

DETECTION OF CYCLIST AND PEDESTRIANS AROUND HEAVY COMMERCIAL VEHICLES

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ABSTRACT

Large trucks have significant blind spots, and urban settings often bring these vehicles in close proximity to vulnerable road users (VRUs). Over 13% of VRU fatalities in Canada in 2016 involved collisions with heavy commercial vehicles. Transport Canada launched a multi-year field trial, in collaboration with municipal partners, to evaluate the state of VRU detection and warning technologies. The project evaluated cyclist and pedestrian alert systems retrofitted onto different types of heavy-duty commercial vehicles. Prior to the field trial, in-depth assessments were conducted on a test track to identify suitable systems for more extensive long term testing. The equipment had to accurately and reliably alert drivers of an imminent risk of collision, based on a time to collision warning, as well as limiting the number of false positive detections. Five different candidate systems were subjected to a series of simulated “urban environment” scenarios performed on a close track. The results of these tests are presented in this paper. The technologies included, ultrasonic, radar, 360 video cameras, smart cameras, and a combination of these systems. The test scenarios were based on the most common real world VRU-truck collisions identified from collisions investigation reports. Six dynamic and four false positive scenarios were created to test the capabilities of sensors designed to alert the driver of surrounding VRUs. Data were recorded on the timing of audio and visual alerts, the GPS position of the vehicle/VRU, the velocity and environmental conditions. All the detection systems were installed on a single vehicle, traditional cabin dump truck. Three test dummies were used: a 50th percentile male, a 7 year-old-child and an adult cyclist. The results suggested that the current VRU detection and warning technology may not be sufficiently mature to fully address the risks. No single system could successfully warn the driver in time to avoid a collision in all of the test scenarios. The smart camera system performed best overall and was selected for more extensive testing on different vehicles in a multi-city field operational test.

INTRODUCTION

A common challenge for heavy-duty commercial vehicles circulating in urban areas is that they have large blind spots that can easily conceal vulnerable road users (VRUs). These risks are compounded by higher driver workload of having to maneuver large vehicles in heavy mixed urban traffic. Even in a low speed setting, a pedestrian can easily be in harm's way without having a large speed differential with the heavy-duty commercial vehicle. In 2016, 393 VRUs, 21% of all road fatalities [1], lost their lives on Canadian roads. Of these, 52 VRUs or 13.2% of those fatalities were directly attributed to heavy-duty commercial vehicles. The aim of this research was to evaluate the performance of VRU detection and warning systems to address the safety issues surrounding heavy-duty commercial vehicles operating in urban settings.

Discussions on road design, road segregation, signalization and other countermeasures have been brought forward to address the issue [4][5]. In terms of countermeasures, operators might benefit from systems that warn of VRU's close proximity and at risk. Such system used in combination with the mirrors installed on the vehicle can enable the operator to take actions to avoid a collision in a timely fashion. To improve current heavy-duty commercial vehicles, Transport Canada scanned the market for off-the-shelf solutions that could assist the operator in an urban setting [6]. A wide array of technologies were observed and studied for this evaluation: smart camera technologies, radar based alert system, ultrasonic proximity sensors and 360 view camera setup were evaluated.

In order to evaluate the performance of aftermarket solutions, ten urban scenarios were designed from detailed fatal or severe injury collision investigations. The track testing evaluated system performance in these most common hazardous situations.

METHOD

Background

The test scenarios were developed based on one hundred detailed cases analyzed by Transport Canada's collision investigations teams over the last ten years [2]. The cases were investigated due to the high sensitivity of VRUs' fatalities implicating heavy-duty commercial vehicles, as well as the need to better understand the dynamics and parameters leading to these needless events. For this study, the most common scenarios were categorized and reproduced in a closed course environment. Six scenarios were developed for direct conflict and four designed to identify false positive situations.

