Addis Ababa University
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Traffic Control Methods and Safety Assurance at 'Sebategna' Area –Level Crossing

By
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Addiss Abeba, Ethiopia

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A Thesis Submitted to the School of Electrical and Computer Engineering
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Declaration

I, my name and my signature noted bellow declare that this thesis is my original work; there is no the same work submitted both in AAU and other universities. All materials used in this work are also acknowledged and referenced with honorable respect.

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Date: April-03-2015

I certified that the above statement made by the student is correct to the best of my knowledge and it has been submitted for examination with my approval as university advisor.

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Abstract:

Today railway transportation is one of the modern and basic transportation systems in developed countries due to its mass transportation system. But, rail-road level crossing related accidents are more dangerous than other transportation accidents in terms of loss of human life, injury, damage to railway property, severity and death rate etc. and there still remain level crossings requiring improvements. Since our country's railway system is modern type of railway system, this thesis assesses the modern type of traffic control systems that are used at level crossing in order to reduce the fatal accidents that could occur at these conflicting places in general and the 'Sebategna' area level crossing of the Addiss-Abeba Light Rail Transit (AA-LRT) in particular depending on the experiences of developed countries that use modern railway transportation.

The main parameter in traffic control at level crossing is sight distance of a train from road users. So, various elements that have effects on determining the sight distance are stated, various mathematical equations of sight distances at different states of the road users are established depending on the stated elements, and particularly the sight distances for different road users of the 'Sebategna' area level crossing i.e. position of control sensors and distance of the block sections near the level crossing are determined, appropriate traffic control systems i.e. signals, signs and road markings are selected and displayed graphically using AutoCAD software.

The results of this thesis shows carefully selected fail-safe type of active control systems along with signs and road markings is necessary in order to achieve safe, reliable, and efficient traffic control and safety assurance at the 'Sebategna' area level crossing. So, this thesis can help to the Ethiopian Railway Corporation and other sectors as an instrument in designing traffic control systems at level crossings.

Key Words: - Traffic Control, Safety Assurance, Addiss-Abeba Light Rail Transit, Level Crossing

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List of abbreviations (acronyms)

- AA-LRT- Addiss-Abeba Light Rail Transit
- CREC-China Railway Engineering Company
- CS- Control Signal
- CSL- Control Signal Light
- ERC- Ethiopian Railway Corporation
- ITS- Information Technology System
- RCA- Road Construction Authority
- TCD-Traffic Control Devices
- UK-United Kingdom

Introduction

Rail-highway Level crossings are physical interface or potential points of conflict between road and rail transport systems both of which operate as entirely separate entities. According to the different experiences of countries with developed rail industry like New-Zealand, U.S.A, India, Japan, Australia, France, Germany, UK, Sweden, Netherlands etc, rail-road level crossing related accidents are more dangerous than other transportation accidents in terms of loss of human life, injury, damage to railway property, severity and death rate etc [4].

In these sample countries, the train has right-of-way in these conflicts, and it is the driver's responsibility to give way to the train. It is a natural rule because train takes a lot more time and distance to stop than a car at similar speed; i.e. stopping distance of a train is typically at least 10 times longer than that of a road vehicle. Furthermore, trains can't change direction to avoid collision in the same way as road vehicles. The system of traffic-control devices (TCDs) located at a level crossing is intended to aid the road users in carrying out this responsibility. Existing TCD practice may not be providing the driver with the correct information required in optimal form where and when it is needed.

Improvements to signs and road markings may foster more appropriate driver behavior at passive rail-highway grade crossings. In response to this concern, a variety of suggested improvements to current practice have been put forth in recent years in different countries. Therefore, all level crossings must be protected through the use of appropriate traffic control devices.

Purpose of the study: This thesis is intended to provide best practice guidance on the use of traffic control devices related to level crossings to both road and rail practitioners. This thesis includes a critical evaluation of recent research and recommendations, collection of new information, and formal analytical activities.

The general purpose of this thesis is to assess and provide guidance: on the use of traffic control devices, on operational policies affecting traffic movement across level crossings and activity such as road works on or adjacent to level crossings; While the particular aim is to build on the specifications for appropriate signals, signs, road-markings, illumination devices and other traffic control devices for use at the 'Sebategna' area level crossing of AA-LRT as set down in the

Traffic Control Devices (TCD) specifications of developed countries that use railway transportation to permit safe and efficient operation of rail and highway traffics.

Our country, Ethiopia, is a progressive country that has already started the rail way industry. So, to avoid or minimize all these fatalities that could occur at level crossings, appropriate use of traffic safety methods is unquestionable. With due regard for safety and for the integrity of operations by highway and railroad users, the public-road authority and the railway corporation should entitled to jointly occupy the right-of-way in the conduct of their assigned duties. This requires joint responsibility and more efforts for improving safety at level crossings.

Chapter 1

Level crossing and causes of accidents at level crossings

1.1. Introduction

Rail-highway Level crossings are the physical interface or potential points of conflict between the road and rail transport systems both of which operate as entirely separate entities or organizations.

According to Section 4 of the Railways Act 2005, a level crossing is defined as any place where a railway line crosses a road on the same level or the public is permitted to cross a railway line on the same level and includes a bridge used for both rail vehicles and road traffic on the same level but does not include a railway line on a road that is intended solely for the use of light rail vehicles.

According to *Peter's* (Peter Hughes, Director, ITS Innovations of Australia) definition**; "**Level crossings are the point where the railway has the least amount of control over people's actions."[6].

1.2. Classification of level crossings

We can classify level crossings in different ways; one way is public and privet.

1.2.1. Public level crossings: These are level crossings on legal roads or on operational railway land. Many of these level crossings are subject to a deed of grant which sets out the conditions on which each is provided and maintained. There are two types of public level crossings:

a. Pedestrian level crossings: These level crossings provide for the passage of foot traffic, mobility devices, wheeled recreational devices and frequently cyclists. They may be with in a road reserve but separated from the roadway or they may be isolated, stand-alone level crossings, including level crossings at station platforms.

b. Vehicular level crossings: Vehicular level crossings include all level crossings carrying road vehicles. These level crossings may incorporate adjacent foot paths to provide for pedestrian level crossings of the railway track. Where there are no adjacent footpaths, the vehicular level crossing could also provide for pedestrians, mobility devices and wheeled recreational devices.

1.2.2. Private level crossings: Statutory level crossings were provided by statute at the time the railway was constructed and were needed to give legal access to detached portions of private land where no other legal access existed.

These level crossings have never been systematically recorded and the legal right can now only be ascertained by reference to the original land title deeds as they applied immediately before and after the creation of the railway.

The other type of level crossing classification is Rail operation and Tramway level crossings.

1.2.3. Rail operations level crossings: are located on railway property and are used in the operation of railway business. They are generally, because of their limited use, level crossings with passive control. Rail operation level crossings can be defined in two categories. These are:

a. level crossings purely in use for the operation of the railway; *These are called rail access level crossings.*

b. level crossings typically providing access to rail access providers' or rail operators' facilities (eg. marshaling yards, depot, workshops where railway lines and level crossings are present); *These are called public access level crossings.*

1.2.4. Tramway level crossings: Traditionally, tramways operate on roads and mix with other users although reserved, off-road sections are a feature of many tramways.

The five main Level Crossing Types and their respective accesses are listed in the following table.

Level crossing type	**access**
Public	All vehicles and road users
Limited access	Truck and trailer combination prohibited, or all trucks and buses prohibited
Pedestrians crossing	Pedestrians, bicycles (and mopeds) only
Service road crossing	Maintenance vehicles (< 12 m), pedestrians
Pedestrian crossing between Platforms	Pedestrians, maintenance and service vehicles (< 12 m)

Table1.1 level crossing types and their respective accesses

1.3. The main causes of accidents at level crossings

Pat's (Pat Latter, Executive Director, NFA Innovations of Australia) *description* [6]; Rail level crossing collisions typically involve serious injury and frequently involve fatalities. Considerable evidence highlights that the causes of level crossing accidents is quite different from other road accidents. The majority of level crossing accidents do not involve behavior such as excessive speed, drug and alcohol impairment, or other forms of risk taking. Rather, fatal accidents at level crossings are caused most frequently by unexpected driver error. The major problems for road users at railway level crossings appear to be:

Complacency: associated with attributions about the road transport network, rail movements and train capabilities, and the timing and operation of railway crossing signals.

Late detection of hazard: arising from lapses, it is the most critical problem faced by a road user. Without detection there can be no processing of information and no decision process as to the most appropriate response.

According to *Estonian Experience [5],* Causes of level crossing accidents are: Disregard of prohibiting traffic lights, disregard of the requirements of traffic sign "Stop and give way", exceeding speed limit by 5-20 km/h, exceeding speed limit by more than 20 km/h, car driver carelessness and recklessness etc. The table blow shows some of the reasons for the occurrence of railway level crossing accidents 2006-2007 (Estonian Experience) [5].

Table 1.2: causes of rail way accidents

Accident reason	**2006**	**2007**
Disregarding prohibiting traffic light	5	3
Disregarding traffic sign "Stop and give way"	5	5
Hitting a train that has already reached the level crossing	5	1
Slippery road	4	3
Inappropriate driving speed	2	4
Lack of driver's license	1	-
Drunk driving	1	-
Starting a movement without making sure that there is no train approaching	1	-

Parking car inside railway track clearance	–	1
TOTAL	24	17

From the above table we can conclude that disregarding prohibited traffic light, disregarding traffic sign "Stop and give way", hitting a train that has already reached the level crossing, slippery road, and inappropriate driving speed are the main causes of level crossing accidents.

At *passive controlled* rail-highway grade crossing, the traffic-control system does not inform roadway users of the approach or presence of trains, locomotives, or railroad cars. This passive system is in contrast to *active controlled* rail-highway grade crossing traffic control systems, such as flashing light signals or automatic gates. Example, in United States approximately 3,500 incidents and approximately 400 related fatalities; in the U.K in 2009 a total of 3,200 incidents of misuse; in Finland, in 1999–2009 annually between 42 and 64 accidents was reported; and most of them occurred at passive crossings where road and rail traffic volumes are low.

Although level crossing technology has continued to evolve over recent decades; for those at-grade crossings that still have only passive TCDs there has been no clear improvement in driver behavior or crash experience. Research studies and field experience have shown that drivers frequently fail to comply with TCDs at rail-highway grade crossings, do not have good understanding of the meaning and implications of TCDs, and do not understand risks and responsibilities associated with passive crossings [3].

Because of the costs involved in installing and maintaining to upgrade levels of crossing control (i.e. flashing lights, automatic gates, and grade separation) it is not feasible to upgrade many of these sites. Therefore, there is a need to identify relatively low-cost improvements to TCD practice at passive grade crossings that will promote safer driver behavior and result in safety benefits.

According to the various data's of the stated countries [4], accidents at level crossings are on a decline in the long-term. However, almost half of railway operation accidents occur at level crossings especially at passive controlled level crossings and there still remain level crossings that require improvements. In light of such conditions, the ERC should use modern type of traffic management system at level crossings to prevent level crossing accidents.

Chapter 2

Control devices used at level crossings for safety

2.1. Introduction

To reduce the impacts due to accident operational consequences at level crossing and to increase safety and human awareness is important to introduce new technologies in the level crossings operational management, but high safety requirements together with high railway standards are presently hindering technological upgrade of level crossings. In many countries level crossings on less important roads and railway lines are often "open" or "uncontrolled", sometimes with warning lights or bells to warn of approaching trains.

In Europe despite the best safety precautions, i.e. operations are fully automatic; in the event of a malfunction, the fail-safe principle applies; the safety system takes over and prevents a level crossing from opening by mistake; nevertheless, most incidents still occur at level crossings. Car driver carelessness and recklessness are usually to be blamed. That is why, it is recommended to replace level crossings with tunnels or bridges where possible.

