IMPROVING INCIDENT DETECTION KPI ON SANRAL'S FREEWAYS IN GAUTENG

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ABSTRACT

The South African National Roads Agency Ltd (SANRAL) primarily relies on CCTV cameras to detect traffic incidents occurring on the Freeway Management System (FMS) network. On the Gauteng FMS network, over 90% of the incidents are detected using CCTV cameras. The operators have to manually pan, tilt and zoom each camera to detect incidents along the freeway.

Traffic incidents are the major cause of severe or fatal injuries, congestion and delays on the freeway. They may also result in secondary incidents such as rear-end or multi-vehicle collision. It is therefore of utmost importance that the incidents are detected and cleared within the shortest time span. In the current contract, SANRAL has set the 'Incident Detection KPI' as 3 minutes. In other words, on average, incidents have to be detected within 3 minutes from the time of occurrence of the incident. Once the incident has been detected, the operator would rewind the video footage to determine the 'occurrence time' of the incident. However, in most cases (approximately 70%), the occurrence time of the incident is unknown. This is predominantly because the camera was facing away from the incident location (facing the opposite direction).

This study aimed at improving CCTV surveillance, given the current infrastructure and resources; thereby increasing the number of incidents with an occurrence time. The study assumed that there would be no changes to the current camera positions, type of camera being used and operational structure. It was also assumed that there would be no additional cameras or human resources.

Several surveillance methods were evaluated. The proposed surveillance method was tested using a before and after study. Incident data from May 2017 was used as the "before" and incident data from May 2018 (three months after implementation of the proposed new method) was used as the "after" period. The results of the analysis showed that subsequent to the implementation of the automated pre-set surveillance method, the number of incidents with an occurrence time increased by approximately 15% – an increase of approximately 500 incidents. The paper eludes to some of the shortcomings that still exist in the new method and possible ways of overcoming it.

1. INTRODUCTION

The South Africa National Roads Agency Limited (SANRAL) is mandated by the National Transport Policy to implement incident management (IM) programmes on the entire national road network of South Africa (Department of Transport, 2017). The IM programme was implemented and it is managed under the contract for the Design-Build Operation and Maintenance (DBOM) of the Gauteng Freeway Management Systems (Gauteng FMS). The objective of the IM programme is to mitigate any adverse effects of traffic incidents such as congestion, injuries and fatalities. To do so, one of the critical focus areas of the programme is early detection of traffic incidents (SANRAL, 2016).

The Gauteng FMS thus utilizes a network of Closed Circuit Television (CCTV) cameras, Variable Message Signs (VMS), Vehicle Detection Sensors (VDS) and incident response vehicles that are deployed along the freeway network to assist with IM. Each of the components has a specific purpose in the management of incidents on the freeway. The CCTV cameras have the primary role and are the primary source of detecting incidents that occur on the Gauteng FMS. On average, over 90% of incidents are detected by CCTV cameras. Figure 1 shows the deployment of cameras along some sections of the Gauteng FMS network and Figure 2 shows a typical view from a CCTV camera.