Equipment

Transport Canada owned a 1988 GMC Brigadier at its test facility. This test specimen represented a heavy-duty commercial vehicle, equipped with a dump box. The test vehicle was instrumented with RT4002 Inertial GPS Navigation Systems and RT-Range from Oxford Technical Solutions (Ox-TS) to measure the vehicle's position, heading, vehicle speed, angular velocities (yaw, roll, and pitch rate), linear acceleration (longitudinal, lateral and vertical) and distance to target. Three 4-Active articulated pedestrian dummies (50th percentile adult male, 7-year old child, 50th percentile adult cyclist as shown in figure 1) paired with the Soft Pedestrian Target (SPT-20) system from Anthony Best Dynamics were used to safely and accurately challenge the detection systems. The dummies were pulled by a track system and synchronized to produce dynamic conflicts between the heavy-duty commercial vehicle and the VRU. Used to evaluate passenger vehicles' ADAS systems (Advanced Driver Assistance Systems), the standardized dummies provided reliable and repeatable test conditions. These pedestrian/cyclist dummies are designed to be impacted by a vehicle. They have a radar signal cross section similar to a human and are articulated to mimic human motions which enable the evaluation of the detection system's safety and accuracy.



Figure 1. Surrogate dummies

Procedure

The scenarios chosen challenged the aftermarket crash avoidance technologies with a 5 seconds time to collision. The position of the VRU was recorded with respect to the position of the truck to evaluate when/where on that path to collision, the system warned the driver of the presence of the VRU. Audible and visual signals were analyzed. Videos images of the interior and exterior of the vehicle were recorded as well. The system had to provide enough time to direct the driver’s attention towards the critical situation.

All systems provided either an audio or a visual signal to warn the driver about the proximity of a VRU. For the six dynamic scenarios, the smart camera technology offered a two stage warning. This extra time enabled up to 1 second of additional heads-up warning for the driver to react in certain scenarios. Radar technology was also very effective at identifying the dummies, but also triggered the alert when passing by inert objects – leading to a greater incidence of false positives. Ultrasonic sensor technology and 360 degrees view cameras only offered the benefits during four stopped scenarios, where it provided a warning of an incoming VRU into the blind spot in very close proximity of the vehicle.

Five systems were acquired and installed on the same vehicle. See Table 1 for details and specifications. All systems were tested independently from each other to ease the signal acquisition. Two systems were installed by the manufacturer’s technicians and one was installed by PMG technologies based on the manufacturer’s instructions.

Table 1.
Warning Systems

ID	Provider/ type	Location on Truck	Range	Driver signal
A	Ultrasonic proximity sensors	4 units along the front bumper of the vehicle 4 units along the bed of the truck on each side	1m – 2m. The testing was performed with the setting at 2 meters detection	Visual: LED light (light) Audio: Beep
				Position in cabin: A, B Pillar and middle of dashboard
B	360 view camera	3 cameras on the box, located high up: 1 at the back, and 1 on each side. 1 camera was fixed on the edge of the hood All digitally stitched.	The view really is for the close proximity of the vehicle. Approximately 2 meters around the truck.	Live monitor
				Position in cabin: Center Console
C	Radar	The radars were located on each side of the truck and activated with the turn signal. A camera was located on each side of the vehicle from the wheel fender location looking backwards.	The radar has a very narrow scan. Our radar was setup at 15 meters and had a field of view of 30 degrees.	Visual: gradual proximity light bar Audio: Beep
				Position in cabin: A, B Pillar
D	Smart Camera	3 smart cameras were located around the vehicle 1 at the front, 1 on each side of the truck pointing forward	To be determined based on VRU movement and direction	Visual: various color indicating proximity Audio: Beep
				Position in cabin: A, B Pillar and middle of dashboard
E	Smart Camera + Radar	One unit pointed at the back of the vehicle	Close proximity of the vehicle laterally within 2.5 meters.	Audio

Emergency braking procedure. In order to minimize the risk of damaging the dummies, an emergency braking procedure was established. The technician had a screen monitor indicating where to drive on the course and a red warning when to apply the brakes fully to avoid a collision. This sequence of hard braking was calculated to mimic an emergency braking procedure and to stop the heavy-duty commercial vehicle within a meter of the dummy. The time was recorded between the onset of the alert system and the moment the technician starts applying the brakes. Therefore, a negative time results indicated that the warning occurred after the brakes were applied, leaving no time for a reasonable warning period to allow an operator in a real world condition to understand the situation and act accordingly.