2.2. Safe operations of rail-road level crossings

Today different companies such as German engineering giant Siemens Mobility are involving in finding new technologies for improving the safety level at level crossings. The company's Simis LC is marketed as a fail-safe microcomputer system that can easily be adapted to the conditions of individual level crossings and customer-specific requirements. One of the problems with railways is components in the past have become obsolete very quickly and if a level crossing requires amendment then entire renewal is often the only solution.

The Four Measure pillars for Traffic Safety at Level Crossings Promoting effective measures that take into account the conditions of each level crossing are:

a. Promoting replacement of level crossings with grade-separated crossings, structural improvements, and improvement of grade separation facilities for pedestrians.

b. Improving level crossing maintenance facilities and implementing traffic regulations.

c. Promoting integration and elimination of level crossing.

d. Implementing other measures to ensure safe and smooth traffic at level crossings.

A single accident at a level crossing can produce serious consequences. In an area where there are a series of level crossings with especially long wait times and high traffic volume, or at level crossings where railway lines intersect with main roads, the developed countries promote improvements of the level crossings such as grade separation, structural improvements, development of grade separation facilities for pedestrians, level crossing maintenance facilities, traffic regulations or installing necessary level crossing safety equipment, level crossing integration and elimination, and introducing grade-separated and alternative rout possibilities at crossings as much as possible in the case of new road constructions, road reconstructions or new railway constructions, which is one of the radical traffic safety measures. Moreover, these measures will also contribute to the facilitation of traffic and environmental protection by reducing traffic congestion.

Structural improvements that are necessary to build walkways or improve narrow ones at level crossings can be implemented without integration or elimination of level crossings in proximity, taking the urgency into consideration; And proceed with research and development to design more advanced traffic safety facilities related to level crossings by making use of information technology (IT), and will also actively regulate offenses by vehicles at level crossings.

Also, in view of the fact that many level crossing accidents are caused by pedestrians crossing in front of approaching trains or vehicles getting caught in railway tracks, it is necessary to improve safety awareness among motorists and pedestrians and familiarize them with emergency measures such as how to operate the emergency button when a level crossing problem occurs.

For the most part we typically use visual warnings as protection at level crossings. These are either active such as flashing lights or passive such as signs. Modern conveniences such as vehicle insulation and sound systems often prevent drivers from hearing audible warnings. Visual warnings rely on the driver to be concentrating and interpreting the warning in a timely manner. The problem is that driving does neither take place in isolation nor as a highly focused activity but during other distractions. Researches demonstrate that distraction is not unusual but quite typical within a normal driving scenario.

2.3. Control devices

It is clear that adequate sight conditions from the road to the railway are a necessary precondition for level crossing safety, especially at passive level crossings. All level crossings must be protected through the use of appropriate traffic control devices. The devices installed or marked at or near level crossing depend on a range of factors including:

• Level crossing type.

• Volume and speed of rail, and road traffic.

• Mix of road and rail traffic using the level crossing.

• Alignment of the approaches to the level crossing.

• Other physical attributes of the level crossing and its surrounds.

There are two types of level crossing controls: Passive and Active.

2.3.1 Passive control: vehicular and pedestrian traffic control at level crossing is achieved by the provision of signs and road markings installed at and in advance of level crossings but not activated by an approaching train. Their purpose is to indicate to the road user that it is their responsibility to check for the approach of trains prior to crossing the railway lines; i.e. road users must be able to see the approaching train so far in advance that they can be certain that traversing the track is safe if there are no trains in sight. The different signs and road markings are described in chapter three.

2.3.2. Active control devices: vehicular and pedestrian traffic control at level crossing uses flashing lights, bells, barrier arms, gates or a combination of these devices; so that it is not necessary for the road users to see the train. Control devices of this nature are activated by the approaching railway traffic automatically or manually. The main Railway-activated control devices used at level crossings are:

- Flashing lights and bells (FLBs)
- Half-arm barriers (HABs)
- Pedestrian gates
- Active signs

2.3.2.1. Flashing lights and bells (FLBs): An FLB consists of two red traffic signals mounted horizontally on a red and white striped pole. The pole may also support traffic signs and a warning bell which is intended to alert pedestrians and cyclists to the impending passage of a train. The assembly can be used by itself on the left side of the carriageway or may be duplicated or triplicated for multiple approach angles, multiple-traffic lanes or high-traffic volumes (with a potential for overtaking).

When activated, the lights flash alternately and the warning bells ring. When flashing, this signal indicates that drivers must stop before entering the controlled area of the level crossing (defined by the limit lines) and remain stationary during the flashing period.

In some urban situations, the bells (primarily intended as a warning to pedestrian and cycle traffic) may not be activated during normal sleeping hours. In these circumstances, a Bells Off (AX11) sign must be installed and the sign must indicate the times during which the bells will be switched off. So the Sequence of Operation if a train is approaching the level crossing, the Flashing highway signals shall commence and continue to flash alternately and the warning bell shall commence and continue to sound and vice-versa if no train is approaching or when the rear of the train passes clears of the level crossing.

2.3.2.2. Half-arm barriers (HABs): In some situations, HABs are used in conjunction with FLB controls. At level crossings where HABs are installed, bells will always operate until the barrier arms reach the lowered position. Pedestrian level crossings may be uniquely protected by bells mounted on a pole. In these cases, a Look For Trains (WX8) sign must be placed on the signal pole facing approaching pedestrians and the railway lines must be clearly visible in each direction.

Barriers are lowered a minimum period (usually five seconds) after the lights and bells have been activated. Vehicles on the level crossing can exit the level crossing control area because the barriers obstruct only half the carriageway. Barriers are intended to enforce compliance with flashing lights and reinforce the warning system by providing a physical boundary to access on to the railway.

2.3.2.3. Pedestrian gates: Where pedestrian and train movements are high, automatically activated pedestrian gates may be justified. These provide positive control of pedestrian movements and also provide good levels of pedestrians and cyclists service across the railway line(s) when the gates are open.

2.3.2.4. Active signs: Active level crossing warning signs are intended for use where full railway level crossing flashing signals cannot be justified.

These control devices are activated through signaling circuits upon the approach of a train to a level crossing. The activation of these circuits has three basic mechanisms – distance, predictor and manual.

Distance: the majority is set to operate a predetermined distance along the railway to give a minimum alarm warning time period before a train operating at the fastest speed permitted to reach the level crossing. In some instances, the warning time may be increased further by multiple railway lines or nearby stations. When HABs are installed, the barriers may be held down for a second train if there would not be sufficient time for the barriers to rise and fall again before the second train would reach the level crossing.

Predictor: Where stations are located near level crossings, additional equipment may be installed to adjust the warning time to account for a stopping or non-stopping train. Predictor mechanisms operate control devices by determining the approaching train speed and adjusting the activation of the level crossing so that the length of time between activation and the train reaching the level crossing is constant for all train speeds.

Manual: Use of road traffic signals as level crossing control devices may be considered only where:

• The level crossing is extremely close to an existing road intersection that must be controlled by traffic signals

• The maximum rail speed is 15km/h and it is feasible for rail movements to be stopped before crossing the road

• The installation of standard FLB controls is not feasible due to:

– Space constraints

– Insufficient railway traffic to justify the installation of FLBs.

In these cases, the rail movement cedes the right of way. The approach of a train or operation of a manual signaling device by a rail participant initiates a rail phase. The rail movement may not proceed until the appropriate T-aspect is displayed.

Sufficient Cross buck standard (WX6) signs should be mounted on traffic signal poles so that a sign is clearly visible to drivers from all road approach directions.

The automatic alarms at a manually controlled crossing are started by the rail operator before the train crosses the road. In such cases, the rail speed will normally be no greater than 25km/h so the train can, if necessary, be stopped before crossing the road. There will be no fixed time between the start of the alarms and the train entering the crossing but the rail operator would normally wait until any approaching road traffic has stopped before proceeding.

Where there is a high degree of pedestrian and commuter train traffic on two or more railway lines additional warning devices may be installed. These may include a secondary audible alarm of a different volume and frequency to the standard level crossing alarms. In addition, an electronic sign warning of a second train coming may be installed for pedestrians.

Additional time allowances for angled or wide crossings are necessary because, as the intersection between the road and the railway deviates from 90^o, the distance travelled by vehicles and pedestrians to clear the crossing is also lengthened.

2.3.3. Traffic signal integration with level crossing signals

Where an intersection controlled by traffic signals is near a level crossing (not necessarily actively controlled), integration of the railway signaling circuits to force phases in the traffic signals may be used and is particularly appropriate where limited stacking space is available for vehicles at the level crossing. This integration between the intersection signals and those at the level crossing require specialized planning and input from the rail access provider.

Normally integration will be required where the signal controlled intersection is within 30m of the level crossing and should be considered where this distance is up to 60m.

Protecting of Level Crossings by Signal integration is possible where trains regularly approach level crossings more than once per day and the movement over the crossing is not to proceed for operating reasons, then a signal (or a Main Line Indicator) should be provided to regulate the level crossing operation.

This signal or Main Line Indicator may be operated by one of the following methods:

- Operators or safe working Key and/or duplex lock
- Staff Contact box
- Staff Lock
- Driver's push buttons
- Remotely controlled via the level crossing monitor or other remote control system
- Whistle activation or other method suitable for the situation

2.3.4. Locomotive-mounted warning devices

The operation of locomotive horns, whistles or similar is required in some circumstances and is optional in others. The requirements for trains to sound these warning devices are governed by the operating rules of the rail access provider.

In circumstances where a locomotive engineer's visibility of an approaching level crossing is poor, the rail access provider may provide whistle boards requiring the sounding of a warning device. At other level crossings, the operation of the warning device is at the judgment of the locomotive engineer. This degree of flexibility allows, for instance, locomotive engineers on trains operating late at night through residential areas to decide for minimizing disturbance by reducing the sound of the warning device.

Chapter 3

Standard traffic safety signs and road marking layouts

3.1. Introduction

Signs and road markings installed or marked at and in-advance of level crossing are used in aiding rail-road traffics. These are mostly passive control methods. For more description we can see them separately as signs and road markings [3].

Signs can be classified as sings used at level crossings and in-advance of level crossings.

3.2. Signs used at level crossings

Signs installed at level crossings i.e. adjacent to or within the railway corridor, are the responsibility of the rail access provider in consultation with the road construction authority (RCA) [3]. The different signs used at level crossings are shown in table A1 in appendix A.

3.3. Signs used in advance of level crossings

Signs installed in advance of level crossings are the responsibility of the road construction authority (RCA) in consultation with the rail access provider [3]. The different signs used in advance of level crossings are shown in table A2 in appendix A.

Since this thesis is mainly intended for traffic control methods and safety assurance at level crossings, the rules or polices of Signs used at level crossings and these signs used in advance of level crossing selected in this level crossing are described below [3].

1. Stop (RP1) or Give Way (RP2): A Stop (RP1) sign is installed as part of an RPX2 or RPX4 assembly and a Give Way (RP2) sign as part of an RPX3 or RPX5 assembly at level crossings not controlled by signals or permanent level crossing keepers. The decision as to whether a Give Way or Stop sign is appropriate is primarily based on the view lines available at a level crossing determined by applying the criteria described in Sight distances at level crossings.

The minimum requirement on any approach to a level crossing is a Give Way control in the following circumstances:

• If the approach visibility (S2) can be met, a Give Way sign must be installed.

• If the approach visibility (S2) cannot be met but the restart view (S3) can be met, a
Stop sign is installed.

• If the approach visibility (S2) and the restart view (S3) cannot be met, the crossing will need to be carefully assessed to determine whether active control is justified or changes to the operating conditions (example: restriction on road or rail speeds, limitations on vehicle length) need to be imposed.

