Driving reflect the Central Limit theorem since each random variable used to generate a respective Quality Metric distribution is in fact an averaged value of events measured during a given transit. These respective averages from successive transits – both AI Assisted Driving and Manual Driving – create Normal distributions from which our case in point AI Assisted and Manual Speed Metric values are computed.

At this point we have partitioned the AI Assisted Driving process into a series of discrete usage-based segments and defined a series of Quality Metrics that offer powerful UBI cornerstones for further actuarial inference.

Now our objective shifts to deriving a Composite Quality formula to combine the respective Quality Metrics compiled for the below driving environments (ref: figure 2 and associated text):

- AI Assisted Driving (AAD)
- Default to Manual (DM)
- Transfer of Control (TOC)
- Manual/normal (M)

in a composite formulation giving appropriate weight to their individual characteristics. Hence for our case in point: Speed Metric (SM) -- we would end up with a Composite Speed Metric(SM_{Com}) as a function of:

$$SM_{Com} \rightarrow f(SM_{AAD}, SM_{DM}, SM_{TOC}, SM_{M})$$

Analogously, the derived formulation will also provide us with composites of the other Quality Metrics:

- Acceleration: $ACC_{Com} \rightarrow f(ACC_{AAD},\ ACC_{DM},\ ACC_{TOC},\ ACC_{M})$
- Deceleration: $DCL_{Com} \rightarrow f(DCL_{AAD},\ DCL_{DM},\ DCL_{TOC},\ DCL_{M})$
- Erratic Driving: $ERR_{Com} \rightarrow f(ERR_{AAD},\ ERR_{DM},\ ERR_{TOC},\ ERR_{M})$

Before proceeding further, it is important to note that there are likely multiple alternative formulations that can be derived that will roughly give equivalent composite results that can be used as part of deriving usage-based liability rates for the spectrum of driving that encompasses significant AI Assisted Driving. For that reason, we purposely go into detail on each step of the following derivation. Not only to facilitate understanding, but to support further refinements of the formulations or, for that matter, to find possible errors and oversights

Step by Step Detailed Formulation

We have chosen the following Composite formulation because it reflects, so to speak, the “nature and physics of the problem” of melding Usage Based scoring from related but at the same time disparate modes/distinct sequence of control. The formulation should also remain valid if we change the value of the Quality Metric from for example the mean of the Quality Metric distribution to the median or other measure.

As a starting point and using our case in point: Speed Metric; let’s assume we only have to compound two Quality Metric Domains, **Manual and AI Assisted Driving:**

$$SM_{Com} \rightarrow f(SM_{M}, SM_{AAD})$$

For ease of notation in the following formulations, we list the relevant abbreviated notation in the following Table 2:

Term	Abbreviation
Speed Metric	SM
Composite Speed Metric	SM_{Com}
Manual Driving	M
AI Assisted Driving	AAD
Speed Metric for Manual Driving (M)	SM_M
Speed Metric for Assisted Driving (AAD)	SM_{AAD}
SM_{Com} for M and AAD	SM_{M+AAD}
SM_{Com} for M and DM	SM_{M+DM}
SM_{Com} for AAD and TOC	SM_{M+TOC}
% Manual Driving	$\%_M$
% AAD Driving	$\%_{AAD}$
Variance: M	S_M^2
Variance AAD	S_{AAD}^2
Variance DM	S_{DM}^2
Variance TOC	S_{TOC}^2
More Than	>
Less Than	<
Default to Manual	DM
Transfer of Control	TOC
Percent Accidents under TOC	$\%_{Accident\ TOC}$
Speed Metric for TOC	SM_{TOC}
Percent Accidents under DM	$\%_{Accident\ DM}$
Speed Metric for DM	SM_{DM}

Table 2: Relevant Abbreviations

Proceeding now with the composite of Speed Metric for $Speed\ Metric_M$ and $Speed\ Metric_{AAD}$

Formulation A

SM_{M+AAD}

when: $SM_M > SM_{AAD}$

$= (\%_M) \times SM_M + \%_{AAD} \times [SM_M + (S_M^2/S_{AAD}^2)] \times (SM_{AAD} - SM_M)$

when: $SM_M < SM_{AAD}$

$= (\%_M) \times SM_M + \%_{AAD} \times [SM_M + (S_{AAD}^2/S_M^2)] \times (SM_{AAD} - SM_M)$

In the above two expressions for the Composite of Speed Metrics of Manual and AI Assisted Driving (SM_{M+AAD}) our base value that we build the composite around is SM_M as we expect to have the most experience with manual driving for most if not all the period where *AAD* will debut.

Hence going left to right:

We insert SM_M and weigh it by the mileage accrued under Manual: $\%_M$.

