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Railroad-Highway Grade Crossing Accidents: The Problems

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The paper will address the crisis of railroad-highway grade crossing accidents in the United States. A railroad-highway grade crossing is where a public or private roadway crosses railroad tracks.

Over the years, there have been many studies and programs to warn the general public of the hazards of crossing railroad tracks. However, the same types of railroad-highway crossing accidents continue to occur, despite attempts to educate the public. As will be discussed, communication between transportation professionals and coordination of railroad and highway operations also contributes to the crisis.

The most effective way to eliminate grade crossing accidents is to provide grade separation of the railroad from vehicle and pedestrian traffic. This has been completed at 39,681 locations[1]. It is a very expensive proposition. Therefore, it has been done only in urban areas, and along limited access highways and arterials. The cost of constructing a grade separated crossing is estimated to be five million dollars per location.

There are currently 274,874 railroad-highway grade crossings in the United States, of which 166,035 are public, 106,715 are private, and 2,124 are for pedestrians only.[2] Of these, 195,542 grade crossings are located in rural America and 79,332 in urban America. In 1994, there were 4,979 accidents which resulted in 615 fatalities and 1,863 injuries. Each year there are about 1.8 accidents per 1000 grade crossings, or an average of one accident every 105 minutes.

Each railroad has its own particular Operating Rules which shall conform to the Federal Railway Act, and this paper will discuss the impact of these Operating Rules as they relate to grade crossings.

Grade crossing accidents can be divided into the following categories: Roadway Design & Maintenance; Vehicle Operations; Pedestrian Impatience;

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and Railroad Operating Procedures. Each type of accident has unique aspects. The scope of grade crossing accidents include the following range:

Roadway Design & Maintenance:

1. **Vehicles Stuck On The Tracks** - Vehicle stalls or undercarriage gets caught on the tracks.
2. **Limited Sight Distance** - Driver's sight distance is restricted due to undergrowth and/or obstructions.
3. **Signing** - Inadequate signing on approaches to the grade crossing.

Vehicle Operations:

1. **Train Speed Variation** - Passenger trains travel faster than freight trains.
2. **Racing Train To Crossing** - Being first at the crossing does not mean that the driver has the right-of-way.
3. **Running Into Train** - Driver runs into the side of a freight train.
4. **Gate Slalom** - Driver goes around the gates when they are down.
5. **Front End & Rear End Collisions** - Driver causes the vehicle's front end or back end to be within the train's operating envelope.
6. **Multi-Track Crossing** - Driver does not look both ways to see if another train is coming from the opposite direction.
7. **Driver's Impatience** - Driver does not wait for the warning devices to stop (Flashing REDs), to see if another train is coming on the adjacent track.
8. **Emergency Vehicle Priority** - An emergency vehicle does not have the right-of-way.
9. **Traffic Signal at Rail Crossings** - Traffic signal controls vehicle traffic on public roadways, but may not clear vehicles from tracks before the train comes.

Pedestrian Impatience:

1. **Pedestrians Crossing Around Train** - At low level platform stations, pedestrians cross in front or in back of train, without checking to see if another train is coming on another track.
2. **Pedestrian Short Cut Route** - Pedestrians take the shortest distance between two points by crossing the tracks.

Railroad Operating Procedures:

1. **Flagging Procedures At Grade Crossings** - A flagperson stops pedestrians and vehicles as a train crosses the roadway.
2. **Track Crossing In Freight Yards** - Vehicles cross the tracks to service railcars stored on the tracks.

The above types of accidents have occurred ever since the first railroad started operating. Over the years, the railroads and public safety agencies have sponsored educational programs to inform motorists and pedestrians of the hazards of crossing railroad tracks. The Operation Lifesaver Program is a Federal Crossing Improvement Program, under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), to educate groups on the hazards of grade crossings. This program is operated through the railroads, and volunteers give this program in 49 states. This program has been somewhat effective. Between 1994 and 1995, railroad grade crossing accidents declined by about 8.3 percent to 4,565, fatalities declined by 9 percent to 559, and injuries declined by 4.9 percent to 1,863.[3] However, educational programs address only part of the problem. The crisis is exacerbated by the lack of communication between railroad and highway transportation professionals.

Railroads operate under their own Operating Rules, which shall conform to the Federal Railroad Act (49 CFR). Public highways must conform to various highway acts, and their designs must conform to the American Association of State Highway and Transportation Officials (AASHTO). All traffic control devices must conform to the USDOT Manual on Uniform Traffic Control Devices (MUTCD). The motoring public must conform to Vehicle and Traffic Laws, which require all public and private jurisdictions to conform to the Manual on Uniform Traffic Control Devices. The fundamental problem is that the railroad and public/private agencies do not coordinate their operations, thus confusing the public.

RAILROAD GRADE CROSSING REQUIREMENTS:

When railroads were first built, flaggers were required at all grade crossings to protect pedestrians, bicyclists, horses, carriages and/or wagons. Flaggers were discontinued as the number of grade crossings increased with railroad expansion, and flagger control became unmanageable and costly. Passive devices were then created and implemented.

Passive Devices:

Passive Devices consist of two types of warning signs, Crossbuck signs and Railroad Advance Warning signs, which are required at each grade crossing as stated in the MUTCD Section VIII "Traffic Control Systems for Railroads - Highway Grade Crossings":

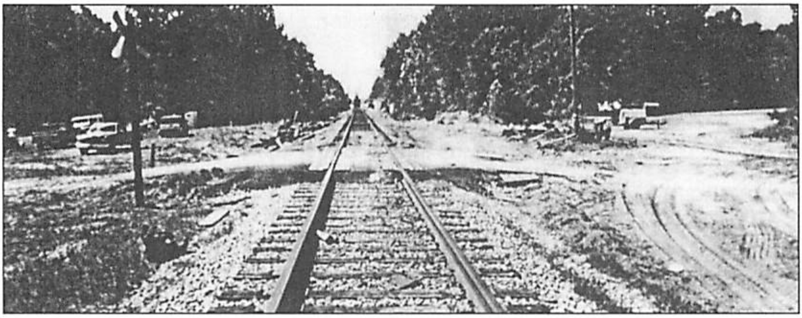
> **Crossbuck Signs (R15-1,2)**[4]
> Crossbuck signs shall have a white reflectorized background with black letters. As a minimum, one crossbuck sign shall be used on each roadway approach to every grade crossing (public and/or private), alone or in combination with other traffic control devices. Crossbucks should be placed at least 12 feet from the track.
>
> **Railroad Advance Warning Signs (W10-1)**[5]
> Railroad Advance Warning signs shall be used on each roadway in advance of every grade crossing, and they shall be placed at least 100 feet from the crossing, or as required in the MUTCD.
>
> **Pavement Markings**[6]
> Pavement markings should be installed in advance of a grade crossing, and they shall consist of an X, the letters RR, no passing markings, and certain transverse lines. Pavement markings shall be placed at crossings where an engineering study indicates there is a significant potential conflict between vehicles and trains. Stop lines should be placed at least 15 feet from the tracks.
>
> **STOP Signs**[7]
> A STOP sign shall be used only after an engineering study has determined compelling reasons for its use, and it should only be an interim measure until active devices can be installed.