2. Cross buck (WX6 or WX61): Level crossing position indicators or cross buck signs must be installed at all level crossings. Wherever possible, they should be installed as part of RPX1, RPX2 or RPX3 assemblies. Installation of a cross buck (WX6) sign in an RPX1 assembly (ie on poles also mounted with flashing lights and bells (FLB) or half-arm barriers (HAB)), while highly desirable may be impractical in some cases because the existing poles could require major base stabilization work.

3. Cross- buck for private level crossings (WX62 or WX63): Where a private level crossing operates with low-road speeds and has a narrow, unsealed road formation, some reduction in the size of the cross buck can be justified. The cross-buck for private level crossings (WX62) or where there is more than one railway line (WX63) may be installed alone or preferably above either a Stop sign (RP1) or Give Way sign (RP2). The use of either an RP1 or RP2 sign is based on the sight lines at the level crossing described above.

4. Tramway cross buck (WXT): Where a tramway crosses a road and the trams that use it have right of way, similar standards to those applying to railway level crossings apply. In these cases, the standard cross buck (WX6 or WX61) is replaced by a tramway cross buck (WXT or WXT1) sign.

5. Cross buck for private level crossings (WX62 or WX63): An appropriate [number of] track signs must be added to RPX1, RPX2 or RPX3 assemblies and incorporated into a WX63 private level crossing cross-buck where more than one railway line is crossed. The WX7[n] sign is never installed separately.

6. Bells off (AX11): In suburban residential locations, level crossing alarms may have been programmed to alter the ringing of bells outside normal working hours. Where this is the case, the rail access provider will have installed the Bells Off sign on the FLB pole.

At level crossings equipped only with FLB, the sign will indicate the period that the bells will not operate.

At level crossings equipped with barrier arms, the sign indicates the period during which the bells only sound until the barrier arms have lowered fully to the horizontal position. This is necessary to warn cyclists and pedestrians of the hazard of the lowering arms.

Switching off the bells reduces the safety of cyclists and pedestrians.

7. Stop on Red Signal (RP61): A Stop-On-Red Signal sign may be added to RPX1 assemblies to emphasize the requirements for drivers to stop when the level crossing flashing signals are operating. Stop- On- Red Signal signs must be mounted on RPX1 assemblies with a minimum clearance of 1m from the underside of the sign to the surface of the adjacent roadway, trafficable shoulder whichever is the critical dimension.

8. Look For Trains (WX8): A Look For Trains sign (WX8) may be used on RPX2 and RPX3 assemblies. It may also be used as a supplementary sign below level crossing alignment (WX40–WX42) signs. A WX8 sign should be installed separately at a pedestrian maze. They may also be installed where there is no pedestrian maze at a footpath (separated from a road) crossing the rail corridor.

9. Poles used for mounting signals, barrier arms and signs: Poles used for mounting *signals* should have reflectorized red and white alternate bands at least 225mm wide. Poles used to mount *signs* at level crossings may have similar reflectorized red and white alternate bands but, if not, the pole should be painted white.

Barrier arms may be mounted on separate poles behind but in line with the RPX1 assembly. A separate pole may be used when:

a. it is not practical to mount the flashing signals and WX6 sign on the same pole because of the required angle for the signals and sign or

b. the barriers have been added to an existing FLB installation.

When the barrier is on a separate pole, the barrier pole is seldom visible to motorists from a distance and thus there is little value in installing reflectorized bands.

10 Barrier arms: A barrier arm must have:

• on the front (traffic side), a strip 50mm high of alternate red 280mm wide and white 180mm wide retro-reflective markers and

• on the reverse (rail side), a pattern of inline, equally spaced red 50mm high and 280mm wide retro-reflective markers at least:

– three (on arms up to 10m long) or

– five (for arms greater than 10m long).

Any area of the arm not covered by the markers must be white.

Barrier arms should be extended to the centerline of the road.

All parts of the barrier arm or, depending on the skew of the railway line relative to the road, the barrier counterweight must be at least 1.7m from the nearest rail.

11. Level crossing flashing light assembly (RPX1): A basic level crossing flashing light assembly (RPX1) consists of a cross buck (WX6) sign mounted above the signal head on a signal or barrier pole. The pole forms part of the assembly. A supplementary [number of] track (WX7 [n]) signs must be added at level crossings with more than one railway line.

RPX1 assemblies, normally installed on the left-hand side of the road, must be at least 2.4m clear of the nearest rail edge (3m from the nearest railway line centerline). The limit line indicating the point where vehicles must stop if a train is approaching the level crossing should normally be installed 2m in advance of the RPX1 assembly.

RPX1 assemblies should be clearly visible to approaching drivers for a distance of at least 120m on rural roads and at least 60m on urban roads. The assembly may be placed on the right-hand side if the visibility cannot be achieved by installing it on the left-hand side and may be duplicated where the geometry means drivers approaching will benefit.

Where there are two or more traffic lanes on approaches to level crossings controlled by flashing light signals, a second RPX1 sign combination should, if practicable, be installed on any median island or on the right-hand side of the road. The gap between individual signs on the RPX1 assembly should be approximately 100mm.

12. Standard level crossing Stop (RPX2) or Give Way (RPX3) assemblies: A standard level crossing stop assembly (RPX2) consists of a cross buck (WX6) mounted above a Stop (RP1) sign, while a level crossing give way assembly (RPX3) consists of a cross buck (WX6) sign mounted above a Give Way (RP2) sign.

RPX2 and RPX3 assemblies should be installed on both sides of the road and must be at least 2.4m clear of the nearest rail edge (3m from the nearest railway line centerline). The limit line indicating the point where vehicles must stop if a train is approaching the level crossing should normally be installed 2m in advance of the RPX2 or RPX3 assembly.

RPX2 and RPX3 assemblies should be clearly visible to approaching drivers for a distance of at least 120m on rural roads and at least 60m on urban roads.

Where a level crossing on a side road is within 30m of the through road, the RPX2 or

RPX3 assembly must be installed on both sides of the road and oriented toward approaching drivers.

The recommendation to duplicate stop or give way passive signs was introduced in 2012. Cost considerations mean that it will take a number of years to phase these changes in. As such, duplication should be considered where the level crossing is being upgraded, or as part of a general sign or road maintenance program. This change is intended to apply to passive signs only and should not be used to infer a requirement for signals to be duplicated.

13. Private level crossing Stop (RPX4) or Give Way (RPX5) assemblies: they are used at private level rail- road level crossings.

14. Railway Not In Use (AX12): Where a railway line ceases to be used and the period of disuse is likely to be of sufficient duration, the RCA must clarify the status of the level crossings to ensure appropriate and safe use by road users.

The RCA should only proceed when they have received formal notification that the railway line is out of use and is unlikely to be used for a specified period.

All regulatory signs, i.e. Give Way (RPX3), Stop (RPX2) and flashing light (RPX1) assemblies, relating to the level crossing should be removed on all road approaches to the disused railway line and a Railway Not In Use (AX12) sign installed at the former positions of the regulatory signs. In the case of flashing light assemblies, the signal heads must be hooded or turned from view as an alternative to immediate removal.

All permanent warning signs and markings relating to the level crossing should be removed on all approaches to the disused railway line. Railway Not In Use (AX12) signs, maintained by the

RCA, should remain in place until the railway lines have been sealed over or removed from the roadway or the railway line reopened.

The railway lines at any level crossing must not be sealed over without the explicit written permission of the rail access provider.

If the rail access provider intends reopening the railway line, the RCA must be given advance notice (at least four weeks) and the Railway Not In Use (AX12) sign must be removed and regulatory signs (depending on available sight distances) must be installed before the level crossing is reopened to rail traffic. Note that; for this purpose, the use of the railway line by vehicles used for inspection and any routine maintenance of the disused railway line or rail corridor does not constitute a reopened railway line.

The installation of regulatory signs located at and within the railway corridor at any reopened level crossing remains the primary responsibility of the rail access provider in conjunction with the RCA.

Once notified that the level crossing is to be reopened, the RCA is responsible for the installation of standard permanent warning signs and markings outside the railway corridor.

15. Trains running (T235): Where a railway line is reopened road users need to be reminded that trains are again running and the trains running sign should be installed for an adequate period after the train use has resumed. This sign may also be used:

• where an event (eg a running or cycle race) may be occurring along the road and participants may believe movement of trains has been controlled for the duration of the event, or

• road works are taking place adjacent to, or including, the level crossing and road users may believe the movement of trains is being controlled or the level of roadwork activity requires reinforcement that trains are operating. The sign should be installed as near as practicable to the level crossing.

Signs used in advance of level crossing

1. Level crossing ahead –type of control (WX3, WA1 or WA2): these signs should be installed on the left-hand side of the road on approaches to level crossings equipped with flashing signals, Stop signs or Give Way signs respectively where the RPX1, RPX2 or RPX3 assemblies are not clearly visible to approaching drivers for a distance of at least 120m on rural roads and at least 60m on urban roads with an appropriate supplementary [distance]m ahead (WG3) sign.

On multilane approaches, a second WX3, WA1 or WA2 sign, as appropriate, should be installed on the right-hand side of the road.

These signs should be installed in advance of level crossings by not less than the distance shown in Table 3.1.

Table 3.1 below shows minimum distances at which signs should be installed

Distance A: in advance of level crossing where no intermediate sign installed

Distance B: in advance of any intermediate sign installed

Road operating speed (km/h)	Distance (m)	
	A	B
50	65	50
70	100	70
100	160	100

2. Level crossing alignment (WX41 right angles): the WX41 sign may be used in advance of a level crossing where the RCA considers it would improve awareness of the crossing. A Look For Trains (WX8) sign may be installed approximately 100mm below a level crossing alignment (WX41) sign. There should be an uninterrupted view of the sign over a distance of 120m on rural roads and 60m on urban roads according to table 3.1.

3.4. Road marking

Experiences of the developed countries that use railway transportation shows, as road marking at level crossings is generally outside the rail corridor, it will normally be the responsibility of the RCA. Specific exceptions to this apply where the level crossing is a private granted level crossing or a rail operations level crossing where the rail access provider is responsible.

The RCA must liaise with the rail access provider before installing any new road marking in the vicinity of a level crossing.

Road marking contractors must ensure any necessary permit to enter has been obtained for any work that influences on the rail corridor.

Rail access providers should also have clear procedures when RCAs or their delegates seek approvals in relation to work planned near the railway corridor, particularly on roads approaching level crossings. In addition, rail access providers should provide contractors with defined procedures when work is conducted within the rail corridor, particularly work at level crossings that could affect traffic on a road. This will include requirements to advise and, where necessary, gain agreement of the RCA to a traffic management plan. The main road markings and requirements are listed below.

1. **Centerlines:** a centerline marks on the approaches to level crossings where the road width is greater than 6m. Centerlines should be marked in the following manner:

• Color – reflectorized white

• Width – 100mm

• Stripe – continuous

• Length – at least 30m on urban roads and at least 50m on rural roads.

Centerlines must terminate at least 2.4m from the nearest rail edge (3m from the centerline of the nearest railway line) and 2m from FLB signals and HAB.

2. No-passing lines

a. General: Marked no-passing lines must be placed on all approaches to level crossings. No-passing lines on approaches to level crossings may need to be extended in situations where sight distance limitations on the road prior to a level crossing also require the application of an overtaking restriction. Overtaking restrictions on the approaches to level crossings must be marked in the following manner.

– No-passing lines:

- color – reflectorized yellow
- width – 100mm, offset 100mm from a centerline marking or another overtaking line
- stripe – continuous
- length – varies – see (b), (c) and (d) below.

