TRANS-SAFE

TRANSFORMING ROAD SAFETY IN AFRICA

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Radical improvement of road safety in low- and medium-income countries in Africa

D3.2: Recommendation for the Deployment of Automated Enforcement Systems for Stakeholders

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Abstract	This report comprehensively describes the implementation experiences of Automated Speed Enforcement System in Lower- and Middle-Income Countries.

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LIST OF ABBREVIATIONS

Acronyms	Full meaning
ANPR	Automated Number Plate Recognition
ASE	Automated Speed Enforcements
ASC	Average Speed Camera
ASE	Automated Speed Enforcement
SDG	Sustainable Development Goals
DSD	Dynamic Speed Display
EU	European Union
FHWA	Federal Highway Administration
GRSF	Global Road Safety Facility
HPR	Healthy People Rwanda
JAES	Joint EU-Africa Strategy
LiDAR	Light Detection and Ranging
LMIC	Lower- and Middle-Income Countries
MSC	Mobile Speed Camera
RADAR	Radio Detecting and Ranging
RLC	Red-Light Camera
RNP	Rwanda National Police
SSC	Static/Spot Speed Camera (other alias: Fixed Speed Camera)
TIRF	Traffic Injury Research Foundation
USD	United States Dollar
SMS	Short Message Service
VRU	Vulnerable Road Users
WHO	World Health Organization

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EXECUTIVE SUMMARY

Safe Speed is one of five pillars in the Safe System Approach for road safety. Vehicle speed plays a critical role in influencing the risk of an accident. In a case of traffic accident, the impact speed has significant influence on severity of injuries up to fatal outcome. Maintaining speeds at reasonable levels is important not only for reducing severity of accidents but also for sustaining the long-term economic development of a country. Enhancing road safety heavily relies on effective speed management that advocates for 3 supporting pillars of Engineering, Education and Enforcement. Yet, ensuring compliance to speed limits and curbing dangerous driving speeds is known to be a worldwide problem. Often, drivers misjudge the perceived dangers of over-speeding by understating the potential risk.

Numerous Lower- and Middle-Income Countries (LMIC) are experiencing an escalating crisis in road fatalities and injuries. The 2018 WHO *Global Status Report on Road Safety* highlights excessive speed as a critical issue in these regions. Furthermore, the report points to insufficient law enforcement as a primary cause of accidents, leading to dangerous driving practices. Recognizing these challenges, governments in these areas have implemented laws and regulations focusing on speed limits, alcohol consumption, and the introduction of speed enforcement programs to enhance road safety. **Automated Speed Enforcement (ASE) is one of the measures that have shown its effectiveness to contribute positively in reducing the speeding problem and proven to be cost efficient (Figure 1)**.

However, as existing research highlighting the benefits of Automated Speed Enforcement predominantly focuses on High-Income Settings, this report aims to investigate whether similar effects are observable in Lower- and Middle-Income Country. Criteria for implementing such systems are often a predetermined factor for a successful outcome. Therefore, this report also analyzes which factors are significant to influence driver behavior and public perception of road safety.

The primary focus of LMIC studies is a comprehensive analysis of Rwanda's implementation of the Automated Speed Enforcement program which pioneers an automated approach in Low-Income Countries for speed management. Based on these findings, **this report proposes widely applicable implementation guidelines for other LMICs with a focus on African continent interested in adopting automated speed enforcement as a key road safety tool.**

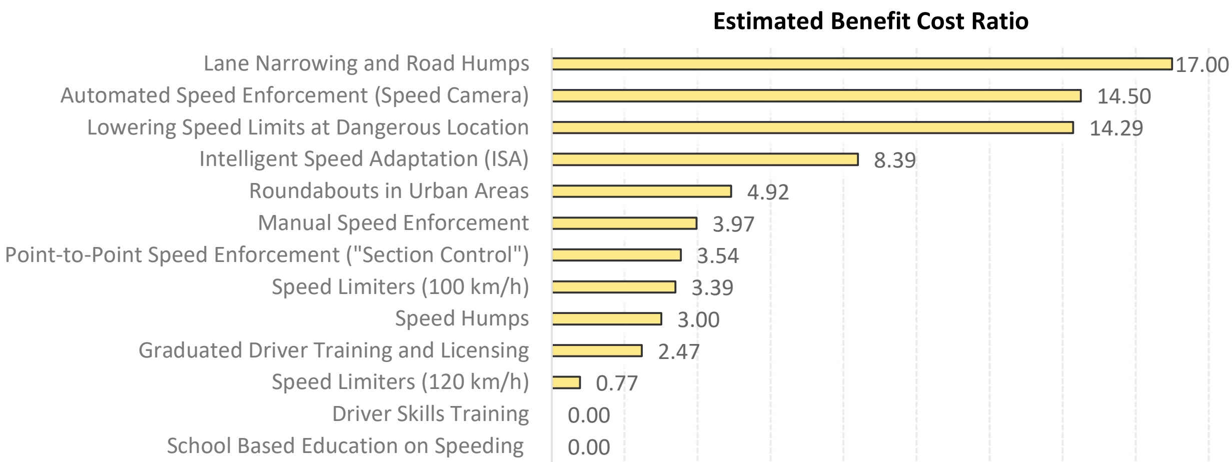

Figure 1: *Calculated benefit to cost ratio of various types of speeding intervention (Job & Mbugua, 2020)*

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1. MOTIVATION

This white paper explores the impact of **Automated Speed Enforcement** (ASE) systems in Lower- and Middle-Income Countries (LMIC). It addresses the speeding issue, emphasizes the need for enforcing speed limits, discusses implementation criteria, and highlights the experience of Rwanda, the first low-income African countries that adopted a nation-wide automated speed enforcement. This document also provides a concise recommendation for ASE program deployment.

About TRANS-SAFE

The TRANS-SAFE project involves national, regional, and city level demonstrations to test different types of innovative and integrated Safe System solutions, complemented by a comprehensive toolbox, capacity development, policy support and replication activities. To maximize impact, the project brings together in a consortium, highly committed cities, road safety agencies and experts from both Europe and Africa. Building on numerous synergistic projects, networks, and a strong technical experience among partners, the consortium will deliver on project objectives through highly effective and innovative approaches to sustainable road safety development, thereby ensuring that road safety systems and interventions from this project deliver on the recommendations of the Road Safety Cluster of the African-EU Transport Task Force, adopted in 2020. The consortium members have experience and expertise in Africa-related research as well as development-related research in collaboration with local actors in various countries of Africa at many levels. Ultimately, the project will help deliver on the Joint EU-Africa Strategy (JAES) and advance countries' progress towards the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs). TRANS-SAFE leverages on existing partnerships to collaboratively design sustainable interventions that aim to radically transform road safety systems in Africa.

1.1 SPEEDING PROBLEM

Speeding is a problem, which is observable almost worldwide. In general, there are three basic approaches how to reduce the speeding: **(i) Engineering** treatment, **(ii)** Road Safety **Education** and **(iii)** Higher **Enforcement** Rate.

The main motivation for speed reduction is the traffic safety. The severity of traffic accidents depends on many factors; however, besides to the accident type the impact velocity belongs to the most important as shown in **Figure** 2. We can state that the increasing speed significantly increases the risk of fatality, in other words lowering the impact speed also reduces the severity of the accident.

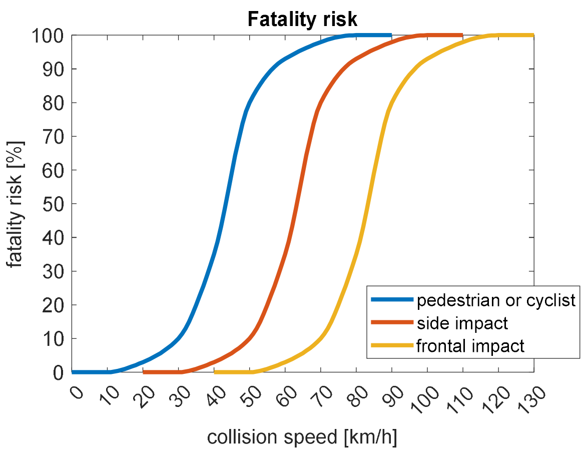

Figure 2: *Relation of impact speed to fatality risk for different types of collision* (**Grzebieta, 2019**)

From this point of view, the speed limits are important to be respected and their violation penalised. The reduced speeds are particularly

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important for the Vulnerable Road Users (VRU) in the urban traffic environment.

On the other hand, the speed lowering can also reduce the efficiency of the transport system. The optimal speed from the road traffic efficiency is considered to be about 70 km/h (Rodrigue, 2020). However, it is obvious that the reduced economic efficiency of the transport system cannot be compared to the load of economy lost caused by injuries and fatalities.

1.2 BENEFIT OF AUTOMATED ENFORCEMENT SYSTEMS

Despite the various outcomes of the latest research of ASE-systems effectiveness, the existing body of research consistently demonstrates that speed cameras serve as a highly effective intervention for reducing vehicle speed which primarily contributes in reducing number of accidents, injuries, and traffic fatality (Ebot Eno Akpa et al., 2016; Joubert, 2016; Martínez-Ruíz et al., 2019; Tankasem et al., 2019; Job, 2022)

First, ASE-systems present an effective approach to expand the capacity of speed management resources, surpassing the limitations of traditional policing methods. ASE can play a significant role to maintain complacency of speed limit in areas, where constant police presents is hardly maintainable.

Second, it increases the speed compliance rate in the enforcement zone. The effectiveness of ASE-systems can be attributed to their ability of real-time traffic offence detection and identification of the offender. The implication of consequent penalty for speeding mitigates speeding intention and ensures compliance to speed limits.

