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## Road user behaviour analyses based on video detections: Status and best practice examples from the RUBA software

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### Abstract

To a large extent, traffic safety improvements rely on reliable and full-covering accident registration. This is difficult to obtain in practice. Hence, surrogate measures as traffic conflict studies can contribute with more information. To make these studies more efficient, a software called RUBA has been developed. It works as a watchdog – if a passing road user affects defined part(s) of the video frame, RUBA records the time of the activity. It operates with three type of detectors (defined parts of the video frame): 1) if a road user passes the detector independent of the direction, 2) if a road user passes the area in one pre-adjusted specific direction and 3) if a road user is standing still in the detector area. Also, RUBA can be adjusted so it registers massive entities (e.g. cars) while less massive ones (e.g. cyclists) are not registered. The software has been used for various analyses of traffic behaviour: traffic counts with and without removal of different modes of transportation, traffic conflicts, traffic behaviour for specific traffic flows and modes and comparisons of speeds in rebuilt road areas. While there is still space for improvement regarding data treatment speed and user-friendliness, it is the conclusion that, at present, the RUBA software assists a number of traffic behaviour studies more efficiently and reliably than what is obtainable by human observers.

### KEYWORDS:

Traffic safety, Video analyses, Conflict study

### Background for the software development

Traffic accidents are one of the main killers in the societies. More than 1.25 million fatalities and 50 million injured are registered each year (1). Most countries in the industrial world have experienced significant reductions in the number of fatalities since the 1970s (2). Also, a specific marked reduction has been recognised since the initiation of the financial crisis in 2007-8 (2). However, as the crisis fades, the number of fatalities has started to rise again (2,3), and the societies are still far from the ideal situation regarding traffic safety as described most thoroughly by the Swedish Vision 0 (4).

As focus on traffic safety increased, it also became clear that not all traffic safety problems could be identified and quantified proper from traditional traffic accident registrations (5). This is partly because of the skewness of registration depending of accident and road user type and the general dark figures in traffic accident registration (5,6), but also due to the limited information available in traditional traffic accident data. Therefore, surrogate measures might show a truer pattern than traditional accident data. One of the most well-reputed surrogate methods is the traffic conflict study (TCS) as thoroughly described by Hydén (7) and elaborated further on in many cases, see e.g. (5,8,9).

A TCS is normally made for individual locations, often intersecting ones, and the basic idea is to register any activities where absence of an avoidance activity would have resulted in an accident. This is termed 'conflict'. The time between the avoidance activity and the accident if no avoidance was made defines if the conflict is serious or not (5,7).

Originally, the TCS registration was made by reporters, i.e. persons who monitored the traffic activities manually. The work load was high as it required one person per traffic flow to study (10). Later, video registration took over. Cameras placed with overview on relevant parts of the location recorded the traffic behaviour. Subsequently, analyses were made based on the recorded videos. However, even though the analysis work moved to an office space, it was still very time-consuming (10). Therefore, with the upcoming video analysis tool, more of the analysis work can be made automatically or semi-automatically. One of these software systems developed for video analyses is the 'Road User Behaviour Analysis (RUBA), which will be elaborated on here. The remaining part of this paper consists of a brief introduction to some of the available on-the-shelf products, presentation of RUBA, how it works, selected case studies and a discussion on the possibilities and shortcomings with the RUBA software as it is now.