– No-passing advance warning lines should be marked in advance of all overtaking restrictions:

- color – reflectorized yellow

- width – 100mm, offset 100mm from a centerline marking or another overtaking line
- stripe – 13m (three stripes) on urban roads, and 13m (five stripes) on rural roads
- gap – 7m
- the lines must commence (start, begin) 60m in advance of no-passing lines marked on urban roads and 100m in advance of no-passing lines marked on rural roads.

b. Approaches to level crossings *without* intermediate warning signs: A continuous no-passing line must be marked from the level crossing ahead steam train (WX1L or WX1R) warning signs to the limit line at the level crossing. No-passing advance warning lines must be marked in advance of the continuous no-passing line.

c. Approaches to level crossings *with* intermediate warning signs: A continuous no-passing line must be marked from the intermediate warning sign (i.e. level crossing alignment (WX40, WX41 or WX42) or advance warning type of control signs (WA1, WA2 or WX3)) to the limit line at the level crossing.

d. Approaches to level crossings on side roads: Where a level crossing is located on a side road less than the appropriate level crossing ahead steam train (WX1L or WX1R) warning sign distance from a main road intersection, a no-passing line should be marked from the main road intersection to the limit line at the level crossing.

3. Flush medians: Flush medians on the approaches to level crossings can assist in channeling traffic across the railway line. The edge of a flush median is legally a no passing line and therefore no passing lines are not necessary and should not be marked when there is flush medians.

Drivers are able to use the flush median where they are turning right and when they do this they may overtake queued vehicles in the normal lane. As undesirable overtaking over the level crossing may occur, a flush median where there is right turning in close proximity to the level crossing is not recommended unless some form of physical barrier can be installed to prevent the overtaking.

4. Limit lines: a. General: Limit lines must be marked on all sealed approaches to level crossings to indicate the safe positions for vehicles to stop, if necessary, to avoid conflict with trains.

Limit lines must be marked at right angles to the approach road centerlines, unless site constraints make this impractical, and every part of the line must be at least:

– 2.4m from the nearest rail edge (3m from the centerline of the nearest railway line), and

– 2m in advance of an FLB or a lowered HAB

Limit lines should normally be installed at the minimum permitted clearance from the railway line to ensure drivers are encouraged to stop where adequate restart views are available and to minimize the time for vehicles to clear the railway after stopping.

b. Limit lines for level crossings controlled by Stop signs: Limit lines at level crossings controlled by Stop signs (RP1) must be marked in the following manner:

– Color – reflectorized yellow

– Width – One 200mm wide line on urban roads and one 300mm wide line on rural roads

– Stripe – continuous.

c. Limit lines for all other forms of level crossing control: Limit lines for all other forms of level crossing control must be marked in the following manner:

– Color – reflectorized white

– Width – one 200mm wide line on urban roads and one 300mm wide line on rural roads

– Stripe – continuous.

5. Pavement messages: a. General: Any symbols, lettering used for roadway messages or other markings on sealed approaches to level crossings and at the level crossings must conform to the dimensions and form specified in the TCD rules.

Pavement messages must be marked in the following manner:

– Color – reflectorized white

– Letter height – 2.4m on urban roads and 3.6m on rural roads.

b. Give way marking: The TCD Rule requires either a Give Way triangle for new markings or the word 'give' followed by 'way' to be marked on the road surface of all sealed approaches to level crossings controlled by Give Way (RP2) signs. The triangle or the word 'way' must be marked approximately 10m from the limit line.

c. Stop marking: Where practicable, the word 'stop' must be marked on the road surfaces of all sealed approaches to level crossings controlled by R2-1 Stop signs.

The word 'stop' must be marked approximately 10m from the limit line.

d. Rail X marking: Where practicable, the TCD rule requires the word 'rail' followed by the symbol 'X' to be marked on the road surface of all:

– approaches to level crossings where the posted speed limit is 70km/h or higher

– multilane approaches to level crossings.

Approaches to level crossings *without* intermediate warning signs must have the symbol 'X' marked approximately 10m in advance of the level crossing ahead steam train (WX1L or WX1R) warning signs to the limit line at the level crossing.

The word 'rail' is to be marked approximately:

– 15m in advance of the symbol 'X' on urban roads

– 25m in advance of the symbol 'X' on rural roads.

Approaches to level crossings *with* intermediate warning signs must have the word 'rail' marked approximately 15m beyond the intermediate warning sign (i.e. level crossing alignment (WX40, WX41 or WX42) or advance warning – type of control signs (WA1, WA2 or WX3)) to the limit line at the level crossing.

The symbol 'X' is to be marked approximately:

– 15m beyond the word 'rail' on urban roads

– 25m beyond the word 'rail' on rural roads.

The 'rail X' marking may also be used on the approach to any level crossing the RCA considers necessary because of high approach speeds, restricted visibility, environment problems such as sun or fog.

6. No stopping lines: On urban roads, no-stopping lines should be marked on the approaches to level crossings in the following manner:

• Color – reflectorized yellow

• Width – 100mm

• Stripe – 1m

• Gap – 1m

• Length – 20m minimum.

The length of a no-stopping restriction may need to be extended on the approaches to some level crossings to ensure signs and control devices are visible from a safe stopping distance.

In rural areas, no-stopping lines may also be marked on the approaches to level crossings when the RCA considers vehicles could park and restrict the visibility of signs and control devices from a safe stopping distance.

7. **Cross hatching (clear zones):** Where the departure of long vehicles or queues of traffic from a level crossing may be blocked by a nearby intersection or other traffic control device, an escape lane or clear zone should be provided.

Cross-hatch markings may be used to define a clear zone area that drivers should not enter when their departure from a level crossing is blocked.

Cross-hatched clear zones should be marked in the following manner:

• Color – reflectorized yellow

• Cross-hatch line – 100mm wide

• border line – 100mm wide

• should not, on any lane, extend beyond 2.4m from the nearest rail edge (3m from the centerline of the nearest railway line).

8. Emergency escape zones: Emergency-escape zones utilize cross hatching that are used to indicate the emergency escaping place provided if there.

The above described road markings are the main road markings that are used mainly to provide safe operation of railway transportation. The ERC should use the appropriate road markings at each level crossing in order to provide safe and reliable railway transportation to our society.

Chapter 4

General requirements of standard traffic signs, road markings and signals

4.1. Introduction

The general requirements of signs, road markings and signals that are installed or marked at and in-advance of level crossings (i.e. height, color, location, alignment etc) varies from place to place, from level crossing to level crossing and the kind of traffic control method selected. These different criteria or requirements are described in this chapter.

4.2. Level crossing geometry and its environs [3]: The geometry and vicinity elements include:

• Number of operational railway lines, including shunting lines

• Number of traffic lanes each way – view along the railway line could be obstructed by traffic in adjacent lane

• Grade on each approach to the railway line(s) – critical when the railway forms a 'hump' in the road affecting the passage of heavy and long vehicles across the railway lines

• skew of the road to railway line – view along railway line affected by degree of skew

• Proximity to sidings, road intersections and other traffic generation.

View lines or visibility: Much of the data described above are essential inputs for calculation of the view lines required at the level crossings for both drivers and pedestrians that will determine in chapter 6. For drivers, there are two critical view lines considered:

• **the restart view line** – the minimum distance , along the railway line(s) from the driver's eye position in a vehicle at the stop line position of the closest railway line, required to allow the driver to start from a stopped position and clear the railway line before a train arrives.

• **The road approach visibility line** – the minimum distance along the railway line(s) from the level crossing that either:

– A driver is able to see a train and stop before reaching the level crossing or

– A driver continues at the approach speed and crosses the level crossing safely ahead of a previously unseen train or a train far enough away to be clearly not a collision threat.

The main items that we have to consider in determining the general requirements for standard traffic signs, road markings and signals (i.e. height, color, location, alignment etc) are:

1. **Visibility:** is sight distance from drivers, cyclists, pedestrians or road users in general to train from all directions of the level crossing at appropriate distance for safely stop or cross the level crossing before or after the train arrive the level crossing in consideration.
2. **Design Speed:** is the horizontal and vertical geometry (including the longitudinal profile of the road over the rails) suitable for the 85th % traffic speed; i.e. the road super elevation should not conflict with the rail profile or vice versa.
3. **Readability by Drivers:** this is any sections of roadway or railway which may cause confusion, i.e.
   - disused pavements or rail tracks should be removed
   - disused signs, pavement markings or signaling equipment should be removed properly
   - street light and tree lines should conform to the road and/or rail alignment
   - all railway tracks in use should be clearly noticeable
4. **Widths:** there must be adequate traffic lane and carriageway widths, appropriate shoulder or border widths (example; for broken down or emergency vehicles), adequate approach and departure stacking distances available for long vehicles, enough space to prevent queuing over the rails suddenly occur due to unexpected downstream events examples: right turn vehicle giving way to opposing traffic, pedestrian crosswalk, guard crossing etc.
5. **Drainage Structures:** drainage structures in the vicinity of the crossing safe for run off vehicles to crisscross. For more discussions on the structural requirements of a level crossing use [3].

4.3. **General specifications of traffic signs**

4.3.**1. Sign size:** For permanent traffic signs on urban roads, the smallest sign plate described in the TCD specifications is normally installed. For example warning signs would be a minimum of 600mm × 600mm. However, 750mm × 750mm or larger signs should be installed where the RCA supposes it is necessary due to traffic conditions and visibility. On rural roads, the sign size is increased and the largest sign specified would normally be installed where operating speeds are higher than normal e.g 85 percentile speed exceeds 100km/h. Thus, for warning signs on rural roads operating at normal speeds the warning sign plate size is 750mm × 750mm, while on roads where speeds are higher, 900mm × 900mm or larger signs should be installed.

Any supplementary sign component of a traffic sign assembly should match the size of the main component of the combination. All supplementary signs are mounted 100mm below the main diamond sign or 100mm below any other supplementary sign in the order specified.

4.3.2. Placement and number of signs: it is important to carefully assess the placement and orientation of signs at level crossings to ensure a driver approaching from any direction receives adequate warning or instruction. The alignment of the road relative to the railway line and the location of the level crossing in relation to nearby driveways or intersections can lead to unusual driver approach angles that need to be taken into account. However, these alignment and location issues can also lead to a large number of signs in close proximity with the possibility of some signs being obscured by others, or drivers being incapable of fully comprehending all of the messages trying to be conveyed.

4.3.3. Active protection

Active protection [3] for pedestrians, particularly at isolated pedestrian level crossings, may be justified. The types of protection include:

- Bells plus flashing lights or flashing indicators
- Second train coming illuminated signs
- Automatic pedestrian gates.

The level of protection is largely determined by the pedestrian and cycle demand and the frequency of train use.

Chapter 5

General calculation methods of sight distances at level crossings

5.1 Introduction

This section describes the formulae and parameters used to assess sight distance available at level crossings. In some countries like the U.S.A. and New Zealand, the prevailing sight distance guidelines are well justified and documented, whereas in other countries like Finnish the guidelines are less clear [8]. In this chapter different sight distance formulas for different road and rail users related to the type of the railway lane will establish.

5.2 Variables used to determine sight distance

The main factors that are used for determining the road users' sight distance requirement at level crossings in different counties are shown in the table below [8].