Active Devices:

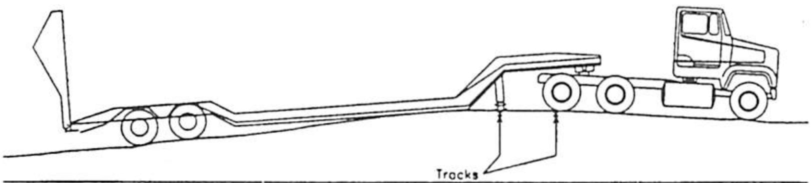
Active devices are passive devices with additional flashing lights (Wigwag Signals[8]), bells, and/or gate controls. The installation of flashing lights, and/or bells, with or without gate controls, depends upon an engineering study conducted by each state's transportation department. The only mandated controls at a grade crossing are the passive devices. When active devices are used, they shall conform to the MUTCD. Under current highway acts, the USDOT has programs to install flashing lights, and/or bells, with or without gates, using federal funding. After the Active Devices are installed, the railroad company is responsible for maintenance.

Traffic Signals at Railroad Crossings:

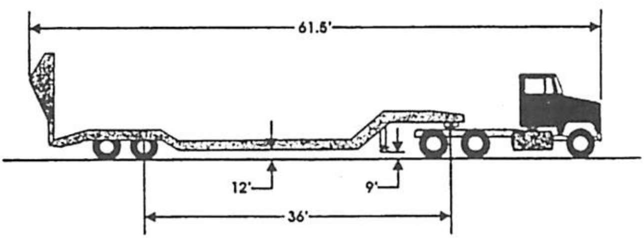
Many grade crossings are located near or at highway intersections where a traffic signal is used to control highway traffic. If a traffic signal is located within 200 feet of a grade crossing, then the traffic signal should[9] be equipped with railroad preemption. Railroad preemption is a special timing sequence to



Location of the accident



Vertical profile of accident crossing



Schematic of accident truck (not to scale)

Figure 1
Vehicle stuck on the tracks

control traffic to clear vehicles from the grade crossing, and to keep the area between the grade crossing and the intersection clear of vehicles.

ROADWAY DESIGN AND MAINTENANCE:

Railroad property generally is measured from the center line of the track or tracks to the right-of-way lines. This area is under the jurisdiction of the railroad company and it is responsible for all grade crossings within its right-of-way. A problem arises when the highway is under the ownership of private or governmental agencies. Jurisdictional and coordination problems are reflected in the following types of accidents:

Vehicles Stuck On the Tracks

Many railroad-truck accidents occur when the low body of a truck's undercarriage is caught on or between the tracks (see Figure 1). The slope of the roadway leading to and from the tracks is too steep for heavily laden or low body trucks and cars. The railroad company paves over the tracks between the right-of-way lines and meets the existing roadway pavement. It is the responsibility of the railroad company to conform to the AASHTO standards within its right-of-way, but not to pave beyond the right-of-way lines. It is the highway owner's responsibility to bring the pavement up to AASHTO standards, and to meet the pavement at the right-of-way lines.

AASHTO standards require that the surface of the highway should not be more than 3 inches higher (+0.9%) nor 6 inches lower (-1.8%) than the top of the nearest rail at a point 30 feet from the rail (see Figure 2).[10] Many jurisdictions do not comply with or know about these design standards. It is the responsibility of the private or public agencies to design, build, and maintain a roadway that conforms to the above AASHTO standards.

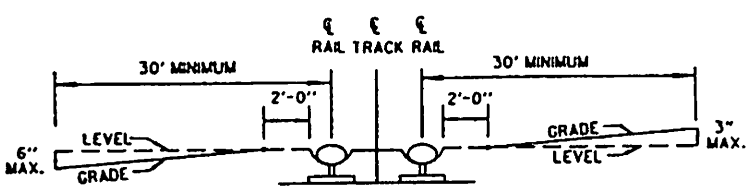


Figure 2
AASHTO Standard for Grade Crossings

To address the problem of improper roadway clearances over the tracks, the USDOT National Committee on Uniform Traffic Control Devices (NCUTCD) has proposed that new "Low-Boy" signs be installed at the nearest intersection, or where a truck can make a U Turn (see Figure 3). Optional "Low-Boy" signs

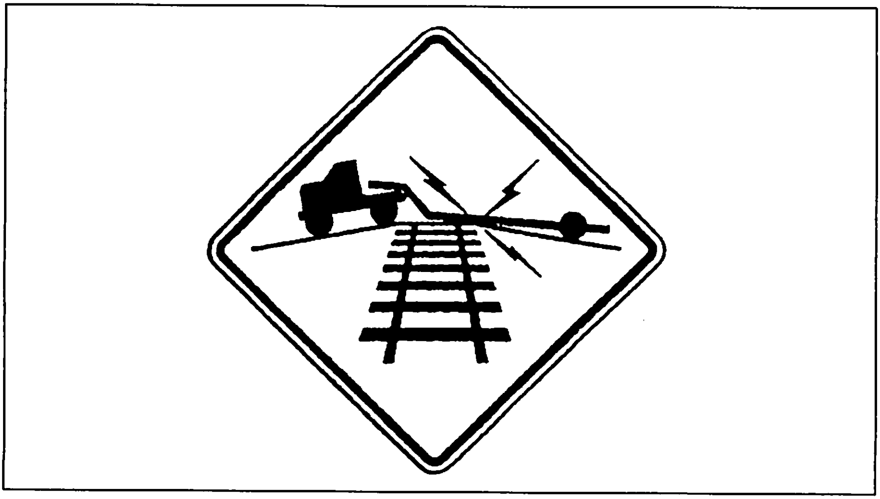


Figure 3
"Low-Boy" sign (W16-__)

can also be used, such as "Low-Boy Trucks Prohibited" or "Use Next Crossing" (with appropriate arrow).[11]

Limited Sight Distance

Limited sight distance at a railroad crossing is a common problem, and it can be caused by foliage, buildings, curvatures in the tracks, and railcars/trucks left too close to the grade crossing. If the sight distance problem is due to a building or a tunnel, then active devices should be used. However, if the sight distance problem is due to foliage or a railcar, then it is the responsibility of the railroad to remove the obstructions.

