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PROVING THE CASE FOR SATELLITE DATA AND ITS CONTRIBUTION TO ROAD SAFETY

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WORLD BANK GRSF-FUNDED PROJECT PROVES THE CASE FOR SATELLITE DATA AND ITS CONTRIBUTION TO ROAD SAFETY

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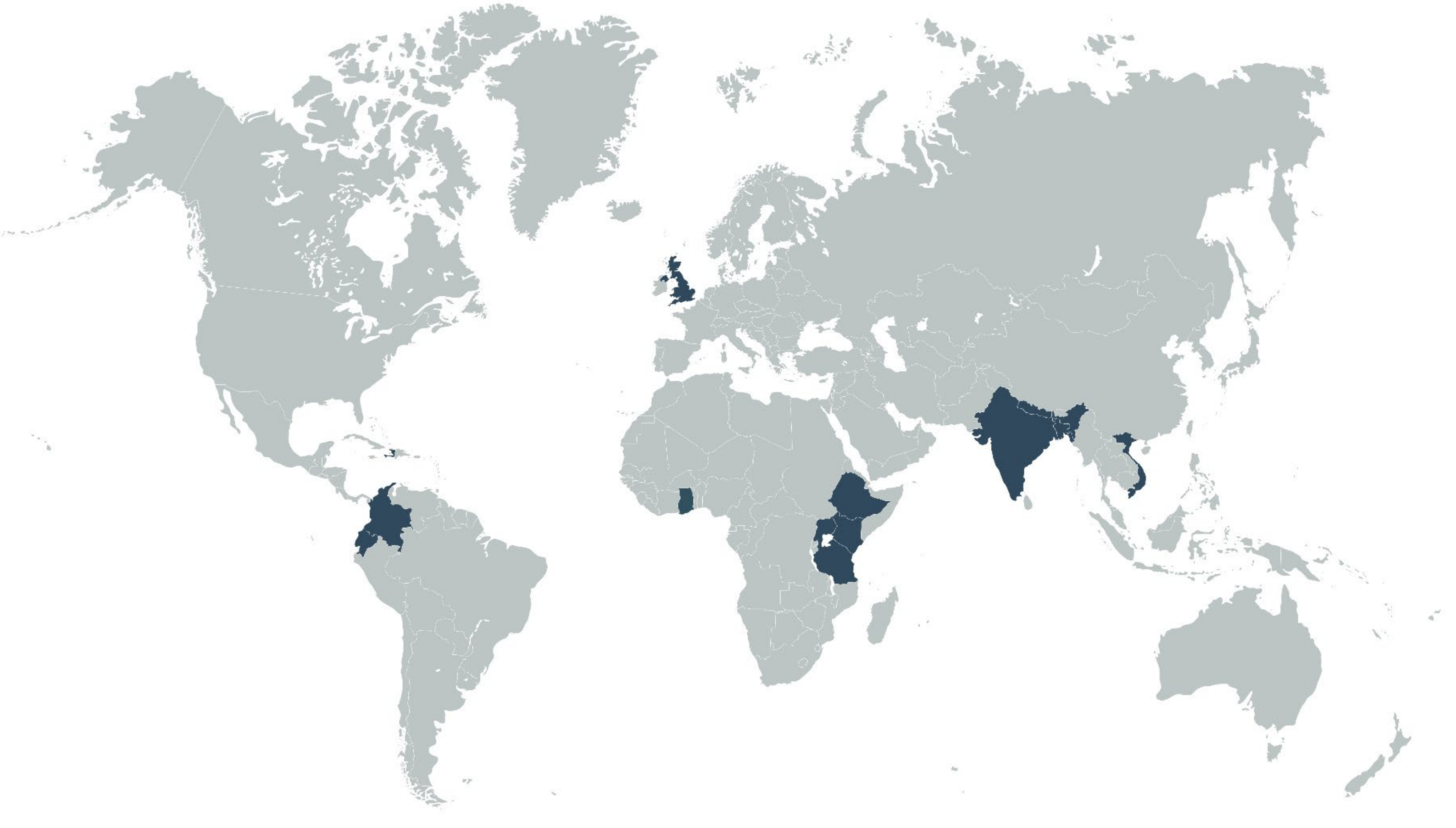


Every year, 1.35 million people lose their lives while driving, cycling, or walking on the road. Another 50 million are seriously injured. As stated in the UN Road Safety Strategy, road traffic crashes are ubiquitous yet invisible. Most of the time deaths and injuries from road traffic crashes remain almost invisible to society at large.