Variables	**Finland**	**U.S.A.**	**Canada**	**Sweden**	**New Zealand**
Speed of train	x	x	x	x	X
Type or length of road vehicle		x			X
Maximum speed of road vehicle		x			
Acceleration of road vehicle		x			X
Width of level crossing		x			X
Departure time			x		
Vertical alignment of road					X
Crossing angle etc.					X

Table5.1. Factors Used in the Determination of Sight Distance Requirement at Level Crossings of a Single Railway Line in Different Countries

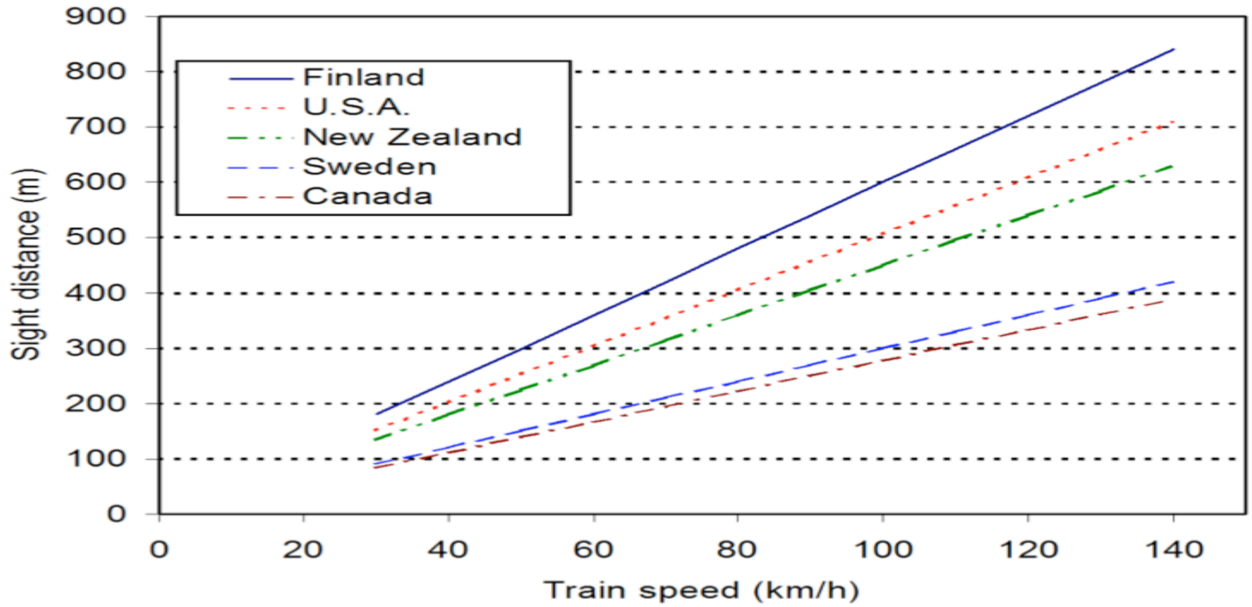


Fig5.1. Required sight distance from the road users' to the railway trains in different countries for level crossings of a single track and 25m length of vehicle combinations [8].

From the above Fig5.1, we can understand that the required sight distance for Finland and USA are longer while for Canada and Sweden are shorter than New Zealand.

Setting of sight distance requirements uses to avoid unnecessarily long sight distance requirements because, long sight distances are often difficult to achieve and excessive sight distance requirements may lead to unnecessary reductions of train speed. Similarly, short sight distance causes dangerous accidents. The figure5.1 above shows the sight distance requirements of different countries.

The design vehicles assumed for these calculations are:

• The maximum length vehicle generally able to use the roads without special conditions, i.e. 22m.

• the maximum design vehicle, which is set at 25m (vehicles greater than 20m may use roads subject to conditions described in Land Transport Rule: Vehicle Dimensions and Mass 2002, which also requires vehicles over 25m long to have written permission from the rail access provider to cross any level crossing) or

•The maximum length single-unit vehicle (truck or bus) able to use the roads without special conditions, namely 12.6m (except for a limited number of buses which are permitted to be 13.5m).

From this figure5.1 we can see that considering similar design vehicles and train speeds, different methods of sight distance determinations can cause different results due to the different determinant factors of the level crossing in question. So as much as possible considering every sight distance determinant factors at a level crossing leads to determine appropriate sight distance of the road users for safe, reliable and efficiently use of that level crossing.

The vehicle dimensions and performance characteristics used in these procedures is subject to change if new information becomes available. When assessing sight distances at level crossings views obstructed by permanent features; such as terrain and buildings should be clearly distinguished from views obstructed by growth such as hedges or fencing. It is always preferable to remove view obstructions than install stop controls at crossings. The Railways Act 2005 gives the rail access provider powers to remove or lower trees, hedges and walls that obstruct level crossing views.

5.3 Approach visibility

A road vehicle driver(s) approaching a level crossing with a Give Way (RP2) sign needs to be able to either:

• see an oncoming train in time to stop before reaching the level crossing or

• continue at the approach speed and cross the level crossing safely ahead of a previously unseen train or a train far enough away to be clearly not a collision threat.

The required sight triangle to achieve this approach visibility at passive and active controlled level crossings is calculated as stated on the next (these are modified equations of [3]).

The essential sight distance requirements at level crossings consist of four potential measurements; these are used for a single or many road users and described below.

5.3.1 Vehicle stops after seeing train and before reaching the level crossing: The value of S_1, the minimum distance of an approaching road vehicle(s) from the nearest rail at which the driver must be able to see an approaching train from either direction in time to stop if necessary before reaching the level crossing, i.e. to stop at the give way line, is given by:

$$S_1 = \frac{(R_T + B_T)V_v}{3.6} + \frac{V_v^{\;2}}{254(d+G)} + \frac{(L+R_w)}{\sin Z} + C_v \qquad \text{………....................1}$$

Where:

d = coefficient of longitudinal deceleration.

G = approach grade in meters per meter, positive upgrade, negative downgrade.

R_T = total awareness reaction time in seconds (general case assumption 2.5 seconds).

B_T = brake delay time in seconds.

R_w= length of road parallel to the railway; it is *zero* if there is no parallel road.

Other notations are described in 5.3.3 below.

5.3.2 Vehicle able to continue at speed and cross safely before train reaches level crossing

The value of S_2 is the minimum distance of a train from the level crossing at which the road vehicle driver(s) needs to be able to see the train approaching from either direction in order to cross safely ahead of it without reducing speed, if there are no approaching trains within distance S_2 to the level crossing. This principle is shown in the figure below.

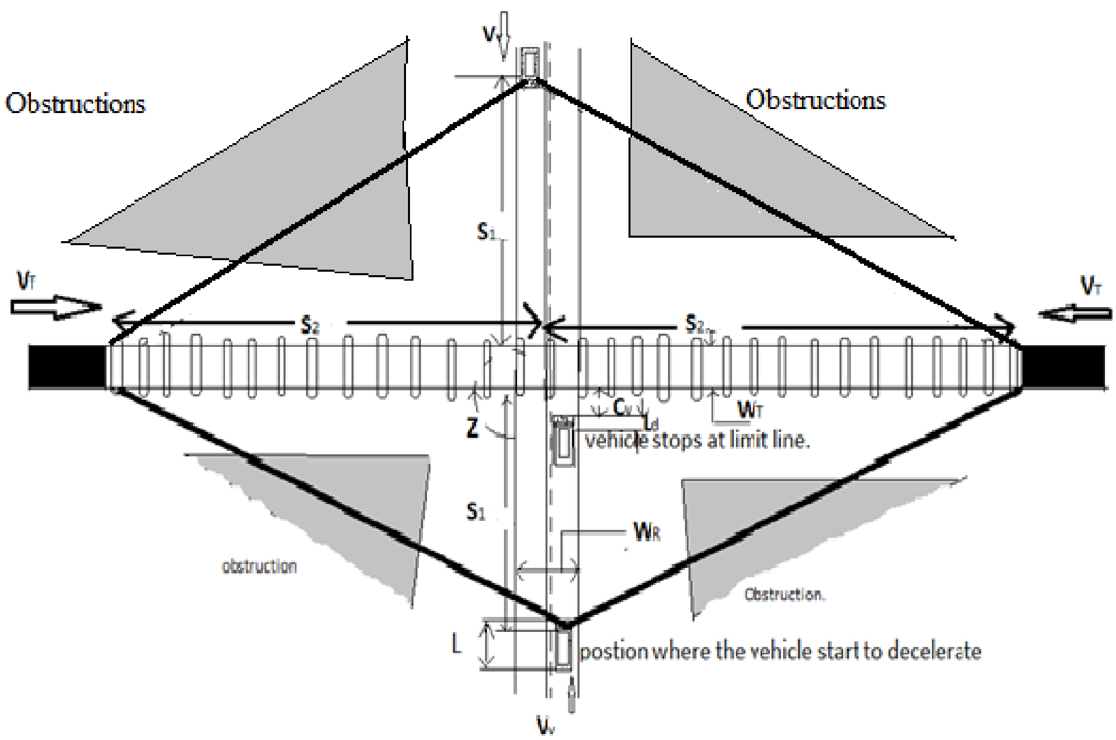


Figure5.2. *Approach visibility* at passive and active controlled level crossings using the 'Sebategna' area as reference

This approach visibility is shorter of the two distances measured along the railway and is given by the equation:

$$S_2 = \frac{V_T}{V_v}\left[\frac{(R_T + B_T)V_v}{3.6} + \frac{V_v^2}{254(d+G)} + \frac{W_T + L}{\sin Z} + 2C_v\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots..2.1$$

Equation 2.1 is if there is no parallel highway to the railway, but if there is parallel highway like the 'Sebategna' area of AA-LRT railway, we use the following formula:

$$S_2 = \frac{V_T}{V_v}\left[\frac{(R_T + B_T)V_v}{3.6} + \frac{V_v^2}{254(d+G)} + \frac{W_T + R_w + L}{\sin Z} + 2C_v\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..2.2$$

Where the notations are defined in equation (3)

A train, if present, needs to be visible to a road vehicle driver between any two points within the sight triangle.

5.3.3 Restart view: A road vehicle driver(s) when stopped at the stop line needs to be able to see far enough along the railway to be able to start off, cross and clear the level crossing safely before the arrival of any previously unseen train. The required sight triangles to achieve this are shown diagrammatically in Figure 5.2.below.

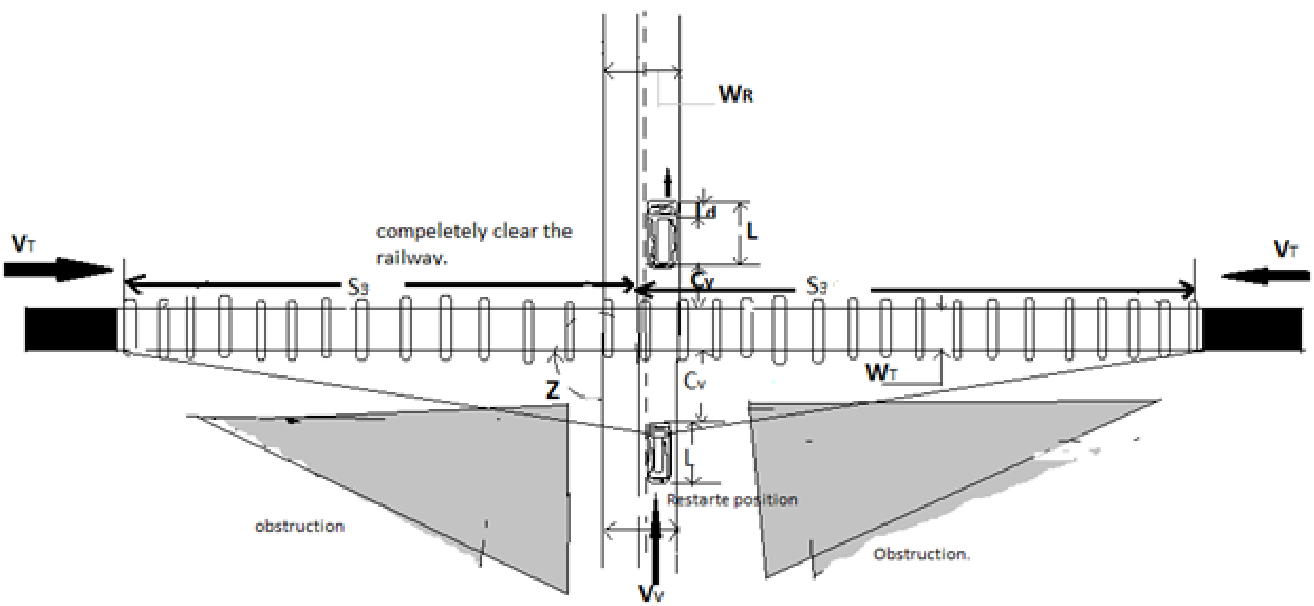


Figure5.3**.** *crossing visibility* at passive and active-controlled level crossings using the 'Sebategna' area as a reference

Distance S_3 is the *longer of the two distances* measured along the railway. It is the minimum distance from the center of the level crossing at which an *approaching train from either direction* must be seen in order for the design vehicle to start off from stopping and clear the level crossing safely.