Test Protocol

Table 2 below describes the dynamic scenarios, and Table 3 contains the scenarios depicting false positives used for the project. Each scenario was repeated 5 times with each system and test configuration. This enabled repetitive data and ensure that the vehicle and VRU had the same interaction each time.

Table 2.
Collision Scenarios

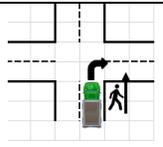
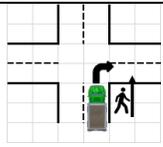
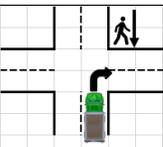
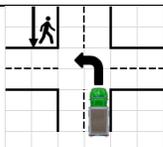
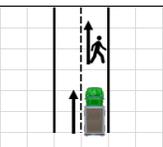
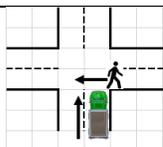
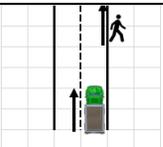
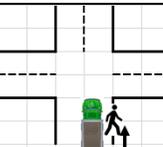
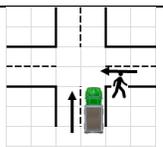
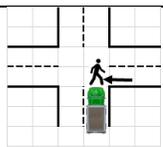
	<p>Scenario #1</p> <p>$V_{truck} = 10 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = 50% front of truck</p>		<p>Scenario #2</p> <p>$V_{truck} = 10 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = right side of truck, behind front wheel</p>
	<p>Scenario #3</p> <p>$V_{truck} = 10 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = 25% front of truck (left corner)</p>		<p>Scenario #4</p> <p>$V_{truck} = 10 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = 25% front of truck (right front)</p>
	<p>Scenario #5</p> <p>$V_{truck} = 20 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = 25% front of truck</p>		<p>Scenario #9</p> <p>$V_{truck} = 20 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = 50% front of truck</p>

Table 3.
False Positive Scenarios

	<p>Scenario #6</p> <p>$V_{truck} = 20 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = 0% front of truck, 1 meter distance between truck and pedestrian</p>		<p>Scenario #7</p> <p>$V_{truck} = 0 \text{ km/h}$ $V_{ped} = 8 \text{ km/h}$ Impact zone = none, pedestrian between curb and truck, 1 meter zone</p>
	<p>Scenario #8</p> <p>$V_{truck} = 20 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = none, stops at edge of curb</p>		<p>Scenario #10</p> <p>$V_{truck} = 0 \text{ km/h}$ $V_{ped} = 5 \text{ km/h}$ Impact zone = none, pedestrian walks in front of truck, 2 meters away from bumper.</p>

The dummy was activated 5 seconds before impact and was triggered by a speed trap. Sound probe was used to trigger the alert provided by the crash avoidance system in order to include a timestamp before impact. A GoPro Camera was filming the inside of the vehicle to capture the visual portion of the alerts, the surrounding of the vehicle and to emphasize the important blind spots from inside the cabin. Two cameras were posted outside to capture the dynamics of the scene. This helped in situating the dummy with respect to the truck and to validate testing in case the dummy did not start, fell or simply behaved differently from test to test.

As testing progressed, not all scenarios were tested with each of the technologies due to limitations of certain system and time constraints. For example, the cyclist dummy was on loan for a limited period of time. Table 4 contains the matrix of the tests performed.

Table 4.
Test Matrix

		Scenarios									
		Dynamic						False Positive			
System	Dummy	1	2	3	4	5	9	6	7	8	10
A	Adult	X	X	X	X	X		X	X		
B	Adult	X	X	X	X	X	X	X	X	X	X
C	Adult	X	X				X	X	X	X	X
D	Adult	X	X	X	X	X	X	X	X	X	X
	Child	X	X				X				
	Cyclist	X	X		X		X	X	X	X	
E	Cyclist							X	X		

RESULTS

The results collected during this project focused on parameters such as; the type of warning (audio, visual), the time at which the alerts are produced before the emergency braking procedure. The systems were evaluated based on the lead time in the form of an audio or visual alert provided to the operator of the vehicle. Also, the false positive scenarios helped assessing the potential of nuisance during daily operation of a heavy-duty commercial vehicle in an urban environment, where these vehicles are surrounded by hundreds of VRU on a daily basis.