Third, speed of vehicle can be reduced which results in decreased accident & injury risk for all types of road users, especially VRUs (see **Figure 2**). Studies evaluating the impact on speed behaviour consistently reported a reduction in mean speed, along with a notable decline in the 85th percentile speed (Hamzah et al., 2013; Ebot Eno Akpa et al., 2016)

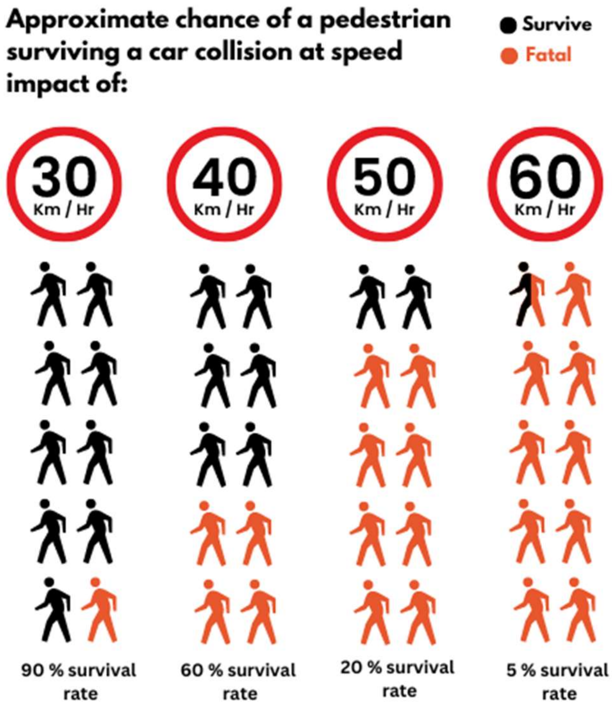


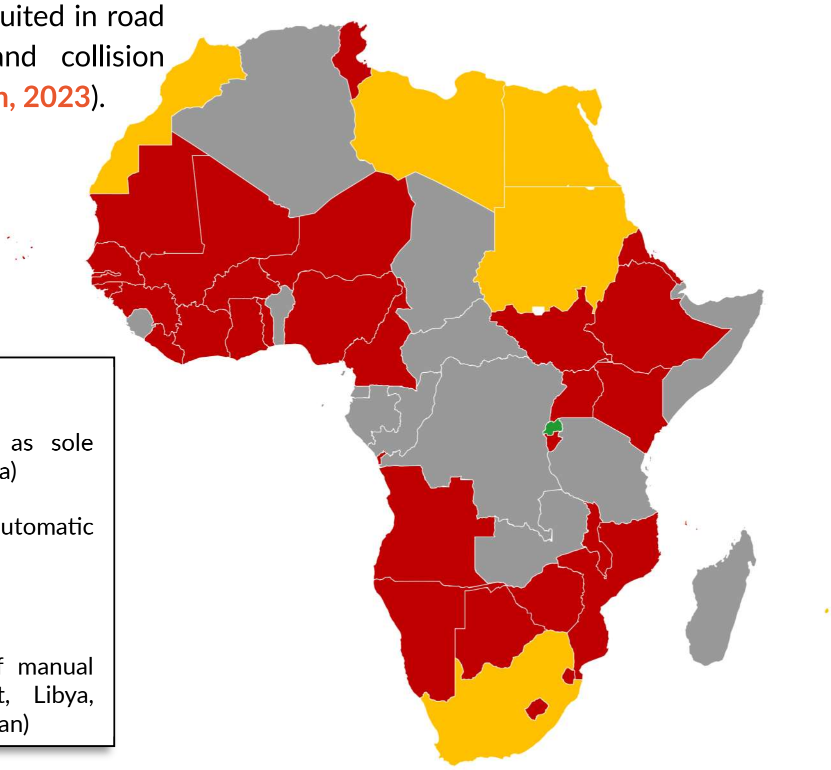
Figure 3: *At slower impact speeds, pedestrians are much more likely to survive car crashes; for example, at 30 km/h, typically only 1 in 10 crashes is fatal* (Grzebieta, 2019)

Fourth, in addition to their known safety benefits, the traffic data recorded on speed cameras could be used for traffic analytics. The insights gained from speed camera data also aid in understanding the correlation between speeding and road traffic accidents, thus provides a data driven interventions and improvements to prevent accidents.

Driving at lower speeds also accommodate potential errors made by drivers and provide more time to apply corrective measures. If critical situation arises, the reduced travel speed is associated with a shorter stopping distance of vehicles. In such case, drivers can better observe their surroundings, spot potential collisions with other dynamic road users and react safely in time, thereby mitigating the risk of collisions.

The low speed of vehicles is crucial for the safety of pedestrians and cyclists in mixed traffic conditions, especially within urban areas or locations with limited dedicated pedestrian infrastructure. The scientific correlation between the likelihood of a pedestrian fatality and the impact speed counts as the deciding factor that can contribute to numbers of pedestrian fatality and injuries (refer **Figure 2**). To maximize their safety benefit, speed camera enforcement is particularly well-suited in road sections with known speed and collision challenges (European Commission, 2023).

The 2018 Global Status Report on Road Safety (WHO, 2018) surveyed the deployment of different types of speed enforcement around the globe. It revealed a low penetration of ASE systems in African continent, with **only seven countries having experience deploying such systems**. Notably, Rwanda stands out as the sole country implementing a nationwide ASE system. In contrast, 47 out of 54 African countries lack any form of automated enforcement tools. The African continent could significantly benefit from the proper deployment of ASE systems to address its high traffic fatality rates, excessive speeding behaviours, and the underreporting of traffic accidents.



Enforcement type:

Automated: completely using ASE as sole speed enforcement measures. (Rwanda)

Manual: manual policing with non-automatic measures of citation

n.A: information not Available

Partially Automated: mixed used of manual policing and ASE systems (Egypt, Libya, Mauritius, Morocco, South Africa, Sudan)

Figure 4: *Distribution of speed enforcement type in African continent (WHO, 2018)*

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2. CRITERIA FOR ASE IMPLEMENTATION

Careful assessment of critical factors is fundamental to launching a successful ASE-program as part of a speed management campaign. Key criteria for an effective ASE program include significant political support, appropriate type of ASE, establishing a fair prosecution system, and developing a comprehensive plan for system evaluation. Through analysis & highlights of the latest research findings, this chapter aims to outline a structured framework for policymakers and stakeholders, guiding them in the strategic planning and execution of ASE programs for enhancing road safety.

2.1. POLITICAL SUPPORT

The ASE program has proved to be very important in reducing road traffic accident and the severity of resulting injuries. A successful ASE program involves many factors, political support being one of the most important. Political support in these aspects helps guarantee the sustained functionality and effectiveness of the ASE program, ensuring its reliability, accuracy, and durability. These elements are crucial for maintaining public trust and ensuring the program's success in promoting road safety. An in-depth analysis or study on the establishment of a national ASE program, discussions about maintenance, dependability, and the role of political support in ensuring these factors would further enrich the understanding of the program's viability and effectiveness.

The ASE program is expensive and, in most instances, requires external human resources and equipment importation. Most African countries may lack the capacity needed to establish and run an ASE program without external assistance. In that regard, Political support is mandatory for successful implementation of the ASE program. The political support is needed in almost all steps of the program. The following are some areas that require support:

1. **Preparation and coordination:** ASE programs require high level coordination to bring together different stakeholders from several disciplines including enforcement bodies, infrastructure, health, development agency, local governance, utilities, regulation and legislation. Also, the preparation involves conducting needs assessment, evaluating the availability and quality of data to plan evidence-based interventions. In case there is need of external support an existing political relationship and/or partnership with a Country that has the capacity may play big role to attract investors or find vendors. Political support also makes it easier to collaborate with foreign entities, such as gaining technical advice or financial assistance from organizations and nations that have successfully implemented ASE schemes.

2. **Program design:** To be successful, ASE program design requires many steps that are difficult to fulfill in absence of political will and support:

    a. Availability of digital and physical infrastructure like internet, electricity, data servers

    b. Allocation of resources: With political backing, the funding and resources required for the creation and implementation of the ASE program can be guaranteed. These covers hiring qualified staff, developing infrastructure, and acquiring top-notch equipment. It is important to secure funding for the program beyond the self-funding as ASE's primary objective is safety rather than income generation.

c. The Legal Structure: Supportive legislative measures are formulated and put into action with the help of political backing. This entails creating and approving laws, policies, and rules that will guide the implementation and enforcement of program. It also includes establishing a reasonable violation fine structure, payment system and procedures for contesting violations. To ensure compliance with these regulations and impose sanctions on those who violate them, political will is a prerequisite.

3. **Program implementation**: As for previous phases, this also requires political support to be successful. The government may lead, guide or support different implementation steps:

   a. Pilot: It's important to choose pilot sites considering variety of locations then monitor carefully what works and the challenges. The evaluation of the findings may also guide the scale-up.

   b. Public consultation and sensitization: implementation policies should consider varying perceptions of safety and opinions of all road users not just those subject to fines. The public should be sensitized about the importance of ASE and how it will work. With the political will, the campaigns may be incorporated in existing public gatherings and use all potential channels to reach the population. Political support has a tremendous impact on the public image and adoption of the program. When leaders speak out in support of the importance of ASEs in improving road safety, it raises public awareness and acceptance of the effort. The public should be informed that ASE is a supplement, not a substitute for classic police enforcement, enabling officers to focus on other indispensable and time-sensitive activities. ASE can extend the reach of speed control operations beyond the small area officers can patrol at any given time, which is particularly beneficial in the vast public road network. The government should understand that the primary aim of ASE is the deterrence not the apprehension of speeding drivers.

   c. Ensuring technical testing and quality assurance of ASE equipment.

   d. Management of revenues: To avoid the common suspicion that the ASE program is used to generate income, the revenues from fines should be managed in a transparent way. For some users, the revenues are managed through the national treasury, but many people advocate that they should go into a dedicated road safety fund (Denise Beaton et al, 2022).

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e. Data management: The government should ensure that collected data are kept safely to avoid any breach of privacy.

f. Evaluation: It is important to report the contribution of the ASE program such as the impact on speed, crash, road injuries, and deaths.

2.2 TECHNICAL CRITERIA

The advancement of ASE-systems has benefited from the rapid growth of remote sensing technologies, enabling more precise and efficient object detection and monitoring. This chapter outline the commonly used ASE-types for speed enforcement and generally describe the system mechanism.

2.2.1 SPEED MEASURING SYSTEM

The speed measurement system can be divided into two primary categories:

(1) ***Enforcement System***, which monitors and enforces speed limits, issuing penalties for violations.

