

Sudan University of Science & Technology
College of Graduate Studies

Train Traffic Control Simulator
محاكٍ للتحكم في حركة القطار

**A dissertation submitted as a partial fulfillment of the
requirements for the award of the degree of Master Science in
Electronics Engineering (Communication)**

Prepared by:

Amna Mohammed AlzainEbrahim

Supervisor:

Dr. Fakher Eldin Mohamed Suliman

September 2009

آية

ز

[إِنَّ الَّذِينَ آمَنُوا وَعَمِلُوا الصَّالِحَاتِ كَانَتْ لَهُمْ جَنَّاتُ الْفِرْدَوْسِ نُزُلًا*
خَالِدِينَ فِيهَا لَا يَبْغُونَ عَنْهَا حِوَلًا* قُلْ لَوْ كَانَ الْبَحْرُ مِدَادًا لِكَلِمَاتِ
رَبِّي لَنَفِدَ الْبَحْرُ قَبْلَ أَنْ تَنْفَدَ كَلِمَاتُ رَبِّي وَلَوْ حِصًّا بِمِثْلِهِ مَدَدًا].

صدق الله العظيم
سورة الكهف - الآيات (107 - 109)

Dedication

To my latest dad

To my family

To my friend.....

Acknowledgment

When we smile ,we show great pleasure.

When we smile , other smile.

Other smile , and we smile for their pleasure which go deep inside us as an overwhelming joy to those who showed us the illumination of knowledge.

Family is as a dove carrying the rich ocean of recognition that helped us reap their fruit.

We appreciate them all for their good deed in thinking , sending them a herald of acknowledgement, For, who don't thank man , don't thank Allah.

Finally, I thank Dr. Fhaker Eldin Mohamed Suliman,

As well thanks go to Sudan Railways Corporation engineers (Khartoum South Department).

Abstract

The Railway is considered as one of important ways of transportation, the manual switch named semaphore that is used to control train track is a traditional way, it delays the train and needs more efforts from the signal man. Controlling Railways electromechanically reduces the time and effort. In this research, a train traffic control program was designed to simulate the open and close of the semaphore automatically. The program controls two trains moving between Khartoum, Khartoum Bahri and Kadaru stations. The program was designed using Visual Basic. It contains an interface window which is easy to use and provides related information. The simulator program was tested successfully and it can be improved to control more tracks and stations.

ملخص البحث

تعتبر السكة حديد وسيلة نقل مهمة، المفتاح اليدوي المستخدم لتغيير مسار حركة القطار في محطات السكة حديد المعروف باسم semaphore أصبح وسيلة تقليدية ويؤدي إلى تأخير الزمن ويتطلب جهداً من رجل الإشارة . التحكم في مسارات القطارات الكتروميكانيكيا يوفر الزمن والجهد . في هذا البحث تم تصميم برنامج محاكاة لفتح وقفل الـ semaphore آلياً. تم التحكم في قطارين يسيران بين ثلاثة محطات هي: الخرطوم ،الخرطوم بحري والكدرو . تم تصميم البرنامج باستخدام لغة الـ VISUAL BASIC . تضمن التصميم نافذة تداخل للمستخدم سهلة التعامل وتوفر معلومات ذات صلة. تم اختبار برنامج المحاكاة بنجاح ويمكن تعديله ليطبق علي عدد أكبر من المسارات والمحطات.

Table of Content

Subject	Page
الإلية	
Dedication	
Acknowledge	
Abstract	I
Abstract (In Arabic)	II
Table of content	III
List of tables	VI
List of Figures	VII
List of Abbreviations	VIII
Chapter One: Introduction	1- 3
1.1 Previews	1
1.2 Problem Statement	1
1.3 Research Objectives	2
1.4 Research Methodology	2
1.5 Expected Results	2
1.6 Research outline	3
1.7 Introduction Visual Basic 6	3
 Chapter Two: Background	 4 - 25
2.1 Evolution of Train Control Systems	4
2.1.1 Functional Classification	4
2.1.2 The place and Continuity of Transmission of Signaling Information	5
2.1.3 The Method of Transmission	5
2.1.4 The Type of the Transmitted Information	6
2.1.5 The Type of Intervention	7
2.1.6 Determining the Position of the Train	7
2.2 Traffic Control Systems Standards	7
2.3 Testing and Inspection Of Railway Signal and Traffic	9

Control Systems	
2.4 Advanced Train Control System	9
2.5 Railway Applications	9
2.5.1 Fiber Optic Sensors on the Railway	9
2.5.2 Examples of Possible Applications5	10
2.6 Radio based railway signaling and traffic control system	11
2.7 Railway Signaling	11
2.7.1 Block Signaling	12
2.7.2 Automatic Block Signal	12
2.7.3 Fixed Block	14
2.7.4 Moving Block	15
2.7.5 Fixed Signals	15
2.7.6 Mechanical Signals	15
2.9 Railroad Switch	16
2.9.1 Roller Coaster Switches	17
2.9.2 Classification switch	17
2.9.3 Components of switch	18
2.10 Relays	18
2.11 Development of Signaling	20
2.12 Automatic Train Protection	23
2.13 Safety Analysis for Train Control System	24
Chapter Three: Train Traffic Control Simulator	26 - 33
3.1 Introduction	26
3.2 The TTC State	26
3.3 Step of the TTC State	28
3.4 Train Traffic Control Methods	29
3.5 Explaining the program	31

Chapter Four: Results and Discussion	34 - 41
Chapter Five: Conclusion & Recommendations	42
5. 1 Conclusion	42
5. 2 Recommendations	42
References	43
Appendix (A)	A-1
Appendix (B)	B-1
Appendix (C)	C-1
Appendix (D)	D-1

List of Table

Table	Title	Page
3.1	State 1 and state 2 for the design	36
3.2	State 3 and state 4 for the design	37
3.3	State 5 and state 6 for the design	37

List of Figures

Figure	Title	Page
2.1	British lower-quadrant semaphore stop signal	15
2.2	Two track B and C	20
2.3	double switch or double slip	24
2.4	Schematic drawing of (a) unoccupied track circuit and (b) occupied track circuit	26-27
2.5	an axle counters detection point, in the UK	28
2.6	The GSM-Railway network	31
2.7	Factors Affecting Information Systems Development in an Organization	35
3.1	Three Station Diagram	36
3.2	Traffic Between kh to k	38
3.3	Traffic Between k to kh	38
3.4	Traffic Between kh to kh-B and k to kh-B	39
3.5	The Flow Chart	41
4.1	GUI main screen	42
4.2	Train traffic control simulator	43
4.3	Train traffic control simulator	44
4.4	Train traffic control simulator	45
4.5	Train traffic control simulator	45
4.6	Train traffic control simulator	46
4.7	Train traffic control simulator	47
4.8	About screen	47
4.9	Help screen	48
4.10	Help screen	48
4.11	Help screen	49

List Of Abbreviation

ATS	Automatic Train Stop
ATCS	Advanced Train Control System
AREMA	American Railway Engineering and Maintenance of Way Association
ATP	Automatic Train Protection
ATC	Automatic Train Control
CCS	Common Control Signal
CRC	Cycle Redundancy Check
DMI	Driver Machine Interface
ETCS	European Train Control System
EVC	European Vital Computer
FRA	Federal Railroad Administration
FOCs	Freight Operating Companies
GUI	Graphical User Interface
GPS	Global position system
IT	Information Technology
LDTL	low density traffic lines
PTC	position train control
PLC	Programmable Logic Controller
PSP	Product Safety Plan

RTUs	Remote Telemetry Units
RBC	Radio Block Center
SCADA	Supervisory Control and Data Acquisition
TOCs	Train Operating Companies
TTC	Train Traffic Control
UK	United Kingdom

Chapter One

Introduction

1.1 Previews:

A principal challenge in introducing new railroad traffic control technology, like position train control (PTC), is to convincingly demonstrate that safety will not be compromised. The Federal Railroad Administration (FRA) has established guidelines for submitting a performance-based Product Safety Plan (PSP), which is to include a risk analysis of potential accident scenarios. A key driver of risk is the frequency with which events occur that may be precursors to hazardous situations leading to accidents. Such events may be the intersection of a train with a device or certain situations of train-to-train proximity. Reliable estimates of the probabilities of these events, or exposure metrics, can be derived through the simulation of a rail line operation, which realistically replicates train movements and the system of traffic control. The General Train Movement Simulator for Safety Evaluation was designed with the short-term goal of supporting the risk analysis of new rail technology. The simulator can be extended to enable the analysis of additional sources of risk, and it may have additional applications as well, such as the analysis of rail line capacity. [1]

1.2 Problem Statement:

- To design a train traffic control simulator with friendly GUI.
- Move the train between three stations and to control using program of computer.

1.3 Research Objectives:

- Design the control algorithm for the traffic of a train that moves between three stations.
- To design a TTC (Train Traffic Control) simulator.
- To design a friendly GUI which make it easy to run the simulation and provides necessary information about TTC.

1.4 Research Methodology:

- Study and understand TTC.
- Understand parameters affecting the system.
- Define the parameters for the proposed system.
- Design the flow chart of the system (Design the control Algorithm)
- Define the control parameters.
- Design the GUI of the simulator.

1.5 Expected Results:

- At the end of the research it will be design the simulation system to control two trains moving between three stations at all ways available.

- The display reaction (TTC) will be very easier and content the basic information and help the steps.

1.6 Research outline:

The dissertation research contains four chapters plus this introductory chapter. Chapter two studies the train traffic control, simulation of train traffic control and types of it. Chapter three describes the simulation and program design. Chapter four provides results and discussion. Chapter five concludes the work provide recommendations.

1.7 Introduction VISUAL BASIC 6:

Programming means designing or creating a set of instructions to ask the computer to carry out certain jobs which normally are very much faster than human beings can do.