Performance of alert systems

Each system was evaluated individually.

System A. The ultrasonic sensors were located at the front of the vehicle as well as on the left and right side of the vehicle under the dump box. The range of this technology is limited to a 2 meters detection range, which rendered all the testing at speed obsolete. It warned the operator of a potential risk after the emergency braking procedure was engaged. One advantage of the system was demonstrated during the scenario for detection of VRU when the truck was stopped. It warned the operator if the VRU was in close proximity of the vehicle as in scenario #10. At each scenario from #1 to #5, the ultrasonic sensor alerted the driver of close proximity between 0.3 to 1.0 seconds on average after the emergency braking procedure was triggered.

Table 5.
System A warning time [seconds] with regards to emergency braking procedure

Scenarios	1	2	3	4	5
Time [seconds] at emergency stop (all negative values mean that the truck had initiated the emergency braking)	-0.298	-1.592	-0.905	-1.004	-0.993

In one test scenario, (#10) where the truck is idling at an intersection, the driver was alerted that pedestrians were crossing in close proximity, 2 meters in front of the truck. The ultrasonic sensor saw the pedestrian and generated an audio alert for all 5 tests. This could be a benefit to ensure that the way is clear in a congested area before starting to engage the intersection. The second scenario that could promise an advantage was Scenario #7 where a pedestrian would walk up to the right hand side of a vehicle, directly in the blind spot of our test vehicle. For 3 of the 5 tests, the ultrasonic system alerted the driver that there was activity on the side of the truck. The operator could then confirm the level of attention required by using the mirrors. One note regarding that system, if a large amount of people crossed in front of the vehicle, the level of annoyance could be high since the system would generate an alert for each VRU.

System B. The 360 view camera assisted the operator during tight manoeuvres. The top view camera did not have a field of view large enough to enhance safety in a dynamic situation. In other words, the VRU was in a critical position before he appeared on the monitor and did not provide enough time to react. Having to look at a monitor, could also lead to distraction. Due to the configuration of our test truck, the front camera was at a different height. The blind spots created at the stitching of the video was emphasized. It provided a clear view around the vehicle when stopped, increasing the operator’s capacity to see around the vehicle but it could give a false sense of security if objects can’t be properly defined through distortion. For our vehicle, the blind spot of the vehicle should not coordinate with the blind spot of the camera. They should be phased out to provide better coverage. Table 6 showed that the time when the VRU was identifiable on the monitor was after the emergency braking procedure was initiated.

Table 6.

Time to emergency braking procedure to appearance of VRU in the System B.

	Dynamic						False Positive			
	1	2	3	4	5	9	6	7	8	10
Average (3 tests)	0.075	-0.532	-0.895	-0.956	-1.595	-0.811	-1.695	N/A Note 1	-0.791	N/A Note 2

Note 1: The picture of the dummy deformed while standing in the blind spot. The dummy was positioned in the stitching zone of the video cameras. In this test configuration, the front camera mounted on the fender had the dummy identifiable for 4.16 seconds. System C detected the VRU and stopped warning the operator at the same time that the dummy walked out of the video streaming zone. This indicated that in that configuration, the radar covered the same zone as the camera field of view.

Note 2: For all the test, it was possible to see the dummy, waist down in the camera field of view. We did not performed the test with the child dummy, but in this configuration, the hood would have hidden the dummy from the operator and most of the dummy would have been shown on the screen, based on the height of the dummies.

Figure 2 below shows the dummy on the 360 view camera 0.43 seconds after the braking procedure was initiated. The monitor on the dashboard, right of the steering wheel was used by the technician to maintain a repeatable route and to activate the emergency braking procedure at the right time.