(2) ***Information System***, which monitors and informs road users about their real-time speed without imposing penalties.

The most common **Enforcement Systems**, including Mobile, Static, and Average Speed Cameras, are used for monitoring vehicle speeds on various road types. These systems typically feature a speed detection module and a photo documentation system to record infractions, capturing essential data such as vehicle/driver identification, incident time and location, direction of movement, and measured speed.

As a driver exceeded predetermined speed limit threshold, system equipped with camera capabilities takes photographic evidence of the speeding incident for legal proceedings. Automated Number Plate Recognition (ANPR) technology can effectively identify vehicle owner or driver through license plate cross referencing with available database. This enables the automated issuance of personal speeding tickets for traffic rule violations.

A. Mobile Speed Camera (MSC)

MSC operate through manual usage by road authorities or police. These devices utilize various technologies, such as handheld speed guns or integration within police vehicles. Depending on the needs, speed-gun with RADAR or LiDAR technology are the most widely used equipment for measuring vehicle speed using radio waves and optical lasers, respectively. Both tools work similarly by sending a transmitting signal that bounce off the oncoming vehicle and the reflected signal

Figure 5: *Application of MSC in Rwanda to monitor vehicle speed. (Mesic et al., 2024)*

is received with a time delay to the original source.

To optimize the MSC-implementation, it is recommended that law enforcement personnel receive an individual training from the device manufacturer. This training serves to prevent any potential misuse during operation and misinterpretation of measurement outcomes.

B. Stationary Speed Camera (SSC)

Stationary Speed Cameras (SSC) are permanent fixtures installed near or above roadways to monitor vehicle speeds and capture images of vehicles exceeding set speed limits. These systems integrate camera and speed detection modules (RADAR or LiDAR) to trigger image capture during speed violation or use solely camera technology for speed monitoring and recording. Recently, LiDAR speed camera has gained popularity over RADAR for its reliability of accuracy in speed detection (VIION, 2023). Furthermore, advancements in artificial intelligence, particularly deep-learning models, have streamlined these systems to simultaneously monitor speed and document speeding incidents (Connie et al., 2018). With the goal of a continuous observation, ASE device can relieve the tedious task of physical surveillance from police forces.

C. Average Speed Camera (ASC)

The ASC calculates the average speed based on the known distance between entry and exit points and the time each vehicle takes to pass through. In general, a vehicle is documented at the entry checkpoint using ANPR technology and the detected plate is matched at the exit point to record the total travel time regardless of the road lanes the vehicle enters or exits (see **Figure 6**).

This average speed highlights a fairer speed measurement of the time taken to travel from entry to exit point of surveillance area and forgoing momentary speed peaks. Furthermore, this method eliminates the so called "kangaroo effects" within the enforcement zones, i.e., when drivers deliberately slowed down before enforcement section and speed up again after to make up for the "lost times". On the other hand, this method does not record any peak limit within zones that may indicate a high-speed violation.

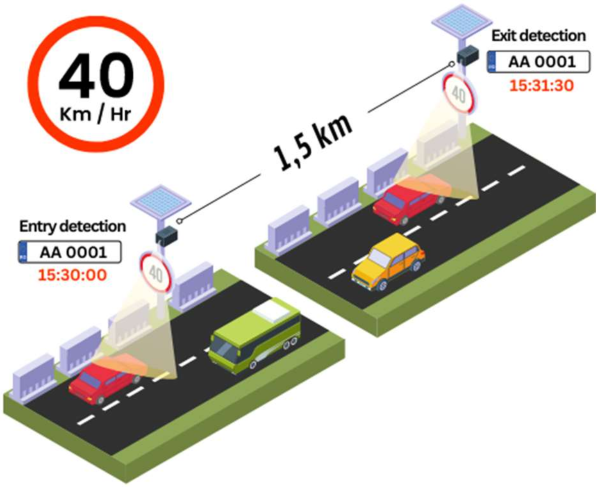

Figure 6: ASC collects data of license plate and time of entry & exit within the enforcement zone. In this case the red vehicle was calculated to be traveling 60 km/h on average in a 40 km/h zone.

D. Induction Loop

Pairs of inductive loops, normally insulated electrical wire, conduct an electrical current and create an electromagnetic field, making the loop an inductive element in a circuit. The inductance, determined by factors like wire size, length, turns, and insulation, changes when a vehicle passes over it, enabling vehicle detection. The loops are positioned closely on roads to track the time vehicles take to travel from one wire loop to the next at which momentary speed is calculated. While these sensors offer high accuracy, their necessitate cutting into the pavement for installation and upkeep expenses make them less common globally (VIION, 2023). Furthermore, the system's effectiveness is sensitive to extreme weather, loop placement (surface or embedded), and wire size.

The primary appeal of Information System lies in its low-cost approach to reducing speeds by providing interactive feedback to drivers through the display of the speed (**Figure 7**). Most common type of information system ranges from a speed display radar to speed display trailer. These methods are recommended for use in urban environments where pedestrian and vehicular traffic may conflict (Pérez-Acebo et al., 2021)

Since speed displays are meant to only capture and display vehicle speed, these devices are RADAR or LiDAR based and intended to inform drivers about their current speed, give visual cues about their behaviour and **not to impose any traffic fines**.

The main advantage of speed displays is their cost-effective method of lowering speeds through direct interactive feedback to drivers. Dynamic Speed Displays (DSD) vary in feedback, from passive displays that show current speed (**Figure 7**) and depend on absolute speed difference, activate the displays with messages like "SLOW DOWN" for breaching or "THANK YOU" for complying to the speed limit. They may also include elements like smiley faces to encourage self-assessment of driving behaviour, although these don't give specific instructions of the supposed corrective or maintain good driving behaviour.

Information Systems are not commonly equipped with a photographic capability, newer models may however include a covert photo device capable of capturing photographic evidence of the speeding incidence. Information systems are commonly deployed in urban areas with relatively free-flowing traffic, including school and residential zones.

Figure 7: *Rollout of speed RADAR sign in Ghana Accra-Tema Motorway (**Adams, 2022**).*

2.2.2 DATA MANAGEMENT & SECURITY

The collection of speed citations involves the collection of personal data. therefore, data management platform requires robust security and data protection protocols to reduce risks of unauthorized access and misuse of sensitive information (Job, 2022). A robust protocol covers the entire data lifecycle, spanning from data collection through camera systems, data management within the database, the subsequent data processing stages, data storage and using collected data for ASE evaluation (Job et al., 2020)

Speeding instance documentation should only collect as much data necessary to substantiate the processing of citations. Essential data usually include incident photos, speed camera information, time of incident, location of incident & ASE, captured speed and actual speed limit (Job, 2020).

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The regulation of liability for traffic violations, such as speeding, can vary between countries. General regulation differs liability assignment to **vehicle owner** or **vehicle driver**. Countries with *vehicle-centric* enforcement approach focuses the speed camera system to capture the vehicle's license plate. The legal assumption here is that the owner of the vehicle is responsible for any traffic offence committed with their vehicle, making them liable for any speeding fines regardless of the actual driver at the time of the offense.

On the other hand, *driver-centric* enforcement systems require a clear image of the offender's face (Germany for example). This photographic evidence is crucial for positively identifying the individual responsible for the offense, ensuring that traffic fines are accurately imposed on the actual offender not the vehicle owner. Therefore, raises the technical requirements of the camera systems to capture clear picture of driver in varying conditions. This approach has the benefit of fairness use in which the vehicle is used by multiple individuals or is a part of a larger fleet. Whichever liability approach, data management and security of ASE-system must comply with the legal requirements of the country.

2.3 DETERENCE SYSTEM

In addition to setting a safe speed limit and employing a credible measurement system, effective speed enforcement relies on the support of appropriate sanctions (European Commission, 2018). Types of speeding fines will not be explored here, as they are comprehensively listed in the Global Road Safety - Speed Management Manual (2008) and Sakashita et al. (2021). This chapter focuses on effective penalty strategy to increase overall speed compliance.

Speeding fines typically include **monetary penalties** (flat or incremental), **demerit points**, or severe actions like **license/vehicle confiscation** and **imprisonment** for repeat offenders. Monetary fines, either fixed or based on the degree of speed limit excess, are the most common form of fine.

The WHO's survey of speed enforcement intensity across the African continent indicates need for improvement in speed management. It reports that 30% of African countries have poor enforcement of speed (a score below 3 is considered poor, 4-7 adequate, and above 8 good). Despite this, 44% of African countries demonstrate an adequate enforcement intensity. Notable examples of good speed enforcement practices include Rwanda and Botswana, primarily through their utilization of comprehensive traffic regulation and deployment of automated speed enforcement systems. Elvik (2001) demonstrated that the largest increase in enforcement effectiveness was found when doubling or tripling the enforcement intensity.