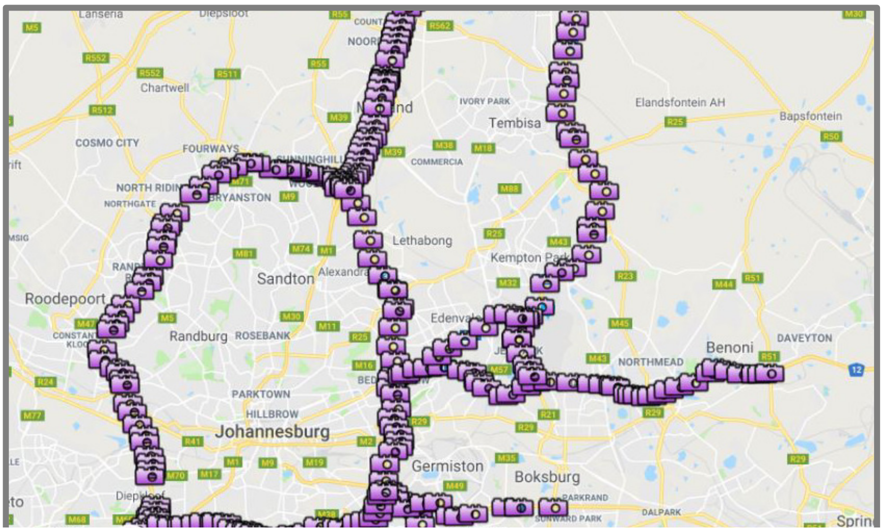


Figure 1: Deployment of CCTV cameras along the Gauteng FMS Network

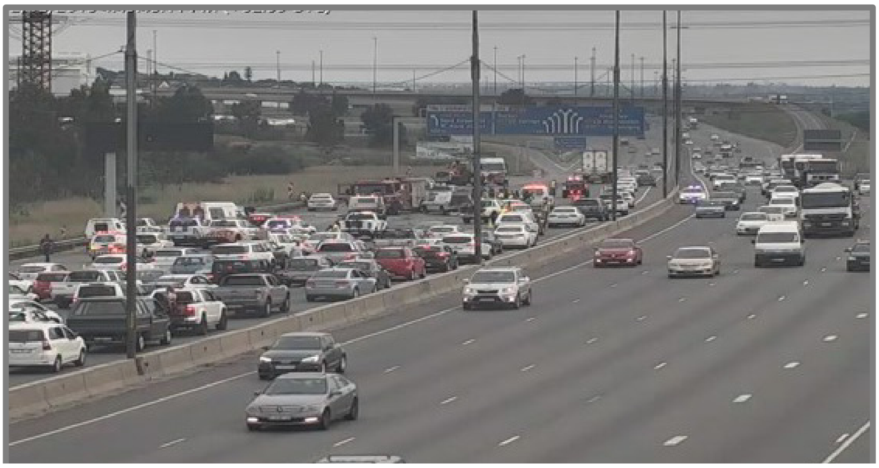


Figure 2: Typical view from a CCTV camera

A team of operators based at the Traffic Management Centre (TMC) monitor the CCTV footages and identify any incidents that occur on the freeway. The number of cameras that each operator monitors depends on a variety of factors including the time of day, traffic volume on the section of road that is being monitored, known hotspot area and the number of operators available per shift. At any point in time, the operators can monitor between 16 and 32 cameras. The operator monitors the cameras on 3 computer screens – two computer screens that display up to 16 camera views on each screen. Any of the camera views can be manually maximised onto the third computer screen to view details of the incident which includes looking for the actual occurrence time of the incident. Figure 3 shows the current setup of an operator's workstation.

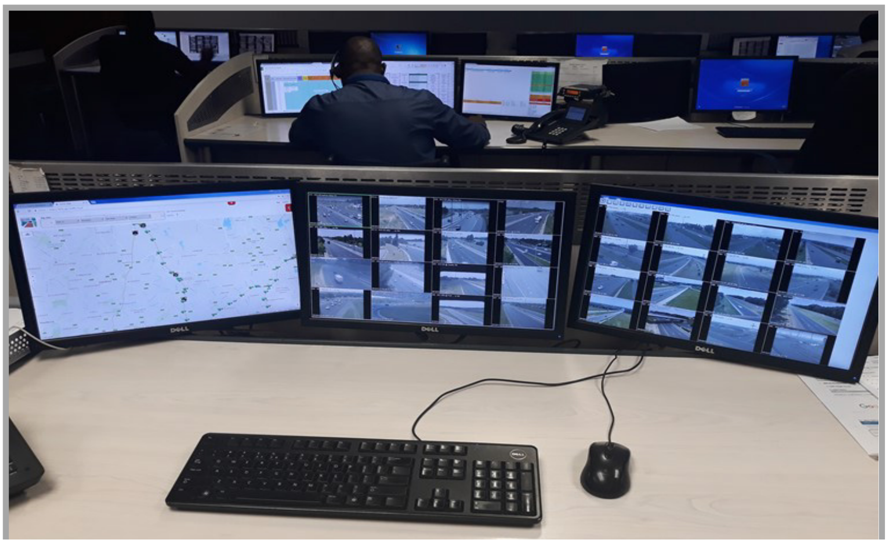


Figure 3: Typical Operator Workstation with Computer Monitors

When an incident occurs, the operator immediately captures the details of the incident in the Advanced Traffic Management Systems (ATMS). Based on past experience, the operators rarely see the incident occurring. Often, the operator observes traffic congestion on their section of the road and then they pan the camera to the front of the queue, only to realise that there has been an incident. The time when the operator detects the incident and registers it on the ATMS is recorded as the "Incident Detection Time". Incident Occurrence Time and Incident Detection Time are two key inputs into the ATMS based on which one of the KPI is measured. In this contract, the detection KPI ensures that incidents are detected by the CCTV cameras within 3 minutes. In other words:

Incident Detection Time – Incident Occurrence Time < 3 minutes

The "Incident Occurrence Time" is the actual time the incident occurred. If the operator did not see the incident occurring, then he/ she may rewind the video footage to determine the Incident Occurrence Time. In 2018, on average, there were 3200 traffic incidents detected per month on the Gauteng FMS. However, the incident occurrence time of approximately 70% of the incidents could not be determined, in spite of being able to rewind the camera footage. This is a cause of concern as it limits the ability to provide quick response, especially at severe crash sites. In addition, it decreases the efficiency of the whole network in terms of congestion and delays.

There are several reasons as to why operators may not be able to accurately detect the time of occurrence of incidents. These include:

- The camera could be facing in a direction away from the location where the incident occurred;

- The camera could be facing the correct direction, but it was zoomed in, well past the location of the incident;
- The operator missed the incident while he/she was manually panning through the cameras;
- The operator missed the incident while he/she was capturing details of the previous incident in the ATMS.