The distance S_3 is determined by the equation:

$$S_3 = \frac{V_T}{3.6}\left[J + G_s\left[2.\frac{\frac{W_R}{\tan Z} + \frac{W_T + R_w + L}{\sin Z} + 2C_v}{a}\right]^{1/2}\right] \text{……………………….3}$$

Where:

R_w = width of a carriageway parallel to the railway

J = sum of the perception time and time to activate the clutch or automatic gear (general case assumption 2 seconds)

L = length of design vehicle

a = average acceleration of the design vehicle in starting gear

G_S = grade correction factor

S_3 =required sight distance from the center of the level crossing to the train (for vehicles stopped in front of a single track level crossing)

V_T = train speed

W_T = distance between outer rails

W_R = width of road (travelled way)

Z= angle between road and railway (degrees)

C_V = clearance from the vehicle stop line to the nearest rail (this can be considered as a zebra at highway)

L_d = distance from the driver to the front of the vehicle.

The time it takes for a road user to cross the track or tracks depends on (a) the traversing distance, which road users must travel to cross the railway line(s), (b) the characteristics of vehicle or pedestrian motion when traversing the crossing and ,(C) the slope of the road.

5.3.4. Pedestrian sight distances: At a level crossing where there is no active control for either roadway or pedestrian traffics, for a train approaching from either direction, the sight distance (S_D) in meters to oncoming trains to enable pedestrians to cross safely is as follows:

$$S_D = \frac{V_T}{3.6}\left[\frac{D}{V_P} + 2\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where: V_T = the highest-authorized speed of the train approaching the level crossing (km/h)

V_P = the walking speed of pedestrians normally adopted as 1m/s. Where there is significant use by mobility-impaired pedestrian(s), walking speed of 0.8m/s is recommended. The formula also provides a safety margin of two seconds providing, example; an allowance for pedestrian(s) reaction and acceleration time.

D = the pedestrian(s) level crossing distance in meters, measured as follows:

-Where pedestrian mazes are provided – from one pedestrian maze opening to the other

- where there are no pedestrian mazes but there are tangible ground surface indicators (TGSI) at holding positions – from one trackside edge of the TGSI to the other.

Chapter 6

Mathematical Models of Sight distances at 'Sebategna' area -Level Crossing of Addiss-Abeba –LRT.

6.1. Introduction:

In this chapter, the different road user sight distances described in chapter 5 above are determined. According to the type of the level crossing, geographical location, traffic volume and speed etc, appropriate traffic control methods are also selected here.

6.2. Description of factors:

The main factors or data that are collected from different sectors, standards and their values with respect to the specified level crossing are described below.

1) *Maximum vehicle length (L):* The stated level crossing is designed to cross by all type of road vehicles. The maximum design vehicle, which is set as 25m long, is used here in (rule of Vehicle Dimensions and Mass 2002, states that vehicles over 25m long should have written permission from the rail access provider to cross any level crossing).

2) *Average acceleration of the design vehicle in starting gear (a):* according to the Vehicle stopping, start-up and clearance parameters standard shown in table 6.1 below, the value of 'a' is $0.36 m/s^2$.

Table 6.1: Standard vehicle stopping, start-up and clearance parameters:

Vehicle type	Brake delay time in seconds ***BT*(s)**	Sum of perception time in seconds ***J*(s)**	Vehicle length in meters ***L*(m)**	Vehicle acceleration ***a* (m/s2)**
Maximum length vehicle	**1.0**	**2.0**	**22**	**0.36**
Maximum design vehicle	**1.0**	**2.0**	**25**	**0.36**

3) *Grade correction factor (G_s):* depending on the grade correction factor standard shown in table6.2 below; in this level crossing we have two values of $G_{s;}$

a. The value of G_s for the road from Ammanuel church and Merkato to the junction of the road in parallel to level crossing is ≈0.80 with grade of -0.025m/m down [9] and

b. The value of G_s for the roads in parallel to the level crossing from the junction of the roads from Ammanuel and Merkato to the level crossing is ≈1.20 with 0.025m/m up grade [9].

This grading is done for preventing from water drainage to the rail way.

Table6.2: Standard grade correction factors:

Grade (m/m)	Grade correction factor (G_S)
-0.12	0.52
-0.1	0.57
-0.08	0.63
-0.06	0.70
-0.04	0.79
-0.02	0.88
0.0	1.0
0.02	1.12
0.04	1.25
0.06	1.39
0.08	1.54
0.1	1.69
0.12	1.85

4) *Maximum train speed (V_T):* though the LRT trains have capacity of 80km/h speed, the highest-authorized design speed of the train approaching the level crossing is 70km/h. So the value of **V_T =70km/h.**
5) *Emergency brake deceleration of train (a_d)* **≥2m/s^2.**
6) *Sum of the perception time and time to activate the clutch or automatic gear (J):* general case assumption **2s**. See table 6.1 Vehicle stopping, start-up and clearance standard parameters above.
7) *Distance between outer rails (W_T):* the distance between the outer rails of the LRT railway is **1.50m,** but since it is double track railway with a distance of 2.5m from each rail; then, the distance from the outer rail of one track to the outer of the other is **W_T = 5.5m.**
8) *Width of road (travelled way) (W_R):* the width of the road crossing the level crossing is **22m**.
9) *Angle between road and railway (Z):* the angle between the road and railway at this level crossing is **90^0.**

10) *Clearance from the vehicle stop line to the nearest rail (C_V):* the standard clearance from the vehicle stop line to the nearest rail is 2.4m, but the actual measured value of C_v in this level crossing is **2.75m.**

11) L_z = length from the end of the parallel road to the vehicle limit line including the 'Zebra' crossing ≈5m.

12) *Width of highway parallel to the railway (R_w):* the width of the two parallel roads are similar; R_w =**10m** carriageway and 4.5m walkway each.

13) *Coefficient of longitudinal deceleration(d):* though the speed of road vehicles vary from zero to more than 100km/h, the maximum allowed speed of road vehicles with in town district is less than or equal to 60km/h, so according to the Coefficient of deceleration for road vehicles (trucks) shown in table 6.3 below the value of d = 0.29.

Table 6.3: Coefficient of deceleration for road vehicles (trucks)

Vehicle speed (km/h)	Coefficient of deceleration (*d*)
<95	0.29
95 - 105	0.28

14) *Approach grade (G):* the two approach grades in meters per meter, (positive upgrade, negative downgrade) according to the standard in table 6.2 above are: -0.025m/m and +0.025m/m up.

15) *Brake delay time in seconds (B_T):* according to Table 6.1 above Vehicle stopping, start-up and clearance standard parameters; B_T = 1s.

16) *The pedestrian level crossing distance in meters (D):* since the stated level crossing is double track railway width W_T = 5.5m with parallel roads of width R_w =10m each, the value of D, where there are no pedestrian mazes or tactile ground surface indicators (TGSI) at holding positions, is: $D = R_w + W_T + 2C_v \Rightarrow D = 10 + 5.5 + 2*2.75 = 21$....................6.1

17) *Total perception (awareness) reaction time in seconds (R_T):* General case assumption 2.5s.

18) *The walking speed of pedestrians (V_P):* it is normally adopted as 1m/s. Where there is significant use by mobility-impaired pedestrians, a walking speed of 0.8m/s is recommended. According to the information gathered by inspection, a lot of crazy and impaired pedestrians use the stated level crossing. So a walking speed of V_P = 0.8m/s is appropriate. The formula also provides a safety margin of 2 seconds e.g. an allowance for pedestrian reaction and acceleration time.

19) *The 85th percentile road vehicle speed at the position at which a driver will first recognize and react to the level crossing controls (km/h) (V_v).* Since the longest design road vehicle is considered here we can use V_v = 20km/h.

20) L_d = distance from the driver to the front of the vehicle: general case assumption 2m. The values of the variables are listed in the following table 6.4:

Table6.4 variables and their values

Variable	**Value**
Maximum length vehicle (L)	25m
a = average acceleration of the design vehicle in starting gear.	$0.36m/s^2$
G_S = grade correction factor.	0.8 and 1.20
C_V = clearance from the vehicle stop line to the nearest rail (if there is no parallel road to the rail)	2.75m
L_z = length from the end of the parallel road to the vehicle limit line including the 'Zebra' crossing.	5m
L_d = distance from the driver to the front of the vehicle	2m
d = coefficient of longitudinal deceleration.	d = 0.29
G = approach grade in meters per meter, positive upgrade, negative downgrade.	-0.025m/m and +0.025m/m
B_T = brake delay time in seconds.	1s
V_p =The walking speed of pedestrians	0.8m/s
V_v = road vehicle speed at the position at which a driver will first recognize and react to the level crossing controls (km/h)	20km/h
R_T = Total perception (awareness) reaction time in seconds.	2.5s
J = Sum of the perception time and time to activate the clutch or automatic gear.	2s
V_T = maximum train speed	70km/h

a_d = *emergency brake deceleration of train*	**≥2m/s²**
W_T = distance between outer rails	5.5m
R_w= width of parallel highways	10m each.
W_R = width of road (travelled way)	22m
Z= angle between road and railway (degrees)	90^0
D = the pedestrian level crossing distance in meters from each walkway.	D =21m

6.3. Mathematical equations and their results

Different mathematical equations of sight distance at level crossing are explained in chapter5 above. Now, using the values in the above table 6.4, their respective value with respect to the 'Sebategna' area level crossing is determined here below. The different results determined next are depending on the road condition agreement between the rail access and road authority near a level crossing; i.e. concrete asphalt. If there is any problem on the road near the level crossing only the speed of the road users varies and the sight distance also varies but doesn't cause any change on the equations.

Note: the values of the different variables below are guiding values where to locate the position of the block sections or traffic control methods.

6.3.1. Vehicle stops after seeing train and before reaching the level crossing: The value of S_1 is:

$$S_1 = \frac{(R_T + B_T)V_v}{3.6} + \frac{V_v^{\,2}}{254(d+G)} + \frac{(L+R_w)}{\sin 90} + C_v + L_z \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.2$$

$$S_1 = \frac{(2.5+1)20}{3.6} + \frac{20^2}{254(0.29+(-0.025))} + \frac{(25+10)}{1} + 2.75 + 5 = 68.14m$$

This is for both the road vehicles that travel from St. Ammanuel church and Markato to the level crossing.

These values of S_1 indicate that train approaching indicators should be available at a distance of 68.14m for the road vehicle that travels from St. Ammanuel church and Merkato to the level crossing.

6.3.2. **Vehicle able to continue at speed and cross safely before train reaches level crossing:**

The value of S_2 is:

$$S_2 = \frac{V_T}{V_v}\left[\frac{(R_T + B_T)V_v}{3.6} + \frac{V_v^{\,2}}{254(d+G)} + \frac{W_T + R_w + L}{\sin Z} + 2*C_v + L_z\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.3$$

$$S_2 = \frac{70}{20}*\left[\frac{(2.5+1)*20}{3.6} + \frac{20^2}{254*(0.29+(-0.025))} + \frac{5.5+10+25}{\sin 90} + 2*2.75+5\right] = 267.4m$$

This is for the road vehicles that travel from St. Ammanuel church and Merkato to the level crossing.