Figure 2. Dummy identifiable 0.43 seconds after emergency braking initiated during Scenario #1

During dynamic scenarios, it was not possible to see the pedestrian on the screen on time for the operator to start the emergency manoeuvre. Two tests had 0.03 seconds lead time to the emergency procedure. This was not sufficient for the operator to realize that an action was required. As well, the operator needed to monitor the screen and this might distract from other safety tasks.

System C. The radar units were first installed on each side of the vehicle oriented backwards. This configuration would assist in detecting a VRU coming from behind especially, in combination of the camera view associated from the front fender view looking backwards. This configuration was found however not very practical to detect VRU while turning into an intersection unless they are coming from behind the vehicle. In order to increase the number of test configurations, the radar units were re-positioned frontward and therefore detecting VRU along the side of the road while the vehicle is turning. It was observed that it would increase the potential detection in Scenarios #1, 2, 3 and 4. The rearward configuration was useful in testing Scenario #7. The alert in that configuration was not sustained since the dummy travelled to position itself in the front right corner blind spot, in the opposite direction of the radar.

The radar operating field of view was kept as configured originally. This radar system was also configurable into various depth and width. For the purpose of testing here, we kept the original configuration. Radar results were produced for Scenarios #1, 2, 6, 7, 8 and 9. During Scenario #7, the system alerted 7/7. For Scenario #9, the system detected the pedestrian 4/5 and too late by an average of 0.7 seconds.

System D. The smart camera system warned the driver using two different alerts. The first alert was a visual amber light that assisted the driver in directing its attention where the potential risk was (left, right or in front). Since all our scenarios were in close proximity, the system rarely warned only of an amber alert. As the vehicle and pedestrian intend on crossing paths, the alert turned on visually red and accompanied with an audio signal. There were still blind spots around the vehicle even with this camera system. The concept was to warn the driver before VRU were too close to the vehicle. This was the only system used with the 3 dummies since it had the capability to identify both pedestrians and cyclists. It was decided due to time constraints and a generous loan from NHTSA, to limit the number of scenarios with the cyclist dummy and select the most likely conditions to represent a truck/cyclist conflict. The same configurations were used for all dummies and therefore only the shape of the VRU would be different between the adult, child and cyclist. The edge cases studied in this project were very critical

situations and the system did not always warn on time. Nevertheless, this system warned when necessary as opposed to the other systems studied. For example, the Scenario #7 did not warn the driver that pedestrians were crossing in front, unless the vehicle was starting to move. This type of approach is beneficial to limit the number of nuisance alerts to the operator.

On average, Scenarios #1, 3, 5 and 9 using the adult dummy produced audio alerts that were generated before engaging the emergency braking procedure. The same observations were made using the child dummy and the cyclist dummies as seen in table below. Only Scenario #2 (right turn and impact below the front wheel) was more challenging for this system. In all tests, the alert was generated after the emergency braking procedure was initiated. The system also generated amber warnings, which increased the response time in Scenarios #4, 6, 7, 8 and 9. It was possible to calculate a certain number of time increment using the videos from the cabin. For Scenario #9, the cyclist gained 0.98 second prior to the red warning/audio and the child gained 0.82 second. The adult gained 0.98 second as well. The Scenario #5 produced an amber warning signal that was 2.28 seconds before the red alert. And even if small, the Scenario #10 gained 0.31 second with the amber alert.

System E. The system was ordered from England and installed by PMG Technologies following the instruction provided. The system was a single unit containing the camera and radar and designed to detect cyclists only. Two relevant Scenarios (#6, 7) were tested. This system detected the cyclist using image recognition and decided if the cyclist was in arms way before alerting the driver. The system was not very reliable to detect cyclist, it could have been the speed differential with the truck, the proximity, or other parameters. The company was helpful in troubleshooting the device. Nevertheless, we could not get it to generate an audio alert using our surrogate cyclist dummy. For the purpose of our testing, we had to respect the required height and therefore locate the camera in the middle of the truck, at the front of the dump box. It is important to notice that the system was designed and calibrated to be affixed on a city bus at the A pillar location. The system appeared to work well for very particular situations. More work should be carried with a real cyclist since the manufacturer was not convinced our cyclist dummy could trigger the system as effectively.