Visual Basic is the most popular. Not only it is easily to learn because of its English-like syntaxes, it can also be incorporated into all the Microsoft office applications such as Microsoft words, Microsoft Excel, Microsoft PowerPoint and more. Visual Basic for applications is known as VBA. With VB 6, you can create any program depending on your objective. For example, you can create educational programs to teach science, mathematics, language, history, geography and so on. You can also create financial and accounting programs to make you a more efficient accountant or financial controller. For those of you who like games, you can create those programs as well. Indeed, there is no limit to what program you can create! There are many such programs in this tutorial, so you must spend more time on the tutorial in order to learn how to create those programs. [2]

Chapter Two

Background

2.1 Evolution of Train Control Systems:

There are three common ancestors: (France, USA, and Germany) for train control systems have been developed historically in many different ways throughout the railway companies.

Despite the common ancestors, almost all existing systems are fully incompatible with each other.

Time has come to standardization on a European level, which is the ultimate target of the new European Train Control System, the ETCS.

The pre-ETCS European train control systems will be classified using multiple criteria: functionality, the place and continuity of transmission of signaling information, the method of transmission, the type of the transmitted information, the type of the intervention and method used for determining the position of the train.

2.1.1 Functional classification:

There are auxiliary systems, which just give additional safety, but trains are still driven according to the track side signals. Since the operation of these systems is based only on the aspect of the next signal.

The minimum safety requirement for such systems is quite simple is subsidiary. In most cases, these systems are installed on high-speed tracks, with very high safety requirements.

The transmitted signaling information must conform to the actual traffic situation this also means that the connection to the locomotive from the traffic control system must be permanent.

The integrity of the transmitted signaling information must be maintained on the whole transmission route, by using some form of Cycle Redundancy Check (CRC).

The on-board equipment must provide high reliability and safety level. Usually it is achieved with active redundancy.

2.1.2 The place and continuity of transmission of signaling information:

Transmission of the signaling information can be done continuously, or at discrete locations (e.g. at signals). When non-continuous transmission used, the vehicles pick up the information from active or passive devices placed along the railway track. Thus, the validity of the information also depends on the location of the train, and each message is valid until the train reaches the next track side device. In some cases, this can be a real disadvantage, since a restrictive change of the following signal can not be transmitted after the train passed the last device. However, such systems are widely used, since they are cheap, easy to install and operate, and can operate independently from other systems.

With continuous transmission, there is permanent connection between the track side devices and the locomotive's on-board unit. This is essential for high-speed operation.

2.1.3 The method of transmission:

There are four different ways of train control systems use to transmit the signaling information:-

- 1- The oldest method is the mechanic contact, where the active track side device directly hits or pulls a brake valve to release the brake pressure and force the train to stop. This technique is still used on some underground/metro lines (usually called ATS – Automatic Train Stop).
- 2- The electro-mechanic contact (used by the French system) is somewhat

advanced, as the information is carried by a mechanic activation and an electric pulse, Because of the complicated moving parts and the sliding contact, these systems are not considered to be reliable nowadays.

3- To overcome the problem of the moving and sliding parts, the next step of the evolution was the appearance of inductive contacts. Currently this is far the most widely used method for both of continuous and non-continuous systems. Older non- continuous systems use magnets (low frequency transmission), as track side devices. The transmission media for continuous systems can be the rails or a separate loop when using the rails, the amount of transferable information is very limited, due to the poor transfer characteristics of the rails as a conductor. Moreover, the track and traction circuits may disturb the transmission. On the other hand, the loop allows high bandwidth and error-free transmission, but the installation and maintenance is much more complicated.

The modern form of the spot inductive contact is the transponder contact, which operates at high frequency, and allows transmitting complex telegrams with short range radio beacons.

4- With the spread of mobile communication technologies such as GSM, even more sophisticated train control systems were introduced in the 1990s, where the communication between the traffic control system and vehicle is done via wireless link. It has many operational advantages, as there is no need for traditional wayside devices, just aerials and base stations. The highly integrated train control systems of the future (like ETCS level 2) will use this method. [3]

2.1.4 The type of the transmitted information:

The earliest systems were used only for location-dependent warning to achieve higher safety, location dependent stop warning. The American provided even higher comfort and safety, as it was the first

system with target aspect transmission. Proper automatic target braking is possible only when both static and dynamic speed Profile is calculated. This requires the transmission of movement authorities; some systems are also able to transmit the static speed profile.

2.1.5 The type of intervention:

1. Automatic brake intervention.
2. Emergency brake intervention.
3. Full speed supervision.

2.1.6 Determining the position of the train:

Some systems operate without position information at all. (e.g. passing signal with stop).

The German uses relative position information 'the latest systems operate with absolute position information, so that the exact location of the train is always known. Usually this is done by measuring the distance from reference points, marked by track side devices (e.g. some systems determine the absolute location from GPS combined. According to the current researches, this will be widely used on low density traffic lines (LDTL) in the future.[4]

2.2 Traffic Control Systems Standards:

These standards are intended to ensure that railway signal and traffic control systems are installed, modified and maintained in a safe manner.

In these Standards:

"AREMA" means American Railway Engineering and Maintenance of Way Association.

"Approach locking" means electric locking effective while train approaching, within specified distance, signal displaying an aspect to proceed.

"Closed circuit principle" means the principle of circuit design where normally energized electric circuit which, on being interrupted or de-energized, will cause the controlled function to assume its most restrictive condition .

"Fail safe" term used to designate railway signaling design principle, the objective of which is to eliminate the hazardous effects of failure of a component or system. "Qualified person" means, in respect of specified duty, person who, because of the individual's knowledge, training and experience, is qualified to perform that duty safely and properly.

"Railway signal and traffic control systems" means mechanical, electric or electronic signal systems which include Inter locking, Automatic Block Signal Systems, Traffic Control Systems, Cab Signal Systems, including other similar appliances, methods and systems used in non-signaled territory.

"Route locking" means electrical locking, effective when train passes signal displaying an aspect for it to proceed. Will prevent the movement of any switch, movable point frog, or derail in advance of the train within the route entered. May be so arranged that as a train clears a track section of the route, the locking affecting that section is released.

"Test" means to inspect the apparatus and also to subject it to specified electrical and/or mechanical tests to verify its condition.

"Time locking" means a method of electrical locking, effective when a signal has been caused to display an aspect to proceed. Time locking:

Will prevent the movement of any switch, movable point frog, or derail in the route governed by that signal, until after the expiration of a predetermined time interval after such signal has been caused to display its most restrictive aspect.

Will prevent an aspect to proceed from being displayed for any conflicting route.

2.3 Testing and Inspection of Railway Signal and Traffic Control Systems:

Every railway company shall ensure that signal circuits and signal devices, that affect the safety of train operations, are tested and inspected at the minimum frequencies.

Railway companies shall ensure that only qualified persons are engaged in the testing and inspection of railway signal and traffic control systems, Railway companies shall ensure that qualified persons are:

- (a) Properly trained and fully conversant with the requirements of these standards.
- (b) Comply with the requirements of these standards when engaged in their duties.[5]

2.4 Advanced Train Control System:

Advanced Train Control System (ATCS) is a set of specifications designed to document the stated requirements of railroad operational and technical professionals concerning ATCS has hardware system and software system, these specifications of design to facilitate compatibility and standardization without limiting the internal design approaches of individual suppliers.[6]

2.5 Railway Applications:

2.5.1 Fiber Optic Sensors on the Railway:

Sensor Line has contributed fiber optic railway sensor concept to the possible solutions for the overwhelming for company problems that railway vehicle detection systems are anticipated to face in the nearest future. Even some devices far less sensible than sensors are said to be literally disassembled by the strong magnetic fields of eddy-current

brakes. And future engines are going to disturb the frequency range now used for detection purposes, too.

General advantages of fiber optic road traffic sensors also apply to railway wheel load sensors without any restrictions:

- The signals delivered are static (present as long as load applied).
- The signals are load-dependent (carrying information about what kind of vehicle there is).
- Sensor failure can be detected at once (especially before there is a vehicle which might not be detected).
- There is virtually no noise limiting the amplification of small signals.
- These sensors are not affected by whatever electrically or magnetically is happening on the track.

2.5.2 Examples of Possible Applications:

1- Track switch:

These are relatively simple sensors which must only generate at least one signal when a train is present. They are used for example to control Automatic level crossings.

For such purposes the simplest kind of fiber optic railway sensors is sufficient.

2- Gravity Shunting:

Gravity shunting is decelerating a car that is descending from a hump in a way that it will arrive at some given remote point of the track with some given low speed. Being able to do so requires information not only about the car's current speed but also about its weight. Using Sensor Line fiber optic wheel sensors both kinds of information can be obtained at the same time and with the same measurement setup thanks to their analogous response to the wheel load. [7]

2.6 Radio based railway signaling and traffic control system:

Railway signaling and traffic control system which minimizes the wayside equipment and eliminates the pole lines which carry power and signals along the right-of-way is using instead the radio channel between the trains and the central office. Each train communicates with devices, such as passive beacons, which provide zone boundary messages. These devices provide secure messages to a control unit containing a microprocessor which responds to zone boundary messages and provides location information to the central office via radio when the train enters and leaves each zone. The central office has an input and communication processor and a vital processor. The vital processor converts route requests and the zone occupancy messages which are received by the input and communications processor into messages representing the signal aspects (the maximum speed at which the train can proceed), not only for the zone currently occupied, but also for the zone next ahead. The train control unit stores both aspects and displays the aspect for the currently occupied zone. When the train crosses a zone boundary and enters the next zone the new aspect is displayed. The distance for which the aspect remains valid is restricted by the zone boundary beacons and cross-checked by the locomotive odometer. Train stops, which were previously used to limit the distance an aspect is valid, are avoided thereby simplifying the signaling system. [8]

2.7 Railway Signaling:

Railway signaling is a system used to control railway traffic safely, essentially to prevent train from colliding.

The earliest rail cars were first hauled by horses or mules.. Hand and arm signals were used to direct the “train drivers”.

The timetable is set up so that there should be sufficient time between trains for the crew of a failed or delayed train to walk far enough to set up warning flags, flares.