Whereas the global rate of road traffic death is 18.2 per 100,000 population, there is significant variation across the world's regions. Deaths in Africa and South-East Asia are the highest at 26.6 and 20.7 per 100,000 population respectively.

The World Bank (WB), together with the International Transport Forum (ITF) and the Fédération Internationale de l'Automobile (FIA), is working towards the establishment of Regional Road Safety Observatories (RRSOs) worldwide. Improving tools and methodologies to collect reliable data is at the core of this task. Efforts are being made to collect attributes and related key performance indicators (KPIs) for RRSOs that support benchmarking of road safety conditions and allows the measurement and monitoring of outcomes over time.

The agreed Global Road Safety Performance Targets includes Target 4 that by 2030, more than 75% of travel on existing roads is on roads that meet technical standards for all road users (equivalent to 3-star or better) that account for road safety. Target 6 aims to halve the proportion of vehicles travelling over the posted speed limit.

Two key road attributes are vehicle speeds and flows. These two attributes are critical indicators of exposure and risk for all types of road users—pedestrians, bicyclists, motorcyclists and drivers alike. They are also high priority for road safety assessment methods such as Star Ratings.

In high-income countries, this data is commonly available for road networks. Data may be come from permanent or temporary traffic and speed survey equipment, or from other sources such as connected vehicles fitted with GPS or mobile phones. But in low- and middle-income countries (LMIC), data is less readily available, or where it is available, tends to come at a high cost.

Target 4: By 2030, more than 75% of travel on existing roads is on roads that meet technical standards for all road users that take into account road safety.

Target 6: By 2030, halve the proportion of vehicles travelling over the posted speed limit and achieve a reduction in speed-related injuries and fatalities.

Affordable methods of data collection are critical for the success and ongoing monitoring of road safety performance targets. To this end, the World Bank initiated a ground-breaking research and development project to identify and utilise affordable sources of road safety data in Africa.

This award-winning project was delivered by transport behaviour & safety consultants, Agilysis, and the International Road Assessment Programme (iRAP). The first objective was to map where 75% of travel occurs across two countries, Kenya and Ethiopia. The second objective was trial the detection of speed, flow and other physical road features which would allow for the measuring and monitoring of road safety key performance indicators (KPIs).

Agilysis used high resolution satellite images to detect vehicles and calculate speeds. Feature extractions from satellite images is a proven technology used in a variety of sectors including urban development, agriculture and transport. However, it has not yet been proven for road safety.

Satellite data has a number of advantages. The biggest being that it is available globally, and does not require on-the-ground surveys or product deployment for its collection. To prove its viability, testing of feature extraction needed to be done on a range of different road networks.

Equally as important was identifying a solution that could deliver data at a reasonable price. Satellite imagery is generally available as large squares of several km^2. However, national road networks are typically large webs of narrow corridors. This means that the amount of imagery needed to be purchased is very high, but only a fraction of it is used.

Agilysis selected Maxar's Analysis Ready Data (ARD) product to supply the imagery as it was found to be the most cost effective. Maxar's ARD product allows more customisable selection of data which better matches road segments, so only the data needed is purchased. It also delivers images to an Amazon S3 bucket which greatly reduces development overheads for analytical work using machine learning.

Detecting and counting vehicles

A total of approximately 7,500 km^2 of ARD images were purchased, which was sufficient to cover the Kenyan and Ethiopian road networks with a single pass using a 250m buffer (~30,000km of road length). This consisted of 46cm resolution pansharpened visual imagery, formed by combining both panchromatic and multispectral imagery. At this resolution, cars and good vehicles can be quite easily identified. While other small objects can also be seen, it is not possible to reliably identify whether these are pedestrians, bicyclists, motorcyclists or something else.