Figure 3 shows the path used during the scenario #1. The bullet “truck at warning” was repeatable indicating that the relation between the truck and VRU was constant. On that diagram, it is important to notice that the end of the heavy commercial vehicle’s path was not extrapolated to the front bumper, but simply the position of the RT range in the vehicle.

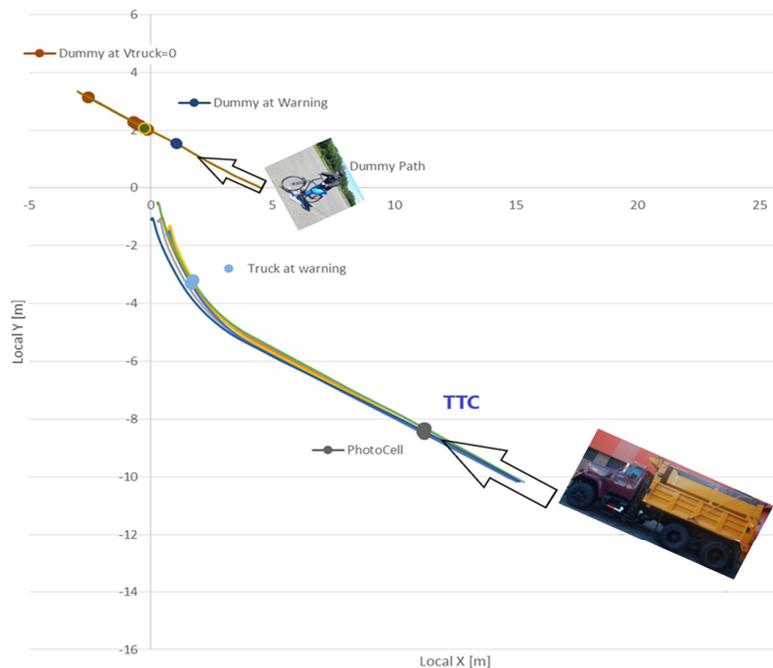


Figure 3. Sample top view Scenario 1 with a cyclist dummy

Table 7 demonstrated the time recorded by the audio warning before the emergency braking procedure took place.

Table 7.
Time to Brake in Seconds [audio warning]

		Scenarios							
		Dynamic						False Positive	
System	Dummy	1	2	3	4	5	9	6	8
C	Adult	n/a	-0.64				-0.78	4.77	3.71
D	Adult	0.57	-0.34	1.55		0.55	0.29		
	Child	0.14	-0.13				-0.15		
	Cyclist	0.19	-0.35		1.46				
A	Adult	-0.55	-1.59	-0.91	-1.00	-0.99		2.14	

The Scenario #2 was a very challenging scenario. It was challenging for the operator of the truck, but ever so challenging for the system to generate a proper alert. This configuration presented very little time for operators to react. It is also described in other studies as a difficult manoeuvre in urban environment [3].

At times, System D generated amber alerts on top of the red and audio alert demonstrated in Table 8 (the audio and red visual alerts were always generated together). Scenarios #5, #9 and #10 provided more time to the driver to react the incremental risk ahead.

Table 8.
Additional warning Time [seconds] by Amber Alert

		Scenarios									
		Dynamic						False Positive			
Technology	Dummy	1	2	3	4	5	9	6	7	8	10
D	Adult					2.276	0.978				0.307
	Child						0.823				
	Cyclist						0.984				

In Table 9, System D generated visual amber warnings only at times, alerting the driver that there is a potential risk. This was found to be very useful especially in false positive scenarios where the driver would not be annoyed of a more aggressive alert due to the low level of risk.