### **An overview of on-the-shelf products**

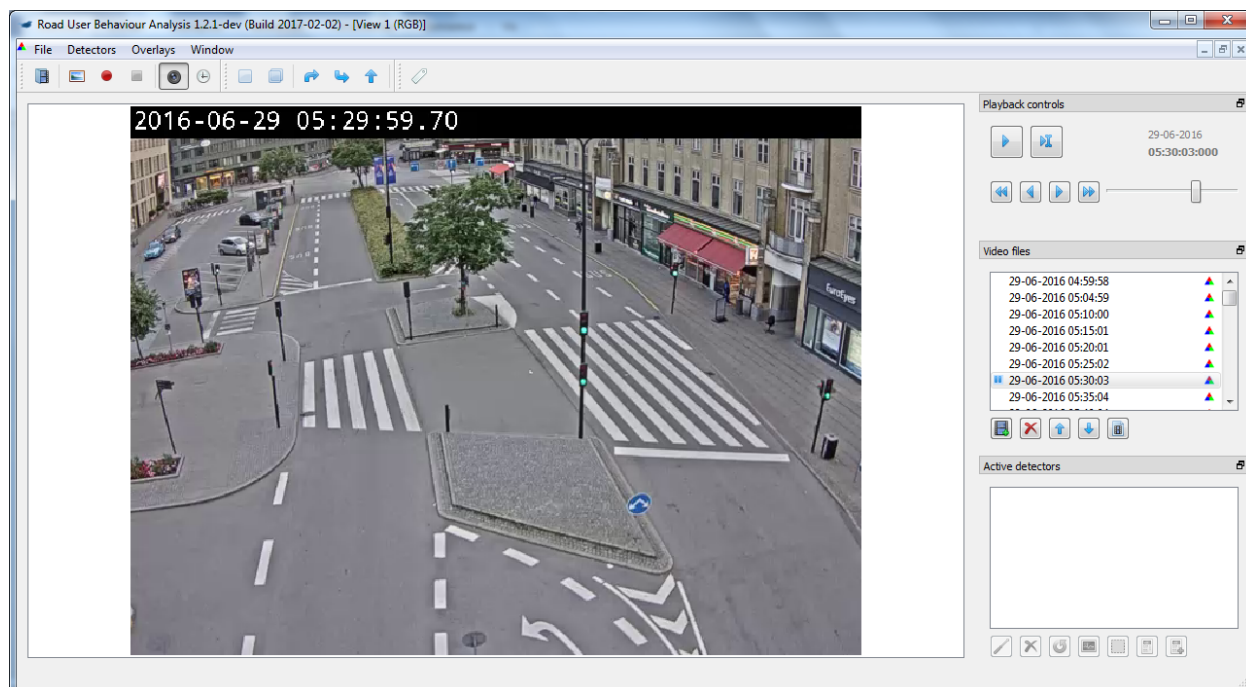
Most available products for traffic analysis come as an integrated solution for both hardware and software. There is a range of products, but the ones mentioned cover the most relevant issues. PedTrax and Smart Cycle from Iteris have their own hardware and can count and measure speed bi-directionally (11). Traffic Flow from Viscando Traffic Systems counts different road users and can detect how road users use the recorded space (12). DataFromSky (13) and Cowi A/S (14) use drone recordings, and can detect speed of individual vehicles and provide trajectories for the beneficiary. A few products and initiatives are available that enable end-users to analyse video recordings on their own computers, i.e. platform independent. The Traffic Intelligence project (15) allows for tracking and classification of road users from video. Recently, the functionality has been extended by the tvaLib library (16) allowing for further analysis and visualisation of the tracking results. Both of the two last-mentioned projects are primarily utilized from the command line and are thus not accessible for most end-users.

### **What is RUBA?**

RUBA is a computer-based video analysis tool for Windows, Linux and MacOS. The analysis is applied to the recorded video files and is thus independent of the hardware used for the video acquisition. RUBA is developed in collaboration between the Division of Transportation Engineering and Visual Analysis of People Laboratory at Aalborg University as a part of the ongoing H2020 project InDeV (17). The program can be used to analyse videos recorded at a specific location where traffic-related problems need to be studied. RUBA works as a watchdog, which means that RUBA can be used for identifying events of relevance in recorded videos and make a time-stamp of the event, so the interesting events can be processed manually afterwards (18).

The advantage of RUBA compared to manual registration is the absence of time-consuming screening of video frames – especially in case of detection of rare events as e.g. traffic conflicts or red-light driving. As most studied cases are somehow unique, it has so far not been possible to estimate the reduction of time use for the video analyses, but it is significant.