The timetable system has several disadvantages. First, there is no positive confirmation that the track ahead is clear, only that it is scheduled to be clear. Second problem is the system's inflexibility. Trains cannot be added, delayed, or rescheduled without advance notice. Third problem the system is inefficient to provide flexibility.

2.7.1 Block Signaling:

Trains cannot collide with each other if they are not permitted to occupy the same section of track at the same time, so railway lines are divided into sections known as blocks. In normal there is only one train is permitted in each block at a time. This principle forms the basis of.

2.7.2 Automatic block signal:

Automatic block signaling, signals indicate whether or not train may enter block based on automatic train detection indicating whether block is clear. The signals may also be controlled by signalman, so that they only provide proceed indication if the signalman sets the signal accordingly and the block is clear.

1- Track circuits:

One of the most common ways to determine whether block is occupied is by use of track circuit. The track at end of each block is electrically isolated from the next block, and an electrical current is fed to both running rails at one end of the block. A relay at the other end is connected to both rails. When the block is unoccupied, the relay completes an electrical circuit, and is energized. However, when train

passes signal and enters the block, it short circuits the current in the block, and the relay is de-energized.

This method does not explicitly need to check that the entire train has left the block. If part of the train is left in the block, that part will continue to be detected by the track circuit.

This type of circuit is used to detect trains, both for the purpose of setting the signal indication and for providing various interlocking functions for example, not permitting points to be moved when train is standing over them. Electrical circuits are also used to prove that switch points are in the appropriate position before signal over them may be cleared. Modern UK trains, and staff working in track circuit block areas, carry operating clips in the event of derailment fouling an adjacent track; the track circuit can be short-circuited. This triggers danger signals on that track and can be used to prevent collision before the crew is able to contact signalman.

2- Axle counters:

An alternative method of determining the occupied status of block is using devices located at its beginning and end that count the number of axles entering and leaving. If the same number leaves the block as enter it, the block is assumed to be clear. Although axle counters can provide similar functionality to track circuits, they also exhibit a few other characteristics. In moist environment an axle counted section can be far longer than track circuited one. The low ballast resistance of very long track circuits reduces their sensitivity. Track circuits can automatically detect some types of track defect such as broken rail. In the event of power restoration after power failure, an axle counted section is left in an undetermined state until train has passed through the affected section. A track circuited section will detect the presence of train in section immediately. [9]

2.7.3 Fixed block:

Most blocks are "fixed", i.e. they include the section of track between two fixed points. On timetable, train order, and token-based systems, blocks usually start and end at selected stations. On signaling-based systems, blocks start and end at signals.

The lengths of blocks are designed to allow trains to operate as frequently as necessary. A lightly-used line might have blocks many kilometers long, but a busy commuter line might have blocks few hundred meters long.

A train is not permitted to enter block until signal indicates that the train may proceed, dispatcher or signaller instructs the driver accordingly, or the driver takes possession of the appropriate token. In most cases, train cannot enter the block until not only the block itself is clear of trains, but there is also an empty section beyond the end of the block for at least the distance required to stop the train. In signaling-based systems with closely-space signals, this overlap could be as far as the signal following the one at the end of the section, effectively enforcing space between trains of two blocks.

When calculating the size of the blocks, and therefore the spacing between the signals, the following have to be taken into account:

- Line speed (the maximum permitted speed each train).
- Gradient (to compensate for longer or shorter braking distances).
- The braking characteristics of trains on that line .
- Sighting (how far ahead driver can see signal) .
- Reaction time (of the driver).

Historically, some lines operated so that certain large or high speed trains were signaled under different rules and only given the right of way if two blocks in front of the train were clear.

2.7.4 Moving block:

One disadvantage of fixed blocks is that the faster trains are allowed to run, the longer the stopping distance, thus decreasing the line's capacity. Moving block system, computers calculate 'safe zone' around each moving train that no other train is allowed to enter. The system depends on knowledge of the precise location and speed and direction of each train, which is determined by combination of several sensors: active and passive markers along the track and train borne tachometers and speedometers (GPS systems cannot be used because they do not work in tunnels). With moving block, line side signals are unnecessary, and instructions are passed directly to the trains. This has the advantage of increasing track capacity by allowing trains to run closer together while maintaining the required safety margins.

2.7.5 Fixed signals:

On most railways, physical signals are erected at the line side indicate to drivers whether the line ahead is occupied and to ensure that sufficient space exists between trains to allow them to stop.

2.7.6 Mechanical signals:

The earliest types comprised board that was either turned face-on and fully visible to the driver, or rotated so as to be practically invisible. This type of signal is still in use in some countries (e.g. France and Germany), by far the most common form of mechanical signal worldwide is the semaphore signal.

Mechanical signals are usually remotely operated by wire from lever in signal box, but electrical or hydraulic operation is normally used for signals are located too distant for manual operation. [9]

2.8 Railroad switch:

A railroad switch, turnout or [set of] points is mechanical installation enabling railway trains to be guided from one track to another at railway junction.

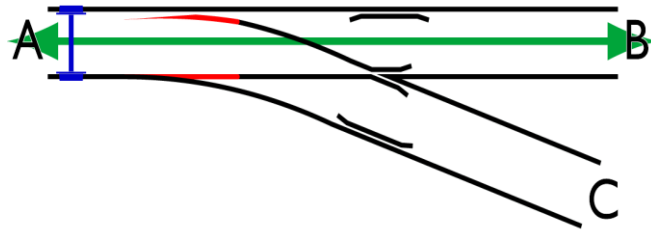


Figure (2.2) Railroad switch

Diagram of right-hand railroad switch, rail track A divides into two: track B (the straight track) and track C (the diverging track).

When the wheels reach the switch, the wheels are guided along the route determined by which of the two points is connected to the track facing the switch. In the illustration, if the left point is connected, the left wheel will be guided along the rail of that point, and the train will diverge to the right. If the right point is connected, the right wheel's flange will be guided along the rail of that point, and the train will continue along the straight track. Only one of the points may be connected to the facing track at any time; the two points are mechanically locked together to ensure that this is always the case.

A mechanism is provided to move the points from one position to the other (change the points). Historically, this would require lever to be moved by human operator, and some switches are still controlled in this way. However, most are now operated by remotely controlled electric motor or by pneumatic or hydraulic actuation.

In trailing-point movement, the wheels will force the points to the proper position. This is sometimes known as running through the switch. If the points are rigidly connected to the switch control mechanism, the control mechanism's linkages may be bent, requiring repair before the switch is again usable. For this reason, switches are normally set to the proper position before performing trailing-point movement.

An example of mechanism that would require repair after run-through in the trailing direction is clamp-lock. This mechanism is popular in the UK, but the damage caused is common to most types of switches. However, some switches are designed to be forced to the proper position without damage. Examples include variable switches, spring switches, and weighted switches.

2.8.1 Roller coaster switches:

Many roller coasters have switches for the siding, or even for double station system,

There are three basic switch designs for roller coasters. Flexing, substituting and table rotating rails have all been used. Flexing the entire rail truss, fixed at one end, to point towards an alternate destination requires manipulating long segment of rail. Substituting segment requires placing two or more segments of rail on flat plate that is moved in its entirety to provide straight or curved track.

2.8.2 Classification switch:

The divergence and length of switch is determined by the angle of the frog (the point in the switch where two rails cross, see below) and the curvature of the switch blades. The length and placement of the other components are determined from this using established formulas and

standards. This divergence is measured as the number of units of length for single unit of separation.

2.8.3 Components of switch:

The points (switch rails or point blades) are the movable rails which guide the wheels towards either the straight or the diverging track. They are tapered on most switches, but on stub switches they have square ends.

In the UK and Commonwealth countries, the term points refer to the entire mechanism, where as in North America the term refers only to the movable rails.

2.9 Relays:

Relays are electro-mechanical devices used for switching. Relays are used to make the signaling logic circuits in the interlocking plants. They consist of one or two magnetic coils (electro magnets) and set of contacts.

Relays can be categorized according to the magnetic system and operation, there are many types of relays:-

1- Neutral Relays:

This is the most elementary type of relay. The neutral relays have magnetic coil, which operates the relay at specified current, regardless of the polarity of the voltage applied.

2- Biased Relays:

Biased relays have permanent magnet above the armature. The relay operates if the current through the coil winding establishes magneto-motive force that opposes the flux by the permanent magnet. If the fluxes are in the same direction, the relay will not operate, even for greater current through the coil.

3- Polarized Relays:

Like the biased relays, the polarized relays operate only when the current through the coil in one direction. But there the principle is different. The relay coil has a diode connected in series with it. This blocks the current in the reverse direction.

The major difference between biased relays and polarized relays is that the former allows the current to pass through in the reverse direction, but does not operate the relay and the latter blocks the current in reverse direction. You can imagine how critical these properties when relays are connected in series to form logic circuits magnetic Stick Relays or Perm polarized Relays.

These relays have magnetic circuit with high retentivity. Two coils, one to operate (pick up) and one to release (drop) are present. The relay is activated by current in the operate coil. On the interruption of the current the armature remains in picked up position by the residual magnetism. The relay is released by current through the release coil.

4- Slow Release Relays:

These relays have capacitor connected in parallel to their coil. When the operating current is interrupted the release of relay is delayed by the stored charge in the capacitor. The relay releases as the capacitor discharges through the coil

5- Relays for AC:

These are neutral relays and picked up for a.c current through their coil. These are very fast in action and used on power circuits of the point motors, where high current flows through the contacts. A normal relay would be slow and make sparks which in turn may weld the contacts together. [11]

2.10 Development of Signaling:

- **Mechanical Signaling**

The olds of system in which the signal and point (switch) machine usually remotely operated by wire form a lever in a signal box now this system is available in Sudan.

- **Electro-mechanical Signaling**

The system with the light signal instead of mechanical signal.

- **Electrical Signaling**

The system used the track circuit, and electrical circuit formed along the running rail. Function is to detect presence or apcance of a train on that option of track.