This paper highlights the new methodology that was developed to increase the number of incidents with an incident occurrence time – thus improving the KPI. It is important to note that the scope of the study was limited to improving the detection KPI using the existing infrastructure and resources available - the existing cameras positions, technical equipment (cameras, wireless communication devices, software) and human resource. Incident data collected from May 2017 (manual surveillance method) was used as the base or control scenario. The new method was piloted for a period of 3 months from March 2018 to May 2018. Incident data collected from May 2018 was compared with the base scenario. The findings of the study are summarised in this paper. The paper also eludes to some of the shortcomings that still exist with the new method and possible ways of overcoming it. The section below describes the manual surveillance method that was used.

2. MANUAL SURVEILLANCE METHOD

The spacing between the cameras on the network range between from 250m to more than 1km. The operator does not have a sequential continuous coverage of the freeway. The operator used a computer mouse to pan, tilt and zoom each camera. By doing so, the operator could view a stretch of the freeway that is within the radius of the camera's view to look for incidents. When an incident was detected, the operator would record the details of the incident in the ATMS. In order to detect an incident timeously, it is essential that an operator is able to view all the cameras and identify the incident as quickly as possible. The way in which the operator pans each camera, how quickly the operator cycles through the cameras and the operators' ability to not miss an incident while skimming through the various cameras determine the efficiency of the operator.

The disadvantage of this method was that the operator had to continuously pan one camera after another, up to 32 cameras, to view the sections of the freeway. This can be a cumbersome exercise, which may lead to fatigue and a drop in efficiency and responsiveness of the operator. Secondly, if the operator takes too long to cycle through the cameras, by the time he/she returns to the first camera, there may be an incident that occurred and was left undetected for a long time. Thirdly, the operator is expected to cycle through all cameras within a specified minimum time (3 minutes). The time constraint forces the operator to quickly skim through the cameras, which may lead the operator missing incidents. However, the advantage of manual surveillance is that when an operator pans the camera, he/she is able to have a comprehensive view of the freeway sections.

3. ALTERNATIVE SURVEILLANCE METHODS

Alternative methods of camera surveillance were then developed with the aim of improving CCTV surveillance to increase the detection of incidents. The following sections provide a description of the alternative methods that were explored.

3.1 Static-continuous view surveillance

Static-continuous view surveillance can be described as the positioning of the camera in a fixed position to view the entire freeway segment from end to end at specific times of the day. On the computer screen, the operator would be able to see the entire stretch of the freeway, without having to pan the cameras.

The direction of the camera view may be determined in such a way that the view is clear of any obstruction during its entire period, and preferably in the direction of the highest traffic volumes. In order to position the camera view clear of obstructions, the IT technician, traffic specialist, operator and supervisor should identify all possible sources of obstructions. Once the obstructions are known, the camera view should be set in the opposite direction of the obstruction. Some of the obstructions that are known include:

- The position of the sun (glare);
- Camera poles/ mast;
- Vegetation;
- Bridge deck, pillars, gantries and other infrastructure.

In this method, for example, each camera view (zoomed out) would be temporarily positioned in one direction during the AM Peak period and changed to the opposite direction during the PM Peak period. In other words, all the cameras would be ideally facing the same direction during the AM Peak period. During the PM Peak period, all the cameras would be rotated to face the opposite direction. Therefore, the camera view is changed only twice during the day. Figure 4 and Figure 5 show the ideal positions for static viewing for roads oriented in the east-west direction, for example, the N4 freeway. The dotted lines show the areas covered by the camera view. The distance between the cameras should not be more than 400m for the method to be feasible – based on the technical specification of the current cameras on the network (Teti Traffic, 2018). Otherwise, it would not be possible to achieve continuous coverage.

The advantage of this method is that it provides the operator with a continuous and holistic view of the freeway segment. In addition, it is less labour intensive for the operator, making it easier for him/ her to identify an incident. It can be said that this could be the ultimate alternative given that the cameras are optimally spaces to provide continuous coverage.