Satellite image of a street in Kenya illustrating vehicle identification process © Maxar

Cars and other large vehicle identified were marked by red bounding boxes. This was then used to train a semantic segmentation AI model. The AI model uses a deep-learning approach to recognise collections of pixels that form distinct object categories.

This process required a large amount of high-quality training data including labelled vehicles on different road networks in the UK, Kenya and Ethiopia. The more training images used, the better the model's accuracy is in identifying vehicles improves. The initial pass in the UK achieved an accuracy score of 0.776, which improved to 0.847 on the second pass. In Kenya a score of 0.882 was achieved after several iterations. These results showed that it was possible to accurately detect vehicles in satellite imagery.

The next step was to count the vehicles travelling on the road network. To do this, detected vehicles were converted into vector geometries, which allowed data analysts to understand what direction the vehicles in the image were travelling. Vehicles were then geospatially matched to individual road segments on a digital map layer within a 15m radius.

Once matched, the number of vehicles were counted for each road section where satellite imagery was available. This was used to calculate the number of vehicles per km. Where there were multiple images for a road section (taken on different dates), the vehicle density was based on the average number of vehicles.

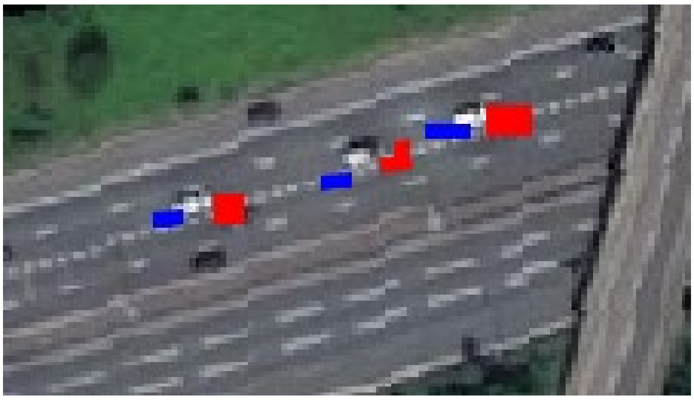
Measuring vehicle speeds

To calculate the volume of traffic, it is also necessary to know how fast vehicles are travelling.

Alongside higher resolution pansharpened visual imagery, the satellite data captures eight bands of multispectral imagery at a lower resolution of 1.84m. Each band is captured at a slightly different time, across a total span of 0.35s. The Agilysis team exploited this time difference to detect vehicle speed.

Vehicle labelling is difficult with a lack of RGB colouring and at a much lower resolution. Rather than rely on this, a technique was developed using light-coloured vehicles that are highly reflective in all multispectral bands. This made it possible to identify the distance moved by these vehicles, and from that distance, calculate the vehicle speed. As only light-colored vehicles are used in the speed detection model, the number of instances where matching may be ambiguous is reduced, particularly in dense traffic.[1] The other benefit is that the simplicity of this approach means it is highly transferable, and is expected to reliably work across all road types and regions.