Next, we construct a parenthesis containing a heuristic how to adjust SM_M if we want it to reflect what we have measured about *AAD* – that is SM_{AAD} and S_{AAD}^2 . We do this by:

1. When $SM_M > SM_{AAD}$ then $(SM_{AAD} - SM_M)$ is negative, which implies that not surprisingly the AI controlled speed has led to a lower/better SM_{AAD} value than the SM_M value.
   a) This negative value $(SM_{AAD} - SM_M)$ means that the composite SM_{M+AAD} will score better than SM_M alone would have. However, the true degree of the SM improvement via AAD needs to also reflects the S_{AAD}^2 value.
   b) Hence, we multiply $(SM_{AAD} - SM_M)$ by the ratio of variances (S_M^2/S_{AAD}^2) Given the heuristic sense that lower speed variance – more constant rate driving – is an element of safer driving – we set the denominator to S^2_{AAD}.
   c) If S_{AAD}^2 is indeed lower than S_M^2, then the quantum $(SM_{AAD} - SM_M)$ is further enhanced. If S_{AAD}^2 is greater S_M^2, it is reduced in impact.
   d) The resulting *negative* product $(S_{AAD}^2/S_M^2) \times (SM_{AAD} - SM_M)$ is added to SM_M completing the "square bracket "computation which represents now an "adjusted" valuation of SM_M that is scaled by mileage and added to $(\%_M) \times SM_M$

2. When $SM_M < SM_{AAD}$ then $(SM_{AAD} - SM_M)$ is positive and everything now is the mirror –image of a. above. This implies that the AI controlled speed has led to a higher/worse SM_{AAD} value than the SM_M value.
   a) This positive value $(SM_{AAD} - SM_M)$ means that the composite SM_{M+AAD} will score worse than SM_M alone would have been. However, the true degree of the SM degradation due to AAD needs to also reflects the S^2_{AAD} value relative to S^2_M.
   b) Hence, we multiple $(SM_{AAD} - SM_M)$ by the ratio of variances (S^2_{AAD}/S^2_M). Given the heuristic sense that higher speed variance – more erratic driving – is an element of less safe driving – we set the denominator to S^2_M
   c) If $S^2_M$is indeed lower than S^2_{AAD}, then the quantum $(SM_{AAD} - SM_M)$ is further increased and further worsens SM_{M+AAD} score beyond that of pure manual driving.
   If S^2_M is greater S^2_{AAD}, the degradation of $(SM_{AAD} - SM_M) > 0$ is reduced in its impact on SM_{M+AAD}.
   d) The resulting *positive* product $(S^2_M/S^2_{AAD}) \times (SM_{AAD} - SM_M)$ is added to SM_M , completing the “square bracket“ computation which represents now an “adjusted” valuation of SM_M that is scaled by mileage and added to $(\%_M) \times SM_M$ giving us the composite SM_{M+AAD}.

The relationship SM_{M+AADD} would be a complete composite valuation of SM if:

- Manual driving (M) had been adjusted to also reflect Default Manual (DM) driving
- AI Adjusted driving (AAD) had been adjusted to also reflect Transfer of Control (TOC) driving (while the vehicle was still under AI control)

But these last SM_{M+DM} and $SM_{AAD+TOC}$ can be derived using almost the same formulation as we used for SM_{M+AAD}.

Accordingly, we are following the same format and logic as Formulation A above:

Formulation B

SM_{M+DM}

when: $SM_M > SM_{DM}$

$$= SM_M + \%_{Accident\ DM} \times [SM_M + (S_M^2/S_{DM}^2)] \times (SM_{DM} - SM_M)$$

when: $SM_M < SM_{DM}$

$$= SM_M + \%_{Accident\ DM} \times [SM_M + (S_{DM}^2/S_M^2)] \times (SM_{DM} - SM_M)$$

Formulation C

$SM_{AAD+TOC}$

when: $SM_{AAD} > SM_{TOC}$

$$= SM_{AAD} + \%_{Accident\ TOC} \times [SM_{AAD} + (S_{AAD}^2/S_{TOC}^2)] \times (SM_{TOC} - SM_{AAD})$$

when: $SM_{AAD} < SM_{TOC}$

$$= SM_{AAD} + \%_{Accident\ TOC} \times [SM_{AAD} + (S_{TOC}^2/S_{AAD}^2)] \times (SM_{TOC} - SM_{AAD})$$

Formulations B and C are almost identical with Formulation A that we detailed step by step. Hence, we defer detailing Formulations B and C except for explaining the introduction of the factors: $\%_{Accident\ DM}$ and $\%_{Accident\ TOC}$ and removal of the mileage weightings $\%_M$ and $\%_{AAD}$.

The answer is rather pragmatic. In the circumstance of SM_{M+DM} and $SM_{AAD+TOC}$ both DM and TOC cover such minimal mileage that weighting their respective impacts by mileage would eliminate them from computational impacts on SM_{M+DM} and $SM_{AAD+TOC}$ respectively**.**

Hence, as a factor of weight/significance, we introduce scaling by $\%_{Accident\ DM}$ and $\%_{Accident\ TOC}$ which are the *nominal* percentage of Manual Accidents that occur during DM and AAD accidents that occur during TOC.

$\%_{Accident\ DM}$ can be determined from insurer records by while $\%_{Accident\ TOC}$ c can be gotten initially as a nominal performance parameter requested from respective Autonomous Navigation Solution Providers and updated by insurer records.