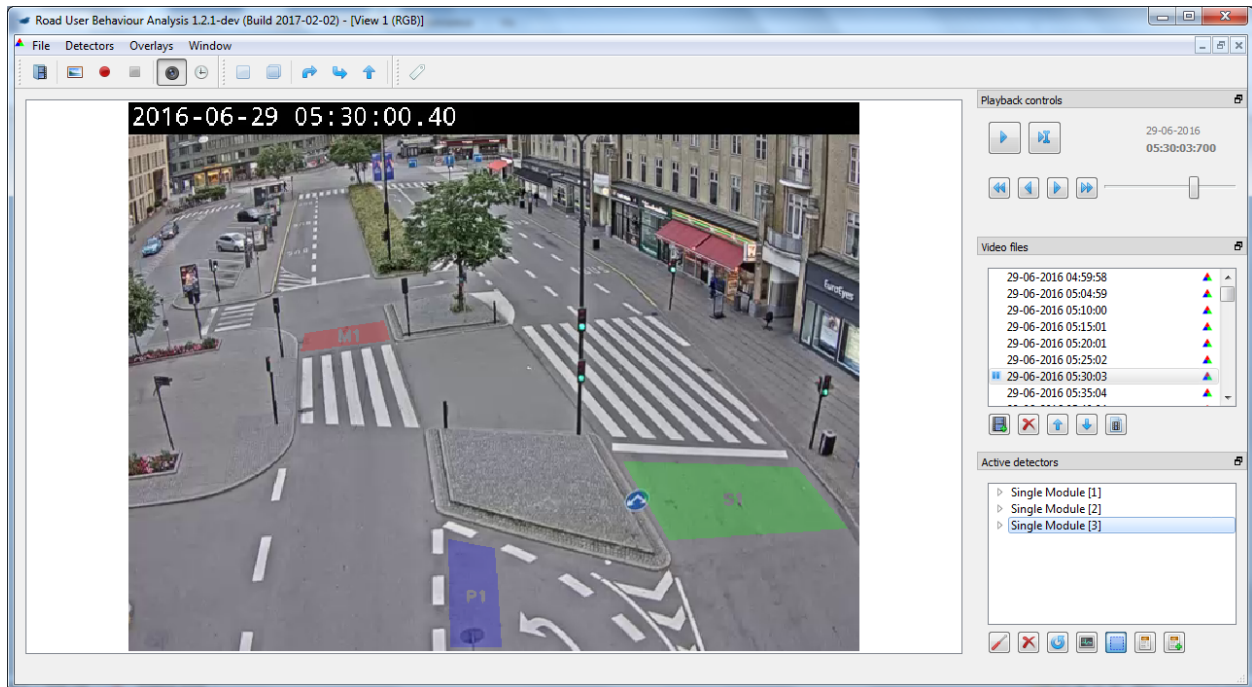
RUBA is available for research work via contact to Aalborg University. It is the aim to share the software with partners in collaborative projects with the aim to use, test and develop the program. Furthermore, academia can access the program – but not the source code – to specific agreed projects. In order to gain further experiences with the software, The Division of Transportation Engineering at Aalborg University is also keen to carry out consultancy services of relevance to RUBA. In the long term, it is expected to make the software freely available to municipalities and consultants.



**Figure 1: The user interface of RUBA.**

Figure 1 shows the user interface of RUBA. RUBA allows a user to draw one or more fields on top of the video in the area or areas where analyses are requested. These fields are called detectors and can register whenever a road user passes the detector. RUBA makes these detections of road user(s) on the basis of colour changes in the videos pixels within the drawn detectors. Every time the colour changes in the detector field, it is assumed that a road user passes the detector, and RUBA makes a time-stamp of the event.

RUBA has three types of detectors: Presence (Blue), Movement (Red) and Stationary (Green). The Presence detector registers if a road user passes the detector area independent of the direction, the Movement detector registers if a road user passes the area in one pre-adjusted specific direction and the Stationary detector registers if a road user is standing still in the detector field. Figure 2 shows the three types of detectors. The parameters to calibrate the detectors depend on the detector type, e.g. the parameters to calibrate a Movement detector are minimum speed, trigger threshold and movement direction, but the only parameter to calibrate a Presence or a Stationary detector is minimum occupation percentage. The minimum speed is the speed which the road user at minimum has to move to be detected, trigger threshold is the sensitivity of the detector, movement direction is the direction in which the road users should be driving to be detected and the minimum occupation percentage is the minimum coverage of the detector to activate it. The sensitivity of the detectors can be calibrated so only road users are activating the detector while movements of the camera view or branches and leaves will not affect the detection.



**Figure 2: The three types of detectors in RUBA.**

The detectors in RUBA can also be combined even if it is not the same type of detectors. A combination of two detectors is called a double module (One detector is called a single module). These double modules could, for example, be used to find events with same time arrival of two road users. RUBA allows the user to create more than one double module or single module in an analysis, but the amount and sizes of the detectors are crucial for how long an analysis will take. This is because it requires more pixel treatment and hence computer capacity. Figure 3 shows an example of a double module with two Movement detectors to register cases with identical time of arrival of a straight-going bike and a right-turning car.



**Figure 3: Double module to detect same time arrival between a straight going bicycle and a right turning car and a straight going bicycle and a left turning car.**

RUBA can be used in a lot of different analysis of traffic-related problems, and at Aalborg University so far RUBA has been used for TCS, counting traffic flows, registration of vehicle speeds and driving behaviour studies (19).