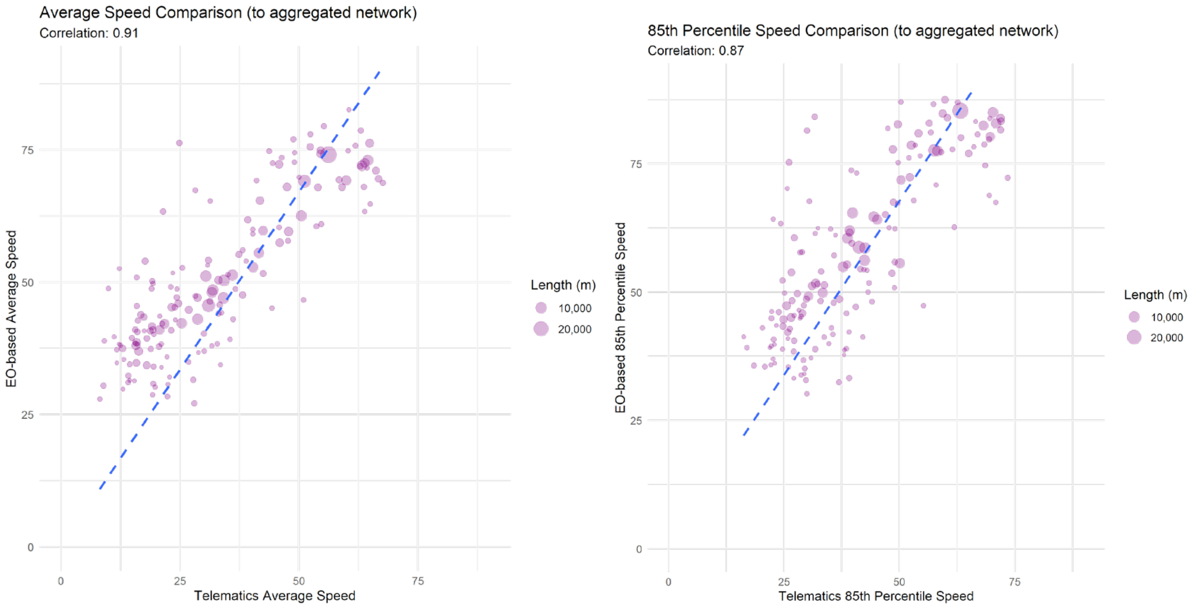
The approach was first tested in the UK where there is significant data from existing traffic surveys and other data sources to validate the findings. Both average vehicle speed and 85th percentile speeds were compared on sections of roads in the UK where data are available from alternative sources. The results were strongly correlated (0.91 for average speed and 0.87 for 85th percentile speed). This result meant that the technique could be applied in the project areas to estimate vehicle speeds.[2]



Satellite image of a road in the UK illustrating speed detection of vehicles moving from blue blocks to red blocks © Maxar

[1] A vehicle speed detection approach in which all vehicle movement is measured would require a more sophisticated matching process to determine which vehicles correspond to each other. It should be noted that because of the low-resolution, only vehicles travelling over 19km/h can be reliably measured.

[2] The project team could not obtain local automated traffic count (ATC) data to further validate the vehicle speed detection approach in Kenya or Ethiopia. However, as mentioned, the approach is considered highly transferrable and reliable.



Comparison of vehicle speed data derived from the project's speed detection approach with data from connected vehicle GPS sources in the UK

Mapping roads carrying 75% of travel for the Kenyan and Ethiopian road networks

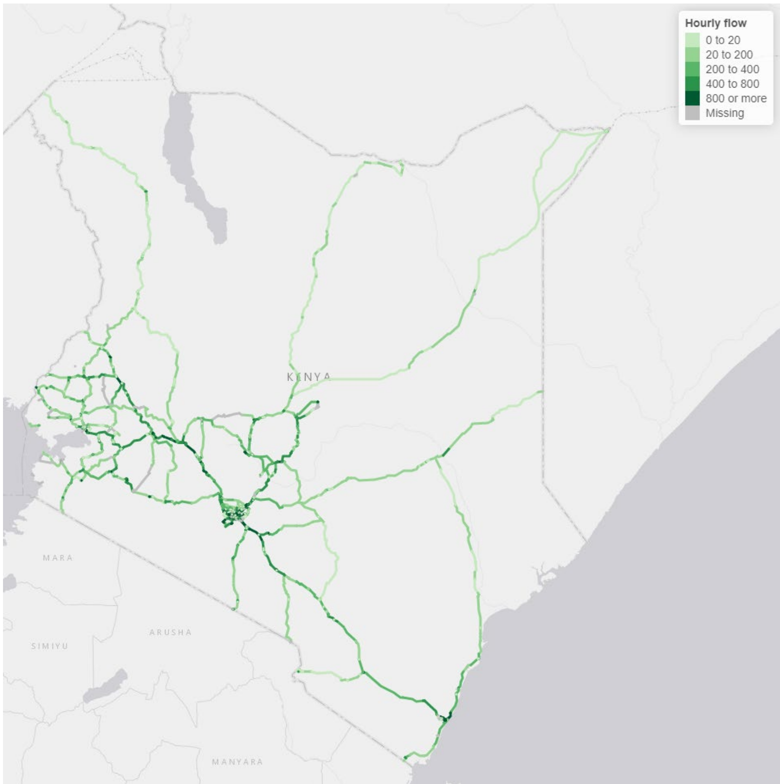
Global Road Safety Performance Target 4 is that roads carrying the majority of traffic (75%) meet safety standards. However, for many countries, first comes the task of understanding which roads this includes.