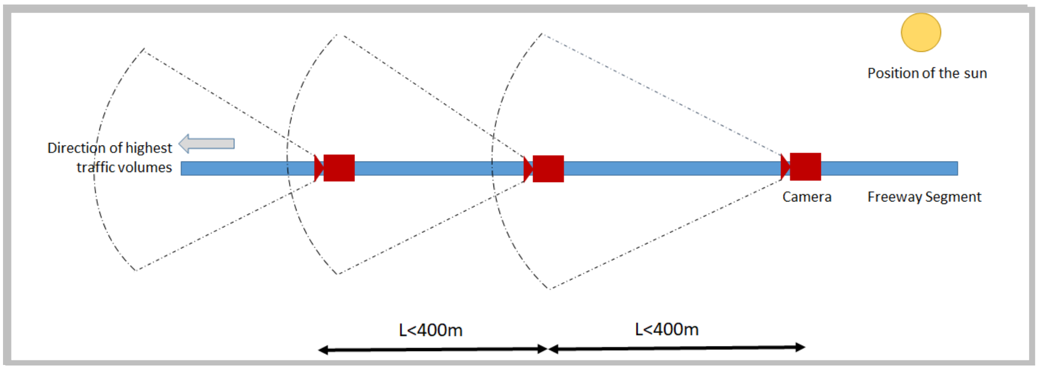


Figure 4: Static viewing of the N4 freeway during the AM period

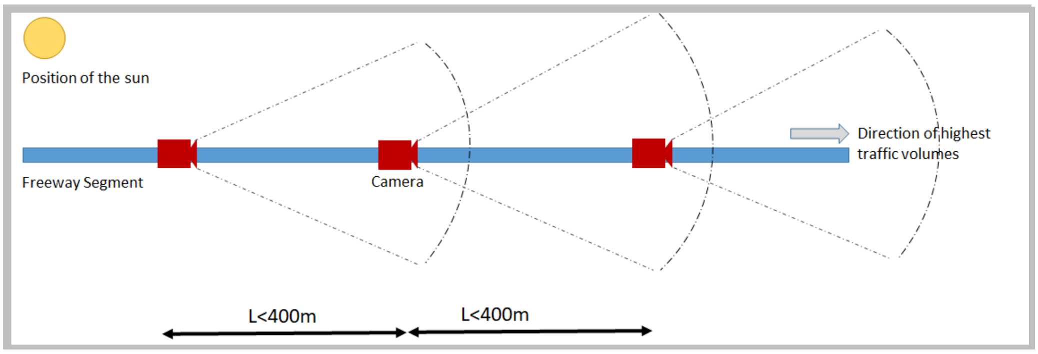


Figure 5: Static viewing of the N4 freeway during the PM period.

3.2 Roaming view surveillance

Roaming view surveillance can be defined as automatically positioning the camera to view various directions for a period of time so as to cover the road segments in its entirety. It is an alternative to the static-continuous view surveillance in cases where it is not possible to have a one-directional coverage. In this method, the cameras keep panning and tilting on either side of the camera pole along the freeway for short durations. For example, the camera will pan and tilt in the east direction for 30 seconds, pan and tilt in the west direction for 30 seconds and then pan and tilt back in the east for 30 seconds. This should happen continuously during all times of the day.

This method would only work effectively on freeway segments, especially if the distance between the cameras is short enough to provide an uninterrupted view of the freeway. This method is limited as the on-ramps, off-ramps and interchange terminals may fall outside the field of vision of the cameras. In urban areas such as Gauteng, the close proximity of interchanges and the presence of C-D roads pose a challenge to this method of surveillance. Figure 6 shows the ideal scenario for roaming view surveillance.

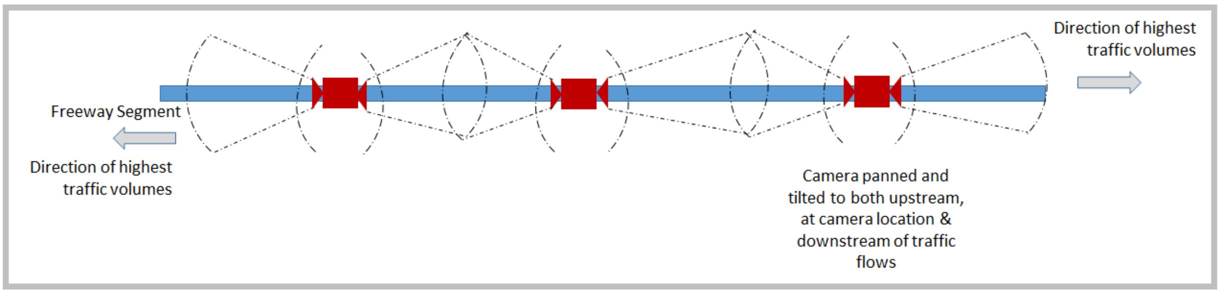


Figure 6: Roaming view camera surveillance

3.3 Automated pre-sets surveillance

Automated pre-set surveillance can be defined as programming the camera to automatically zoom, tilt and pan to different 'viewports'. The cameras would automatically cycle through these viewports allowing the operator to easily view the freeway segments including interchanges.

In order to determine where to view (viewport) and how long to view each viewport, the TMC manager and traffic engineer conducted an analysis to identify the critical factors.

They include the following:

- Obstructions such as overhead sign boards, camera poles and bridge deck;
- Known hotspots on the sections of the road;
- Traffic parameters (speed, density, flow, peak period, direction);
- Geometry and length of the road;
- Environmental factors that may affect traffic patterns such as rainy weather conditions.