The basic circuit:

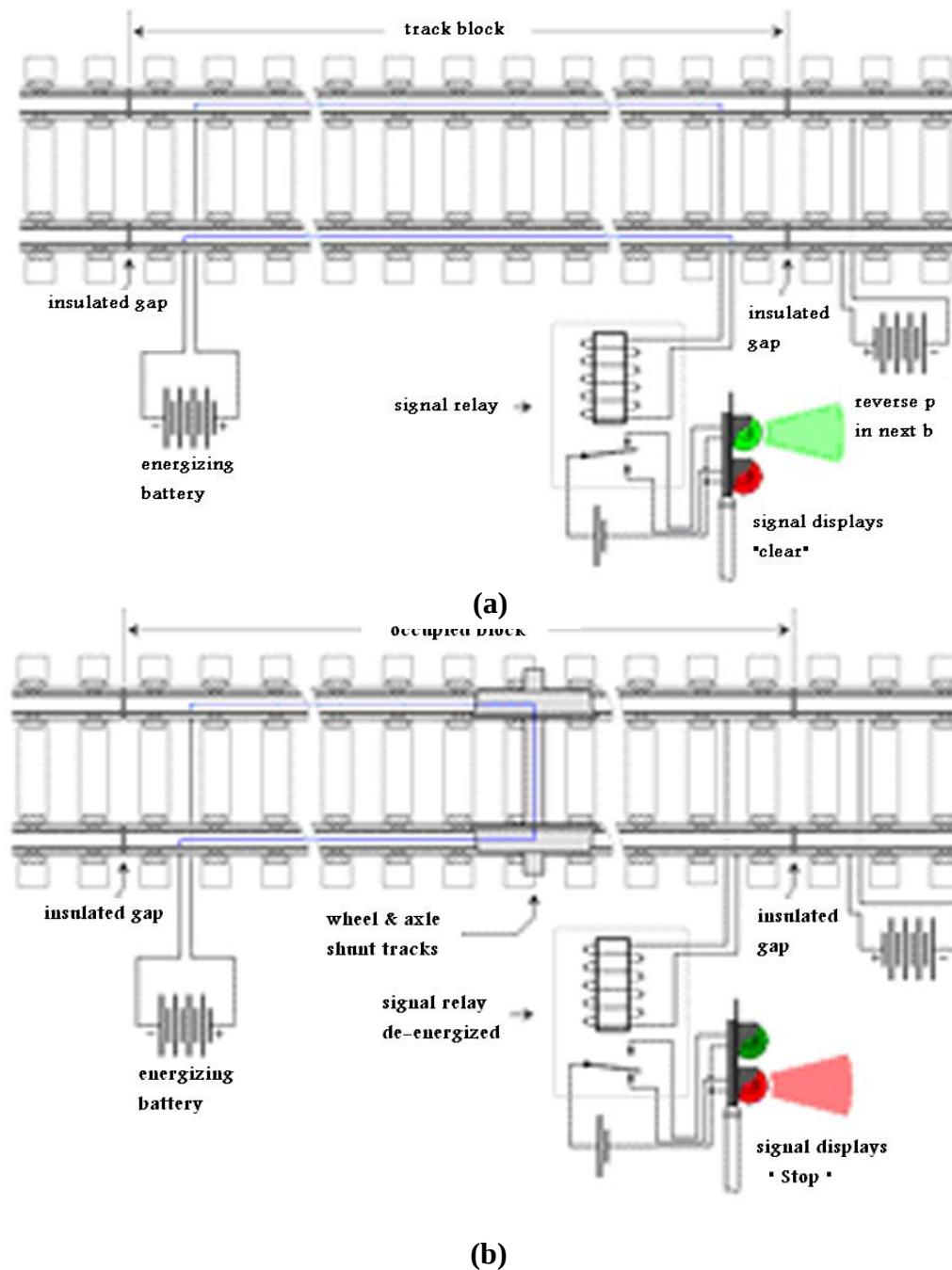


Figure (2.4). Schematic drawing of (a) unoccupied track circuit and (b) occupied track circuit

A track circuit typically has power applied to each rail and a relay coil wired across them. Each circuit detects a defined section of track, such as a block. These sections are separated by insulated joints, usually in both rails. To prevent one circuit from falsely powering another in the

event of insulation failure, the electrical polarity is usually reversed from section to section. Circuits are commonly battery-powered at low voltages (1.5 to 12 V DC) to protect against line power failures. The relays and the power supply are attached to opposite ends of the section in order to prevent broken rails from electrically isolating part of the track from the circuit.

Recently the track circuit is replaced by the system of the axel counter, because the consummation electrical power.

- **Electronic Signaling:**

The system used the Axel counter an axle counter is a device on a railway that detects the passing of a train in lieu of the more common track circuit. A counting head (or 'detection point') is installed at each end of the section, and as each axle passes a head at the start of the section, a counter increment. As the train passes a similar counting head at the end of the section, the counter decrements if the net count is evaluated as zero, the section is presumed to be clear for a second train.



Figure (2.5) an axle counters detection point, in the UK

- **Advantages:**

Unlike track circuits, axle counters do not require insulated rail joints to be installed. This avoids breaking the continuity of long welded rails for insulated joints to be inserted. Such joints introduce a weak point in the rail, where a broken rail is more likely to occur. The cause of many track circuit failures can be traced to problems with insulated rail joints.

- Axle counters require less bonding and cabling in comparison to track circuits, and are therefore generally less expensive to install and maintain.
- Axle counters do not suffer problems with railhead contamination.
- Axle counters are used in places such as wet tunnels experience with axle counters in mainland Europe shows that they regularly achieve up to five times the reliability of track circuits carrying out the same function this has immediate improvement in service reliability as track circuit failure is often the most significant cause of train delay. It also has safety benefits as it reduces the use of degraded modes of operation outside of the control of the signaling system due to failure.

- **Disadvantages:**

- Axle counters may 'forget' how many axles are in a section for various reasons such as a power failure. A manual override is therefore necessary to reset the system. This manual override introduces the human element which may be unreliable too. [10]

2.11 Automatic Train Protection (ATP):

Train safety information received outside the engine is spot data; data transmission points include always two bales on the track.

Bales spots are situated on the places where the data transmission is needed (e.g. the sites where the speed limits changes or where the signals are located).

The engine device consists of the driver panel, extra speedometer displays and the central processing unit, relay unit with its antenna, sensor and control device.

The information on the train is defined by the driver panel for the ATP system. The input data includes the variables needed to count the braking distances of the train e.g.:-

- Train number
- Type of brakes
- Maximum speed allowed to the engine type
- Total length of the train
- Total weight of the train
- Brake weight
- Curving percent
- Train code

On the panel screen the signals in front of the train and the measures demanded by the ATP system can be seen. In addition the optimal speed in a yellow circle and maximum speed in a red circle can be seen.

The function of the ATP system is recorded to the engine registry device. [11]

2.12 Safety Analysis for Train Control System:

Railway automatic train control (ATC) systems are based both on track side and on-board systems.

The increasing level of train traffic is now demanding an increasing safety level, at least Safety Integrity Level. Currently, all communication links of on-board equipment are wired. However,

wireless technologies are becoming more and more popular and they find their way into industrial control and monitoring systems. Elimination of wires as the physical layer to carry data is often referred to as cable replacement. Cable replacement has clear advantages in installation and maintenance cost reduction, and ease of installation. However, error characteristics of wireless links and communication latency make this task antiviral. In this project we will focus on the example of safety critical communication in railway systems.

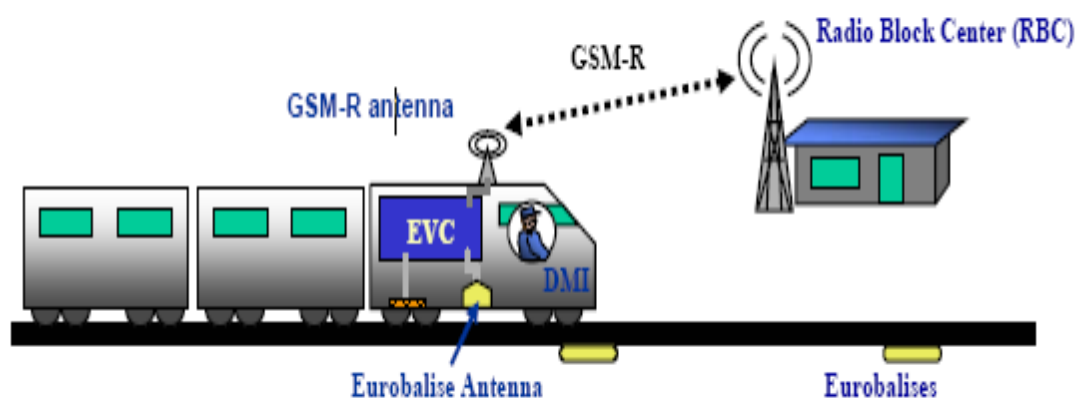


Figure (2.6): The GSM-Railway network

The European train system is based on both track-side and train-borne equipment. The train-borne equipment includes, among others, the European Vital Computer (EVC) and the Driver Machine Interface (DMI). The EVC is the core of the on-board ATC system; it supervises the movement of the train by using the information received both from the “eurobalises” and from the Radio Block Center (RBC) through the GSM-Railway network (see Figure 2.7).

If some messages between EVC and other train components (e.g. DMI) are lost or delayed, unsafe situation might occur that can lead to catastrophes. In some cases the EVC is capable in detecting the unsafe state of operation and then breaks are activated. The train is stopped and the system becomes unavailable.