Table 9.
Test where only amber alerts were generated

		Scenarios									
		Dynamic						False Positive			
Technology	Dummy	1	2	3	4	5	9	6	7	8	10
D	Adult				8		1	5			
	Child						2				
	Cyclist				5		4	15	5	5	4

False Positive. Four tests were designed to trigger false positive situations where an alert to the driver might cause more annoyance than benefits. More alerts generated could overload the operator's tasks and cause distraction

or lead to complacency over time. The various scenarios sometimes generated an alert on a portion of the repetition and sometimes no alerts at all. Table 10 below indicates the rate of success or repetition as well as the outcome during the false positive scenarios. At times, more repetitions were conducted to ensure enough valid data were recorded. This should not be associated directly with the limitations of alert system, but more with the capabilities of the data acquisition equipment.

System C generated alerts for each test corresponding to Scenarios #6 and #7. The radar was not activated via the turn signal during the Scenario #8, and therefore did not generated alerts. System D was the least intrusive during all 4 false positive scenarios. Audio and visual alerts were generated for Scenario #10 only when the truck began to move forward into the intersection. When the pedestrian was crossing in front of the vehicle, no alerts (audio or visual) were generated. As soon as the vehicle moved forward, the immediate danger was communicated with a red visual alert and audio.

Table 10.
Number of Alerts Generated by Scenarios

		Scenarios									
		Dynamic					False Positive				
Systems	Status	1	2	3	4	5	9	6	7	8	10
C	Alerts	-	5				5	10	7		
	No Alerts						1			7	
D	Alerts: audio and visual	10	13	5	6	5	13				3
	Alerts: visual				4		7	11	5	9	
	No Alerts	5	4		3		1		5		4
E	No Alerts							5	6		
A	No Alerts		5	3	3	1		5	2		
	Alerts	6		3	2	4		1	3		5

DISCUSSION

During this evaluation, edge cases of urban driving were studied. A child that runs in front of a heavy-duty commercial vehicle is not something that an operator would encounter everyday but a reliable system should assist effectively in mitigating such rare occurrences. The test scenarios do not take into consideration the “real” environment such as trees, poles, other vehicles and other environmental noise. During testing with System C and System A, it was noticed that the systems alerted when passing by the speed trap setup at the beginning of the test or by any structure used to operate our equipment in the vicinity of the pedestrian test setup. The number of false alerts can play a role in diminishing the impact of the urgency of the situation. Such false alert could drive the operator of the vehicle into complacency and reduce the effectiveness of useful alerts.

Relevance of test scenario

The scenarios proved to be challenging for the systems. These edge cases with short distances at tight urban intersections and close proximity to the VRU required quick response to avoid an impact. Scenario #2, which implicated a VRU during a right turn ended up being challenging for all the systems. No system was able to generate an alert early enough to make an emergency braking procedure efficient. A test that would have started more than 5 seconds earlier than the time to collision (TTC) might have given enough time to System D to understand the complexity of the scenario. Also, the system D was installed on a short wheel base vehicle which might reduce the field of view for that particular point of impact. The system A was inefficient for this test. The system E was inappropriate for this configuration and the radar was outside the field of view range for that

configuration. System C would need to be installed lower and further back from the front of the vehicle. More optimization would be required for Scenario 2. It was also observed that systems C and D could warn of danger in a time range adequate for the operator to stop the vehicle.

Two stage warning

Based on the time required to “brake” to avoid a collision, it was calculated that the system D provided extra time to react due to the alert type. This extra time and the capability to limit the number of alerts were desirable qualities for a driver assistance system. Due to the complexity of the scenarios, most of the instances triggered red alerts and audio right away as an indication of the severity of our test scenarios.

System C used the side view camera when the turn signal was “on”. It was also an interesting mitigation system as the operator required to manually activate the turn signal to gain access to the imagery. It was difficult to use the scale of the radar from amber to red as the object was approaching in close proximity. It did not provide a large amount of time before turning red due to the speed and configuration of the testing. One particular scenario that was interesting, was with the vehicle stopped at the intersection, the system produces a warning sound when the dummy passed the radar, then appeared in the camera view to end up located in a blind spot. It was interesting to see the amount of information transmitted to the driver. The issue with such a system was that, on top of normal driver workload, the operator also needed to focus on the monitor to assess the risk. Having more than one cyclist, or pedestrian executing that manoeuvre at an intersection might cause information overload which could lead to unsafe distraction. More information is needed as such a system might be beneficial on certain vocational vehicles.