Based on this, the pre-sets (viewport, duration of each viewport) and the order of viewing the pre-sets for each camera were determined. It was a collaborative effort between the IT technician, the traffic engineer, TMC manager and operator to determine the pre-sets for each camera. Based on the initial assessment, it was found that the pre-sets for cameras monitoring freeway segments had to be different from those of cameras at interchanges. As discussed earlier, the cameras at interchanges are used to monitor the on and off-ramps and the interchange terminals; hence requiring more pre-sets. Figure 7 shows actual locations of CCTV cameras at an interchange and at a freeway segment.

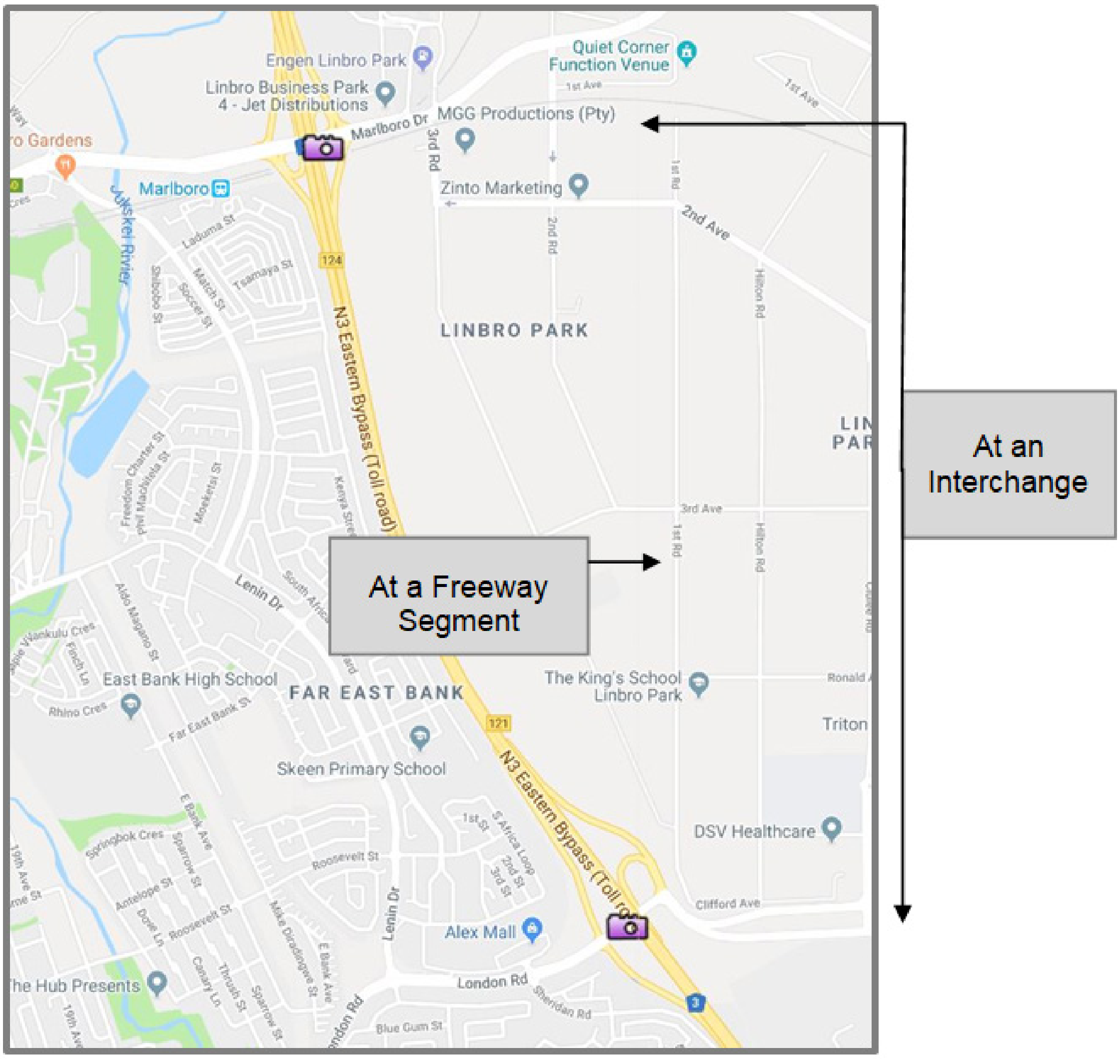


Figure 7: Actual locations of CCTV cameras at an interchange and at a freeway segment

3.3.1 At a freeway Segment

The time allocated to each pre-set was determined based on the five factors mentioned above. Figure 8 shows an example of the 3 locations where the camera would focus during a pre-set tour. At each of the 3 locations, the number of incident occurrences may vary. To determine the time allocated to each viewport (locations 1 to 3), the following steps were followed:

- Obtain traffic data collected using any of the various devices;
- Conduct an incident analysis on the different sections of the freeway segment to identify hotspot areas;
- Map/show incident variation/hotspots. This map would indicate the priority areas to focus on;
- Quantify total incidents in the Eastbound - Westbound direction or Northbound - Southbound direction;
- Depending on the incident distribution, allocate pre-set time per direction. The location with fewer incidents will be allocated less time as compared to one with more incidents;
- The total time allocated will further be divided into positions 1, 2 and 3 depending on the distribution of incidents in that directions;
- The total time allocated to complete all pre-set tours for all the directions and sections of the road (1, 2, 3, 2 and 1) should not exceed 180 seconds (3 minutes).