The following rules cover sight distance at a railroad crossing:

1. AREA[12] requires that each railroad control vegetation by having a vegetation control program with follow-up investigations.

2. NORAC[13] or specific Railroad Operating Rules require that the track foreman be responsible for the safe condition of the track and roadway between right-of-way lines. This includes vegetation control at grade crossings.

3. NORAC or specific Railroad Operating Rules under the section Obscured View of Highway[14] require that:

   "When equipment is standing and obscuring highway traffic's view, an employee must protect the highway traffic against movement on adjacent track. Equipment stored on tracks close to a public (& private) crossing must be placed so as to permit a clear view

for highway traffic using the crossing. Where space permits, equipment must be placed at least 300 feet from the crossing."

Sight distance is measured from the driver's eye when the motorist is stopped at the Crossbuck sign (12 feet from the track). Since the driver is seated about 7 feet behind the front bumper, the sight distance is measured 19 feet from the track. The minimum sight distance a driver's eye can be from the track is as follows:

- The track gauge is 4' 8.5", with the center of the track at 2' 4.25".
- A railcar or engine is 10' 6" wide or 5' 3" from the center of track.
- A railcar can oscillate about 2 feet on its trucks.
- The train's envelop from the track is about 5' 0" from the track (5' 3" -2' 4.25" + 2' 0").

Therefore, the closest point that a driver's eye can be before being in the train's envelope is 12 feet (at the Crossbuck sign). The safe area for a driver to see a train is between 12 to 19 feet. The minimum right-of-way distance from the track to the property line or a building is 20 feet (see Figure 4).

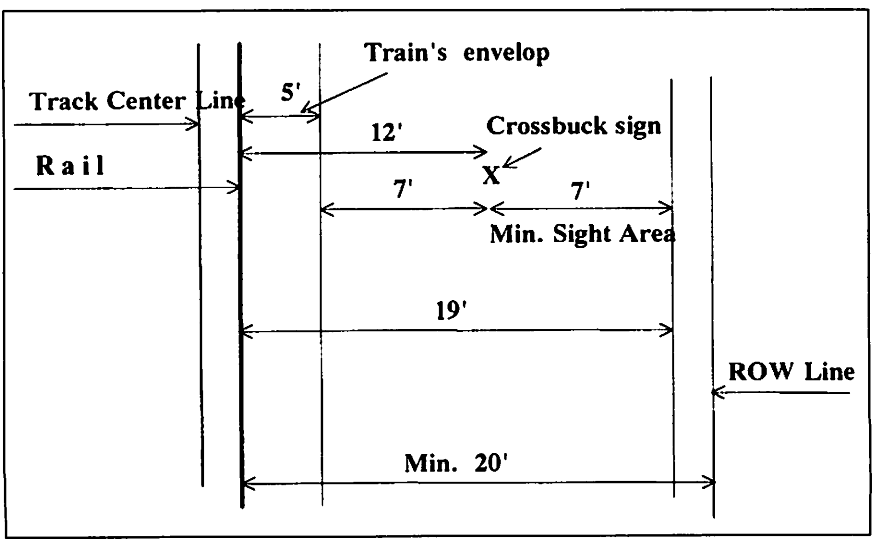


Figure 4
Safe Sight Area for a Motorist

This type of limited sight distance was shown to be the problem at a private grade crossing in Connecticut. The right-of-way was 20 feet from the track, with a four foot high man made earth mound in which the property owner built a 10 foot high chain link fence, and then added privacy slats in the chain link fence. Within the railroad right-of-way the weeds were permitted to grow on top of the earth mound. The vegetation along the fence was 4.5 feet in height for at least 3 feet from the fence. The driver's safe sight area was between 17 to 12 feet, or a 5 foot area to view the tracks. All three persons in a car were killed when a passenger train hit the car at 70 MPH.

Signing

Passive devices consist of Crossbucks and Railroad Advance Warning signs. The Crossbuck signs are placed 12 feet from the track, and are installed and maintained by the railroad company, since they are located within the railroad's right-of-way. However, the Railroad Advance Warning signs are installed by the private or public agency having jurisdiction over the approach roadways. In many jurisdictions, the railroad will supply the signs and the local governmental agency will install the signs and the pavement markings. It is the responsibility of both the railroad and the local highway department to work together to continuously inspect and maintain the signs properly. Any missing and faded signs should be replaced, to reduce potential lawsuits.

At the same Connecticut accident case, the passive devices did not conform to the MUTCD. The crossing was a private road, and under Connecticut Law the responsibility for signing and maintenance came under local jurisdiction. The crossing had no Crossbuck signs and the Railroad Advance Warning signs were installed 18 feet from the tracks. With vegetation blocking the view of the tracks, the driver had to stop and place the vehicle's bumper on the track to see if a train was coming - it did. In this case the town, state, and railroad each requested that the others install the signs. No one did anything for 30 years, until this accident occurred.

VEHICLE OPERATIONS:

A train is heavy, bulky, and inflexible in direction and speed, because it operates on a fixed steel rail with steel wheels, with very little friction. In comparison, a lightweight motor vehicle can choose its path, speed, and direction, and also maneuver. When these two types of vehicles attempt to cross the same grade crossing at the same time, they create the following situations: the driver races the train to the crossing; the driver runs into the side of the train; and/or the driver slaloms the gates.