Chapter Three

Train Traffic Control Simulator

3.1 Introduction

This chapter discusses the design of train control simulation witch designed from foure switch (for track selection) as shown in figure (3.1):

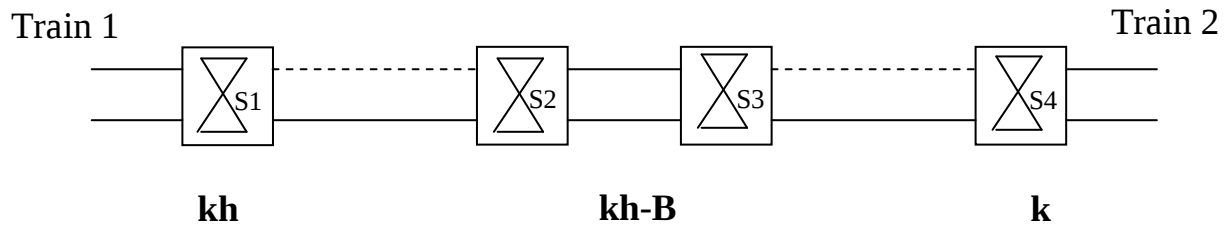


Figure 3.1 Three Station Diagram

3.2 The TTC State:

Four switches are used to design TTC simulation for that at the first we move train 1 and move train 2 between three station .with the flowing table:

Table (3.1) State 1 and state 2 for the design

Moving train	Destination	Switch	Switch state
Train 1	From kh to k	1	Cross
		2	Bar
		3	Bar
		4	Bar
Train 2	From k to kh-B	3	Cross
		4	Cross

Table (3.2) State 3 and state 4 for the design

Moving train	Destination	Switch	Switch state
Train 2	From k to kh	1	Bar
		2	Bar
		3	Bar
		4	Cross
Train 1	From kh to kh-B	1	Cross
		2	Cross

Table (3.3) State 5 and state 6 for the design

Moving train	Destination	Switch	Switch state
Train 1	From kh to kh-B	1	Cross
		2	Cross
Train 2	From K to kh-B	3	Cross
		4	Bar

State 1 to interrupted to state 2, state 3 to interrupt to state 4 and state 5 to interrupted state 6.

3.3 Step of the TTC State:

1- Look for the title of the annex with train move train 1 move from kh to k and train 2 moves to k to kh-B and the case of the four switch as shown in figure (3.2):

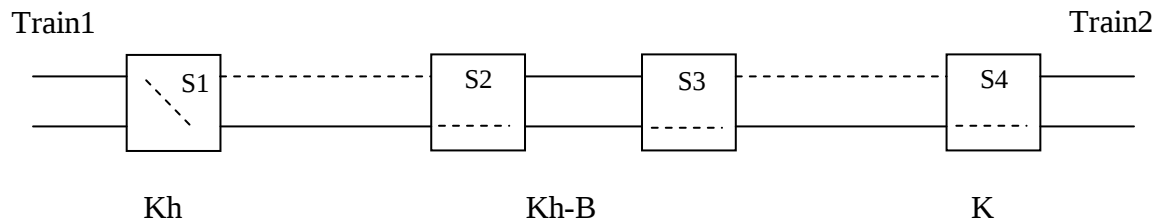


Figure 3.2 Traffic Between kh to k

Means that the switch1 is cross state and switch2 is the bar state, switch3 and switch 4 also but switch 4 switch3 it tacked special state to state train 2 (cross state).

2- If the train 2 move from K to Kh and train 1 move to Kh to Kh-B and it is also the case foure switch figure (3.3) illustrates that mean switch 4 cross state and switch 3 is the bar state ,switch 2 also . and switch 1 is cross but switch 1 switch 2 it tacked special state to state train 1 (cross state) .

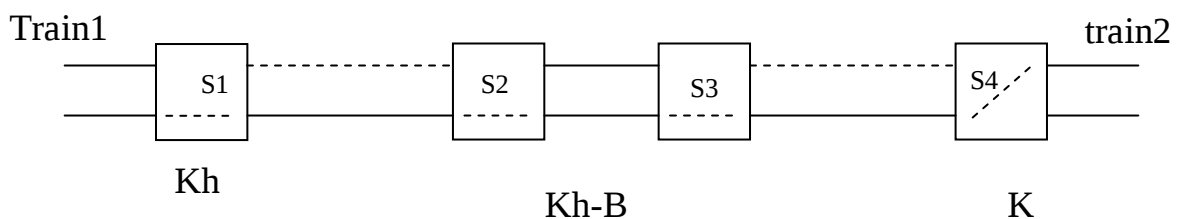


Figure 3.3 Traffic Between k to kh

3- If the train 1 and train 2 move to Kh-B and it is also the case four switch figure (3.4) illustrates that mean switch 1 is the cross state and switch 2 is the bar state and switch 3 is the cross state, switch 4 also is in the cross state.

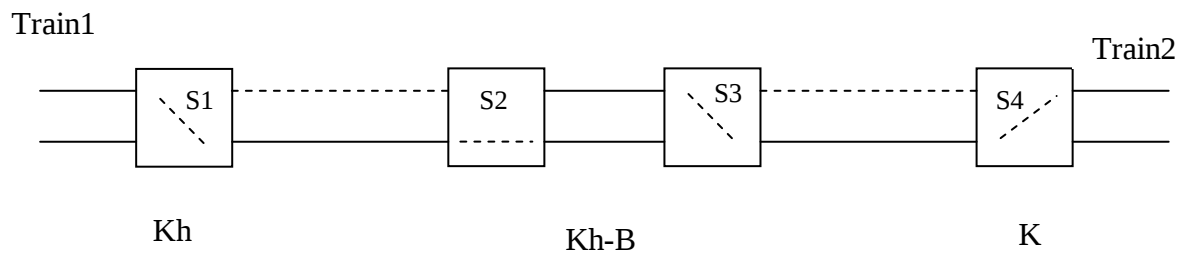


Figure 3.4 Traffic Between kh to kh-B and k to kh-B

3.4 Train Traffic Control Methods:

There are many methods of train traffic control as the follows:

- 1- Simulation program using programming language.
- 2- Electronic Circuit.
- 3- Microcontroller.
- 4- The PLC.
- 5- The SCADA.

A microcontroller is an integrated chip that is often part of an embedded system. The microcontroller includes a CPU, RAM, ROM, I/O ports, and timers like a standard computer, but because they are designed to execute only a single specific task to control a single system, they are much smaller and simplified so that they can include all the functions required on a single chip. A microcontroller differs from Microprocessor, which is a general-purpose chip that is used to create a multi-function computer or device and requires multiple chips to handle various tasks. A microcontroller is meant to be more self-contained and independent, and functions as a tiny, dedicated computer. The great advantage of microcontrollers, as opposed to using larger microprocessors, is that the parts-count and design costs of the item being controlled can be kept to a minimum. They are typically designed using CMOS (complementary metal oxide semiconductor) technology, an efficient fabrication technique

that uses less power and is more immune to power spikes than other techniques.[13]

A PLC (i-e Programmable Logic Controller) is a device that was invented to replace the necessary sequential relay circuit for machine control. It works by looking at its inputs and depending upon their state, turning on/off its outputs, the user enters a program usually via software that gives the desired results.

The PLC mainly consists of a (CPU), memory areas and appropriate circuits to receive input/ output data. We can actually consider the PLC to be a box full of hundreds or thousands of separate relays, counters, timer and data storage locations and they don't physically exist but rather they are simulated and can be considered software counters, timer, etc. These internal relays are simulated through bit locations in registers. [14]

SCADA is (Supervisory Control and Data Acquisition); this system refers to a system that collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data.

SCADA is a term that is used broadly to portray control and management solutions in a wide range of industries. Some of the industries where SCADA is used are Water Management Systems, Electric Power, Traffic Signals, Mass Transit Systems, Environmental Control Systems, and Manufacturing Systems. [15]

A SCADA system performs four functions:

1. Data acquisition

2. Networked data communication

3. Data presentation

4. Control

These functions are performed by four kinds of SCADA components:

1. **Sensors** (either digital or analog) and control relays that directly interface with the managed system.

2. **Remote telemetry units** (RTUs). These are small computerized units deployed in the field at specific sites and locations. RTUs (Remote Telemetry Units) serve as local collection points for gathering reports from sensors and delivering commands to control relays.

3. **SCADA master units**. These are larger computer consoles that serve as the central processor for the SCADA system. Master units provide a human interface to the system and automatically regulate the managed system in response to sensor inputs.

4. The **communications network** that connects the SCADA master unit to the RTUs in the field. [16]

3.5 Explaining the program:

When pressing the button program invoke two function: moving train 1 and moving train 2 and then deleting the nation station (Kh, Kh- B, K) , and show information in three choose the route selected (moving train 1 and train 2) in implementing the moving of one function requires a function of switching settings impose connectivity :

Train 1 moving =switching (sw3- bar ";" bar")

Sw3_bar for connect

(bar station to Kh-B)

Any switch moving has two functions (sw3-bar, sw3-cross) and any switch has two inputs (train 1 or train 2).