As RUBA is under development despite significant use and ongoing improvements, there are still some challenges to take into account. One is that the colour of the videos pixels in a detector field can change without a road user passes through, e.g. if the weather changes, the light in video changes or shadows from example trees or lamppost interferes. In such cases can RUBA in some cases make a time-stamp of a false-positive event regardless of the actual situation.

### **RUBA use cases**

RUBA can be used for different traffic analyses, and three examples of how RUBA can be used is counting traffic flows, registration of same time arrival between road users and registration of the speed of vehicles.

#### *Counting traffic flow – Case study in Aarhus*

RUBA can count traffic flows and volumes. Traffic flows were counted in the City of Aarhus, Denmark through a zebra crossing near the central train station. The study included the cars, buses and trucks, but in this area, there are many bicycles too, which means that the calibration of the detector needs to be done carefully or the detector will detect all the crossing bicycles as well.

Studies counting road users in a specific direction often use the Movement detector, because it is possible to sort out road users going in a different direction. If e.g. the straight-going cars should be counted, but the right-turning and straight-going cars share lane, the Movement detector can be used to

sort out right-turning cars. To count the three types of road user, mentioned before, in this study the Movement detector is used cf. figure 4.

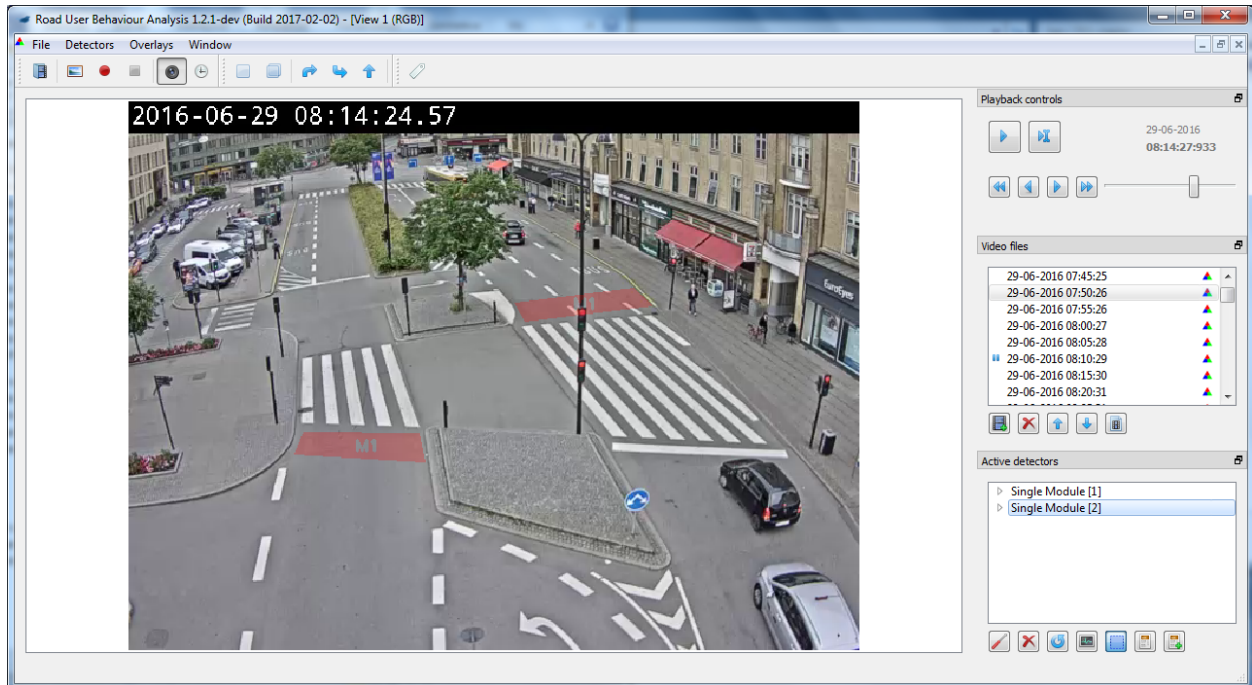


Figure 4: The two movement-detectors in the Aarhus project.

The detectors are placed after the zebra crossings in the two directions so road users yielding for the pedestrians can still obtain the minimum speed to activate the detectors. In Aarhus, it was needed to be sure that the detector did not count bicycles. It was done with the parameters, minimum speed and trigger threshold, as car drivers usually drive faster and the detectors would have to be less sensitive. Figure 5 shows an example where a car but not a bicycle is detected.