The first objective of the project was to map the 75% of travel road network for both Kenya and Ethiopia. This was done using the vehicle count and speed data for each individual road segments.

For each road section of length l meters, with a density of n vehicles per km travelling at an average speed of v km per hour at a chosen point in time. It would then take l/v hours for a vehicle to traverse the section of road. Hence the pool of vehicles along the road refreshes every l/v hours, or equivalently v/l times per hour. At any point in time, there are nl vehicles along the road. In each hour, there are $(nl) \cdot (v/l) = vn$ vehicles traversing the road. Hence hourly traffic flow can be calculated as the product of vehicle density per km and average speed in km per hour.

There were some cases where there were gaps in vehicle count data and/or speed data, as can be seen marked in grey on the map below. These gaps occurred either because imagery wasn't available for these road sections, or no vehicles were observed in the available images. These gaps were filled by inferring data from adjoining roads.[3]

The maps for Kenya and Ethiopia showing both where 75% travel is on the road networks and vehicle speeds are available online at http://africa.roadsafetydata.org/.



Road segment hourly flow estimates in Kenya © Open Street Map Contributors, Maxar

[3] Inferring data for road sections without data was done purely for the purpose of comparing levels of travel across the entire network. These modelled values alone may not be sufficiently robust for an analysis of individual sections of the network and those sections were flagged in our outputs.

Future potential

This project was the first of its kind to prove the use and viability of satellite data for the detection of vehicle speed and flow data—both critical for road safety. As satellite data is available globally, this means that this data can potentially be gotten for every country in the world. This is particularly important for countries where alternative sources of data are not available, do not provide adequate coverage or a prohibitively expensive.

iRAP's AiRAP initiative was established in 2020 to help bring such data into the reach of governments, policy-makers and the road safety observatories. AiRAP is essentially an accreditation process by which approaches to derive road safety data from big data sources, artificial intelligence and machine learning can be checked and validated for use internationally. Accredited data suppliers are then listed on iRAP's website.

Agilysis' approach to derive vehicle flow (AADT) and operating speed data (mean and 85th percentile) from satellite data was subsequently accredited for global application on rural and inter-urban roads and highways.

In applying the approach, there a number of aspects which should be considered. The first is the road network. Thanks to the efforts of Open Street Map contributors, much of the world's road network has already been digitised, particularly higher volume roads. In replicating the approach, it is essential the OSM mapping data is checked for accuracy. This is a potentially time-consuming but worthwhile task. If there are errors in centreline positioning, lack of carriageway separation, or poor labelling of road class then this would impact the success of outcomes.

The second is the quantity and currency of imagery. Satellite imagery increases in cost based on how recently it was captured and how many images are required. To keep data project costs to a minimum, imagery was used that was captured three or more years ago. For countries which have rapid urban expansion or opened new major roads or transport hubs (such as air and sea ports) open within the last three years, using more recent data is recommended. Similarly, reducing the number of sample images for each road section also controls costs. The validated outputs have shown however that even using a single image is capable of producing reliable results.

Satellite imagery is also limited by resolution and may not be practical for regions where there is a large proportion of small vehicles, such as motorcycles. In this project, images with 50cm resolution were used which does not provide enough detail to detect motorbikes. It is hoped that in the near future, images at 30cm resolution become available which would provide the required detail to detect motorcycles.

The last consideration regarding the satellite imagery relates to the time of day the image was captured. The project used imagery from a sun-synchronous satellite. This means images are usually captured at the same time of day, usually mid-morning. This method is therefore not suitable for determining differences in flow and speeds at different times of day, and certainly not at night. New satellite deployments are planned that will make data available at different times of the day but the costs for this are currently unknown.