Limitations

The tests were performed at the same speed under each configuration. This approach was used to normalize the test method between the different systems. Having different systems under 10 various configurations created a large amount of data. The idea was to observe city speed conflicts. With higher speed, the systems would require to detect the vulnerable road user faster to enable more time to react and stop/avoid a collision. It was found from collision investigation that the majority of fatalities implicating VRU occurred at very low speed.

The equipment was not altered or optimized for the test. The approach was to install the different systems and gain experience with their responses. Sensors were slightly optimized based on manufacturer’s installation instructions. But, for this particular application, one could develop the field of view of the radar differently depending on the type of detection desired, the cameras could be oriented a certain way to capture a specific blind spot or the smart camera system could be calibrated with a wider angle due to the fact that it was originally designed for a longer vehicle (City bus).

All tests were conducted up to the point of collision. The brakes were applied at the last second in order to avoid contact with the dummy. The time required to alert the driver was taken from the time our technician applied the brakes before impact. This was performed in order to reduce the impact on our equipment and to provide a repetitive work environment. The hypothesis is that if the technician is alerted before he has to technically perform the emergency brake, the chances of reducing the impact and the collision are greater. The emergency braking procedure was executed manually without the help of a robot or automation. Overlaying the paths travelled during the repetition helped in assessing when similar tests were performed. The speed and acceleration of the various dummies were repeatable and constant within tests.

Each system was tested as received and installed in order to assess the functionalities and responses to a family of surrogate dummies. The vehicle was tested without a load and therefore kinematics in real life could be slightly different. A dump truck with an added loaded cargo such as gravel, dirt or snow would have a different momentum. At the same approach speed, it would require more time and more distance to stop the vehicle due to the kinematics of a loaded truck. A loaded vehicle could also change the height of the vehicle and therefore the angle at which the cameras and radar are originally aimed. Again, this configuration was not explored in this study. The weather conditions for this testing were mostly ideal with no precipitation (snow, rain) or dirt on sensors. Future studies will use new measurement equipment to precisely measure the system sounds and visual alerts.

Candidate for FOT

This study helped us understand the limitations and functionalities of commercially available warning systems for VRU. The system D was selected due to its capabilities to select when or not to warn the operator. This particularity was of interest in the real world application of vocational vehicles. In a following field trial, fourteen vocational vehicles were equipped with this system assisted by telematics to collect valuable field data. This part of the study is currently on-going and will assess the operators' feedback and comments as well as the impact of a year round Canadian weather on the ruggedness of the equipment.

CONCLUSION

The research conducted on the test track corroborated the complexity and short reaction times of real world collision data. The tests revealed a VRU detection and warning system that provided a two-staged alert tended to be more effective. The smart camera warning system helped to increase driver awareness and provided additional time for them to assess the situation and respond. Some scenarios proved too challenging for all of systems tested. The different VRU tests scenarios, created for the purpose of this research, could be used to assess the safety of other systems in the future such as more advanced technologies like automated driving systems. Alerting the operator too frequently, or when it might not be needed, as demonstrated with the false positive scenarios was an important factor when collecting information about a system. Heavy-duty commercial vehicles operate in different environments and some system might be more useful in certain contexts. As a look to the future, a system that works with the operator to identify risk constantly, and in a predictable fashion, may better complement the current mirrors and training provided to the vehicle operators. In terms of the next steps, the performance of the smart camera VRU detection and warning system will be investigated in a field operational test. This research will evaluate the real-world performance of the system over an extended period of time in different cities across Canada. Automatic emergency braking systems may also help to avoid or mitigate collisions between VRUs and heavy vehicles (UNECE VRU Proxi). The results of this research will be used to help inform federal motor vehicle safety policy.

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DISCLAIMER

The contents of this report reflect the views and interpretations of the authors, who are responsible for the results, the information, and their accuracies herein. The contents do not necessarily represent, or otherwise reflect, the official opinion, position or policies of Transport Canada or the Government of Canada.

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