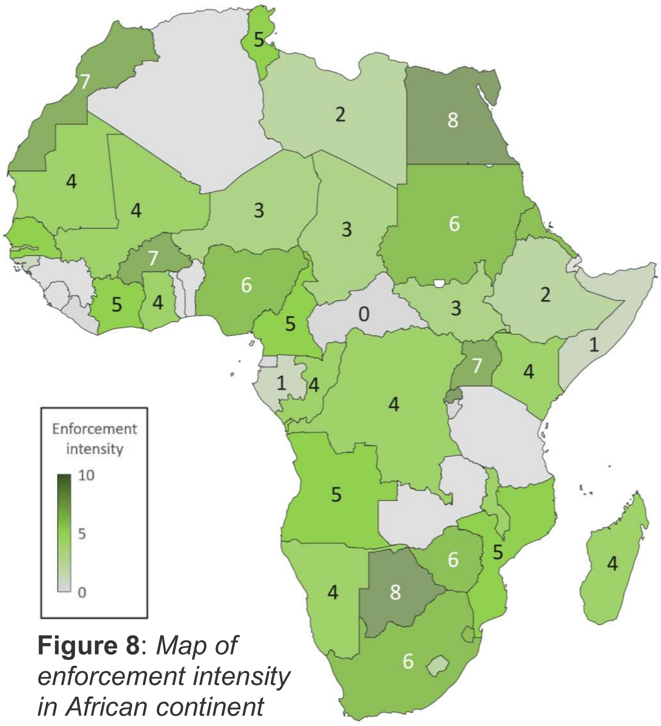

Figure 8: *Map of enforcement intensity in African continent (WHO, 2016)*

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Table 1: *Overview of speeding fines in TRANS-SAFE demo Countries*

Country	Type of enforcement	Fine type	Fine Increment	Highest Possible Fine
Rwanda	Automated	Fixed monetary	**Yes**, fine thresholds are for 10% and 20% above the speed limit. Fine increases if fine is unpaid	Too high fine result in vehicle confiscation
Ghana	Manual	Fixed monetary, License Conf.	**No**, fixed amount of minimum and maximum fines	License revocation after 6th repeated offence
South Africa	Partially automated	Gradual monetary, demerit points, criminal charge	**Yes**, fines severity increases every 4 km/h over the speed limit from minimum of 10 km/h over the limit until maximum of 40 km/h+ over speeding where it will be counted as criminal charge	Max. 15 demerit points reduction, exceed means 3 months of license suspension (accumulated though other road traffic offences)
Zambia	Manual	Gradual monetary	**Yes**, from exceeding tolerance from 1 to 15 km/h over the speed limit. Fines increase for each 15 km/h overspeed to maximum of 60km/h or more above the speed limit	Temporary driver license suspension can be issued after second offence

The influence of a fine can differs based on individual circumstances, like financial resources or the impact of demerit points. Effective penalty system harmonizes the certainty, severity, and swiftness of a punishment (Shakashita et al., 2021). Significant factor in influencing speeding behavior is the **frequency of enforcement** & **perceived detection** in comparison to only raising fine severity alone as demonstrated by Goldenbeld, (2017), Ryeng (2012) and Hössinger & Berger (2012). If there's a low chance of getting caught, just increasing fines won't effectively stop traffic violations.

ASE can help to increase enforcement intensity immensely by having a continuous enforcement presence in comparison to traditional policing methods using Mobile Speed Camera. Tankasem et al. (2019) demonstrated the effectiveness of SSC in increasing enforcement intensity by quadrupling the amount of camera which resulted in approximately **6 to 8 increases in speeding detections** in comparison to normal policing technique (MSC enforcement). Surge of infraction exposed the **ticketing system that it was not able to hand out 70-90% of the speeding ticket.** this is due to lack of administrative resources and difficulties in recognizing captured vehicle license plate.

The revenue from ASE-program should for the most part invested in operational cost of the system and other road safety projects. This way agencies can ensure that implementation of ASE has the main goal to improve road safety and not to generate profit. Transparency in funding information is recommended to be available for public dissemination and investment to the latest road safety initiatives using revenue made from ASE should be clearly stated.

2.4 MONITORING AND EVALUATING ROAD SAFETY IMPACT

Assessing the implementation of new safety measures should be a priority, even at the project planning stage. Therefore, funding for evaluation should be secured according to the scale of the project. This way, safety effectiveness can be objectively measured and monitored to ensure applied measures still works according to the initial goal.

This summary seeks to present good indicators to use when evaluating road safety interventions and describe the importance of each indicator to the evaluation effect. Therefore, a table of key parameters that are significant to the outcome of measures are presented in **Table 2**. We also recommend following the African Transport Policy Program guide on minimum dataset collected at country level to enable harmonized identification and quantification of speeding problem across Africa (**Segui-Gomez et al. 2021**).

Assessing road safety measures generally involves comparing pre- and post-implementation conditions. The evaluation timeframe may vary based on the ASE type and the project scale. To establish significance of result following countermeasure installation, **Federal Highway Administration (FHWA) in the USA recommends a minimum of one year data collection for changes in before-after condition** and **crash data to ensure a substantial sample size (Bagdade et al., 2012; FHWA, 2023).** This method simultaneously addresses the **regression to the mean issue**, where new measure is effective within the short period after deployment, followed by a stable decrease or flat instances once drivers are accustomed to ASE mechanics.

To accurately interpret the effectiveness of an intervention, high-quality data is needed**. The accident database should implement geo-coded and time-stamped accident records.** Making geo-coded accident data publicly accessible can raise awareness among road users about dangerous locations. Example of good public geo-coded crash data is the *German Accident Atlas*[1]. Best practice of crash data collection is to have a verification method for the crash outcome comprising of interconnected databases which links police report data, hospitals record, trauma registry and other sources recording crash data (HPR, n.d)

Overt camera often has a localized effect in speed and crash reduction. But to check if these effects are conclusively due to ASE deployment, stakeholders need to compare intervention sites with control sites having similar road conditions and crash histories but no ASE. Additionally, **a "spill-over" effect** can happen where safety benefits are followed outside of ASE area. Even though this in on itself is a desired effect to generate broader safety benefit across the road network, it can lead to underestimation of the ASE effect (Job 2022). **Martínez-Ruíz et al. (2019)** found that "spill-over" effect can be found at their control sites even when the control sites on average are located 1.5 km away from camera sites.

[1] https://unfallatlas.statistikportal.de/

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Table 2: Selected Indicators for Evaluation

**Colored green is considered an important indicator of evaluation metrics

Type of Metrics**	Evaluation Criteria**	Description
Speed Evaluation and Enforcement Effectiveness	Average / Mean Speed	Evaluating the speed metrics means to at least account for data collection at 24-hour period on a weekday of free-flowing traffic. Comparing the **mean speed** before and after ASE intervention create a good indicator of the reduction effect.
	85th Percentile Speed	**85th percentile speed**: describe the speed at which 85% of all drivers going at a particular road. It indicates a substantial amount of data point of driver speed on the roads. However, the 85th percentile speed only reflect speed at which only the drivers think it's appropriate. Modern methods, considering potential conflicts among road users, are recommended for establishing safer speed limits (Tingvall & Haworth, 1999)
	Number of Speeding Fines	3rd evaluation criteria involve monitoring speeding fines that indicates occurrence and shift in speeding behavior. A substantial data assessment of speed behavior can be done at least after one year before-after period of observation or collecting enough sample.
Road Safety Key Performance Indicator / Impact	**Accident outcome**	Result of an accident can be attributed to 4 categories: **accident with no injuries** (property damage), **accident with light** or **severe** injury and **fatal accident**. Each of the category must be well defined in terms of time frame and the nature of the accident i.e., differentiation of light and severe injury made if hospital admission is needed. To this extend, accident data should be **geo-coded and time-stamped** to monitor crash / injury hotspot overtime.
	Accident location	Analyzing accident sites helps identify environmental factors contributing to accidents, revealing patterns that indicate other high-risk locations. (simple categorization is to differentiate between accident location in urban / rural areas)
	Impact on road users	Agencies could expand evaluation reports by including type of road users involved in an accident (such as heavy-duty vehicle, car-to-car, pedestrian, motorcycle, bicycle, and others) Benefit of this data depth is to enable a deeper accident causation and development of targeted interventions to reduce specific road user conflict and injuries[2]
	Impact with distance	Overt speed cameras effectively reduce severe injuries within a 250m radius, with diminishing impact beyond 500-1000m, as shown by **De Pauw et al. (2013).** Geo-coded accident data can help identify in which radius is the camera effective to reduce accident occurrence.
Opinion Surveys	**Acceptance rate**	This indicator can measure whether the intended effect is still being perceived greatly by the public and could serve as a replication purpose in case similar circumstances arise.
	Safety effect of camera	This metric can also be good indicator on level of understanding from road users for the camera potential effect and whether a wider sensibilization campaign regarding the crucial ASE aspects should be conducted.
	Penalty system	This approach is mainly to assess the perceived fairness of the penalty system. Whether the level of penalty severity, measures to prevent repeat offenders and quality of camera enforcement are considered appropriate
Cost effectiveness (Tang, 2017; Li et al. 2019; Mendivil, 2011)	**Human Factors through cost benefit**	Injuries and deaths result in direct and indirect economic loses mainly through healthcare resources cost. The comparison involves two scenarios: one estimates the economic loss if no intervention is implemented, and the other assesses how i.e. reducing speed with ASE deployment can decrease injuries, save lives and avoid human capital loses. Other cost such as physical or environmental damage caused by missing opportunities to install the cameras can be added.
	Operating Cost	For a sustainable program's management, stakeholders should assess the overall cost-effectiveness of deployed ASE systems, considering expenses like installation, maintenance, legal fees, energy costs, and staffing. This financial analysis is to be compared with the revenue from speed fines to give an objective economic view of the program. Additionally, it's crucial to compare these findings with the human impact in scenarios where the program isn't implemented.

[2] https://transport.ec.europa.eu/system/files/2023-02/Collision%20matrix%20URBAN%202021.pdf

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3. CASE STUDIES

This section highlights ASE-implementation studies from Rwanda and other Lower-and Middle-Income Countries around the globe. Case studies for Rwanda are a result of synthesized quantitative and qualitative studies initiated by local TRANS-SAFE partners Healthy People Rwanda (HPR), the Traffic Injury Research Foundation (TIRF) with funding support from the World Bank. The study investigates the implementation, traffic impact, and public perception of Rwanda's automated enforcement program. The full content will be published at undetermined date in the HPR-website. The compilation of case studies covers the evaluation of common ASE-system employed in LMIC setting (**Annex 2**).

3.1. RWANDA

Rwanda, with the highest road fatality rate among East African nations at 29.7 per 100,000 people, has consistently faced road injuries as a leading cause of death across all ages and genders since 2003, particularly affecting those aged 5 to 44 years (**WHO, 2020; WHO, 2018**). The rise in road fatalities was partly due to rapid economic growth that spurred an increased in mobility and vehicle ownership. Latest Rwanda National Police (RNP) crash data from 2019-2022 shows a very significant reduction of number of serious injuries but a notable increase in minor injuries and property damage crashes.

