# S&T Interventions for MMDA Intelligent Traffic Management Systems

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## 1. INTRODUCTION

According to JICA, the Philippines is losing 3.5 billion pesos daily due to traffic congestion. A growing economy entails greater responsibility for the transportation system. Rather than spending time working in the office or spending time with your loved one, people have consumed it traveling the road. By 2030, if no interventions are provided, the expected loss could reach up to 6 billion pesos per day.

Traffic policies are the main backbone of traffic management. The right policies can ensure the road for everyone's benefit. In analyzing traffic situations, it is necessary to have a grasp of the continuous real-time road situations. Vehicle volume roadside count and classification is a widely used data source for traffic assessments. However, the existing data sources require further improvement in their data quality.

Two popular data collection approaches are (1) paper-based manual counting and (2) crowdsourced floating devices through Waze. The main limitation of (1) is that the methodology is expensive and prone to human errors. Therefore, this methodology is used as either an on-demand or multi-year interval requirement (Department of Public Works and Highways, n.d.). For (2), Waze data enabled an ability to estimate real-time situations from a bird's eye view. Average speed was calculated to derive the operation metric for MMDA (MMDA, 2022). However, its main limitation is its data quality.

We discuss in detail the limitations of the crowdsourced floating device through Waze. First, Waze data usage can be complementary and provide significant value to traffic management (Inrix, 2018). However, the sampling and stratifications of data are crowdsourced, leading to incompleteness and variable nature of data. Furthermore, consider the problem of sample size. Suppose limited Waze users are available in a particular segment. In that case, the average speed is highly dependent on the driving behavior rather than the overall road condition in that specific segment. Averaging speed as a proxy metric is only reliable when the sample size is large and consistent (Surowiecki, 2005).

This paper aims to present Research and Development (R&D) Interventions that focus on further improving the data quality by developing cost-effective technology that complements the strengths of paper-based counting and crowdsourced data. We propose to use an alternative continuous real-time data collection method. Concretely, a low-cost outdoor intelligent camera network system that utilizes recent advances in Artificial Intelligence (A.I.) can be used to collect essential traffic counts and classification. It is a continuous real-time system as these cameras would continuously gather data, which complements Waze data's broad but inconsistent coverage. It is low-cost as surveillance cameras can be installed without civil works requirements compared to the traditional magnetic loop piezoelectric sensors (UK Department for Transport, 2018).

## 2. CURRENT STATUS

The current industry standard for developed countries is to install devices along primary highways known as Automatic Traffic Counters (ATC), to count and classify vehicles 24 hours a day, seven days a week (U.S. Department of Transportation, 2016). This device uses a sensor fusion approach of inductive loop and piezoelectric sensors array. Afterward, the secondary and tertiary roads can use a small sample of paper-based counting interpolated with primary highway data. Through this cost-effective method, traffic management gains a visible monitoring dashboard of the status on all roads. Alternatively, Waze data can also be interpolated with the ATC to provide more reliable traffic with better coverage.

However, the main limitation of existing ATCs is the prohibitive costs of their installation (i.e., cabling under road surfaces). Thus, in a budget-constrained country such as the Philippines, current approaches have focused on cheaper and less reliable methods, such as tube counting and paper-based counting. Like the inductive loop method, the main limitation of tube counting is that vehicle classification relies on a vehicle’s number of axles. In the context of the Philippines, the axle-based classification causes confusion on whether the car is a private or public transport such as jeepneys, UV Express, or tricycles.

On a positive note, a vital advantage of the Philippines compared to a developed country is that expensive legacy data collection systems are non-existent. Hence, S&T interventions are more flexible without considering the cost of migration. In other words, interventions can focus on leveraging the recent advances in Artificial Intelligence to provide cost-effective and reliable ATC.

An intuitive approach would be to use a CCTV camera system together with Computer Vision Algorithms to count and classify the vehicles visually. Relative to manual counting, the proposed approach enables continuous real-time data collection. Compared



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to the traditional magnetic loop piezoelectric sensors method, the main advantage of the CCTV camera system is that the vehicle classification is like the human-based counters. In addition, its installation is straightforward as multiple traffic management agencies, such as MMDA, own proper network cabling for their existing CCTV system.

CCTV Camera system for traffic counting must still be improved toward the operational requirements of ATC for the outdoor environment (UK Department for Transport, 2018). As evaluated by the UK Department for Transport for ATC operation environment, camera-based approaches have a poor performance in the nighttime and severe weather conditions. Consequently, this limitation implies that the ability to track reliable traffic estimates when travelers go home is still unreliable.

In addition, the constraints in using AI for traffic applications have already been stated in both government agency (UK Department for Transport, 2018) and existing literature (LeCun & Misra, 2021). Current AI technologies require sufficiently large amount of labeled annotation for each new environment. What it implies in regard to R&D is that a collaborative iterative approach with the transport management agency can significantly help meet the dataset requirement, minimize datadistribution mismatch, and address the required data network infrastructure.

## 3. PROPOSED R&D INTERVENTIONS

In this section, we propose on the following R&D interventions to enable cost-effective Intelligent Traffic Management Systems. The main objective of every intervention is to address the current constraints of using Video-Based CCTV Vehicle Counting and Classification through Artificial Intelligence. While our proposed interventions would not focus on developing real-time approach, we believe that the real-time system will follow once a more cost-effective approach is realized,

### 3.1. Robust 24/7 Camera-Based Vehicle Counting and Classification System

Concretely, our proposed intervention is to meet the operational requirements of ATC by improving night-time and weather conditions capability. Robust Machine Vision is still a significant issue in computer vision basic research (Dai, et al., 2021). Thus, rather than focusing on regular cameras alone, our recommended approach is to focus on *sensor fusion.* In other words, we aim to address the limitation on the hardware level rather than software alone to provide the robust capability. Some examples include but are not limited to:

(a) Multi-spectral imaging (MSI). Utilize different wavelengths that can still see vehicles even during tough conditions. One example would be to use infrared wavelength on nighttime and inclement weather condition. It was shown to be successful for safety driving situation (Hwang, Park, Kim, Choi, & Kweon, 2015), but requires extending the scope towards outdoor CCTV environment.