Train Speed Variations

Freight trains move at a slower speed than passenger trains. A freight train's speed varies between 10 to 60 MPH in populated areas and higher in the Plains states. Passenger trains reach speeds of 60 to 80 MPH, and there are plans to increase passenger train speeds in excess of 120 MPH. Train speed depends on the class of track and the average stopping distance for a train. A freight trains consisting of 146 cars and 4 locomotives traveling at 60 MPH on a level grade (plus or minus 1%) requires 2,000 feet (empty) to 5,400 feet (loaded) to stop. A freight train must come to a stop gradually or the cars will derail. The braking distance depends on the weight in each car, the braking force of each brake on each truck or each car, and the time it takes the air pressure to reach each car.[15]

A passenger train traveling at 60 MPH requires at least 2,000 feet to stop in an emergency. NYC subway electric cars require at least 220 feet to stop at 30 MPH, since each wheel has an air brake, and each truck has a dynamic motor for use during braking. Electric subway cars have an emergency uniform deceleration rate of 3 MPHPS (4.41 fpsps).

Racing Train to Crossing

A motor vehicle has much more maneuverability than a train, and it can increase and decrease speeds at a much faster rate than a train. For a vehicle to cross a single track and clear the train's envelope, a distance of 20 feet (10 feet plus 5 feet on each side of the railcar) at a speed of 30 MPH (44.1 fps) takes only 0.45 seconds.

To warn a motorist that a train is approaching a grade crossing, a whistle post may be placed between 300 to 1,800 feet, with an average distance of 1,320 feet, from the crossing.[16] If a train were traveling at 30 MPH and blew its whistle at 1,320 feet, it would take the train 30 seconds to reach the crossing. However, if the train were traveling at 70 MPH (103 fps), then the train would reach the crossing in 12.8 seconds. If a motorist were traveling at 20 MPH (29.4 fps), and saw and heard the train coming, and also correctly assumed the speed of the train, then the motorist would have only a second or two to cut in front of the train.

A truck carrying hazardous material must stop between 15 to 50 feet before the crossing. The time it takes for the driver to shift gears and clear the track may take longer than 10 to 30 seconds, depending on the load and size of the truck.

To improve a motorist's perception and proper judgment, the sight distance should be increased to the maximum distance at each grade crossing, as shown in Table 1.

Running Into Train

There have been cases of vehicles running into the side of a freight train at night. This type of accident has occurred in open country at grade crossings with passive devices only. A long freight train does not have any lights or windows to emphasize the dark railcar bodies. One method to increase the visibility of the side of a freight car is to place reflectorized tape or paint along its body. This requires maintenance by the railcar owners. The NCUTCD[17] has rec-

Table 1
Sight Distance for Combinations of Highway Vehicles and Train Speeds

	Vehicle Speed (mph)							
	0	10	20	30	40	50	60	70
Train Speed (mph)	**Distance (d_T) Along Railroad From Crossing (ft)**							
10	240	145	105	100	105	115	125	135
20	480	290	210	200	210	225	245	270
30	720	435	310	300	310	340	370	405
40	960	580	415	395	415	450	490	540
50	1200	725	520	495	520	565	615	675
60	1440	870	620	595	620	675	735	810
70	1680	1015	725	690	725	790	860	940
80	1920	1160	830	790	830	900	980	1075
90	2160	1305	930	890	930	1010	1105	1210
	Distance (d_H) Along Highway From Crossing (ft)							
	n/a	70	135	225	340	490	660	865

Note: All calculated distances are rounded up to next higher 5-foot increment.

Assumptions: 65 foot truck crossing a single track at 90 degrees; flat terrain. Adjustments should be made for unusual vehicle lengths and acceleration capabilities, multiple tracks, skewed crossings, and grades.

Source of Formulas: Traffic Control Devices Handbook, Washington, DC FHA, 1983 Railroad-Highway Grade Crossing Handbook, 2 ed., 9/86, FHWA-TS-86-215, pages 131 to 135.

ommended that two sided crossbucks (with RAILROAD CROSSING) be used at all grade crossings using passive controls only. This will create a white strobe light effect as the headlight reflects off the back of the crossbuck in the space between the railcars.

Gate Slalom

Gate Slaloming is a common practice of drivers who choose not to wait the 20 to 25 seconds for a train to arrive, and they go around the gates as they are closing or are closed. The time factor is more critical in gate slaloming, because typically the vehicle is about to or has already stopped, and the driver then decides to go around the gates. The minimum distance for a single track is about 50 feet (15 feet from track to gate, 5 feet for track gauge, plus 15 feet in front of gate). The time it takes the driver is about 1.7 seconds to slalom the gates at an average speed of 20 MPH (29.4 fps), for 50 feet of slalom distance. The maximum acceleration rate for a standard vehicle is 7.5 fpsps[18], and to transverse 50 feet takes 1.8 seconds from a dead stop condition.

The timing of the gates is set by FRA Regulations at 20 seconds. The gates are activated when the train is 20 seconds from the crossing with the following procedures:

1. The flashing lights and bells start immediately and remain on until the trains passes over the detection area.
2. Gates start to come down in 3 seconds.
3. Gates are down in 12 seconds.
4. Gates are down for 5 seconds before the train is permitted to cross the roadway. Therefore, the total time is 20 seconds.
5. A train can enter the crossing any time after 20 seconds.
6. When the train leaves the detection area, the gates ascend in less than 12 seconds,[19] and flashing lights and bells end when the gate is at 85 degrees.[20]

Therefore, a successful slalom runner has a minimum of 5 seconds to out race the train. If a train is traveling at 30 MPH (44.1 fps), then a 100 car train would take at least 193 seconds or 3 minutes to clear the grade crossing. A 150 car train would take about 5 minutes to clear the grade crossing. ***This encourages slalom running.***

The slalom runners are caught when they expect a slow moving freight train but a high speed passenger train arrives instead. The detection devices are set for the track speed: for example, at a maximum track speed of 60 MPH (88.2 fps) at 20 seconds, the detection system starts at least 1,764 feet ahead of the crossing. However, if a freight train were traveling at 30 MPH, then the train would reach the crossing 40 seconds after the crossing was actuated. ***At this point - impatience is a killer.***

Methods to reduce slalom running

1. The ideal solution would be to separate high speed passenger service from low speed freight service, by each having its own tracks with separate detectors and maximum track speed.
2. The Four Gate System is being experimented with in Europe, and it provides for closing all the lanes of traffic with gates on both the approach and exit lanes to the grade crossing. This does not stop a motorist from slaloming during the first 9 seconds, but it can entrap a vehicle on the

Table 2
Four Gate System Timings

Gate	O	O	O	O	O	O	g	g	g	G	G	G	G	G	G	G	G	G	D	D
Gate 1	O	O	O	g	g	g	G	G	G	G	G	G	G	G	G	D	D	D	D	D
Time (sec.)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Key: Gate 1 – Approach lane Gates.
Gate 2 – Exit lane Gates.
O – Gate Up.
g – Gate going down without interfering with vehicle traffic.
G – Gate going down and blocking vehicle traffic.
D – Gate is Down.

tracks between the gates after 10 seconds. Table 2 shows the timings of a two gate and a four gate system:

3. Another ideal solution, which is more economical, is to use a motor vehicle motion microwave detection system to select between high speed or low speed track detection systems.