In implementing a function switch 3_bar move switching function twice train1, train2 in put for the switch 3 pipe line terminal and the same title recounts the moving of the train 1, train 2 are working cross ,bar for every switch setting there can describe this work flow chart :

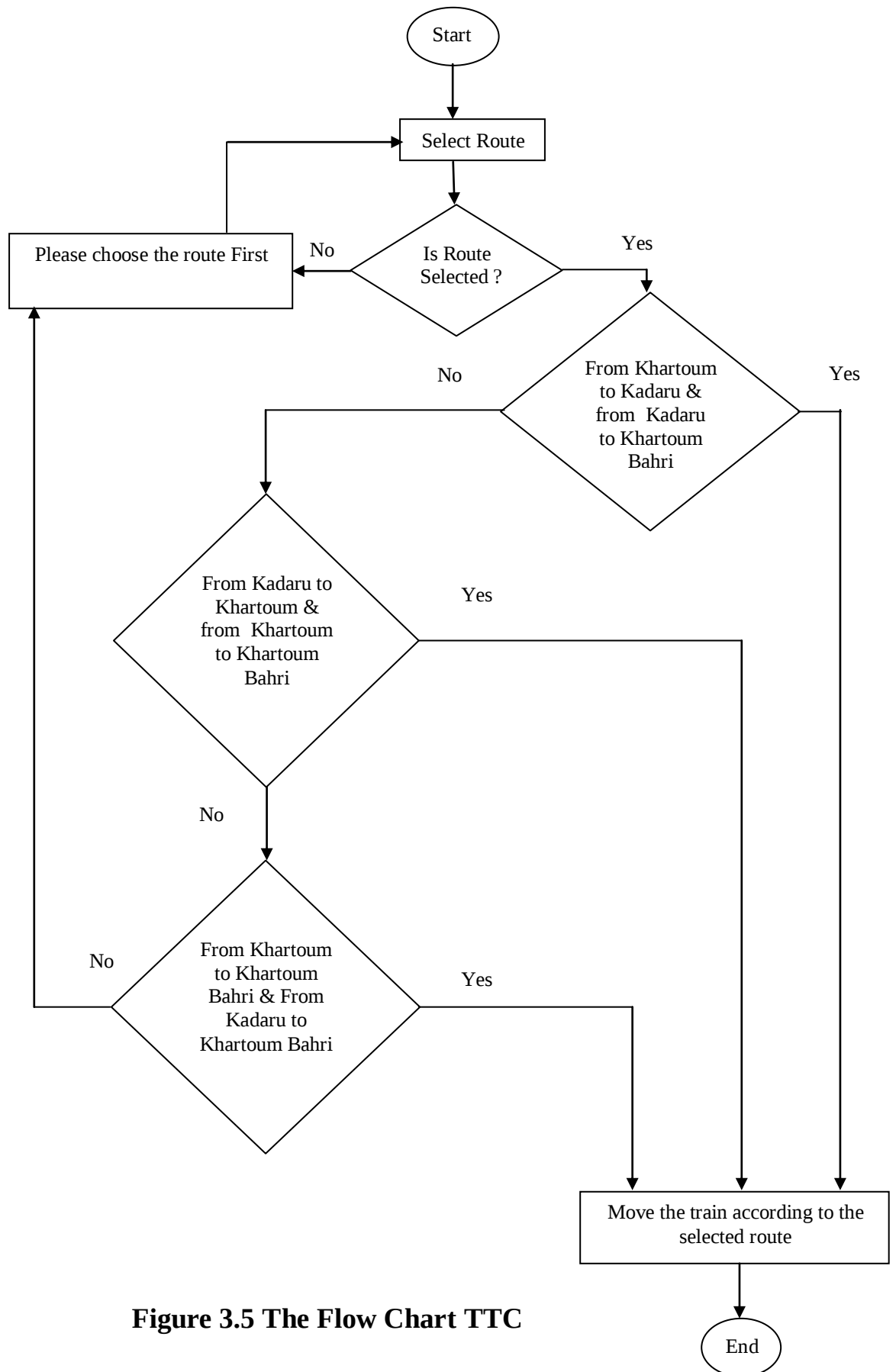


Figure 3.5 The Flow Chart TTC

Chapter Four

Results and Discussion

In this chapter the results of the Train Traffic Control Simulation will be discussed.

In figure 4.1 the GUI main window is shown. :

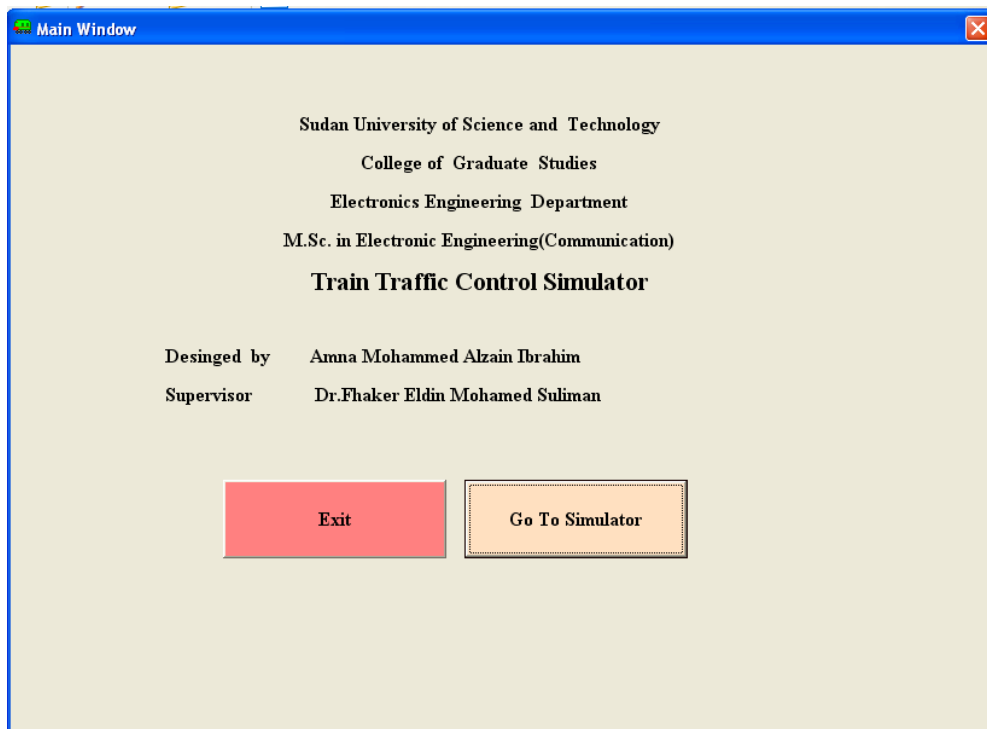


Figure (4.1) GUI main screen

The first screen content the name of the university, name of researcher and the name of supervisor also contains two bottoms:

- 1- Exit
- 2- Go to simulate

Click on the go to simulator bottom to enter of the program and show the following screen:

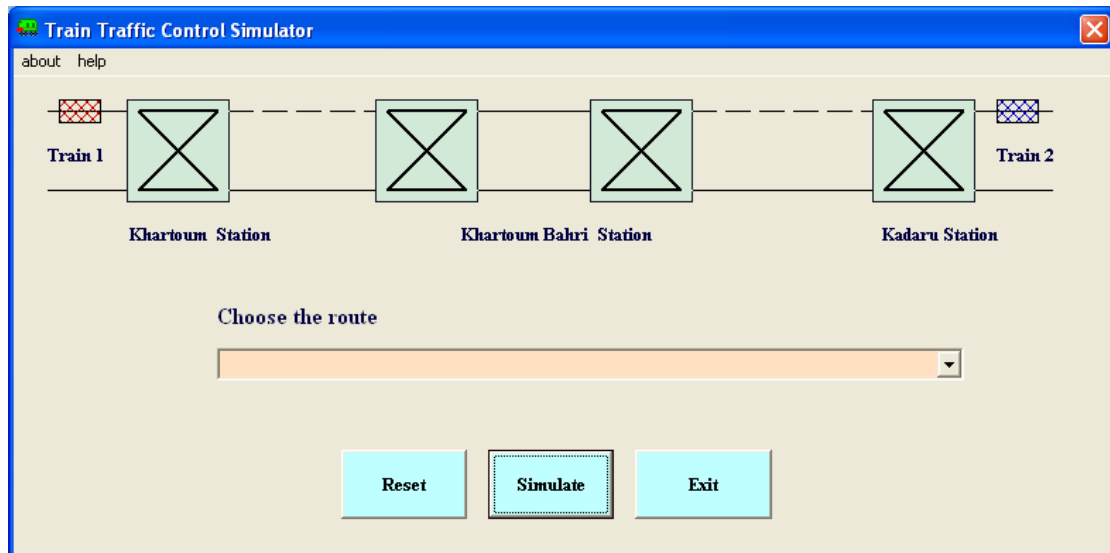


Figure (4.2) Train traffic control simulator

This screen (train traffic control simulator) figure (4.2) contains a tab (bar) where about and help will come later explained adding that contain the master plan for research, this scheme consists of two trains in addition to the three stations (Khartoum, Khartoum Bahri and Kadaru).

These stations linked to the track circuit (track system), each station has a switch, but in a Kh-B there are two switches because it is a center. Normally these switches were opened and closed manually. The screen contains the options that will be implemented. These options under the title choose the route also includes the three bottoms:-

- 1- Exit
- 2- Simulate
- 3- Reset

When the user clicks at the exit bottom for the GUI main screen, and the reset bottom is not used now, because each train at the end position. When will be click on the simulate bottom it will be display the following screen:

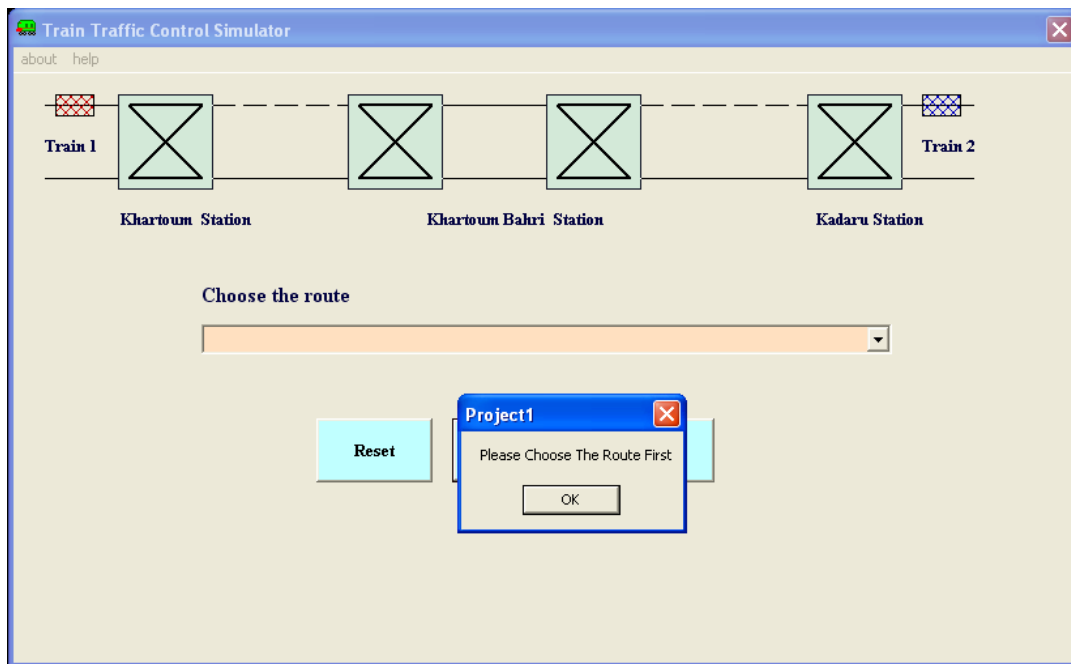


Figure (4.3) Train traffic control simulator

This screen looks like figure (4.2) but it contained a small window (project1) it displayed (please choose the route first), when will choose **OK** bottom it will be exit of this window. At the field of the (choose the route) when it pushes the right arrow bottom it will show three options and shows the following screen:

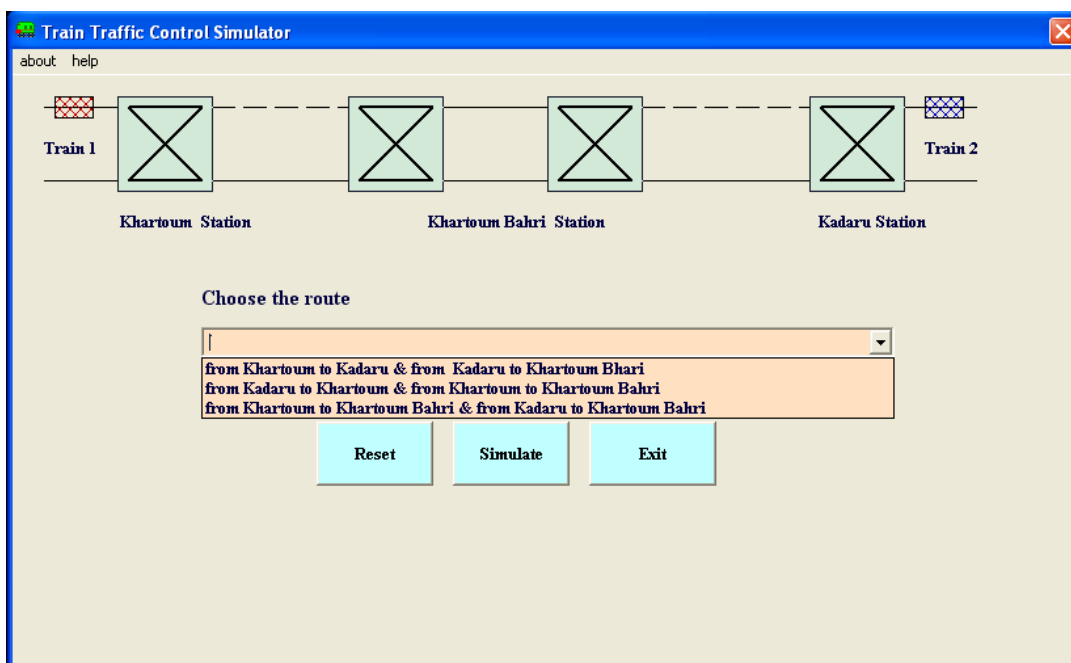


Figure (4.4) Train traffic control simulator

To choose the first option and to click the simulate bottom and shows the following screen:

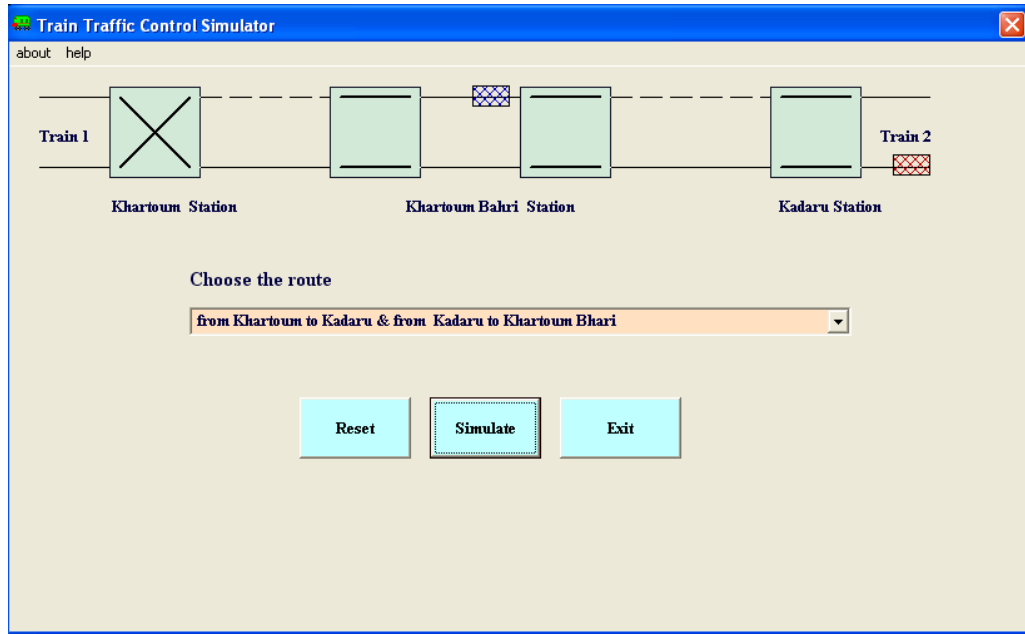


Figure (4.5) Train traffic control simulator

This screen looks like screen figure (4.4), but will move the two trains according to which option was chosen will be any movement between the three stations (train 1 from Kh to K and train 2 from K to Kh-B) when it click on the bottom reset of the each train it will return to the first location (train1 to the Kh, and the train 2 to the K). Click on the arrow at the bottom choose the route once again and choose the second option and click the simulate screen it will appear the following screen:

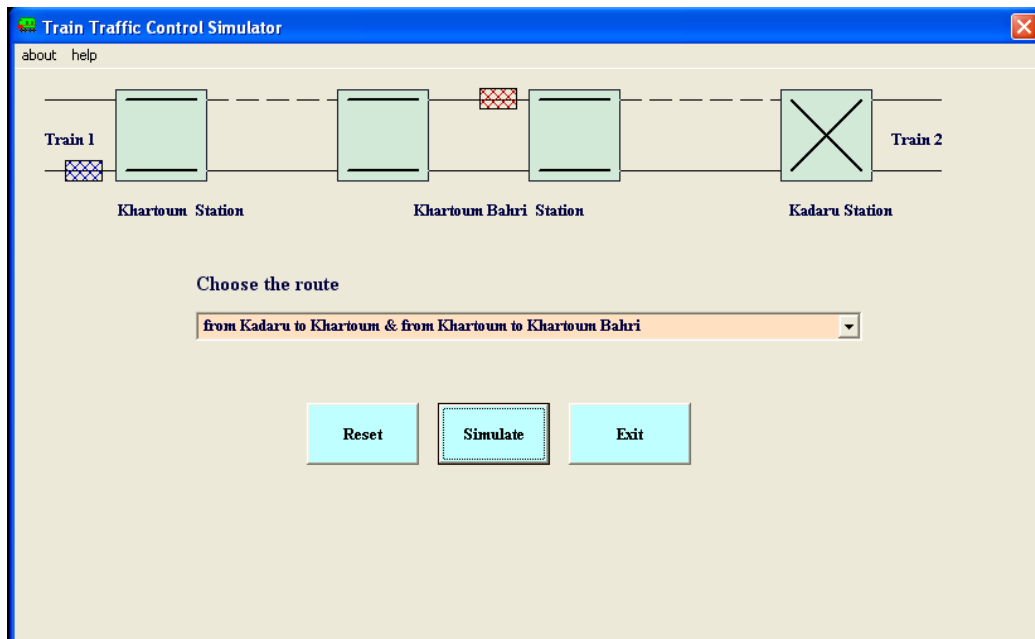


Figure (4.6) Train traffic control simulator

This screen show in figure (4.6) is a reversal for the previous screen, where the new trains will be moving in the opposite direction, according to a chosen option (train 1 from kh to kh-B and train 2 from k to kh) and also when the click on reset bottom is due to the new trains will be to the initial location of the train 1 to kh and train 2 to k. Click on the arrow at the bottom to choose the route and select the third option. If on the simulate button is clicked it will show the following screen:

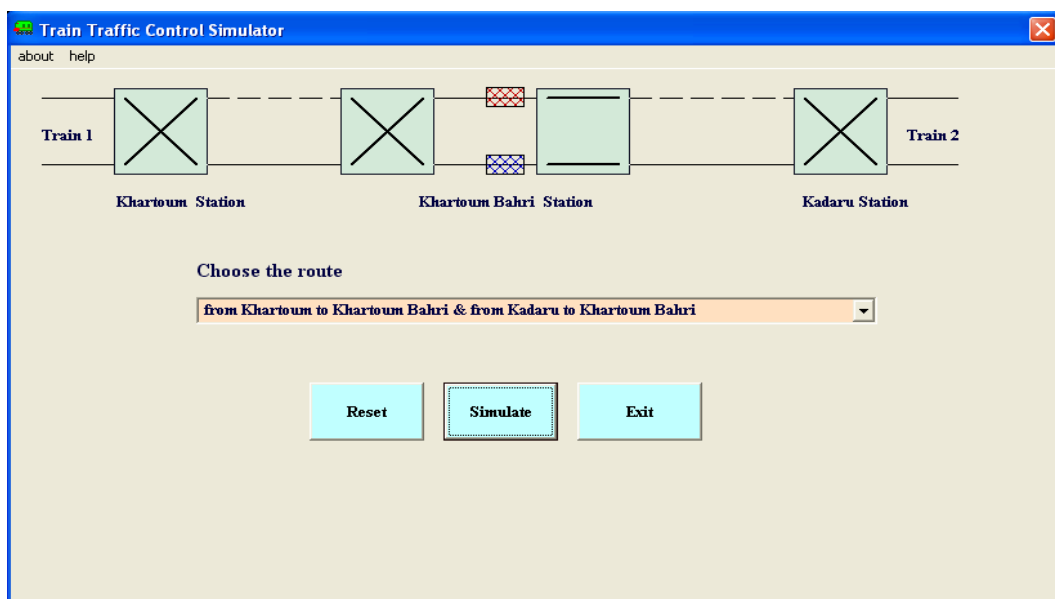


Figure (4.7) Train traffic control simulator

This screen look like the previous screen, but at this moment would be to move any train from the kh-B station, train 1 from kh to kh-B and train 2 from k to kh -B ‘and also when will click on reset bottom it would return any train to the initial location (train 1 to kh and train 2 to k).