(b) Radio Frequency (RF)-specific radar sensors (RFRS). Specific RF wavelengths can pass rainy and nighttime capabilities. For example, cameras fused with LIDAR data was shown to have robust capability for self-driving cars (Nobis, Geisslinger, Weber, Betz, & Lienkamp, 2019). However, further experiments must be done to make it applicable towards outdoor CCTV environment.

(c) Tag Internet of Things (IoT) sensors (Tag-IoT) that also act as "lane lights." In this option, these tag IoT sensors reflect whether certain vehicles have already passed through a particular location. It is like parking sensor (Bosch Connected Devices and Solutions GmbH, 2018) but extended for highway traffic condition. On other hand, further research is needed to be applicable on the classification on a moving vehicle.

**Table 1: Comparative Analysis of different sensor fusion methods**

| | MSI | RFRS | Tag-IoT |
|---|---|---|---|
| **24/7 Data Quality** | All Day and All Weather | Proven to be useful in self-driving vehicle situation | Proven to work on outdoor parking despite lighting and weather conditions. |
| **Scalability** | Limits and Engineering constraints such as high altitude, severe typhoon condition requires further research | applicability towards CCTV scenarios is unexplored | Requires multiple nodes along road surfaces. Applicability on moving vehicles with different classification requires further research |
| **Installation Requirements** | Adaptable with existing Network Camera System | Might require roadside installation | Requires installation of multiple nodes along road surface. Can Use LoRaWAN technology to remove cabling requirements |
| **Operational Cost** | Requires a specialist on the maintenance of Specialized Cameras | Additional cost in operating LIDAR sensors | Continuous monitoring of status of multiple nodes is needed for high data quality |

### 3.2. Portable Counters

Specifically, we propose on improving the cost of scaling through Portable Camera Counters. It can be considered as cost-effective as a single unit can be deployed in multiple areas. While it may reduce the extensive spatiotemporal data in one location, adding mobile features expands the capacity to collect data from various roads. It can be thought of as upgrading the reliability of paper-based approaches. Hence, despite a limited budget, a country like the Philippines can still gather reliable data. However, it must be emphasized that developing portable cameras should withstand the operational requirements of paper-based approaches (UK

Department for Transport, 2018). Furthermore, addressing the extensive data variety requirement in a practical and cost-effective manner must be further explored.

A promising option is to explore an iterative collaborative approach with the end user. The research can start with using a pre-trained model such as AWS Panorama as a general-purpose counter. Afterward, during operation, a continuous performance monitoring is implemented to assess for any distribution mismatch and assess the need for further re-training.

Consequently, as the number of iteration increases (also known as Sprint in Agile Methodologies), we enable faster adoption, reduced distribution mismatch, and more performant portable counter applied in the context of the Philippine roads and vehicles.

### 3.3. Multi-View Camera Imaging

The trade-off between object identification and monitoring is a well-known issue. This is known as Detection, Observation, Recognition, Identification (DORI) standard (British Security Industry Association, 2021). The key question arises on the possibility of doing both tasks using a single camera, which can be made possible by performing image stiching on multiple cameras with different lenses. The same approach was used on recent mobile phones such as iPhones.

We propose using the same method to develop a CCTV that monitors vehicle and recognizes traffic violators. The main advantage of our proposed approach is to improve reusability of a single camera. In addition, having single camera improves on the ff installation constraints such as: (1) proper location of installation, (2) proper brackets, (3) different viewpoints on different setups. Furthermore, the said innovative CCTV has added value to the traffic management system rather than just vehicle counting and classification alone.

The potential engineering challenge in this research is the synergy of multiple varifocal lenses with respect to multiple image sensors. In mobile phones, fixed lens has been the popular choice. On the other hand, outdoor cameras often used Pan-Tilt-Zoom (PTZ) option to make monitoring more versatile.

## 4. CONCLUSIONS

In this paper, we propose Science and Technology R&D intervention that will be beneficial towards an intelligent traffic management system in the context of a developing countries, such as Philippines. Our key insight is to leverage the advances in Artificial Intelligence to have a cost-effective approach for a limited budget constraint. We summarize our proposed interventions as seen in Figure 1.

We also demonstrate that the existing research literature showed that our proposed intervention is not farfetched idealism, but adjacently within the grasp of existing work. We hope that funding agencies will be use this information to improve transportation woes.

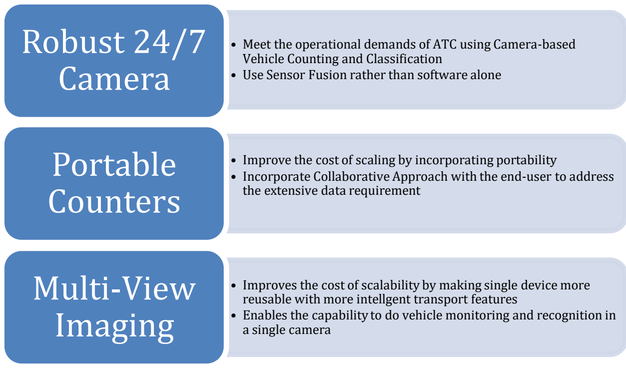


**Figure 1: Summary of Proposed Interventions for Intelligent Traffic Management Systems**

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