THE TRANSIT BUS

THE PROBLEM

Daily travel of this type of vehicle requires constant stop and go at congested bus stops, many turning maneuvers in heavily congested traffic situations and generally in the area of many pedestrians, including those entering and exiting the bus and in areas of more and more bicycle traffic. It is imperative for such driving that the operator be given an exterior mirror system that shows the operator the area surrounding the vehicle and does so with clarity so that potential accidents with vehicles, persons and other objects are prevented.

HOW WELL ARE WE DOING IN THE AVOIDANCE OF ACCIDENTS WITH EXISTING EXTERIOR MIRROR SYSTEMS?

Reporting data, estimates, and fact sheets are available for review and provide the following insight;

1. BUS OPERATOR TYPES AND DRIVER FACTORS IN FATAL BUS CRASHES: RESULTS FROM THE BUSES INVOLVED IN FATAL ACCIDENTS SURVEY (UMTRI 2008-37) provides

   The authors state in a study of data from 1999-2005 (7 years)
   2629 persons killed in traffic crashes involving buses (bus defined as vehicle Carrying 9 or more persons, not for personal use)
   778 killed in transit bus accidents.
   45.5% of those killed in transit bus accidents were pedestrians or bicyclists.
   Virtually all of single-vehicle bus involvements were collisions with pedestrians or bicyclists.

2. COMMERCIAL MOTOR VEHICLE FACTS-November 2011 issued by the Federal Motor Carrier Safety Administration provides for the year 2009

   254 killed in bus crashes (bus defined as vehicle carrying 10 or more passengers) in 221 crashes
   20,000 injuries in 11,000 crashes
   47,000 property damage only accidents

3. COMMERCIAL MOTOR VEHICLE FACTS December 2010 issued by the Federal Motor Carrier Safety Administration provides

   Average Cost per crash of commercial motor vehicle
   $7,200,000 Fatal crash
   $331,000 Injury crash
   $18,000 Property Damage Only Crash
4. The United States Department of Transportation it is presentation entitled; Transit Connected Vehicle Research for Safety Update. August 2, 2011 presented the following regarding transit bus accidents:
   Over 100 fatalities with thousands of injuries annually.
   Pedestrian and bicycle fatalities 46% of fatalities.
   Approximately 35% of all pedestrian-bus crashes occur during turning maneuvers, 49% of fatal bus-pedestrian crashes occur during turning maneuvers and 85% occur during left turns and 15% occur during right turns.

5. The United States Department of Transportation implemented on 7-20-2011 a Study entitled; Bus Driver Intersection Task Analysis Investigation of Bus-Pedestrian crashes, which states; this project seeks to form a foundation for the development of solutions to reduce left-turning bus collisions with pedestrians at intersections.

6. A targeted search of the internet indicates major cities all over the country are continuing to report fatalities in transit accidents and especially in left turn bus-pedestrian accidents and agencies are being called upon to solve the problem.

6. Because Transit buses operate in such close proximity to pedestrians, other vehicles and objects the Transit bus is about 15 times more often to be involved in a collision than other vehicles. (Source SIDE COLLISION WARNING SYSTEMS FOR TRANSIT BUSES-Dept. of Civil and Engineering, Carnegie Mellon University) In the March 2013 Commercial Motor Vehicle Facts issued by the Federal Motor Carrier Safety Administration for the years 2009-2011 total collisions involving property damage only averaged 42,000 per year and average total of 56,000 total crashes for this same time period.

   IT MUST BE NOTED THAT PER REGULATIONS TRANSIT AGENCIES DURING THIS TIME PERIOD ARE ONLY REQUIRED TO REPORT PROPERTY DAMAGE ONLY INCIDENTS WHERE THE ESTIMATED DAMAGE TO PROPERTY IS $25,000 DOLLARS OR MORE. THERE IS NO WAY TO KNOW THE TOTAL NUMBER OF INCIDENTS WHERE PROPERTY DAMAGE IS NOT ESTIMATED TO REACH THE $25,000 THRESHOLD SO ACTUAL FIGURES COULD BE ASTRONOMICAL.