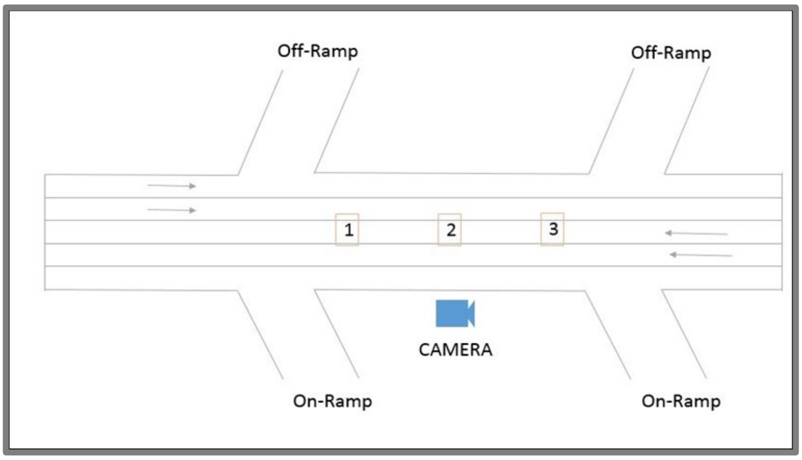


Figure 8: Setting up of pre-sets on freeway segments

3.3.2 At an Interchange

Figure 9 shows an example of pre-set locations of a camera located at an interchange. The steps (i to v) followed for a freeway segment would apply for cameras positioned at an interchange. The total time allocated to complete all pre-set tours would follow the cycle of 1, 4, 3, 5, 2 and 1. The time allocated and the number of cycles per pre-set tour would depend on the type of interchange. For example, a full clover would have more segments to view than a partial clover interchange. A full clover would, therefore, require more pre-set cycle tours compared to a partial clover interchange.

These cycle lengths would be optimized by setting smaller pre-set cycle lengths to increase the opportunity to capture the occurrence of an incident. By so doing, the operator would be able to monitor all the cameras within the required 3 minutes.

4. SELECTED SURVEILLANCE METHOD

The three alternative methods were evaluated by looking at the pros and cons of each method. The pros and cons are presented in Table 1.

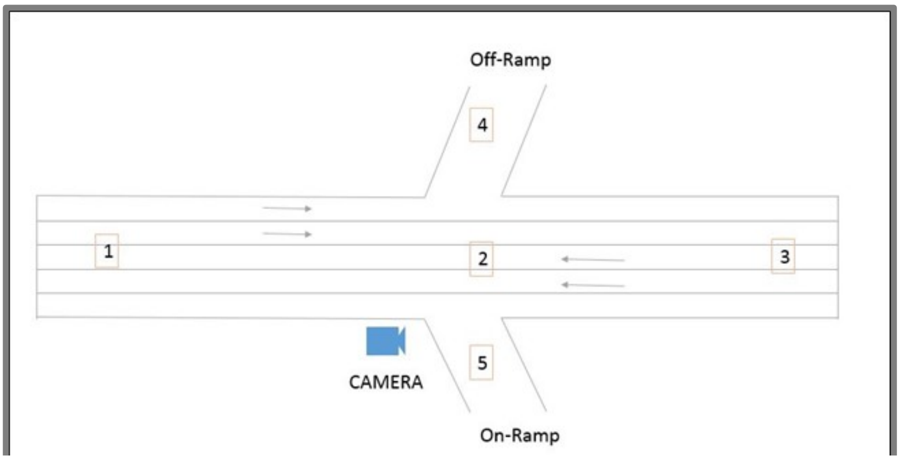


Figure 9: Setting up pre-sets at an interchange

Table 1: Pros and cons of the alternative methods

Method	Pros	Cons
Static-continuous view surveillance	▪ A continuous and holistic view of the freeway segment; ▪ Less labour intensive.	▪ If the distance between cameras is more than 400 meters, the method may not be feasible and this was the case along some of the road sections. Infill cameras may, therefore, be required, which falls outside the scope of this study.
Roaming view surveillance	▪ A continuous and quick view of the freeway; ▪ Provides the operator with a holistic view of the roadway segment; ▪ Less labour intensive for the operator to survey the freeway.	▪ Incidents that may occur on the ramps and on the cross streets may not be detected (may not have a continuous view of the full network). Infill cameras may, therefore, be required, which falls outside the scope of this study.
Automated pre-set surveillance	▪ The camera is able to view the segment or interchange within 3 minutes; ▪ More than one pre-set cycle may be possible within 3 minutes. This allows the operator to see the segment multiple times with 3 minutes; ▪ Continuous and quick view of the freeway; ▪ Provides the operator with a holistic view of the roadway segment; ▪ Less labour intensive for the operator to survey the freeway.	▪ Setting up of pre-sets for each camera is time-consuming and cumbersome; although it is once off.