Now to complete the Composite of SM reflecting, segmented in Figure 2:

- Manual Driving
- AI Assisted Driving
- Transfer of Control
- Default Driving

We go back to Formulation A and for convenient notation adopt:

- $SM_{M+DM} \rightarrow SM_M^I$
- $SM_{AAD+TOC} \rightarrow SM_{AAD}^I$

Then we can complete the Composite of SM with all four states: Manual, AI Assisted Transfer of Control and Default Driving by using Formulation B and Formulation C to give us SM_M^I and SM_{AAD}^I respectively and then plugging them into Formulation A which now becomes **Formulation A_{prime}**:

Formulation A_{prime}

$SM_{M+DM+AAC+TOC}$

When $SM_M^I > SM_{AAD}^I$

$$= (\%_M) \times SM_M^I + \%_{AAD} \times [SM_M^I + (S_M^2/S_{AAD}^2)] \times (SM_{AAD}^I - SM_M^I)$$

When $SM_M^I < SM_{AAD}^I$

$$= (\%_M) \times SM_M^I + \%_{AAD} \times [SM_M^I + (S_{AAD}^2/S_M^2)] \times (SM_{AAD}^I - SM_M^I)$$

AI Assisted Driving Quality Metrics as a Crash Forensic Tool

With the incremental advent of AI based transfer of driving responsibility from the human driver to the "pseudo AI driver", it is prudent for the insurer view INSA as not only as a usage-based insurance platform but also as the cornerstone for crash forensic investigation to apportion[15] negligence between the insured driver and a third-party AI navigation package. Autonomous Driving creates a whole new litigation "ball-game" that may necessitate the insurer to investigate a client insured driver as well as the "co-AI pseudo driver's role to manage apportioning the insurer's liability in part or whole to a Solution Provider.

The array of INSA Quality Metrics computed for the Nexus of Transfer of Control: AAD, TOC and DM (figure 2), provide a wealth of actuarial and forensic insight and inference. One case in point will now be

[15] Also, to defend a client insured driver and shift the insurer's liability in part or whole to a Solution Provider. Autonomous Driving is a whole new "ball-game" and current litigation roles in auto accidents are very likely to fundamentally change.

elaborated upon related to apportioning accident blame between the human-driver and the AI Assisted Driving pseudo driver.

For these purposes we refer back to INSA Nexus of Transfer of Control dynamic data snapshots:

- Hand-Over Time Lag Quality Metric[16] (HOTL)
- Transfer of Control Quality Metrics[17] (TOC)

Both these Metrics contain a wealth of forensic insight but for brevity we will only at this point focus on simple Null Hypothesis analysis.

Circumstance	Inferred Responsibility
1. If accident occurs under AAD with no attempt to re-engage the driver	AI Solution Provider Product Liability
2. If accident occurs after AAD has attempted to re-engage the driver Null Hypothesis related to: H_0: $HOTL_{Accident} > HOTL_{Average}$	Insured driver Degree related to p_{Value}
H_0: $TOC_{Accident} > TOC_{Average}$	AI Assisted Driving Solution Provider Degree related to p_{Value}

Table 3: Circumstance of accident vs. Inferred Responsibility

AI Assisted Driving as a UBPLI New Business Opportunity

INSA Usage Based Product Liability Insurance (UBPLI)[18] provides a unique Autonomous Level 4 and 5 Usage Based product liability insurance product[19]. Although we have posed in this document INSA Usage-Based Assisted Driving Insurance (UBADI) as the bridge between manual driving UBI personal

[16] Figure 4 and related text
[17] Respective Quality Metrics of: Speed, Acceleration, Deceleration and Erratic Driving -- that takes place under AI Assisted Driving immediately preceding the signaling the driver to resume control until they actually resume manual control.
[18] http://www.imageautomationltd.com/insa/documents/Autonomous_Vehicle_Useage_Based_Product_Liability_Insurance.pdf
[19] At Level 4 and 5 the specification of self-driving-- to the exclusion of the driver -- make them fit the product liability mold much better than AI Assisted Driving where the operator/driver is integral to safe operation

liability and usage-based entry level autonomous driving personal liability, it is premature to preclude that legislation will not edict as "Product Liability" even entry level AI assisted driving packages.

If events take the "product liability" course, INSA positions the insurer to strategically use the concept of Nexus of Transfer of Control and specifically INSA Driving Quality Metrics like formulations C to directly configure an AI Assisted Usage Based Product Liability Insurance offering.

UBADI is not only an actuarial tool but also a cornerstone of new business stability across the auto industry that will be increasingly in flux.

Monetization INSA Quality Metrics as Premium Rebates

The following document, accessible via the internet:
http://www.imageautomationltd.com/insa/documents/Monetization of INSA Quality Metrics as Premium Rebates.pdf

was written over a year ago but is linked to this document because it complements and completes the discussion of mapping INSA Quality Metrics to premium rates. The approach described herein lends itself directly to the Composite Quality Metric we detailed above and the new Handover Control Lag-Time Quality Metric also disclosed in this document.