4. New York State is currently experimenting with a Wireless Grade Crossing Video System, in which a video camera is permanently installed at a grade crossing and a monitor is located in the engine cab with a range or 3 to 4 miles (15,840 to 21,120 feet). New York plans to run trains at 125 MPH by 1999 between Buffalo to New York City via Albany. Currently, there are more than 100 grade crossings along this route. At 125 MPH (183.75 fps) the detection of the train shall be greater than 3,700 feet from the grade crossing. At 125 MPH the train would require at least 3,000 feet to stop. Therefore, if a vehicle slaloms the gates or cuts in from of the train at least 2 seconds (368 feet) from the grade crossing, what can the train engineer do! The video cameras will only be able to document the accident. In addition, which grade crossing would the train engineer look at when the highways are less than half a mile apart? The only type of grade crossing accident that the video cameras may reduce is the vehicle stuck on the tracks (Low Boy) type, since the train engineer can view the vehicle at least 90 seconds before the grade crossing, and begin to slow down.

Front End & Rear End Collisions

The driver stops either end of his vehicle within the train's envelop. The train's envelop is that area on the sides of the train which can catch an object and drag it along. The dimensions of this envelope are based upon the width of the railcar, which is 10.5 feet. The gauge for the track is 4' 8.5". The railcar extends 2.85' from the track, and the railcar can move about 2 feet on its truck in either direction. Thus, the train's envelop is 5 feet beyond the track. Therefore, if the front end or back end of any vehicle is within the 5 foot envelop of the track, the chances are that it will be struck by the train. Another 5 feet should be added for wind draft from high speed trains. That is one reason why the Crossbucks and Active Warning Devices are placed at least 12 feet from the track.

Multi-Track Crossing

On major railroad corridors there are more than two tracks crossing the highway. There shall be a sign under the Crossbucks stating the number of tracks to be crossed. The problem arises at grade crossings that have only passive and/or active devices without gate controls. The driver assumes that when a train passes, it is safe to cross. A train coming from the opposite direction would be visually blocked by the first train.

There are three methods to reduce multi-track accidents:

1. The driver should not enter the tracks until the rear of the train has passed a given distance to give the driver a clear view of other tracks.

2. The driver should not enter the tracks until the flashing light and bells end, and wait for a clear view of the tracks.

3. Where active devices without gates are installed, the flashing lights and bells should be extended up to 3 seconds, depending on the speed of the track. The distance the detection system should end or extend to upon leaving the grade crossing would be 132 feet at 30 MPH; 265 feet at 60 MPH; and 400 feet at 90 MPH.

Driver's Impatience

Drivers are upset by delays, and they will take chances to save a few seconds or minutes. When a driver waits for a traffic signal, a 20 second wait is often misinterpreted as a 2 minute delay. Therefore, when a driver is stopped by an activated railroad control, the wait seems to be forever. A 10 car passenger train can take between 25 to 40 seconds to pass, while a 150 car freight train can take up to 5 minutes to pass.

To improve public recognition of the hazards of grade crossings, the Operation Lifesaver Program should be extended to local public service and public access TV stations, with interviews and videotapes.

Emergency Vehicle Priority

In an emergency, who has the right-of-way? For example, in an actual case in Virginia a shopping center was on fire, and the only access road to the shopping center was across the railroad tracks. The first fire vehicle responding to the alarm reached the grade crossing just before a train. The train had the right-of-way, since its stopping distance was greater than half a mile. However, the fire truck tried to exercise its right-of-way priority. It lost, killing the firemen.

Traffic Signal at Rail Crossings

When a signalized intersection is located within 200 feet of a grade crossing, the traffic signal should be preempted to remove all traffic from the grade crossing and restrict any additional traffic from approaching the grade crossing. The MUTCD shows samples of preemption plans for a traffic signal and its sequences under various conditions. Preemption shall occur immediately upon activation of the train detection. At the same time that the flashing lights and bells are activated, the traffic signal controller shall go into railroad preemption. Preemption shall stay on until the train leaves the detection circuit. The preemption sequence shall start immediately, and the current phase shall terminate with vehicle clearances, and then go to the phase which will clear all the traffic from the grade crossing. After the grade crossing has been cleared, the preemption can cycle to a phase which will not interfere with the grade crossing. "Pedestrian clearance may be abbreviated in order to provide the track clearance display as early as possible."[21]

Traffic signal timings and phasing are based upon the following principals:

1. A phase is that part of a cycle length which is allocated to a specific traffic movement or combination of movements, such as through & right turns; dual left turns; left and thru movements; and concurrent or exclusive pedestrian movements.

2. A cycle length is the total of all the different phases.

3. Each phase has it own timing module with the following timing intervals: Min. Green; Max. Green; and Yellow and Red Clearances. The timings can be set for each interval.

4. Included in the Max. Green interval are the Pedestrian WALK, Flashing DON'T WALK and Solid DON'T WALK timing intervals. The walk time varies between 5 to 7 seconds for activated controls, and higher for fixed time controls. Flashing DON'T WALK is based on 4 fps pedestrian walking time and the length of the crosswalk, i.e. 15 seconds are required for a 60 foot wide street.

5. If the combined WALK and Flashing DON'T WALK times are greater than the Max. Green interval, then the Max. Green time will extend to the

completion of the Flashing DON'T WALK interval. If the Flashing DON'T WALK time ends before the Max. Green time, then a Solid DON'T WALK will appear until the WALK interval is reactivated in the next cycle.

6. The Yellow Clearance interval is from 3 to 5 seconds, and the All Red Clearance interval ranges between 1 to 5 seconds, with total clearance time ranging between 5 to 8 seconds. The combined Yellow and Red clearance intervals assumed in this paper total 5 seconds.