To check the appropriateness of the position of the control devices we have to calculate the time necessary for the road vehicles and train to cross the level crossing safely. i.e:

$$T_{v2} = \frac{S_v}{V_v} \Rightarrow T_{v2} = \frac{76.39m*3.6\sec}{20m} = 13.75\sec \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.4,$$

Where: $S_v = S_1 + W_T + C_v = 68.14 + 5.5 + 2.75 = 76.39m$

T_{v2} = necessary time for a vehicle moving with a constant speed of V_v = 20km/hr to cross the level crossing before unseen train at S_2

$$T_t = \frac{S_2}{V_T} \Rightarrow T_t = \frac{267.4m*3.6\sec}{70m} = 13.75\sec \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.5,$$

Where T_t = necessary time for the train to cross the level crossing from S_2.

From these two values of necessary times, we can conclude that, the equations are exactly appropriate.

Since this distance S_2 shows the position of the sensor on the railway that shows the presence of a train at that position, we have to choose the best precondition distance that the road vehicle can cross safely the level crossing. In this case the value of S_2 should be greater than or equal to 267.4m. This distance S_2 =267.4m from the center of the level crossing to the far rare of the nearest block section to the level crossing shows the position of an active control that indicates the entrance or absence of a train at that block section.

6.3.3. Restart view: A road vehicle driver when stopped at the stop line needs to be able to see far enough along the railway to be able to start off, cross and clear the level crossing safely before the arrival of any previously unseen train. The value of S_3 is:

$$S_3 = \frac{V_T}{3.6}\left[J + G_s \left[2.\frac{\frac{W_R}{\tan Z} + \frac{W_T + R_w + L}{\sin Z} + 2(C_v) + L_z}{a} \right]^{1/2} \right] \text{..................................6.6}$$

$$S_3 = \frac{70}{3.6}\left[2 + 1.20 \left[2.\frac{\frac{22}{\tan 90} + \frac{5.5 + 10 + 25}{\sin 90} + 2(2.75) + 5}{0.36} \right]^{1/2} \right]$$

Since the value of

$$\lim_{\theta \to 0}^{\tan\theta} = \infty; then: \frac{22}{\tan 90} = 0.$$

i.e. W_R has no effect if $Z=90^0$.

$$S_3 = \frac{70}{3.6}\left[2 + 1.20 \left[2.\frac{0 + \frac{5.5 + 10 + 25}{\sin 90} + 2*(2.75) + 5}{0.36} \right]^{1/2} \right] = 431.65m$$

This is train sight distance for the drivers from both St. Ammanuel and Merkato directions. This equation uses positive grade because the two roads parallel to the level crossing are inclined up to prevent from water drainage to the railway.

To check the appropriateness of the position of the control devices we have to calculate the time necessary for the road vehicles and train to cross the level crossing safely. i.e:

$$T_{v3} = \frac{S_{v3}}{V_v} \text{..6.7}$$

$$where, S_{v3} = R_w + 2*C_v + W_T + L + L_z \Rightarrow S_{v2} = 10 + 2*2.75 + 5.5 + 25 + 5 = 51m.$$

But, since V_v is not known and can't be constant here, we have to determine the time necessary for the road vehicle to cover the distance S_{v3} using constant acceleration method with $a=0.36m/s^2$; and this gives:

$$S_{v3} = 0.5*a*T_{v3}^{\ 2} \Rightarrow T_{v3} = \sqrt{\frac{2*S_{v3}}{a}} \text{...6.8}$$

$$T_{v3} = \sqrt{\frac{2*51m}{0.36m/s^2}} = 16.83\sec$$

And the time required for a train to cross the level crossing from $S_{3.2}$=431.65m is:

$$T_{t3} = \frac{S_{3.2}}{V_T} \Rightarrow T_{t3} = \frac{431.65m * 3.6\sec}{70m} = 22.2\sec$$

From these two values of necessary times, we can conclude that, the equations are exactly appropriate. The road vehicle can clear the level crossing 5seconds before the train arrive the level crossing.

6.3.4. Pedestrian sight distances: At a level crossing where there is no active control for either roadway or pedestrian traffic, for a train approaching from either direction, the sight distance (S_D) necessary in meters to oncoming trains to enable pedestrians to cross safely is as follows:

$$S_D = \frac{V_T}{3.6}\left[\frac{D}{V_P} + 2\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.9$$

$S_D = \frac{70}{3.6}\left[\frac{21}{0.8} + 2\right] = 549.3m.$ This is for the pedestrians that cross the level crossing from Merkato to Ammanuel and vice versa.

So the control device which use for guiding the pedestrians that use the level crossing shall be install at ≥ 549.3m from the center of the level crossing in both directions.

To check the appropriateness of the position of the control devices we have to calculate the time necessary for the pedestrians and train to cross the level crossing safely. i.e: the train needs

$T_{tD} = \frac{S_D}{V_T} \Rightarrow T_{tD} = \frac{549.3m * 3.6\sec}{70m} = 28.2\sec$ to cover the distance. And the pedestrians need

$$T_p = \frac{D}{V_p} \Rightarrow T_p = \frac{21m}{0.8m/s} = 26.3\sec.$$

The two values of time show the appropriateness of the equation, i.e. the pedestrians can travers the level crossing 2sec before unseen train at S_D arrives the level crossing.

From these different results found above we can generalize that the length of block section or position of control sensors near a level crossing varies from place to place or level crossing to level crossing depending on the obstructions, geographical nature of the roadway near the level crossing and the width of the roads in parallel to the railway.

Since the A.A- LRT uses block section method of train control system, the block section where the stated level crossing lied should start beyond the determined sight distances in both directions from the center of the level crossing in order to get enough time for individuals to cross the level crossing safely. The different sight distance calculation formulas established are based on the shortest time a train can reach the level crossing after it can first be seen by a road user at the specified distances. Taking the emergency brake deceleration of the trains AA-LRT use, i.e. $\geq 2m/s^2$, the trains decelerate for more than 94m distance to stop during emergency breaking (longer during normal breaking) i.e,

$$S = \frac{V_o^{\ 2}}{2 * a_d} = \frac{(19.44m/s)^2}{2 * 2m/s^2} = 94.5m..7.1$$

Where a_d= emergency brake deceleration of train $\geq 2m/s^2$

V= maximum train initial velocity =70km/hr = 19.44m/s

S= distance required to stop during emergency brake.

This shows it is difficult to control the running speed of the train manually by the train driver. Since the time a train takes to arrive at a level crossing linearly decreases with increasing its speed, the determined distances are based on the maximum speed of train to assure the safe and reliable time for the road users travers the level crossing. That is why the time a train takes to arrive the level crossing is greater or equal to the time a road user need to cross the level crossing in all determined sight distance calculations.

Depending on the actual nature of the 'Sebategna' area level crossing and experience of developed countries that use railway transportation, active control along with passive control is appropriate. According to the outcomes of the different mathematical models, the graphical representation of the 'Sebategna' area level crossing along with the selected appropriate traffic control methods and descriptions is shown in chapter 7 below.

Chapter 7

Graphical Design of the 'Sebategna' Area -Level Crossing of AA- LRT

7.1. Introduction: The AA-LRT has two types of level crossings [2], square type (two level crossings with in a square which are under independent control) like the Tilahun Gessesse square and non-square level crossing like this 'Sebategna' area level crossing. The position of the active control systems or the different sight distances, and signs and road markings are determined in the chapters above. In this chapter the graphical representation of the 'Sebategna' area level crossing, with the carefully selected traffic control systems and their appropriate locations, is graphically shown and described.

7.2. Design of 'Sebategna' area level crossing and its descriptions

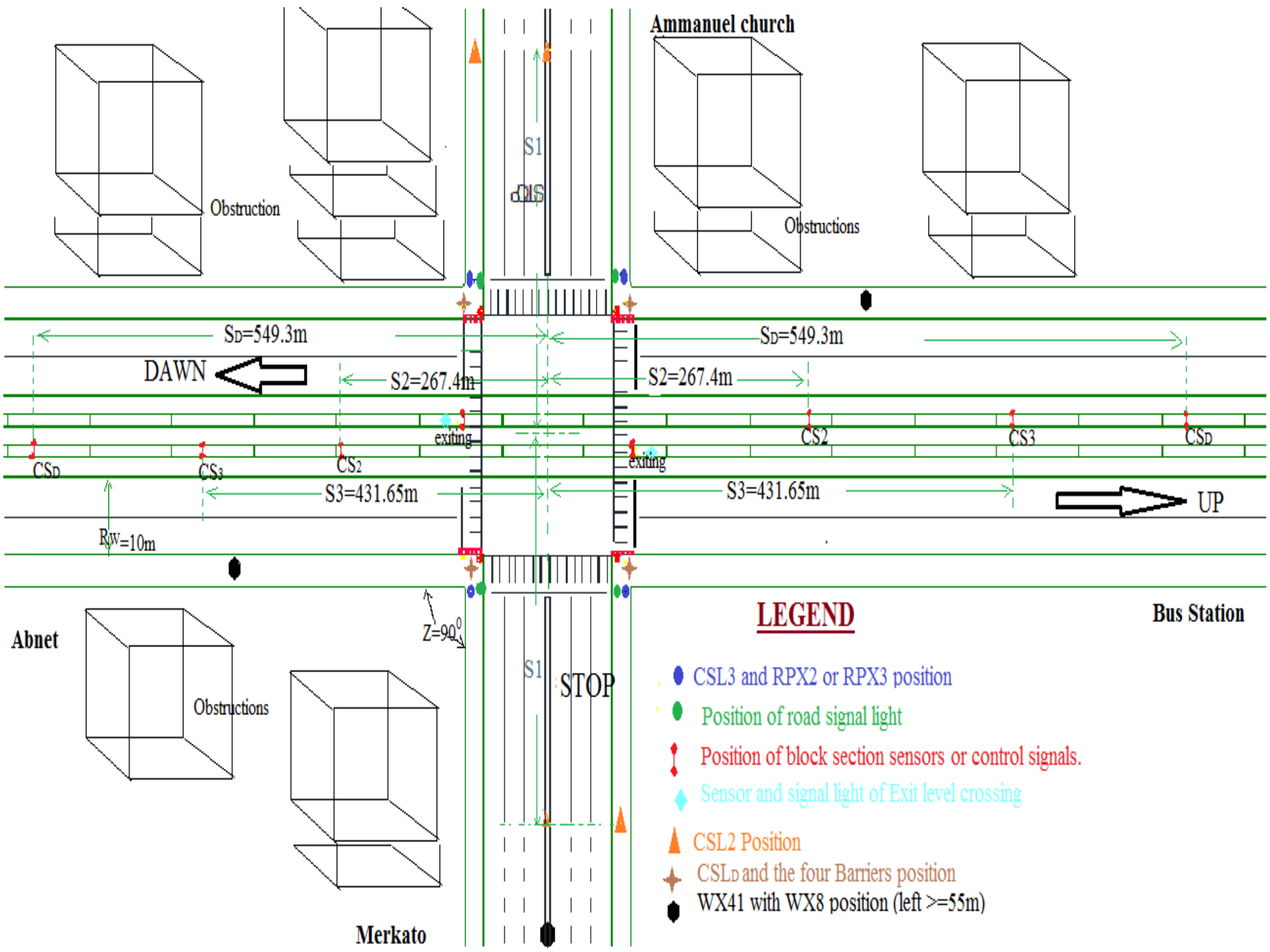


Fig: 7.1 'Sebategna' area level crossing

According to the different sight distances determined in the four equations in chapter 6, the position of the appropriate traffic control sensors, signal display screens, signs, road markings and lay outs of the 'Sebategna' area level crossing are displayed in the graph above.

Description of the graph of 'Sebategna' area level crossing above

The different control methods shown in the above figure are described below.