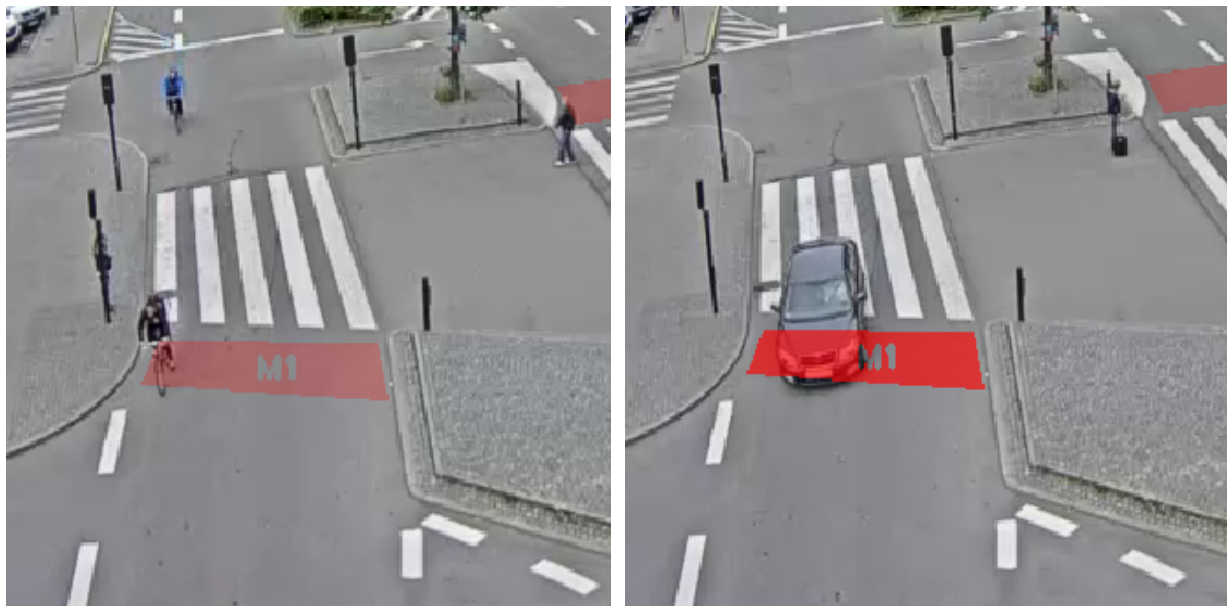


Figure 5: Demonstration of the ability to only detect cars, trucks and buses, and not bicycles.

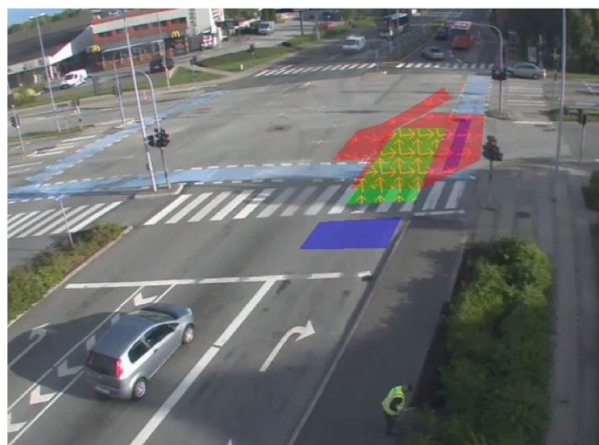
*Registration of same time arrival of road users – Case study of crossroads solutions for bicycles*

Another project in which RUBA was used was Road crossing for bicycles. The project focused on bicycle safety in road crossing and the effects from different kinds of bicycle lanes/paths (8,9).

Specific modules for RUBA were developed to decrease the numbers of false-positive registrations in this study. These modules were as follows: 1: one for straight-going bicycles, 2: for right-turning cars and 3: for left-turning cars. Each of the three modules contains of at least four detectors. Figure 6 shows an example of the use the three modules. The module for straight-going bicycles has four detectors: three Presence detectors (blue) and one Movement detector (red). The module for right-turning cars has five detectors: three Presence detectors (blue), two Movement detectors (red). There is one Stationary detector, which detects when a car is stationary in the detector (green). The module for left-turning cars has six detectors: two Presence detectors and four Movement detectors.