CLEARLY, TRANSIT BUS ACCIDENTS CONTINUE TO BE VERY COSTLY TO SOCIETY; IN TERMS OF LIVES LOST AND/OR DAMAGED; DOLLARS CONSUMED IN COMPENSATING THE VICTIMS, AND PROPERTY DAMAGE COSTS.
IT IS CLEAR THAT EXISTING MIRROR TECHNOLOGY DOES NOT PROVIDE AND ANSWER

IN ADDITION THERE ARE THE DOLLARS SPENT BY TRANSIT AGENCIES IN ATTEMPTING TO RESOLVE THE PROBLEM OF ACCIDENTS SOLEY WITH THE USE OF VIDEO CAMERAS AND OTHER ELECTRONIC TECHNOLOGY AND THE MILLIONS OF DOLLARS SPENT BY THE GOVERNMENT IN RESEARCHING THE PROBLEM TO DETERMINE CAUSATION AND SOLUTIONS SOLEY THROUGH THE USE OF VIDEO CAMERAS AND OTHER ELECTRONIC TECHNOLOGY IS NOT THE SOLUTION.

If reduction of accidents is the goal, existing attempts do not appear to be producing solutions, and we suggest that it is time to look at new mirror technology for an answer.

Any upgrade of mirror systems must first begin with an understanding of the problems with existing systems, namely “blind spots” and “distortion”.

The Transit operator gets no help in choosing mirror systems from the Federal Motor Carrier Safety Administration, the government body that has control over the transit agency. The only requirements for mirrors on transit buses is found in the Federal Motor Vehicle Safety Standards which specifies a 7” x 7” flat glass exterior mirror shall be placed upon the vehicle at the time the vehicle is delivered to the buyer of the bus. The operator can then add supplemental mirrors as it desires and most of the time this involves the use of the standard convex mirror to expand the view provided to the operator. Further requirements include the provision of an interior mirror of no specified size, mirrors on the passenger side of the bus must be installed 81” above the ground level to prevent pedestrians from being struck by the mirrors as the bus goes down the street.

This approach results in varied mirror configurations in use by the transit agencies and we have attached 3 photos below, of the more common combinations in use.
Figure 1

Bus equipped with 8” x 8”
Flat glass and 6” convex mirror

Figure 2

Bus equipped with 8” x 8”
convex mirror

Figure 3

Bus equipped with case type mirror containing both flat glass and convex mirror in same case
In all situations where the standard convex mirror is used to provide a wider field of view two problems are encountered; 1. The scope of view provided by the convex mirror and, 2. The problem of distortion.

1. SCOPE OF VIEW

The first problem common to all of the mirror configurations shown above is that they rely upon the standard convex mirror to provide an expanded view for the operators. It is true that the standard convex mirror provides an expanded view but what must be remembered first is the “scope of that view” provided by the mirror.

Scope of view provided by the standard convex mirror can best be illustrated by the attached figures 4 and 5.

As is illustrated by Figure 4 the scope of view provided by the standard convex mirror comes from the face of the mirror in a cone shape which widens out as the distance from the mirror face grows. As the illustration shows this leaves an area along the side of the bus that is not seen by the driver when the mirror is viewed. This area is what is referred to as a blind spot with the larger part of it being by the
door area where it would be expected to have passengers congregate. (Remember the mirror is required to be located 81” or 6.75 feet from the ground so the blind spot starts at this level and reduces as distance is traveled to the rear of the bus.) To see objects in the blind spot area drivers are required to take their eyes off the road and look into the area before maneuvering the bus in the turn and this approach is hindered by the fact that many transit agencies are still using the old style high coin boxes, which preclude the operator from seeing in the area by the door even if the head were turned to look into this area.

A further area of study about blind spots has to include the scope of view provided by the existing mirror systems out from the side of the bus for a view necessary for lane changes i.e. to see if vehicles, persons or other objects are in the area where the operator intends to take the bus as it goes through its turning maneuver. This area can be illustrated by Figure 5.

**Figure 5**

Note- The two cones on the left side of the picture indicate the scope of view provided by the flat and convex case type mirror on the bus (approximately 20-30 degrees). The space between these cones and the line indicated on the right side of the picture is the entire side area that is unseen in the mirrors and which can only be seen by the operator turning and looking into the area. (approximately 60-70 degrees)

Requiring the operator to turn and look into this blind area on the right side of the transit bus to make sure the area is unoccupied is also hindered by the operator’s
ability to see through the area of the door much of which is blocked by construction beams and the door itself. The following picture (Figure 6) is taken from the operator’s seat and illustrates what the operator sees looking into the door area of the typical transit bus.