From the comparison of the pros and cons of the 3 methods, it was determined that the automated pre-set surveillance method would be the only feasible method given the current scope. Regardless, it was found to be the most feasible option.

5. IMPLEMENTATION OF THE AUTOMATED PRESET SURVEILLANCE

The setup and implementation of the automated pre-sets were conducted in March 2018. The pre-set times were set for each camera. Table 2 shows the pre-set time allocation for each camera. The fifth column shows the time determined to view all segments covered by a camera. This time must add up to 180 seconds (3 minutes) to allow the operator to view all freeway segments at least once within the KPI time.

With this method of surveillance, the operator may get to view a segment more than once within the KPI time and this increases the opportunity to capture more incidents at their time of occurrence.

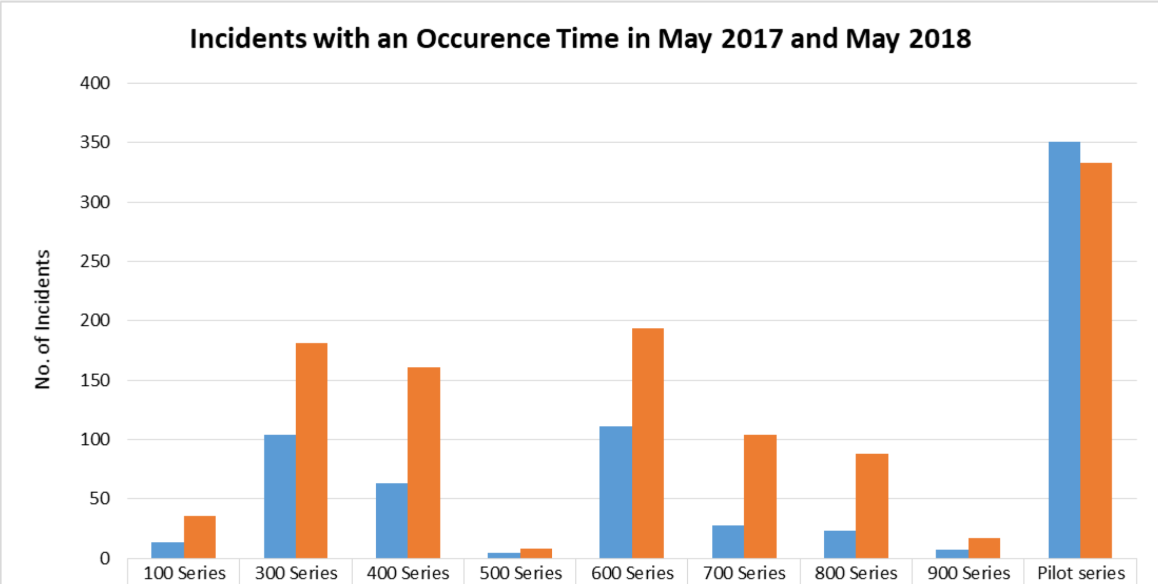
As mentioned earlier, the methodology was implemented in March 2018. In the first two months, operators were familiarizing themselves with the new method. A before and after analysis was then conducted to determine the increase in the number of incidents as well as its efficiency.