- Control signal light (CSL_3): this is the signal display screen that shows the presence or absence of a train at a distance S_3 from the center of the level crossing in both direction of the rail way. This is signal light that notifies vehicle drivers to restart off from stop at the limit line and could cross the level crossing safely before unseen train at S_3 in both railways arrive at the level crossing.
- Control signal light (CSL_2): this is the signal display screen that shows the presence or absence of a train at a distance S_2 from the center of the level crossing in both direction of the rail way. This signal light notifies, unless other determining factors occur, vehicle drivers can continue with speed ≥20km/hr to cross the level crossing safely before unseen train in both railways arrive at the level crossing.
- Control signal light (CSL_D): this is the signal display screen that shows the presence or absence of a train at a distance S_D from the center of the level crossing in both direction of the rail way. This is signal light that notifies pedestrians to cross the level crossing safely before unseen train in both railways arrive at the level crossing.
- Barriers ($B_{1.1}$, $B_{1.2}$, $B_{1.3}$, $B_{1.4}$): These are barriers used to guide pedestrians that cross the level crossing from the four corner pedestrian walking ways. These barriers are necessary; because, most of the pedestrians may not know the meaning of the pedestrian control signal light (S_D), can't understand the serious accidents of railway transportation, there may be creasy and intoxicate ones that can't violent the rule……etc.
- The road signal lights: are used to guide the road users (vehicles and pedestrians) when there is no trains approach to the stated block sections or level crossing.
- Control signals (CS_2, CS_3, CS_D): These are sensors that shows the presence of a train at distances S_2, S_3, and S_D respectively from the center of the level crossing in both directions and send message to the control signal light display screen.

- There must be a sensor at the ends of the block sections of the level crossing that notify the clearance of the train from the level crossing and enter to the next block section at both rails (up and down).
- RPX2 or RPX3: these are standard signs used at level crossing, installed at similar locations with CSL_3 to guide the road vehicles.
- WX41 with WX8: these are standard signs used in advance of level crossing, installed at ≥55m from the limit line to the left of the road.
- The values of the different parameters and dimensions are shown in the figure.

7.3. Description of control process of the traffic control signal lights

Table7.1. below shows description of control process of signal light for the rail and road users at 'Sebategna' area level crossing.

Train position	**Action of train approaching display screen**		**Action of road vehicle crossing the level crossing display screen**	**Action of road vehicle moving parallel to the level crossing display screen**	**Action of pedestrian crossing display screen and barrier**
	vehicle	pedestrian			
When a train doesn't arrive (reach) the level crossing (normal condition)	Green	Green	One of the three different colors	One of the three different colors	.One of the two colors. .barrier: vertical
When a train enter to the far rare of S_{D2}	*Green*	Red	One of the three different colors	One of the three different colors	.screen: Red .barrier: horizontal
When a train enter to the far rare of $S_{3.2}$	Yellow		yellow	Red and yellow	.screen: Red .barrier: horizontal
When a train enter to	Red	Red	Red	Green	.screen: Red

the far rare of S_2					.barrier: horizontal
When another train approaches from other direction: 1.before the 1st train is between S_{D2} and $S_{3;}$	Green	Red	One of the three different colors	One of the three different colors	Red
2.before the 1st train is between S_3 and S_2	Yellow	Red	Yellow	Red and Yellow	.color: red .barrier: horizontal
3.before the 1st train enter but doesn't leave S_2	Red	Red	Red	Green	.Color: Red .barrier: horizontal
Train clear in both direction	Green	Green	Green, and reset to the normal	Red, and reset to the normal	.color: Green .barrier: vertical

Note: during the approach of another train from other direction before the 1st train leaves the level crossing, the state of the signal lights should remain with the 1st state in order to prevent the road users' form confusing among the signal lights. It is better if there is train approaching direction indicator along with the signal light on the display screen.

7.4 Results and conclusions

According to the different evidences, standards, and the ‘Sebategna’ area level crossing actual nature and sight distances determined in the different equations and graphical design above, this thesis shows the following independent results which have to be used in the ‘Sebategna’ area level crossing.

In case of control system, since it is not possible to see the train at the determined sight distances by the driver visual view due to the obstructions, geographical nature of the road way near the level crossing, it is impossible to guide the traffic at the ‘Sebategna’ area using passive control or visual eye. The only option is to use carefully selected active control method that could indicate the position of the train along with different signs, road markings and layouts. In such kind of control, though road user can’t see the train by visual sight, these active control devices can give clear information for individuals use the level crossing about the position of the train and the state of the level crossing in order to decide whether to cross or stop before the train arrives at the level crossing. The active control method should be a fail-safe type to prevent accidents during power interruptions.

In case of control barriers as we see from the graphical representation of the ‘Sebategna’ area level crossing we can understand that, since there are carriageways parallel to the railway in both sides, vehicle barrier at the level crossing is not necessary; instead there must be a stop limit line mark for road vehicles along with ‘Zebra’ crossing for pedestrians before the highways parallel to the level crossing and a repeater signal light display screen of the control sensors installed at the determined safe sight distances to warn the road users about the state of the level crossing. But, since it is a sensitive and busy level crossing it is better if there is pedestrian maze; otherwise, there must be pedestrian crossing ‘Zebra’ protected with automated barriers at both gates of the ‘Zebra’ to the level crossing along with pedestrian crossing signal light display screen, Look For Train (WX8) sign and medium voice pedestrian warning alarm. Here the position of the barrier should be programed with the pedestrian crossing signal, i.e. it should do similar task when pedestrians don’t allow entering the zebra crossing, though no trains with in the specified level crossing.

Due to the long emergency braking deceleration distance of the trains AA-LRT use, it is difficult to control the running speed of the train manually by the train driver. Train operator controlled driving method (manual driving mode by viewing which can be used for train speed ≤25km/hr) at level crossings could cause serious accidents and damages among the road users, trains and railway properties in addition to reducing the efficiency of railway transportation due to frequent accelerate and decelerate of the trains especially due to the NS23 train station 80m to the south of the stated level crossing, so applying the rule "*right of way for trains*" and use of *fail-safe type active along with passive traffic control system* is unquestionable in this level crossing.

From the different mathematical models and results found in the previous chapters, we can understand that the distance of block section or position of control devices should vary depending on the safe sight distance of road users at a level crossing. The duration of the different signal light colors on the level crossing display screen for road users depends on the presence and absence of a train in the determined block sections. To insure this, there must be a sensor at the end of the level crossing that indicates the clearance of the train from the level crossing. The signal lights display screen to guide for the trains them salves to indicate the state of the block sections ahead, should install in between the two rail ways besides to the exit sensors.

Recommendation

According to the various data's of the stated countries, accidents at level crossings are on a decline in the long-term though improving traffic control system. However, almost half of railway operation accidents occur at level crossings especially at passive controlled level crossings and there still remain level crossings requiring improvements. The different data collected in this thesis from the different countries about the number and causes of accidents at their railway transportation is not to remind or blame them, but to learn from them and to take the best experiences of the railway transportation system; so as to modify, improve, and benefit from them. In light of such conditions, the ERC should use modern types of traffic management system especially at level crossings to prevent our society from the fatal accidents that could cause at level crossings. History makes someone to know what was there; not to repeat the worst, but to take what was the best.

Taking the future plane of number of trains can cross the level crossing (an average of one train every 1.27minute) [1], and the comfort of the residents around the level crossing, using train approaching notice alarm at the level crossing can cause sound pollution to residents especially at night time and it may not hear by individual vehicle drivers. So train approaching indicator alarm is not necessary (not appropriate); instead, using active control methods as shown in the figure7.1 at the determined distances can give well managed traffic flow at the level crossing.

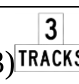
As we know, level crossing is a place where two modes of transportation i.e. railway and highway commonly use. Since most of the signal display screen poles, signs and road markings are installed and marked at the road corridor, and as long as the one and only one aim or goal of the ERC and RCA is to give fast, reliable, efficient and safe transportation to the society so as to enhance the economic development of our country, cooperative work of RCA and ERC is unquestionable for better safe operation and safety assurance at level crossings i.e. unit work is better than individual work.

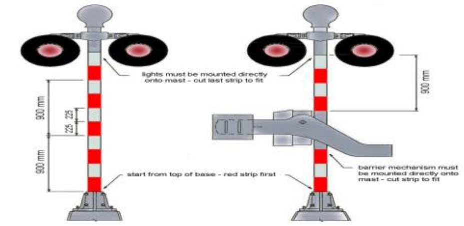
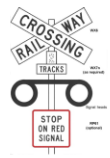
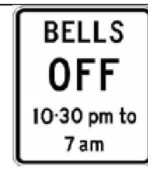
LIMITATIONS

Since the level crossing is in construction, it is difficult to take survey on the number of the different types of road users crossing the ‘Sebategna’ area level crossing. These are the pedestrians and vehicles that crosses from the two way perpendicular roads from Merkato to Amanuel and vice versa, 90^0 turn from Abnet to Ammanuel and from bus station to Merkato, which are main factors to determine the duration of the signal lights used to manage the traffics so as to determine the efficient use of the road or to prepare well programed traffic lights and give priority to more concentrated lane. This is another problem to be filled by other researchers.

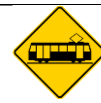
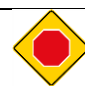
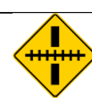
Appendices A;

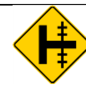
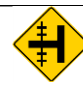
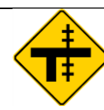
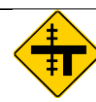
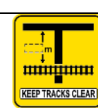
The table A1 List of signs used at level crossings.

Sign code	sign type	Symbol
RP1	Stop	
RP2	Give Way	
WX6	Cross buck standard	
WX61	Cross buck with target board	
WX62	Cross buck with target board – private level crossing	
WX63	Cross buck plus [number of] Tracks with target board – private level crossing	
WX7[n]	Supplementary [number of] Tracks	 WX7(2)  WX7(3)  WX7(4)
AX11	Bells Off	
RP61	Stop On Red Signal	
WX8	Look For Trains	

	Pole used for sign, signal or barrier arm assemblies	
RPB	Barrier arms	There are different barrier arms.
RPX1	Level crossing – Flashing Light assembly	 or 
RPX2	Level crossing – Stop assembly	
RPX3	Level crossing – Give way assembly	
RPX4	Private level crossing – Stop assembly	 
RPX5	Private level crossing – Give way assembly	 
AX12	Railway not In use	
T235	Trains running	

The table A2 List of signs used in advance of level crossings

Sign code	sign type	Symbol
WX1L	Level crossing ahead steam train facing right	
WX1R	Level crossing ahead steam train facing left	
WX2L	Tramway ahead tram facing right	
WX2R	Tramway ahead tram facing left	
WX11	Level crossing ahead exempt supplementary	
WX3	Level crossing ahead flashing signals	
RJ2E	Low-overhead clearance at electrified railway assembly	
WA1	Stop ahead	
WA2	Give way ahead	
WX40	Level crossing at an acute angle to the left	
WX41	Level crossing at right angles	
WX42	Level crossing at an acute angle to the right	
WX5	Cyclist take care railway lines	

WXR1	Level crossing on controlled crossroad to the right	
WXL1	Level crossing on controlled crossroad to the left	
WXR2	Level crossing on controlled side road to the right	
WXL2	Level crossing on controlled side road to the left	
WXR3	Level crossing on uncontrolled side road to the right	
WXL3	Level crossing on uncontrolled side road to the left	
WXL4	Level crossing at controlled T-junction to the left	
WXR4	Level crossing at controlled T-junction to the right	
WXR5	Level crossing at uncontrolled T-junction to the right	
WXL5	Level crossing at uncontrolled T-junction to the left	
WXB1	Controlled intersection beyond level crossing	
WXB2	T-junction beyond level crossing	
WXB3	Short-stacking distance	
RJ51	Route unsuitable for long vehicles	
Distance ahead supplementary		

WG3 (50)	Supplementary 50m ahead	
WG3(100)	Supplementary 100m ahead	
WG3(150)	Supplementary 150m ahead	
WG3(200)	Supplementary 200m ahead	
WX31	Active advance warning signal – prepare to stop	
WX32	Active advance warning signal – hidden queue	
WX33	Active advance warning signal – queued vehicles	
WB1A	Active level crossing warning sign	

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