75% of travel mapping process and cost

There are four main steps in the mapping of 75% of travel for a national road network:

1. Road network selection
2. Data order preparation & quality checks
3. Detection phase, and
4. Results and mapping.

Each step is briefly described in the table below, along with the estimated breakdown of time required by a consultant or technical team working on a new project to define 75% travel for a country.[4]

Activity stages for the mapping of 75% of travel (country-level)

Stage	Description	Estimated % of time required
Road network selection	The road network needs to be carefully considered before the data acquisition process takes place. Roads need to be selected based on classification with likely low-flow roads discounted. If the approach is being used to provide data to specific road corridors, as may happen with an iRAP Star Rating assessment, then it is likely that this stage will not be time consuming. When considering an entire country for the purpose of defining 75% of travel then this would require careful consideration and discussion with local stakeholders.	5%
Data order preparation & quality checks	Order preparation can be time consuming, especially for complex networks over large areas. This is required to ensure ordering rules are met otherwise orders will fail. This also includes reviewing available image stacks, setting cloud cover limits and preparing system to receive the data.	25%
Detection phase	Once the order has been placed and data quality checks have been successful, the detection phase then identifies and counts vehicles together with estimated speeds. These are then matched to the original network.	55%
Results and mapping	Network preparation, smoothing and quality assurance then needs to take place. Raw GIS outputs are the final output rather than dashboards in this case.	15%

The above estimates assume that many of the processes are undertaken by skilled computer scientists, rather than a typical data analyst. Some tasks would be suitable for a GIS technician.

It is Agilysis' estimate that 75% travel mapping as an end-to-end process will cost in the region of $4-$5 per kilometre of road assessed. This includes all costs associated with EO data, cloud computing resources, processing, quality assurance and client liaison. This would achieve outputs including travel vigintiles as well as speeds.

Following the completion of the project in Summer 2022, the approach has already been used by Agilysis to deliver data for clients working in South America, Africa, South Asia, and Oceania.

[4] The overall time required would depend on the size (km length) of a country's road network. These percentages may change slightly depending on the size of the country with very small territories incurring a higher percentage of administration workload. The estimates are also based on the use of existing ML models. Any time required to train new models would incur additional time and effort.

About the project partners

This project was funded by, and performed for, the World Bank Group's Global Road Safety Facility (GRSF) and UK Aid. The project partners were iRAP and Agilysis.

About the World Bank's Global Road Safety Facility (GRSF)

The World Bank's Global Road Safety Facility (GRSF) is a major partner of the Bloomberg Philanthropies Initiative for Global Road Safety (BIGRS) 2020-2025. Under this program, GRSF will continue to support governments to adopt safer road infrastructure designs and improve existing road network to accommodate all road users. In addition, GRSF will conduct assessments of high-risk roads, provide recommendations for improvement, provide technical guidance on speed management, and support governments to adopt crash data management systems. Learn more about GRSF at www.roadsafetyfacility.org.

About Agilysis

Agilysis was set up by an experienced team, all of whom have nearly twenty years invested in transport safety. Blending expertise in research, policy and practice. Leveraging big data analytics and novel approaches Agilysis is contributing to pioneering international research as well as providing consultancy and intervention design based on evidence from a range of disciplines in the transport and health domains. Find out more at https://agilysis.co.uk/

About iRAP

iRAP is a registered charity with the vision for a world free of high-risk roads. The charity is active in over 100 countries and works with governments, development banks, mobility clubs, research organisations and road safety NGOs to provide them with the free tools, systems and training to make their roads safer. iRAP's Star Rating Methodology provides a simple and objective measure of the level of safety which is 'built-in' to the road for vehicle occupants, motorcyclists, bicyclists and pedestrians. A 1-star road is the least safe and a 5-star road is the safest. The charity has influenced the safety of over USD$80 billion dollars of infrastructure investment, has Star Rated over 1.3 million kms and Risk Mapped over 1.6 million kms of road, and trained over 54,000 people globally. iRAP is the umbrella programme for regional road assessment programmes including EuroRAP, ChinaRAP, AusRAP, usRAP, KiwiRAP, IndiaRAP, BrazilRAP, South Africa RAP, ThaiRAP and MyRAP and is financially supported by the FIA Foundation. Find out more at https://irap.org/

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