Figure 6

The problem of the view of the operator is discussed in the Carnegie Mellon University paper Side Collision Warning Systems for Transit Buses at 4, in the following manner:

“It should be noted that the coverage of the right side mirror is quite limited, it makes only a small area close to the bus visible to the driver. The coverage is much more limited than the coverage from the left side mirror because of the greater distance between the driver and the mirror. Many buses have a second mirror for each side with a convex surface giving the driver a larger field of view. But it is very difficult to estimate distances with the convex mirror and it is therefore hard to judge if a situation is dangerous. It also needs to be mentioned that the right side mirror is sometimes obstructed by passengers standing in the bus close to the door either because the bus is full beyond capacity or because passengers are slow to move to the back of the bus.”
They then include a diagram as representative of the blind spots or areas that cannot be seen by the operator which is included as illustrative of the problem.

The diagram gives a good presentation of the blind spots created by mirrors themselves and the old time high fare boxes. Blind areas many times overlooked by those seeking a clear understanding of blind spots but does not take into account the vertical blind spot that begins where the mirrors attached and travels from 81 inches off the ground to a spot towards the rear of the bus where the ground is first seen in the mirrors.

2. DISTORTION

A second, and the most important problem with the use of the standard convex mirror to increase the scope of view and solve the problem of blind spots is the distortion inherent in the mirror itself which interferes with the operator’s ability to judge the location of the vehicles, persons or objects relative to the location of the bus.
The problem is defined by the National Highway Traffic Safety Administration (NHTSA) as follows:

“The main difference between a flat mirror and a convex mirror is that the image of an object viewed in a convex mirror is both distorted and smaller than that of the same object viewed in a flat mirror. Therefore, such an object appears farther away and could be less recognizable when viewed in a convex mirror. Additionally, if the object were approaching or receding, its rate of change in position relative to other vehicles and its speed are more difficult to judge as well. For example, a driver who is not familiar with using a convex mirror on the passenger side may determine that it is safe to change lanes to the right, not realizing that a vehicle to the right rear is too close for the maneuver to be completed safely.”

49 CFR Part 571 Docket No. 2002-12347; Notice 01 at page 2994

The problem of distortion with the use of the standard convex mirror to solve the blind spot problem is as follows: to get the necessary scope of view to eliminate blind spots the area a convex mirror can cover relates to the angle of curvature of the surface. A mirror with a more severe angle of curvature can obviously provide a wider view, however the view is as deformed as the mirror itself so the distortion factor gets worse. NHTSA in petition 12347 supra at page 2994, also states a complaint many times heard by the operators:

“There have been other problems associated with the use of convex mirrors that include double vision, eyestrain, and nausea.”

Distortion requires the operator to take the time to make mental calculations as to the possible location of a vehicle or other moving object seen in the rear view mirror, and the more the distortion the longer the time to make these mental calculations and while this is being done the eyes of the operator are directed to the mirror and not on the road ahead leading potentially to more front end accidents.

SOLUTION TO THE BLIND SPOT-DISTORTION PROBLEM OF THE STANDARD CONVEX MIRROR

The solution to turning and lane change accidents requires consideration of two elements; 1. providing a supplemental mirror technology that provides the necessary view of the proximity area around the vehicle and does so with no distortion of images presented and 2. proper location of the mirror on the bus.

1. M-C North America Inc. has spent the past 7 years developing a wide angle glass that produces images so close to normal size that the distortion factor is negligible. The M-C Glass (patent pending) differs from the standard convex mirror as follows; the standard convex mirror has only one rate of curvature so no possible change in the size of images produced can be introduced while the M-C Glass (US Patent No. 8,172,411) has many rates of curvature in the one mirror surface. Harmonizing
these rates of curvature allow us to control the view provided while enabling us to manage the size of the images presented. The time period for the operator to mentally calculate where the object seen is reduced so that all necessary information is presented to the operator with just a glance.

Can the M-C Mirror technology be an effective tool to reduce accidents?

Omaha Transit had a mirror system similar to Figure 1 above, consisting of a flat glass and a 6” standard convex mirror on both sides of their vehicles. The 6” convex mirrors were replaced with our 7” x 7” mirror containing our M-C Spot Mirror Technology (patent pending) in 2011.

Figures 7 and 8 show actual installation on Omaha Transit buses.

![Figure 7](image1)

Drivers side installation

![Figure 8](image2)

Passenger side installation.

REPORTS BACK FOR THE YEAR BEFORE INSTALLATION OF THE M-C MIRRORS THERE WERE 13 TURNING ACCIDENTS. FOR THE FULL YEAR AFTER INSTALLATION NO TURNING ACCIDENTS. Further as new buses are being added to the fleet, they remove the M-C Mirrors and put them on the new buses.