7. The Traffic Controllers currently on the market have a number of different fire preemption programs for emergency vehicles approaching from different directions, and only one railroad preemption program. The fire preemption programs are designed not to violate any pedestrian and vehicle clearance timing intervals, and start the preemption sequence after the pedestrian and vehicle clearances have been completed.

8. The preemption sequence consists of the following: Detection Of Preemption; Time Before Preemption; Clearance Before Preemption; Track Clearance; Preemption; and Exit from Preemption.

   Table 3 shows a generic traffic signal phasing and timing plan to clear a grade crossing prior to the start of the preemption sequence.

Preemption Sequence

1. *Detection Of Preemption* - input call from the train detector.

2. *Time Before Preemption* - the dwell time set before preemption is acted upon (set to Zero for train actuation).

3. *Clearance Time Prior To Preemption* - the time to clear the current phase before clearing the roadway. This includes setting the Greens, WALKS, and Flashing DON'T WALKs to "0", Yellows to "3", and Reds to "2" seconds.

4. *Track Clearance* - The phase and time to clear track of all vehicles.

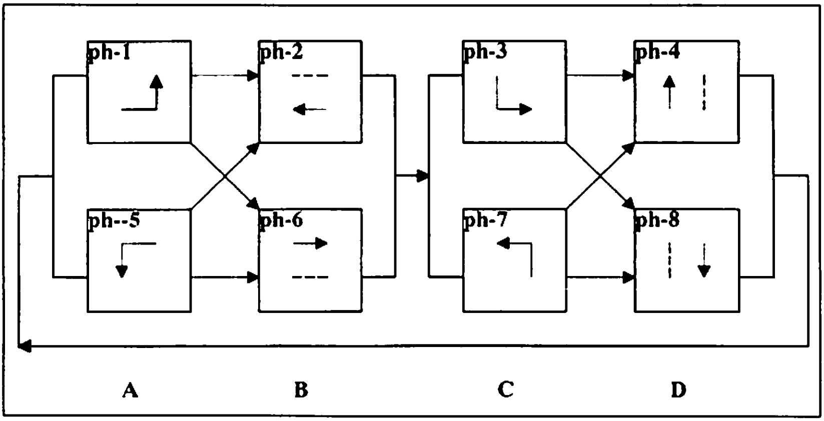
5. *Preemption* - The phasing set to move traffic not affected by the grade crossing. For a high speed train this sequence is not necessary. However, for a freight train this sequence is required.

6. *Exit from Preemption* - The clearing out of the preemption phase and servicing every phase in sequence.

THE PREEMPTION PROBLEM

Table 4 shows the proper minimum timings required upon railroad actuation. When these minimums are violated during *Clearance Time Prior To Preemption* (refer to Table 2) the following problems will occur:

Table 3
GENERIC PHASING AND TIMING CHART



Sample Timing for an 8 Phase Controller

	Phase A Ph 1 & 5	Phase B Ph 2 & 6	Phase C Ph 3 & 7	Phase D Ph 4 & 8
Min. Green	5	0	5	5
Ped. Walk	0	7	0	7
Ped. FDW	0	10	0	15
Max. Green	10	25	10	25
Yellow	3	3	3	3
All Red	2	2	2	2

Total Cycle Length = 90 seconds.

Table 4
CLEARANCE TIME PRIOR TO PREEMPTION

Min. Green	0	0	0	0
Ped. Walk	0	0	0	0
Ped. FDW	0	0	0	0
Max. Green	0	0	0	0
Yellow	3	3	3	3
All Red	2	2	2	2

Procedures:

1. Upon train actuation all Green and WALK and DON'T WALK timing must instantly go to Zero, followed by the Yellow & Red intervals.
2. If train actuation occurs during a Yellow or Red interval, they just complete their timings.
3. Only one phase (1 thru 8) goes to Green to clear the tracks.

1. The train will be through in a minimum of 20 seconds per FRA Regulations.
2. The gates will start to come down in 3 seconds, and block traffic in 7 seconds.
3. The gates are down in 15 seconds.
4. The traffic signal shall be in the track clearance phase in 5 seconds (vehicle clearance only).
5. The above timings give only 15 seconds to clear the tracks.
6. At the start of the Green indication, it takes an average of 10 seconds to clear a 4 car queue in a single lane, and 15 seconds to clear a 9 car queue.[22]
7. After 10 seconds, the entire queue starts moving toward the intersection, thus clearing the tracks. This gives a maximum of 5 seconds for the last car to clear the tracks.
8. If exit gates are used, this will entrap the last vehicle, since the second gate will be blocking traffic after 10 seconds (refer to Table 2).

The above sequence and timings would provide enough time to clear the grade crossing if the current preemption programs permitted it. Many traffic engineers are unwilling to remove the pedestrian clearance interval, because it may cause a pedestrian to be stranded in the middle of the intersection. The primary problem is in the standard railroad preemption software programs being provide by signal manufacturers. Two programs being used currently state the following for the "Clearance Time Prior To Preemption":

For controllers conforming to NEMA[23] standards, it states that *"Non-preempt or non-track clearance active phases include pedestrian walk, pedestrian clearance, minimum green, yellow clearance, and red clearance timings.* ***When the controller is in any one of these intervals, these intervals will not terminate unless the programmed time has passed."[24] "Any phase active at the start of preemption which is not a clearance phase (or hold phase, in the absence of any clearance phases) is subject to shortened interval timings. Any phase selected "next" at the onset of preemption which is not a clearance phase is "de-selected"."[25]*** This means that if a preemption call is received during any of the clearance intervals, then the next phase must be serviced and the clearance interval expired before track clearance can commence.

For the 179 controllers[26] the standards state that *"Preemption Operations begins when the signal has reached the following conditions:*

- *A valid preemption call was received.*
- *Any appropriate Time Before Preemption has expired.*

- *Any appropriate Guaranteed Green Time Before has expired.*
- ***All Pedestrian Walk and Clearances have expired."***

If the signal is in a clearance phase at the time of receipt of the serviceable preemption call, the signal will cycle to the next appropriate phase in the normal signal cycle, at which point calls for all other phases will be deleted. Upon receipt of a serviceable preemption call, the signal will also immediately terminate any pedestrian "WALK" intervals being timed, and commence or complete any appropriate Pedestrian Clearance before cycling to the preemption operation."