The shift in crash outcomes could be correlated to the Rwandan governments and Rwanda National Police's (RNP) road safety strategy to deploy a nation-wide automated speed enforcement program to curb excessive speeds and efficiently enforcing other traffic rules. This program complements existing range of road safety campaign such as "*Gerayo Amahoro*" ("Arrive Safely" in English), aimed at enforcing speed limit through embedded speed governors in commercial vehicles and a series of road safety education campaign for other road users.

Figure 9: *Rwanda, a landlock East-African country with Kigali as Capital city.*

The ASE program, initiated by the RNP, aims to curb excessive speeding and high burden of road safety using modern technology of speed enforcement. The national ASE Program begun with a small-scale pilot study involving 1 Stationary Speed Camera (SSC) and 5 Mobile Speed Cameras (MSCs) to assess the ASE system's fit for Rwanda. The success led to strategic planning and the eventual nation-wide expansion of the program, whereas of May 2023, more than 400 varying types of ASE cameras are actively used for enforcing speed limit across Rwanda's road.

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Figure 10: *SSCs locally called as "Sophia" can monitor vehicle speed from multiple direction and numerous lanes using LiDAR for more precise speed measurement (Vitronic, 2023; Tabaro 2023)*

There are several key aspects that played a significant role in determining the success of Rwanda's ASE-Program:

1) ASE-System for nation-wide speed management: Rwanda's numerous road traffic fatalities & excessive speeding behavior prompted the RNP to endorse ASE-Systems as the main method for managing speed. The Rwandan Development Boards later supported the initiative, aligning with the government's agenda of using technology and digital transformation to address domestic issues. A survey assessing public perception of the decision for ASE program revealed generally positive attitudes and recognizing ASE as a wise investment for enhancing road safety. This positive attitude likely comes from substantial respondents' awareness of speeding as a primary crash risk factor and their personal experiences with road accident.

2) Camera Type and Placement: Rwanda's ASE program uses various cameras, including Red Light Cameras (RLC), and Static and Mobile Speed Cameras (SSC & MSC), strategically placed based on crash rates, infrastructure readiness (data availability & reliable power source), and location needs. Enforcement cameras are also employed to check vehicles with unresolved traffic offences (uninsured vehicle, unpaid traffic fines, etc.). SSCs are preferred in areas with suitable infrastructure, while MSCs cover other high-risk areas where SSCs deemed impractical. Survey respondents viewed the camera variety and nationwide implementation as effective for road safety, disagreeing with the notion that the government overspent on ASE devices. Furthermore, most of the respondent also agreed that the camera location does make sense to achieve a meaningful impact to road safety.

3) Camera Warning Signs: Instead of specific camera signage, existing speed limit signs are utilized near ASE-locations to warn drivers of camera presence. In line with the number of cameras, speed limit signage installation has been increased to help drivers adjust their speed in accordance with the location of ASE-systems. Nevertheless, the RNP encountered public dissatisfaction due to perceived lack of effort in sensitization before the system rollout. The public viewed the decision to post only speed limit signs, and not camera warnings, particularly unfavorable. To this extend, the police intended to emphasize the importance of respecting speed limits, rather than focusing on the camera locations. Research effort was made by the local research group to assess the effectiveness of ASE in terms of spill-over effect around the camera sites, it found a significant localized effect of the system, suggesting that in practice drivers may only slow down near cameras and speed up again after passing them.

4) Effectiveness of Speed Camera: The impact of Overt Static Speed Camera (SSC) on speed outcomes and violations is investigated through a case-control study with 16 equally matched location characteristics and specific analysis on vehicle types (Cars, Motorcycle, Commercial trucks & bus). The results indicated a notable reduction in mean speeds for all vehicles, regardless of their type at locations equipped with ASE cameras compared to sites without cameras. Notably, the study revealed that ASE was linked to a 17% decrease in mean speeds for cars, mirroring findings from a high-income country. In addition, passenger vehicles have been recorded to more likely breaching the speed limit amongst other type of vehicles. This demonstrates the effective role of ASE in curbing motorist speeds within its operational areas.

5) Penalty Rules & Speed Limit: Penalties for speeding are imposed when a driver exceeds the speed limit by 10%, with an increased fine for exceeding it by 20%. Fines can escalate if the offender has missed payment term and has unpaid previous fines. A distinction in fines is made based on vehicle type, with lower fines imposed on two-wheelers compared to vehicles with minimal 4 wheels. A significant portion of frequent drivers in Rwanda found the speeding fines to be fair and the fine amounts ($25 or $50 USD) are reasonable when speed limits were justifiably exceeded. If there's a high amount of unpaid traffic fine, vehicle will be confiscated. Further punishment of license suspension or imprisonment for speed are not considered.

6) Digitalized Fine & Service System: Rwanda's ASE-system utilizes interconnected digital platforms and databases. When a speeding offense is captured by the camera, the system automatically matches the license plate number with the existing database. It then sends an SMS to the registered phone number associated with that vehicle, notifying the owner of the violation and providing a link for cashless payment. The online government service portal "IREMBO" not only manages the payment of various traffic fines, but also facilitates cashless transactions. Through this portal, users can specifically manage their traffic fines and receive SMS alerts when their payments are due.

Police reported some false citations have occurred due to technical problems with the ASE systems. The public frequently engages with the police on social media, particularly Twitter (*currently: X*), to dispute any perceived inaccuracies of the ASE-systems. For further assistance, the RNP offers official communication channels, including phone, email, and police office, where individuals can confirm or contest fines. Communication channels set up by the RNP have reliably resolve this issue.

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3.2 STUDY COMPILATION

1. ***Mobile Speed Camera***

Ponboon et al. (2009) evaluate ASE deployment on a high-accident Bangkok highway section, the effectiveness of Mobile Speed Cameras (MSC) with police intervention was tested in a two-week trial. Two checkpoints were used to measure speed changes before and after MSC deployment, collecting data from 43,293 vehicles. Daytime enforcement reduced mean speeds by 3 to 7 km/h depending on the vehicle type, but nighttime data, where enforcement was absent with covert speed measurement, showed a little to no change in vehicle mean speed. However significant reduction of 8 km/h reduction in truck speeds were observed in the absent of police enforcement.

Overall speed limit compliance further showed, daytime compliance improved, but nighttime had more speed violations. It's worth noting that the effectiveness of speed enforcement, in terms of reducing vehicle speeds, appears to be associated with the active presence and activity of the police. This underscores the evidence that, once police presence is removed, drivers tend speed up.

2. Static Speed Camera

Tankasem et al. (2019) examined a speed enforcement initiative along an urban arterial road in a from Khon Kaen City, Thailand. Evaluation of camera efficacy revealed that vehicle speeds initially decreased after project start, maintaining this trend for half a year. An overall average reduction in speed of 7.48 km/h was documented for 24h period observatory. Additionally, there were indications of reduced accident rates by 5.8%, injuries by 7.7%, and fatality rates by 34.3%. However, the extent to which these effects solely stem from the speed enforcement project itself versus potential influences from concurrent road safety campaigns or spillover effects of other interventions remains unclear.

another Thailand study (Kronprasert & Sutheerakul, 2020) was conducted to analyse the effect of deploying multiple SSC on a mountainous stretch of the Chiang Mai Highway that is known to be accident hot spot. The study assessed before and after speed analysis and conducted surveys with drivers to evaluate their attitudes toward speeding and speed enforcement systems.

The average speed of all vehicles decreased by around 5.5 km/h and the 85th percentile speed dropped by 9 km/h, which indicates a significant speed reduction by large proportion of vehicle passing the road section. Moreover, the number of violators significantly decreased at all speed camera locations along the corridor, showing a success rates ranging from 9% to 34%.

Drivers' opinions were analysed, showing that 64% respondent identified speeding as the primary cause of accidents on mountainous roads, while 69% were unaware of speed limits on such roads. Nevertheless, a significant 71% supported speed enforcement measures, with 70% favouring automated speed camera enforcement, demonstrating strong driver acceptance of these measures due the historical record of road crashes in this context provides justification for the utilization of ASE.

Kaygisiz & Sümer (2019) investigates the impact of fixed speed camera enforcement on traffic accidents in Ankara, Turkey, focusing on 1448 crashes with fatalities or injuries in 2009 and 2011. Following the installation of fixed speed cameras in 2010, there was a 23%

reduction in such crashes, a 50% decrease in fatalities, and a 27% drop in injuries.

These cameras were notably effective in seven out of 18 indicators, including total crashes, injuries, single vehicle accidents, weekday crashes, noon crashes, evening crashes, and summer crashes. The findings support the effectiveness of fixed speed cameras, particularly in reducing traffic injuries and crashes with fatalities or injuries.

3. Average Speed Camera

Ebot Eno Akpa et al. (2016) assess the effect of ASC-systems on passenger and minibus taxi vehicle on 71.6 km stretch of road in South Africa. The findings revealed that for passenger vehicle, both average speed and 85th percentile speed decreased by 5 km/h, accompanied by 6% increase in driver compliance with speed limits. Conversely, minibus taxi showed a minimal speed change despite speed limits of 100 km/h and 120 km/h respectively. 70% of minibus taxi trips exceed the regulatory speed limit of 100 km/h and nearly 34% of their trips exceeded the 120 km/h speed limit.

When comparing the two years prior to the enforcement with the two years during enforcement, all collisions on the enforcement route experienced a 9.6% increase. Despite the rise in accidents, traffic fatality decreased by 79.5%, serious traffic injuries were reduced by 58.5%, and minor injuries declined by 50%. Based on these findings, there's a likelihood that ASC played a part in the decrease of crash severity, given the reduction in average speed during enforcement and the established relationship between speed and crash severity.

Interestingly, survey to twenty drivers that regularly travels the enforcement route revealed that only 10% of the drivers know exactly the ASC-mechanism and their location. Most of the unaware drivers misunderstand how ASC work and mixed it up with the common SSC-mechanism. They tend to slow down before the entry camera and sped up again after they passed the camera, unknowingly that their speed is currently being recorded along the enforcement zone.

3.3 CONCLUSION & RECOMMENDATION

The full result of literature search on ASE evaluation in LMIC-setting & their summarized result can be found **in Annex 2.** The general effect of various ASE-systems has evidently led to reduced speed and numbers of crash, injuries, and deaths. Perception and awareness of road users regarding the ASE systems are still the contention point when deploying ASE-system in LMIC. Effort on public information and sensitization can be improved to optimize impacts on safe driving behavior.