2. Proper location of the mirrors on the transit bus.

As reported earlier in this paper the federal government reports that 85% of turning accidents occur during left turn accidents and 15% in right turning accidents. Newspapers continue to report fatalities in left turn bus-pedestrian accidents. An article in The Oregonian newspaper May 4, 2010 edition by Joseph Rose is an example, where it is reported,
“Trimet is no stranger to left turn accidents such as the one that killed two pedestrians and injured three others in a downtown Portland crosswalk on the night of April 24. In fact earlier this week Oregon’s largest transit agency agreed to pay a record $1.5 million to a woman who lost a leg after it was crushed by a bus turning left into a crosswalk in January 2008. Just three weeks before the downtown bus tragedy one of the 17-ton vehicles hit a woman near a Sellwood-Moreland movie theatre, knocking her out of her shoes. She had the walk signal as the Trimet driver turned left”

Other cities such as Des Moines, IA and Cleveland, OH are also referred to in the article as having had similar experiences. Agencies are experimenting with moving the mirror up or down on the driver’s side or implementing audible signals to warn pedestrians of the left turn.

Figure 9 is a photo from the driver’s seat in a Trimet bus that was included in the article.

![Photo by Thomas Boyd/The Oregonian](image)

M-C North America Inc. submits that this photo clearly illustrates the problem facing the transit operator in the left turn maneuver. The mirror is located so that the operator must turn the head and look down to see what the mirror shows, this means that in making the left turn maneuver the driver must perform 4 separate functions, simultaneously:

1. Look down into the mirrors to see what is shown.
2. And because the “scope of view” of the mirrors leaves a large blind spot on the side of the bus the operator must turn the head further to physically look into the area of the blind spot.
3. Move the head again to see the area surrounding the mirror and A Pillar to see that no objects or persons are covered by the blind spot created by these objects.
4. Look straight ahead for oncoming traffic.
If the operator does not continuously perform these 4 functions throughout the turn, or even lingers at one area too long, an accident can happen and he/she will report that “they did not see the person or object” and the truth is that they could not see the person or object.

A solution lies in reducing the number of functions the driver must perform to make a turning maneuver.


As a cost saving side-note, we also have observed that newer models of the case type mirrors being placed upon the buses to enhance the view are wider than older models. As this is done it must be remembered that the bus is approximately 8.5 feet in width and adding the mirrors makes the bus approximately 10.5 in necessary width clearance. This poses to the transit agency the possibility of mirror damage due to the mirrors striking objects and being broken. Not much information is found about the costs of replacement but in a study conducted by the Florida Department of Transportation entitled: Integrating Transit Into Traditional Neighborhood Design Policies-The Influence of Lane Width on Bus Safety dated June 2010 the authors were given some information by local Florida transit agencies. At page 19 of the report is found the following:

“However, some agencies provided valuable information which is worth sharing. For example, Miami Dade Transit Agency spent $178,556.15 on labor cost just for mirror replacement from year 2004 to year 2008. This is an average of $44,639 per year for labor direct cost only. Hillsborough Area Regional Transit (HART) in Tampa spent $41,421.37 in the first nine months of the year 2007 for mirror replacement, an average of $4,600 per month. HART indicated that eight to twelve mirrors are replaced per month. Lynx (in Orlando) spends 300 to 800 dollars per mirror replacement on material alone depending upon the type of mirror. According to Lynx officials, new coaches are equipped with power mirrors which cost about 800 per replacement. The Jacksonville Transit Authority replaced 63 mirrors in year 2008 alone.”

Proper location of the mirrors in the front of the windshield so they are not required to stick out from the vehicle so far would alleviate some of these costs.
INTERIOR MIRRORS

Interior mirrors on the transit bus do not provide any aid to driving the vehicle and are used primarily to maintain a view of the interior of the bus and the passengers thereon. In such mirrors clarity is important for identification purposes and scope of view to include areas surrounding the location of the driver and the door areas is critical. Agencies use the standard convex mirror in many sizes and shape to provide the operators with the necessary information and result in a bad situation as is shown in the attached photo. (Figure 10) The driver cannot see the front seats, the area surrounding the driver’s station, and the area by the door. Driver is forced to turn and look into the areas physically which is dangerous because the eyes are not on the road.

Figure 10

All of these mirrors have the same clarity issues as above described, which M-C mirror technology is designed to solve.

At M-C North America Inc. we stand ready to discuss your problems with blind spots and distortion and to physically show you what the M-C Glass (patent pending) option can do to solve your problem.

Review our Product page to see our currently available models of mirrors and monitor it for further developments as other models of mirrors are developed.

Richard T. Ince  Jason Enrique
VP, Safety    Director of Safety
M-C North America Inc.  M-C North America Inc.