When a preemption signal is received during the vehicle clearance interval, the next phase is added to the pedestrian and vehicle clearance intervals. Thus, the time to clear the tracks before preemption starts to increase from 5 seconds to 25 seconds. If the preemption signal is received during the WALK or Flashing DON'T WALK intervals, then the pedestrian clearance interval must be satisfied. Thus, the timing before preemption starts at least 20 seconds after receiving the signal. In this scenario, the traffic signal directing traffic across the tracks is still Green when the train passes through the crossing.

There are two known cases where this has happened with tragic results. The first case happened in New Providence, New Jersey on July 12, 1988, at 7:42 am,[27] where the flashing lights and bells were operating and the traffic signal was Green when the commuter train came diagonally through the intersection of Central Avenue and Livingston Avenue in 23 seconds. There were numerous complaints prior to this accident about this traffic signal being Green when the trains were passing through the intersection. This intersection contained pedestrian signals, and if the train preemption were received during any of the clearance intervals, then the traffic controller had to time at least two phases (20 to 40 seconds) before track clearance could commence. This can be an intermittent problem. If a train arrives during the WALK interval, then the track clearance would start in 5 seconds.

The second case involving a School Bus was in Fox River Grove, IL,. on Oct. 25, 1995, where one of many problems was traffic signal conflict. The traffic signal generated similar complaints as the New Providence case, although the controller conformed to NEMA standards. The complaints of citizens was that the traffic light intermittently remained Red during the track clearance phase. A truck driver at 6:40 am the same morning had to run the Red light so that his trailer could clear the track before the train arrived. He was successful. Traffic signal maintenance personnel were at this intersection the day before the accident and a local police chief was investigating the traffic signal at the time of the accident.[28]

In summary, each railroad traffic signal preemption program should be reviewed and evaluated to remove the above noted conflicts. In addition, a white strobe light should be placed at each intersection that has railroad preemption. This will inform pedestrians and motorists that the signal is responding to a railroad detection. Also, the train engineer would see that the traffic signal is in the preemption mode prior to arriving at the crossing.

PEDESTRIAN IMPATIENCE:

Pedestrians are just as impatient as drivers, and they want to walk the shortest distance between two points. Pedestrians are in a rush to catch a train for work or to get home after leaving the train. There are two basic types of pedestrian-related train accidents: pedestrians crossing around the train and pedestrians taking a short cut across or along the railroad tracks.

Pedestrians Crossing Around Train

In suburban areas, train stations often abut a major street which is part of the grade crossing, and they contain active gate controls. Low level platforms are great for pedestrian traffic since they do not have to walk any stairs.

Since vehicles, pedestrians, and trains use the same grade crossing, many problems arise. When a train is in the station, the gates are down, restricting traffic crossing from the grade crossing, thus creating driver impatience. There may be gates to control pedestrians from crossing the tracks, but pedestrians can slalom around the gates and walk in front or behind the stopped train. The problem arises on the adjacent track when an express train passes the stopped train at the station, and pedestrians are rushing across the tracks. Pedestrian accidents are common in these areas. One way to reduce this type of accident is to provide greater distance between the end of the platform and the grade crossing, with a pedestrian fence placed between the tracks.

Pedestrian Short Cut Route

Pedestrians will always seek the shortest distance between two points. Types of short cuts include trestles across rivers or gorges, tracks that split residential areas from commercial areas, and areas near platforms. Installing and maintaining right-of-way fences have had limited success, since a pedestrian can cut a hole through the fence to maintain the short cut. In some cases, suicidal pedestrians walk and/or jump in front of a train. Some try to cross in front of a train and slip on the ballast or rail as a train is approaching. Short cuts across the tracks using electric third rails or catenary systems are extremely dangerous due to the high voltage.

RAILROAD OPERATING PROCEDURES:

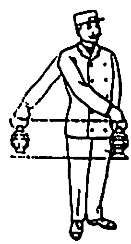
Each railroad company must operate under its own Operating Rules, which shall conform to the Federal Railroad Act CFR 49, latest revisions. These operating rules govern all employees, contractors, and visitors that may enter upon railroad property. There is a conflict of rules at grade crossings. AREA states that at a grade crossing the MUTCD shall govern. The Flagger rules are another source of major conflict between controlling traffic at a grade crossing:

Flagging Procedures At Grade Crossings

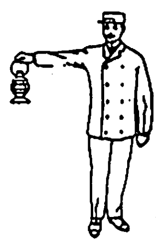
The NORAC[29] rules require that *"When an employee is required to provide on-ground protection at a highway crossing, he must give Stop Signals to pedestrian and highway traffic until the leading end of the train is through the crossing. Stop Signals must be given with a red flag or fusees by day, and fusees or white light at night."* The stop and proceed signals for all railroad employees are shown in Table 5.[30]

Table 5
RAILROAD FLAGGER SIGNALS

STOP
Swung across the tracks



REDUCE SPEED
Held horizontally at arms length



PROCEED
Raised and lowered vertically

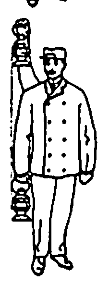
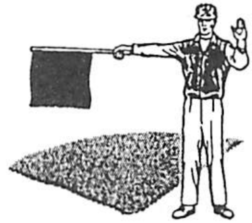
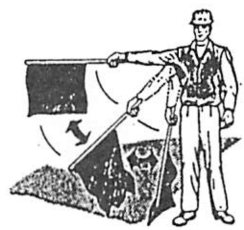


Table 6
MUTCD FLAGGER SIGNALS

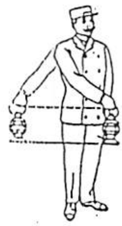
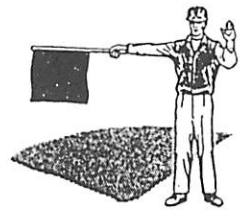
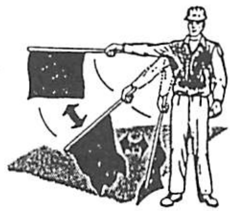
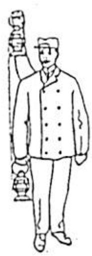
TO STOP TRAFFIC	
TO ALERT AND SLOW TRAFFIC	
TRAFFIC PROCEED	

The Flagger hand signals for highways are illustrated in the MUTCD,[31] and were enacted into law by the Highway Acts, which requires conformance by every private and political jurisdiction in the United States. Table 6 shows the standard Flagger signals as stated in the MUTCD.