Studies in Rwanda have provided crucial insights into ASE programs in a low-income African country, documenting design, implementation, localized speed reduction effects, and public perceptions in Rwanda. Additionally, comparison of Rwanda ASE implementation to the latest international guide to determine readiness for speed camera has been comprehensively compared in **appendix1** (*Job et al. 2020*). These insights offer valuable guidance for other Lower- and middle-income countries, especially located in the African continent, considering the implementation of Automated Speed Enforcement (ASE) programs to address road traffic issues. Conclusively, we included six recommendations to follow when implementing such systems.

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General Recommendation for ASE Deployment in LMIC

Automated Speed Enforcement as Road Safety Tool

Managing speed is important aspect for making roads safer for everyone. Recent studies consistently demonstrates that speed cameras serve as an effective intervention for reducing vehicle speed which primarily contributes to reducing number of accidents, injuries, and traffic fatality, even when deployed in LMIC setting. ASE can contribute to improving road safety alongside other speed management systems.

Essential Collaboration with Local & International Partners

Engagement with wide range of partners, such as policymakers, police, ASE-system manufacturers, international road safety organizations, nations with extensive experience of ASE, research institutes, community leaders and the public, is vital for the success and acceptance of ASE programs. Early collaboration with these stakeholders ensures a variety of perspective and needs are considered, enhancing communication, data access and policy alignment.

Automated Speed Enforcement Should Have Safety as Priority

From the start ASE should be considered to enhance road safety and not to generate profit. This concept of safety can be identified by stakeholders' decision on camera placement, warning sign, fine threshold, quality of camera equipment and management of collected revenue. Stakeholders need to recognize that the main goal of ASE is to deter, not to catch, speeding drivers.

Road Users Should be Included and Given Adequate Information about ASE Implementation.

Certain aspects of the ASE program might not be clear for the public; thus stakeholders should properly plan a sensitization campaign and warning period for ASE-implementation. Comprehensive public information and a sufficient warning can minimize negative experiences and controversies around the program. When people perceive speed management as excessively restrictive, costly, or inefficient, they are less inclined to support these measures.

Frequent Research for Optimal Implementation & Evaluation Strategies

With challenges arising from limited and nonspecific data on road accidents, there is a need for high-quality data systems in accident studies. Its recommended to use the Africa Transport Policy Program's 2021[3] guide on minimum set of road safety indicators to enhance data quality in preparation for ASE programs. This approach promotes decision-making based on data for issue related to these programs and possibility to conduct regular in-depth studies.

Automated Speed Enforcement do not Solve All Road Safety Issues.

Several studies in LMIC found ASE's effectiveness is localized to their enforcement area, therefore ASE should be seen as just one part of a broader speed management approach. Additional methods, like engineering treatments, behavior change campaigns & education, and other type of enforcement e.g., speed limiter on heavy duty vehicle, can be considered to achieve a broader compliance with speed limits. The implementation of ASE should also work holistically with other pillars of the safe system approach.

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[3] Segui-Gomez et al. (2021). Road Safety Data in Africa: A Proposed Minimum Set of Road Safety Indicators for Data Collection, Analysis, and Reporting

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5. REFERENCES

Adams, C. N. (2022). NRSA installs radar to check speed on motorway. Retrieved from https://www.ghanaiantimes.com.gh/nrsa-installs-radar-to-check-speed-on-motorway/

Bagdade, J., Nabors, D., McGee, H., Retting, R. (2012). *Speed Management: A Manual for Local Rural Road Owners*. Report No. DTFH61-10-D-00022, T-10-002. Vienna, VA 22182: Vanasse Hangen Brustlin, Inc. (VHB). Retrieved from https://safety.fhwa.dot.gov/local_rural/training/fhwasa010413spmgmt/speedmanagementguide.pdf

Beaton, M. D., Oakey, M., Newhouse, E., Copley, T. T., Fyfe, M., Karbakhsh, M., . . . Pike, I. (2022). Critical elements of public acceptance and support for automated speed enforcement in British Columbia, Canada. *Journal of Transport & Health*, *26*, 101461. https://doi.org/10.1016/j.jth.2022.101461

Cheng Keat Tang (September 2017). *Do Speed Cameras Save Lives?* London, United Kingdom. Retrieved from Spatial Economics Research Centre website: https://eprints.lse.ac.uk/86567/1/sercdp0221.pdf

Connie, L., Kim On, C., Patricia, A. (2018). A Review of Automatic License Plate Recognition System in Mobile based Platform. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*. Retrieved from https://core.ac.uk/display/235221828?utm_source=pdf&utm_medium=banner&utm_campaign=pdf-decoration-v1

Ebot Eno Akpa, N., Booysen, M., & Sinclair, M. (2016). A comparative evaluation of the impact of average speed enforcement (ASE) on passenger and minibus taxi vehicle drivers on the R61 in South Africa. *Journal of the South African Institution of Civil Engineering*, *58*(4), 2–10. https://doi.org/10.17159/2309-8775/2016/v58n4a1

Elvik, R. (2001). Cost-Benefit Analysis of Police Enforcement: Project Report: The ”Escape” Project. Retrieved from http://virtual.vtt.fi/virtual/proj6/escape/escape_wp1.pdf

European Commission (2018). Road safety syntheses – Speed Enforcement. European Road Safety Observatory. Retrieved from https://road-safety.transport.ec.europa.eu/system/files/2021-07/ersosynthesis2018-speedenforcement-summary.pdf

European Commission (2023). Speed Cameras. Retrieved from https://road-safety.transport.ec.europa.eu/eu-road-safety-policy/priorities/safe-road-use/safe-speed/archive/speed-cameras_en

Federal Highway Administration (FHWA). (2023). *Speed Safety Camera Program Planning and Operations Guide*. Report No. DTFH6116D00040L. McLean, VA. Retrieved from https://highways.dot.gov/sites/fhwa.dot.gov/files/Speed%20Safety%20Camera%20Program%20Planning%20and%20Operations%20Guide%202023.pdf

García-Altés, A., & Pérez, K. (2007). The economic cost of road traffic crashes in an urban setting. *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention*, *13*(1), 65–68. https://doi.org/10.1136/ip.2006.012732

Goldenbeld, C. (2017). Increasing Traffic Fines. Retrieved from https://www.researchgate.net/publication/322790828_Increasing_traffic_fines

Grzebieta, R. *Safe Speed Limits*. Retrieved from RACS Trauma Symposium, Pedestrians - staying safe. Melbourne. website: https://www.surgeons.org/-/media/Project/RACS/surgeons-org/files/trauma-verification/17-r-grzebieta-safe-speed-limits.pdf?rev=be72114dc4ef45689dc3ffa5ede40052&hash=3994BB422E7973A805FBA4C7C061D479

Healthy People Rwanda (HPR). Research on the Impacts of Automated Speed Enforcement in Rwanda to Develop Recommendations for African Countries: Self-Published Compiled Reports. [unpublished research report]

Hössinger, R., & Berger, W. J. (2012). Stated response to increased enforcement density and penalty size for speeding and driving unbelted. *Accident; Analysis and Prevention*, *49*, 501–511. https://doi.org/10.1016/j.aap.2012.03.023

Hussain, Q., Feng, H., Grzebieta, R., Brijs, T., & Olivier, J. (2019). The relationship between impact speed and the probability of pedestrian fatality during a vehicle-pedestrian crash: A systematic review and meta-analysis. *Accident; Analysis and Prevention*, *129*, 241–249. https://doi.org/10.1016/j.aap.2019.05.033

J B Joubert. (2011). A Comprehensive Analysis of the Effectiveness of Speed Camera Enforcement in Decreasing Accident Rate in the Johannesburg Metropolitan Area. *Proceedings of the 30th Southern African Transport Conference (SATC 2011)*. Retrieved from https://repository.up.ac.za/bitstream/handle/2263/17324/Joubert_Comprehensive%20%282011%29.pdf?sequence=3&isAllowed=y

Job, R. F. S. (2022). Evaluations of Speed Camera Interventions Can Deliver a Wide Range of Outcomes: Causes and Policy Implications. *Sustainability*, *14*(3), 1765. https://doi.org/10.3390/su14031765

Job R, Mbugua, L. Road crash trauma, climate change, pollution and the total costs of speed: six graphs that tell the story. Washington DC: Global Road Safety Partnership; 2020.

Job, S., Cliff, D, Fleiter, J.J., Flieger, M., & Harman, B. (2020). Guide for Determining Readiness for Speed Cameras and Other Automated Enforcement. Retrieved from https://documents1.worldbank.org/curated/en/794451581062198463/pdf/Guide-for-Determining-Readiness-for-Speed-Cameras-and-other-Automated-Enforcement.pdf

Kanitpong, K., Ekpanyapong, M., & Inmor, T. (2023). Evaluation of point-to-point speed cameras to control speeding behavior in Thailand. *Journal of Safety Research.* Advance online publication. https://doi.org/10.1016/j.jsr.2023.10.006

Kaygisiz, O., & Sümer, N. (2021). Effects of fixed speed cameras on spatio-temporal pattern of traffic crashes: Ankara case. *Journal of Transportation Safety & Security*, *13*(8), 877–895. https://doi.org/10.1080/19439962.2019.1697775

Kronprasert, N., & Sutheerakul, C. (2020). EFFECT OF AUTOMATED SPEED ENFORCEMENT SYSTEMS ON DRIVING BEHAVIOR AND ATTITUDES ON MOUNTAINOUS ROADS IN THAILAND. *International Journal of GEOMATE*, *18*(68). https://doi.org/10.21660/2020.68.9255

Li, S., Jiao, B., Zafari, Z., & Muennig, P. (2019). Optimising the cost-effectiveness of speed limit enforcement cameras. *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention*, *25*(4), 273–277. https://doi.org/10.1136/injuryprev-2017-042537