Table 2: Camera series pre-set tour cycles

500 Series CCTV Cameras	Locations/Direction	No of Monitored Freeway Segments (Viewports)	Pre-set time for each freeway segment (seconds)	Pre-set time to view all segments (seconds)	No of Pre-set Tour Cycles in 3 minutes
CAM 551	N17 Elands I/C EB AF N17 TO N17 Germiston I/C EB BF N17/Ramp to N3	1	3	3	12
CAM 501		1	3	3	15
CAM 501	N17 WB AF N17 Germiston I/C/Ramp from N3 TO N17 WB BF N17 Elands I/C	1	4	4	18
CAM 551		1	3	3	18
CAM 502	N17 EB AF N17 Germiston I/C/Ramp from N3 TO N17 Germiston I/C EB BF N17/Ramp from N3	5	2	10	9
CAM 327		5	3	10	9
CAM 327	N17 WB AF Ramp to Germiston Interchange TO N17 Germiston I/C WB AF N17/Ramp to N3	7	4	21	3
CAM 502		5	4	20	4
CAM 503	N17 Germiston I/C EB AF N17/Ramp from N3 TO N17 EB BF Ramp to Wits Rifles I/C M37	1	3	3	25
CAM 503	N17 WB AF Ramp from Wits Rifles I/C M37 TO N17 WB BF Ramp to Rand Airport I/C	1	3	3	24
CAM 504	N17 EB AF Ramp to Wits Rifles Drive TO N17 EB BF Ramp from Wits Rifles Drive	4	3	12	8
CAM 504	N17 WB AF Ramp to Wits Rifles Drive TO N17 WB BF Ramp from Wits Rifles Drive	4	3	12	15
CAM 505	N17 EB AF Ramp from Wits Rifles I/C M37 TO N17 EB BF Ramp to Osborn IC M53	1	4	4	12
CAM 506		1	4	4	15
CAM 506	N17 WB AF Ramp from Osborn IC M53 TO N17 WB BF Ramp to Wits Rifles I/C M37	1	4	4	12
CAM 505		1	3	3	14
CAM 507	N17 EB AF Ramp to Osborn IC M53 TO N17 EB BF Ramp from Osborn IC M53	6	2	12	15
CAM 507	N17 WB AF Ramp to Osborn IC M53 TO N17 WB BF Ramp from Osborn IC M53	5	2	10	15
CAM 508	N17 EB AF Ramp from Osborn IC M53 TO N17 EB BF Ramp to Rondebult Road R21	1	3	3	18
CAM 509		1	4	4	15
CAM 509	N17 WB AF Ramp from Rondebult Road R21 TO N17 WB BF Ramp to Osborn IC M53	1	2	2	20
CAM 508		1	3	3	15
CAM 510	N17 WB AF Ramp to Rondebult Road R21 TO N17 WB BF Ramp from Rondebult Road R21	6	2	12	9
CAM 510	N17 EB AF Ramp to Rondebult Road R21 TO N17 EB BF Ramp from Rondebult Road R21	5	3	15	8

6. BEFORE AND AFTER ANALYSIS

The analysis was tested over the entire freeway network by analysing the change in the number of incidents with occurrence time for each camera series for the month of May 2017 and May 2018. The camera series refers to the implementation phase of the project. Figure 10 shows the comparison of the two months. It shows that for all the camera series (except for the pilot series), the number of incidents with occurrence time had increased. The total number of incidents with occurrence time increased from 706 in May 2017 to 1122 in May 2018 – an increase of approximately 500 incidents. The increase in the number of incidents with occurrence time was normalized with the overall number of incidents for each month. After normalising the data, it was found that there was a 15% increase in the number of incidents with occurrence time.



	100 Series	300 Series	400 Series	500 Series	600 Series	700 Series	800 Series	900 Series	Pilot series
May-17	14	104	63	5	111	28	23	7	351
May-18	36	181	161	8	194	104	88	17	333

Figure 10: Incidents with occurrence time – a comparison of May 2017 and May 2018

Even though there was a significant increase, there are some shortcomings that exist, which include:

- System unavailability due to power outages.
- In some locations, the distance between cameras was higher than the ideal 400m for continuous coverage. Infill cameras would be required for continuous coverage.
- An operator views camera footages on the 2 computer monitors and also logs in data in the ATMS on the third computer monitor. When an incident is detected, the operator does not attend to the camera views on the 2 computer monitors and only attends to the computer monitor where the incident details are logged in the ATMS. During the period, all incidents that occur may not be identified. The setup of the operators needs to be restructured such that there is a separate team viewing camera footages and another team capturing the data in the ATMS.
- There are several blind spots on the network that cannot be viewed. These include segments of the freeway under the bridge deck or blocked by camera pole or existing vegetation.

- Bad weather conditions affect the visibility of the camera. Severe weather also affects the wireless communication between the devices and the TMC.
- Some of the older cameras have lesser pixels and lesser clarity as compared to the newer ones. Therefore, during the night, visibility may be limited for incident detection.

7. CONCLUSION

SANRAL relies on manual surveillance of the CCTV cameras to detect incidents along the freeways. Only 30% of the total incidents had an occurrence time. Three alternative methodologies were then developed to increase the number of incidents with an occurrence time; thereby improving the KPI. The automated pre-set surveillance was determined to be the most efficient method, given the current infrastructure and resource constraints. The new method was tested by comparing the data from May 2017 which was used as the “before” and May 2018, three months after implementation of the new method, which was used as the “after” period. The results of the analysis showed that subsequent to the implementation of the automated pre-set surveillance method, the number of incidents with occurrence time increased by approximately 15% - an increase of approximately 500 incidents.

The study also revealed that there are some shortcomings that make it difficult or impossible to attain a 100% record of incidents with occurrence time. This presented an opportunity to mitigate some of the shortcomings. On freeway segments where the distances between cameras were more than the ideal 400m for continuous coverage, installation of new infill cameras was proposed. Proposals were also made to install cameras that have better visibility at night or low-light conditions. It was also recommended that the operator setup at the TMC be restructured such that there is a team viewing the camera footage, while another team captures the data in the ATMS.

In conclusion, the combined effort of the team members (Teti Traffic and Koleko) and the support of the client (SANRAL) assisted in improving incident detection and deploying emergency response on the freeways.

8. REFERENCES

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