The problem arises from the conflicts of different Flagger signal commands. When a railroad employee must stop vehicle traffic at a grade crossing, the railroad requires him to use its Flagger rules. Table 7 compares both railroad Flagger and MUTCD commands.

There are at least two known occurrences of railroad employees using railroad signals to control highway traffic.

Table 7
FLAGGER SIGNALS

Railroad		MUTCD
	TO STOP TRAFFIC	
	TO ALERT AND SLOW TRAFFIC	
	TRAFFIC PROCEED	

The first case occurred on December 6, 1988, between a ConRail switch engine and a gasoline truck, which collided at the Roosevelt Avenue grade crossing near Lafayette Street in Carteret, NJ. The truck driver was killed, and the other witnesses made conflicting statements. Some witnesses stated that there was a Flagger, and others did not see one, but all the witnesses stated that the truck's gears were shifted down when he was approaching the grade crossing, and then shifted up to resume speed. It is assumed that the conductor gave the proper railroad flagging signals to the truck driver, which to the conductor meant stop, but to the truck driver it meant proceed. This would explain why the truck driver started to shift gears and proceed without stopping at the railroad crossing. A driver of a flammable liquid is required to stop at least 15 to 50 feet before the grade crossing, and only proceed without stopping if directed to by the Flagger, as required by New Jersey Vehicle & Traffic Law.

The second case involved a dump truck crossing a railroad track under the control of a Flagger on a short line in southern New Jersey. The conditions leading up to this accident are the same as for the previous accident case. There are a number of accidents at grade crossings which are under the control of a railroad employee Flagger using Railroad Flagging commands to control highway traffic. Railroad Flagger commands are only authorized to be carried out by railroad employees, and not the general public, since the goal is not to have any unauthorized person controlling the movement of a train.

Track Crossing In Freight Yards

The control of all vehicle and train traffic within the yard is by the Yardmaster, and along the main line track the control is under the Trackmaster. In many yard and track areas, the only access to the area is by crossings a track which has been filled in by dirt and gravel, with no warning signs.

The rail storage areas are leased, and the railroads have converted connecting track into storage to be used by transfer companies. To get to these leased sidings within the freight yard, the contractor's employees must cross over active tracks, with no Crossbuck signs marking the track crossing. The Yardmaster may not adequately control the movement of trucks, railcars, and employees within his jurisdiction, which has led to many accidents.

Summary

It is up to the railroad industry and local jurisdictions to work together to improve railroad-highway grade crossings, by bringing all grade crossings up to current standards to reduce the high number of accidents.

It is also up to the railroad industry and local jurisdictions to reduce the present crisis in railroad-highway grade crossing accidents by working together to educate the general public of the hazards of crossing railroad tracks, by improving communication between transportation professionals, and by coordinating railroad and highway operations.

References:

1. FRA July 1995 Report on Highway-Rail Crossing Accident/Incident and Inventory Bulletin No. 17, Calendar Year 1994.
2. Ibid.
3. Operation Lifesaver, Inc. press release for 1995 Grade Crossing Accident Report, dated April 2, 1996.
4. 1983 MUTCD Section 8B-2 Railroad Crossing (Crossbucks) Sign (R15-1,2).
5. 1983 MUTCD Section 8B-3 Railroad Advance Warning Signs (W10-1).
6. 1983 MUTCD Section 8B-4 Pavement Markings.
7. 1983 MUTCD Section 8B-9 STOP Signs (R1-1).
8. ITE Traffic Engineering Handbook, 2nd Edition, 1950, page 287.
9. MUTCD Section 1A-5 - "SHOULD - An advisory condition. Where the word "should" is used, it is considered to be advisable usage, recommended but not mandatory." An Engineering Study should be used to document why the requirement was followed or not.
10. AASHTO A Policy on Geometric Design of Highway and Street 1990, page 843.
11. NCUTCD Review Team March 28, 1996.
12. AREA -American Railway Engineering Association, 1993 Manual for Railway Engineering 1993, Part 9 Railroad Vegetation Control.
13. Northeast Operating Rules Advisory Committee (NORAC), Operating Rule No. 998.
14. NORAC Rule No. 138d.
15. Estimating Train Speed from Braking Distance, Loumiet & Glennon paper present on July 22, 1992 in Oak Brook, Ill NSPE meeting.
16. Railroad-Highway Grade Crossing Handbook, 2 ed., 9/86, FHWA-TS-86-215, page 43.
17. NCUTCD Review Team March 28, 1996
18. Traffic Engineer Handbook, ITE, 1992 Ed. page 37.
19. Railroad-Highway Grade Crossing Handbook, 1 ed., 8/78, FHWA-TS-78-214, page 188.
20. Elements of Railway Signaling, General Railway Signal, 6/79, page 820.

21. MUTCD 1983, Section 8C-6.

22. Greenshields, Shapiro, and Ericksen, Traffic Performance at Urban Intersections, Technical Report No. 1, Yale BHT, 1947. Transportation Rearch Circular No. 212, TRB, Jan. 1980, page 7 foot note. (The time it takes to clear vehicles at a green signal: 1st car - 4 sec..; 2nd car - 7 sec; 3rd car - 9 sec.; 4th car 10 sec.; and each additional car +1 sec.).

23. NEMA - National Electrical Manufactures Association.

24. Microtronics, Inc. User Manual Model 8000/800SS All purpose NEMA Controller.

25. Trafcon, Inc., Model 840 NEMA Traffic Controller

26. Traffic Actuated Processing System Operator's Manual, Jan 1, 1994, NYSDOT.

27. Docket No. 88-1611, Estate of the Goldferb v Township of New Providence & New Jersey Transit.

28. New York Times 10/26 & 27/96; Reporter Dispatch, Gannett Suburban Newspaper (10/26, 27 & 29/96).

29. NORAC, Northeast Operating Rules Advisory Committee Jan. 1,1995, Rule No. 138f.

30. NORAC Rule No. 13 & United States Railroad Administration, New York Central Railroad, Rules for the Government of the Maintenance of Way Department, Effective October 20, 1918.

31. MUTCD 1983 Section 6F-4.