Mendivil, J., García-Altés, A. [Anna], Pérez, K. [Katherine], Marí-Dell'Olmo, M., & Tobías, A. (2012). Speed cameras in an urban setting: A cost-benefit analysis. *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention*, *18*(2), 75–80. https://doi.org/10.1136/ip.2010.030882

Martínez-Ruíz, D. M., Fandiño-Losada, A., Ponce de Leon, A., Arango-Londoño, D., Mateus, J. C., Jaramillo-Molina, C., . . . Gutiérrez-Martínez, M. I. (2019). Impact evaluation of camera enforcement for traffic violations in Cali, Colombia, 2008-2014. *Accident; Analysis and Prevention*, *125*, 267–274. https://doi.org/10.1016/j.aap.2019.02.002

Mesic, A., Krebs, E., Delavary, M., Vanlaar, W., Turner, B., Neki, K., & Nzeyimana, I. (2024). A case-control study of the impact of automated speed enforcement on motorist speeds and speeding violations in Rwanda. *Accident; Analysis and Prevention*, *194*, 107327. https://doi.org/10.1016/j.aap.2023.107327

Muhamad Kamil HAMZAH, Choy Peng NG, Faridah Hanim KHAIRUDDIN, Mohammed Alias YUSOF (2013). The Automated Speed Enforcement System — A Case Study in Putrajaya. *Journal of the Eastern Asia Society for Transportation Studies*. (10), 2133–2146. Retrieved from https://www.jstage.jst.go.jp/article/easts/10/0/10_2133/_article

Naghawi, H., Al Qatawneh, B., & Al Louzi, R. (2016). Evaluation of Automated Enforcement Program in Amman. *Periodica Polytechnica Transportation Engineering.* Advance online publication. https://doi.org/10.3311/PPtr.10939

Partnership, G. R. S. (2008). *Speed management: A road safety manual for decision-makers and practitioners*. Geneva: [World Health Organization].

Patriot, T., Kusuma, A., & Nahry, N. (2020). Analysis of Speed Limiting Using Speed Cameras: Case Study in Indonesian Toll Road. *CSID Journal of Infrastructure Development*, *3*(1), 93. https://doi.org/10.32783/csid-jid.v3i1.119

Pauw, E. de, Daniels, S., Brijs, T., Hermans, E., & Wets, G. (2014). An evaluation of the traffic safety effect of fixed speed cameras. *Safety Science*, *62*, 168–174. https://doi.org/10.1016/j.ssci.2013.07.028

Pérez-Acebo, H., Ziolkowski, R., & Gonzalo-Orden, H. (2021). Evaluation of the Radar Speed Cameras and Panels Indicating the Vehicles' Speed as Traffic Calming Measures (TCM) in Short Length Urban Areas Located along Rural Roads. *Energies*, *14*(23), 8146. https://doi.org/10.3390/en14238146

Ponboon, S., Jiwattanakulpaisarn, P., Kanitpong, K., Kachathong, S., Boontob, N., & Aniwattakulchai, P. (2009). Effectiveness of Speed Enforcement with Police Intervention on a National Highway in Thailand. *Proceedings of the Eastern Asia Society for Transportation Studies*. (Vol.7 (The 8th International Conference of Eastern Asia Society for Transportation Studies, 2009)). Retrieved from https://doi.org/10.11175/eastpro.2009.0.388.0

Rodrigue, J.-P. (2020). The Geography of Transport Systems (5th ed.). Routledge. https://doi.org/10.4324/9780429346323

Ryeng, E. O. (2012). The effect of sanctions and police enforcement on drivers' choice of speed. *Accident; Analysis and Prevention*, *45*, 446–454. https://doi.org/10.1016/j.aap.2011.08.010

Rwanda Political Map with capital Kigali, national borders, important cities, rivers and lakes. English labeling and scaling. Virgil Inter: Virgil Inter.

Sakashita, C. Fleiter, J.J, Cliff, D., Flieger, M., Harman, B. & Lilley, M. (2021). *A Guide to the Use of A Guide to the Use of Penalties to Improve Road Safety*. Geneva, Switzerland. Retrieved from https://www.grsproadsafety.org/wp-content/uploads/2023/05/Guide_to_the_Use_of_Penalties_to_Improve_Road_Safety.pdf

Saroch Boonsiripant, Agachai Sumalee, Jittichai Rudjanakanoknad, Sakda Panwai, Panupong Panudulkitti, Charnwet Haripa, Wiroj Rujopakarn (2013). *Automated Speed Enforcement in Automated Speed Enforcement in Thailand: Evaluations and Recommendations*. Thailand. Retrieved from https://atransociety.com/resources/pdf/pdfResearch2013-2018/2013/Project12-13-002(Dr.Saroch).pdf

Segui-Gomez, M., Addo-Ashong, T., Raffo, V. I., & Venter, P. (2021). Road Safety Data in Africa: A Proposed Minimum Set of Road Safety Indicators for Data Collection, Analysis, and Reporting. Retrieved from https://www.ssatp.org/sites/ssatp/files/publication/SSATP%20Road%20Safety%20Data%20in%20Africa.pdf

Tabaro, Jean De La Croix. (2023). THE INCORRUPTIBLE TRAFFIC CAMERAS OF KIGALI. Retrieved from https://www.ktpress.rw/2023/10/the-traffic-cameras-changing-driving-habits-in-kigali/

Tankasem, P., Satiennam, T., Satiennam, W., & Klungboonkrong, P. (2019). Automated speed control on urban arterial road: An experience from Khon Kaen City, Thailand. *Transportation Research Interdisciplinary Perspectives*, *1*, 100032. https://doi.org/10.1016/j.trip.2019.100032

Tingvall, C., Haworth, N. (1999). Vision Zero - An ethical approach to safety and mobility Claes Tingvall and Narelle Haworth. *6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000*. Retrieved from https://www.monash.edu/muarc/archive/our-publications/papers/visionzero

VIION - Smart Cameras Made SImple. *How Automated Speed Enforcement Cameras Work* [Press release]. Retrieved from https://www.viionsystems.com/index.php/blog/how-automated-speed-cameras-work

VITRONIC Dr.-Ing. Stein Bildverarbeitungssysteme GmbH. *Speed Enforcement: Slow Down: Improved Technology for Safer Roads* [Press release]. Retrieved from https://www.vitronic.com/en-us/traffic-technology/speed-enforcement

World Health Organization (2018). *Global status report on road safety 2018*. Geneva, Switzerland: World Health Organization.

World Health Organization (2020). Global health estimates: Leading causes of death: Cause-specific mortality, 2000–2019. Retrieved from https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death

SUPPORTING DOCUMENTS

ANNEX 1: GRSF GUIDE FOR DETERMINING READINESS FOR SPEED CAMERAS AND OTHER AUTOMATED ENFORCEMENT

Main Issue	GRSF Guide Minimum Requirements	Rwanda ASE Readiness per Stakeholder Accounts (HPR, n.d.)
Political	Do decision makers understand the road safety benefits of managing speeds?	Policy makers, primarily in the RNP, initiated ASE to align with national priorities such as reducing crashes, injuries, and road fatalities.
	Do decision makers accept the value of Automated Enforcement (AE) and is there sufficient political acceptance to introduce an AE program?	In Rwanda, a shared purpose and vision within the government is typical, and ASE implementation was no exception.
	Is there appreciation of the potential income for Government (which could be used for further road safety improvements)?	Income generation potential is acknowledged though funds are centralized with the national treasury and there's also a recognition of cost savings by reallocating tasks for more efficient police resource use.
Legislation and policy decisions that may be legislated	Does legislation identify which agency/ agencies have responsibility for various parts of the AE system?	A coalition of stakeholders collaborate on ASE with standard legislative procedures, but the exact composition and specific responsibilities are less clearly defined.
	Do you have approval to use camera equipment type (type approval)?	It's unclear whether specific legislation governs ASE equipment approval, or if the stakeholder coalition simply consults with suppliers and reaches a consensus on the ASE type.
	Is there a legal process to identify the vehicle and the driver? to prosecute an offender?	Rwanda determines responsibility for speeding offenses based on the registered vehicle owner, identified by the plate number. If fines are not paid by deadlines, they increase, and eventually, the vehicle is stopped at checkpoints and removed from roads until payment. Additional prosecution processes were not detailed.
	Do organizations that need access to ASE generated data; driver licensing data; and vehicle registration data have the legal right to access it?	Respondents indicated that various government agencies collaborate effectively towards their common goal of improving road safety and managing costs through ASE, enabling easy access to data within these agencies.

Main Issue	GRSF Guide Minimum Requirements	Rwanda ASE Readiness per Stakeholder Accounts (HPR, n.d.)
Legislation and polic decisions that may b legislated	Are there data security policies and protocols to: secure roadside data capture and transfer? Secure storage and use? Prevent unauthorized access?	Police own and manage all data that directly address data security issue
	Is there a policy relating to cameras being fit for purpose (e.g., to operate effectively in the environment where they'll be used such as will they operate in extreme heat, cold or humidity?	Infrastructure challenges in Rwanda's ASE design and implementation were recognized. Adaptation includes using battery power as power source when electricity was unavailable at camera deployment sites.
	Are registration plates generally clearly visible at high speeds or in low light?	License plates in Rwanda are standardized in their color, shape, size and mounting on the front and rear of the vehicle. Cameras have a flash available to improve lighting
Organizational & Funding Issues	Do all camera sites allow for accurate speed detection and readable images to be collected? (consider position in relation to rising/setting sun; roadside barriers, change of speed limits for certain times of day e.g., school zones)	Camera locations were selected by stakeholders and other cooperating agencies based on crash, injury, and death hotspots, infrastructure availability (like internet/data and electricity), prior road design research, and stakeholder recommendations. This was informed by two extensive surveys to identify suitable sites.
	Do all camera sites allow for safe operation and maintenance?	Vitronic provided insightful feedback from their camera implementation experience in other countries, suggesting that factors like camera accuracy, safe operation/maintenance, and field of vision were considered in site selection, though this was not specifically stated.
	Are cameras mounted such that the mounting does not contribute to inaccurate speed recording or data capture?	The frequency of incorrect fines is unclear, but it was noted as a challenge.
Camera Maintenance & Calibration	Is there a protocol and appropriate resources for maintenance and calibration of cameras?	Subcontractors (Vitronic) regularly calibrates and maintains these cameras per their contract
Unique Identification of Vehicle from an Image (Vehicle Registration / Identification)	Is there a reasonable proportion of all vehicles registered and correctly displaying ASE-readable vehicle registration plates that uniquely identify that vehicle?	Police reported a very low proportions of unregistered vehicle on roads
	Is legislation in place that compels vehicle registration plates to be correctly positioned so that they can be detected by a speed camera, unobscured and legible that deters drivers from attempting to evade speed camera detection?	Per legislation, police enforce the legal requirement for vehicles to be registered and properly outfitted with a plate on the rear and front bumpers in standardized locations to promote visibility. Accordingly, a visible plate is flash-enabled camera readable