**Module for straight-going bicycles.**



**Module for right-turning cars.**



**Module for left-turning cars.**

**Figure 6: Examples of how to use the three modules.**

The combination of detectors used in this analysis were rather advanced and could be done more simply if more false-positives were allowed. The simpler version to detect same arrival time between a straight-going bicycle and a right-turning car would be to use a double module of two Movement detectors and a double module of a Movement detector and a Stationary detector, so it would also detect if the car yields for the bicycles. For straight-going bicycles and left-turning cars, the simpler version would be a double module of two Movement detectors. Figure 3 illustrates the principle behind the simpler version.



*Registration of a vehicles speed – Case study of speed through a roundabout*

A third study examined how rebuilding of rural single-lane roundabouts to road trains affects driving speed in the roundabouts (19). The study focused on the speed of private cars and was formed as a before-after study. The rebuilding of roundabouts was made to ensure sufficient space for road trains and was mainly made from a reduction of the central island, and the reduced area was added to the driving area due to an increasing width of the lane. Hence the turning radius became bigger. A bigger turning radius could allow road users, especially private cars, to increase their speed through the roundabout. The speed through the roundabouts was estimated in RUBA with two Single modules. The detectors registered when the car enters and leaves the detectors. With the known distance between the detectors, the speed was calculated. The overall result was that the average speed in the studied roundabout went up with 9 km/h (19). Figure 7 shows the detectors from one of the roundabouts. It has to be mentioned that while the actual speed registered with this method is rather uncertain, the calculated speed changes are more reliably as the same uncertainties in the before and after situation are present. The challenge regarding absolute speeds is connected with the inclined angel of recording. It is difficult to define the exact position of the detector areas and the various shapes of different cars etc. can further contribute to this uncertainty.



**Figure 7: Detectors from the vehicle speed study, before the rebuilding.**

**Summary and concluding remarks**

Traffic safety problems are mainly concentrated where there is interaction between road users, i.e. intersections of various types. Consequently, significant parts of the focus have been on the traffic safety of these intersections. Over time it has become clear that traditional accident records are rarely comprehensive and also ethically problematic to use due to the amount of time it takes from data

collection about an identified safety problems until a response. Therefore, surrogate measures are developed to react on the basis of a more comprehensive data set and in a short time. One of these measures is the Traffic Conflict Study (TCS). However, TCS requires a significant amount of video recordings to ensure coherent and reliable data samples. Analyses of this video data are very time-consuming without any software to reduce the manual work load, and it is preferable to do it more unambiguously than a human observer can do. Most available tools for these analyses are connected to the recording camera hardware.

In order to open up for more coherent analyses and increased knowledge of the effect of various road designs on road user behaviour, a platform-independent software can contribute positively in these directions. The RUBA software offers this and can be used to analyse in TCS. Also, it has proved useful to other types of traffic behaviour studies and registrations. RUBA works as a watchdog and basically it registers when the colour pattern in a part of the video frame changes more than a defined threshold. Furthermore, it operates with three type of detectors: Presence, Movement and Stationary. The first detector records if a road user passes the detector independent of the direction, the second detector if a road user passes the area in one pre-adjusted specific direction and the third detector if a road user is standing still in the detector area.

The RUBA software has been used for various analyses of traffic behaviour: traffic counts with and without removal of different modes of transportation, traffic conflicts, traffic behaviour for specific traffic flows and modes and comparisons of speeds on rebuilt road locations. With further development of the software and the associated expected increase in server capacity and computing power, it is expected that RUBA will be an even more efficient tool than it is at present. At the time of writing, automatic detection of red-light driving is being tested. Also, at present, the first test on drone recordings has shown promising results.

There is still room for further improvement, and there is a range of challenges which should be dealt with in order to increase the benefit from RUBA or similar watchdog-based software. Some of the main challenges are the following: 1) to deal with inevitable noise from shadows, changing light conditions, unstable camera installation and other movable objects such as leaves or even birds, 2) to distinguish a detailed movement pattern, as especially for cyclists' body language and eye contact play important roles and 3) to further streamline the working procedure to reduce manual time use. These challenges could be partly met by bigger computing power. It allows, all things being equal, for the use of more detectors without using too much computer time. Also, elements of machine learning would be able to solve some of the raised issues.

Regardless of the mentioned shortcomings from such software tool, RUBA is still more unambiguous and cheaper than if a human observer is to identify various problems in the transport system. Hence, it is a highly relevant tool to contribute to applied field research and, as such, to a cleaner, safer and more efficient road transport system in the future.

### **Acknowledgement**

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