Main Issue	GRSF Guide Minimum Requirements	Rwanda ASE Readiness per Stakeholder Accounts (HPR, n.d.)
Linking vehicle to owner and contacting the owner when an infringement is issued	Is there a reasonable proportion of vehicle registration records that accurately reflect the rightful owner? Does legislation and enforcement support this?	The frequency of incorrect registration records is uncertain, but they are identified as a problem. Legislation exists for this issue, but enforcement may be lax due to the lengthy processing time for formal vehicle ownership changes.
	Is there a system to enable linkage of a detected vehicle to the vehicle owner?	Linkage between a vehicle and the registered owner is accomplished through national identification cards and/or passports, the same document is required for vehicle registration and obtaining a mobile phone number, thus assuring that contact is simple
Delivering Enforcement Notice to Relevant Offender (investigation/ adjudication)	Is there a system by which the owner can be contacted to receive the infringement notice?	When speeding citations are issued the legal process begins with an SMS to the registered vehicle owner who is responsible for paying the fine. Failure to pay can result in compounding penalties and removal of the vehicle from the road until fines are paid.
	Is there a process to identify the offending driver if not the owner?	The registered owner is responsible for identifying and assuring the actual offending driver pays the fine.
System to Manage Offense Contestability	Is there a process to allow a driver accused of speeding to legally challenge the offense?	For further assistance, the RNP offers official communication channels, including phone, email, and police office, where individuals can confirm or contest fines
Process to Ensure Penalty is Applied and Managing Repeat Offenders	Is there a process by which non-payment of penalty can be followed up and resolved?	The police ensure that payment is made through routine checks of all passing vehicles and stopping those with unpaid penalties, vehicles may be confiscated if the fines are too high, repeat offenders are discouraged currently only by too many fines
Penalties for Speeding are Appropriate	Are the penalties for speeding sufficient to deter speeding?	Interestingly, respondents did not share an opinion about the appropriate magnitude of the penalty fine, it has been static for many years prior to ASE.
	Do penalties increase in severity as the speed detected increases?	The penalty fine increases if it exceeds an absolute threshold of 10% and 20% of the limit and also if not paid by the deadline.
	Penalties can be too high, generating police reluctance to apply them. Is this risk managed?	It's not clear if the penalties are too high such that police decline to issue them nor if measures are in place to manage this risk besides general corruption deterrence
	Is there a mechanism for applying a penalty for falsely accepting responsibility for the offence (e.g., fraudulent use of demerit points belonging to another person)?	Repeat offenders were not reported to suffer extraordinary consequences such as revocation of a driver's license. Because there are no demerit points falsely accepting an offense is not likely to occur commonly

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Main Issue	GRSF Guide Minimum Requirements	Rwanda ASE Readiness per Stakeholder Accounts (HPR, n.d.)
Evaluation to Show Road Safety Improvements	Is there a plan to evaluate the safety outcomes of the AE system? Is there funding for evaluation?	Police note improvements in crash, injury, and road death rates following ASE deployment, but apart from reporting total figures in relation to ASE deployment, specific impact evaluations are limited to this study funded by the GRSF.
	Will baseline speed and crash data be collected for this evaluation?	Rwandan cameras activate only after exceeding the speed limit, so regular exposure data for a baseline isn't collected. Pre-ASE crash data exists at the district level but not for specific locations to show impacts around camera sites. The RNP is consistently enhancing their road traffic crash reporting quality, as shown by the geo-coded and timestamped digital database established in 2022 and has also taken steps to create a data center for monitoring road safety improvements.

ANNEX 2 – LIST OF ASE STUDIES IN LMIC SETTING

Authors (year)	Country	ASE-Type	Summarized Result
Kanitpong et al. (2023)	Thailand	ASC & SSC	ASC deployment shows a significant impact over SSC. After the implementation of ASC, which issued warning tickets during experiment, there was a notable decrease in the 85th percentile average speed in the enforcement zone by 10 km/h, reaching up to 20 km/h reduction in some cases. In terms of detection rates, ASC detected 95% of drivers' speeds, identifying 45% as speeding, whereas SSC only detected 10-20% of speeders. Furthermore, drivers passing ASC zone tended to maintain a more constant speed throughout the enforcement zone.
Patriot et al. (2020)	Indonesia	SSC & Speed Limit Sign	SSC contributed to reduce vehicle speed by 8km/h or 9% slower than existing condition. From 302 vehicle samples, 76.6% of drivers respected the speed limit through check at the enforcement point. There are sign of speed manipulation practice after the enforcement point (zone 2) from all types of vehicles with the highest increase of average speed of 10 km/h by passenger car driver.
Kronprasert & Sutheerakul. (2020)	Thailand	SSC	Reduction of mean speed by SSC implementation of 8% (t=0.05); percentage of violators for every corridor reduced, most significant: 34% reduction at location 3. Driver attitude survey showed 64% of drivers are aware speeding is the major cause of accident on mountain roads, 69% unaware of speed limit on the enforcement section and 71% support the enforcement.
Ebot Eno Akpa, N.; Booysen, M.; Sinclair, M. (2019)	South Africa	ASC	Comparison of two years before and after the enforcement revealed an increase of all crash incidence by 9.6%, however all traffic fatality significantly decreased by 79.5%, all serious injuries reduced by 58.5% and all minor injuries were reduced by 50%. Based on the observed data, it appears that ASE substantially influenced the severity of accidents, as evidenced by the notable decrease in average speeds during enforcement periods and the established correlation between speed levels and the gravity of crashes, however analysis of other compounding factor was not observed. Most mini-bus driver treated ASC surveillance the same as SSC, in which kangaroo effects are apparent only in the vicinity of the camera.
Martínez-Ruíz et al. (2019)	Colombia	SSC	A quasi-experimental comparison study with before and after measurements of 12 months and a control site was conducted. After 12 months, there was a reduction of 19.2% of all crashes and a 24.7% reduction of injury and fatal crashes in the intervention area. In comparison areas, this reduction was 15.0% for all crashes and 20.1% for injury and fatal crashes. After adjusted comparisons, intervention sites outperformed comparison sites with an additional yearly reduction of 5.3% (p = 0.045) for all crashes. A spillover effect was found in the comparison areas, however more evaluations are needed to measure the overall effect.
Kaygisiz, Omur & Sümer, Nebi.(2019)	Türkiye	SSC	Following the installation of SSC in 2010, there was a 23% reduction in such crashes, a 50% decrease in fatalities, and a 27% drop in injuries. These cameras were notably effective in seven out of 18 indicators, including total crashes, injuries, single vehicle accidents, weekday crashes, noon crashes, evening crashes, and summer crashes.

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Authors (year)	Country	ASE-Type	Summarized Result
Tankasem et al. (2019)	Thailand	MSC	Before after evaluation indicated that this project decreased vehicle speed by 9.6% and increased number of speed citation six to eight times in comparison to normal policing methos (MSC). 1 year before the and three years of accident records were collected from hospital record along the enforcement corridor which result in reduction in accidents, injuries, and fatalities rates by 5.8%, 7.7%, and 34.3%, respectively following the deployment of SSC system.
Naghawi et al.(2019)	Jordan	RLC + SSC + MSC	The evaluation of the program on crashes and violations was examined based on a "before-and-after" study using the paired t-test at 95 percent confidence level. ASE-systems combined were generally associated with positive impact on crashes. Crash frequency was significantly reduced by up to 63%. Crash severities were reduced by up to 62.5%. Also, traffic violations were significantly reduced by up to 66%. Questionnaire for drivers' opinion and attitude on the ASE program survey revealed that 35.5% of drivers are unaware of AEP in Amman, 63.9% of drivers don't know the camera locations, most drivers knew about excessive speed and red-light running penalties, most drivers reduce their speed at camera locations, 44.4% of drivers think that the program satisfies its objective in improving traffic safety and 52% of drivers encourage increasing the number of camera devices in Amman.
Hamzah et al. (2013)	Malaysia	SSC	Speed spot studies with control sites and the comparison result revealed more than 70%-90% compliance at the camera site and less than half of the drivers in the comparison sites do not comply with the limit. Analysis of 85^{th} percentile speed also revealed that the speed limit only significantly adhered in the camera sites. This study shows the successful effect of ASE in reducing speeding incidents at the deployed area.
Ponboon et al. (2009)	Thailand	MSC	ASE deployment on a high-accident Bangkok highway section, the effectiveness of Mobile Speed Cameras (MSC) with police intervention was tested in a two-week trial. Two checkpoints were used to measure speed changes before and after MSC deployment, collecting data from 43,293 vehicles. Daytime enforcement reduced mean speeds by 3 to 7 km/h depending on the vehicle type, but nighttime data, where enforcement was absent with covert speed measurement, showed a little to no change in vehicle mean speed. However significant reduction of 8 km/h reduction in truck speeds were observed in the absent of police enforcement. It's worth noting that the effectiveness of speed enforcement, in terms of reducing vehicle speeds, appears to be associated with the active presence and activity of the police. This underscores the evidence that, once police presence is removed, drivers tend speed up.
Joubert, J B. (2009)	South Africa	MSC	The deployment of MSC resulted in decline of 44% in the average number of accidents rate per month and average vehicle speed reduction of 10 km/h (14.6% reduction). A steady rise of speed infraction was found in which reasoned with the increasing numbers of vehicle registration.

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