Now go back to the figure (4.2) click at about it will display the screen in figure (4.8):



Figure (4.8) about screen

Now when it closed the about screen and return back to figure (4.2) and click help, it will show the following screens:

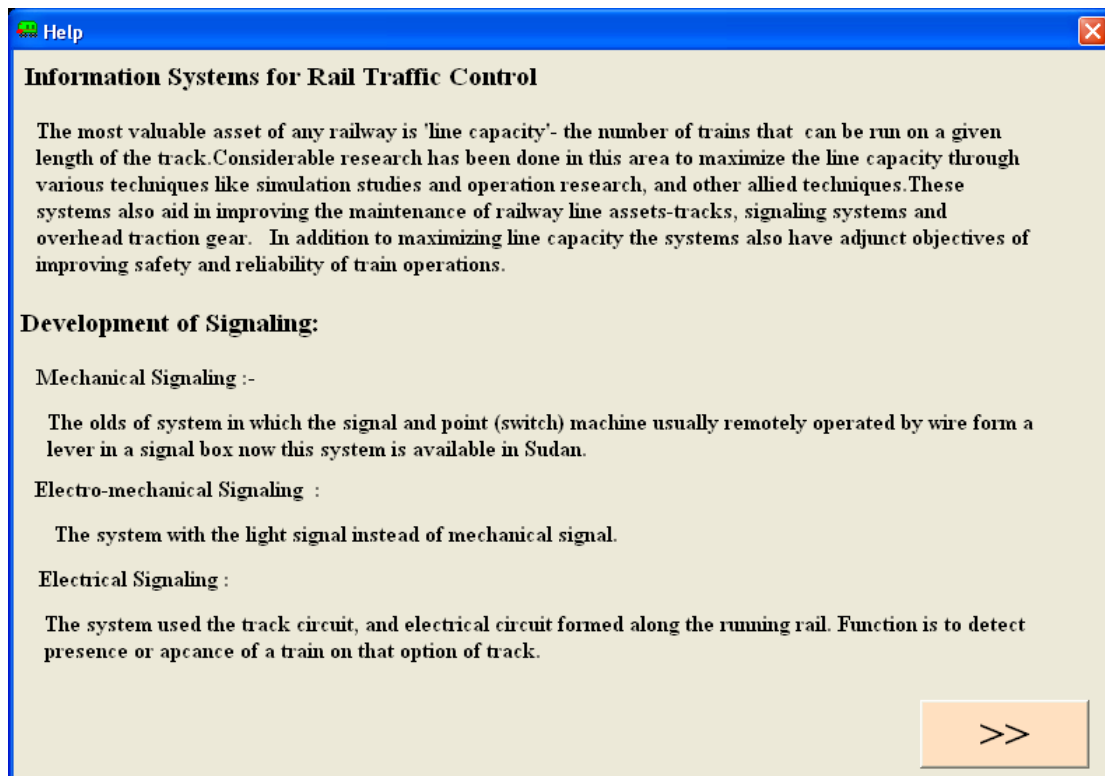


Figure (4.9) Help screen

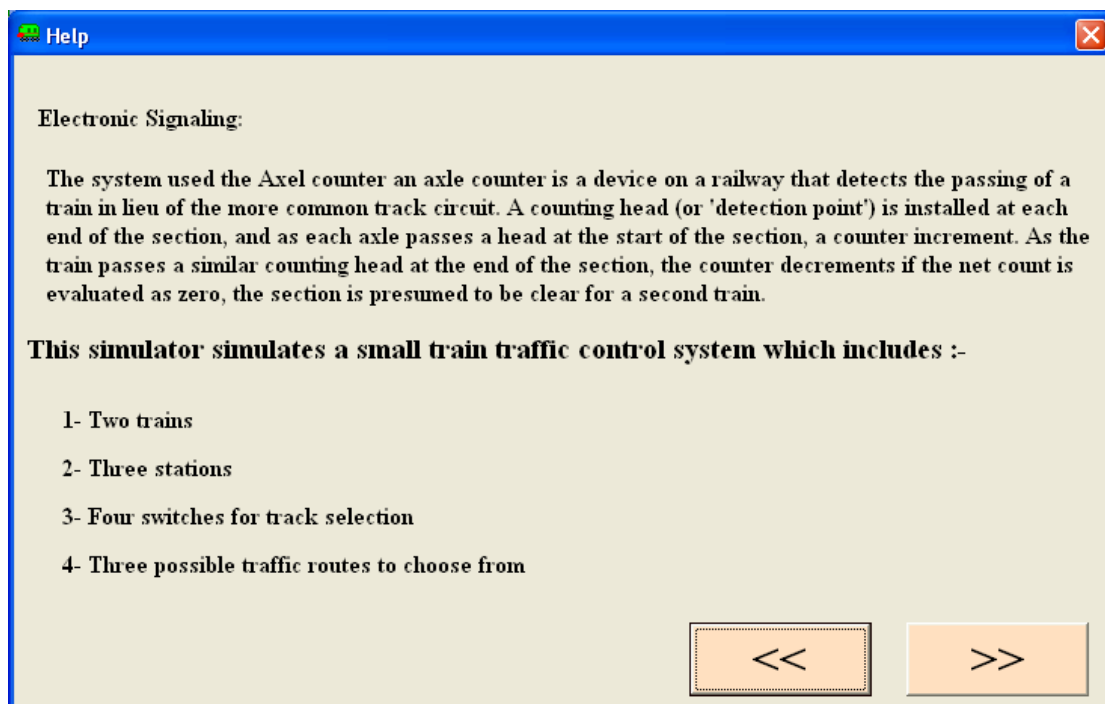


Figure (4.10) Help screen

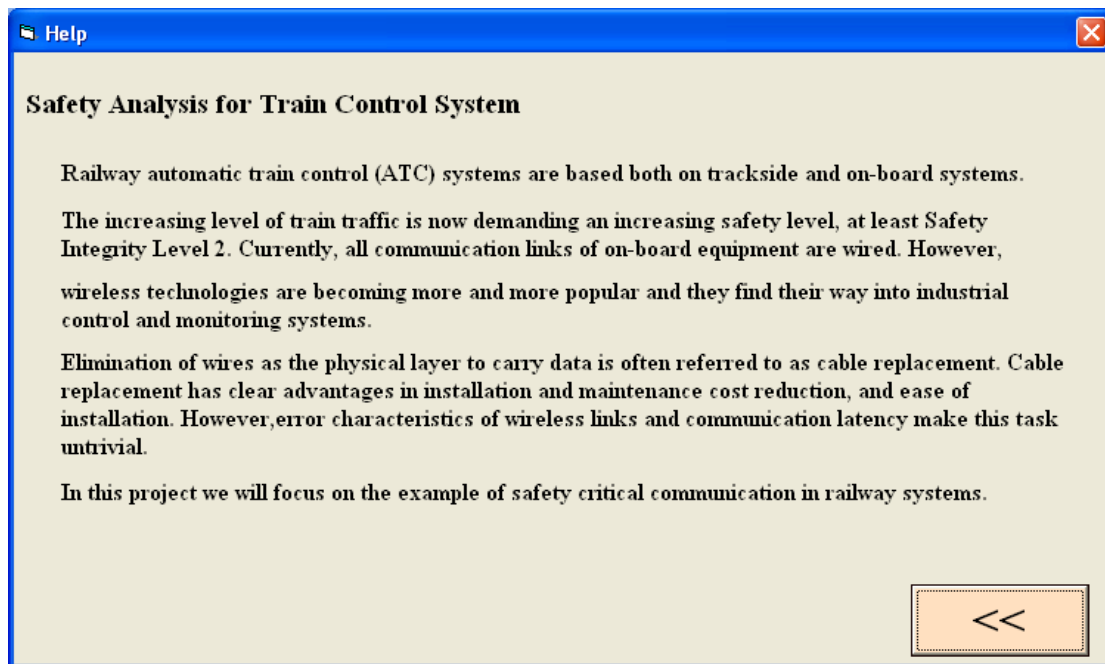


Figure (4.11) Help screen

Chapter Five

Conclusion & Recommendations

5. 1 Conclusion:

A train traffic control simulator was designed with an algorithm that governs the switch from on or off. The code was written using VISUAL BASIC language. The algorithm was tested successfully and reliable results were obtained.

5. 2 Recommendations:

- To recommend that the rail lines of the link between the cities of the Sudan in the form of a circular to be control room in the center.
- Controlled in addition to opening and closing the automatic switches in determining the time and the arrival of the train to the various stations and metabolism in determining the time to crossing a certain distance with the constant velocity.
- We also recommend that the design of electronic chip placed inside the train to be associated with this segment on how the control room sensors or antennas.
- We also recommend a program in the control room is written in a high level of language such as C + + on the segment to be linked with the computer printer port or any other port. Which means that he must be controlled by software and hardware. To design return to web site in <http://hom.swipnet.fe/perz/ctrl.html> .
- At last, research recommends that, to improve the simulation to control more than two trains and tow tracks.

References

1. US. Department of transportation Federal railroad administration.
2. <http://www.vbtutor.net/lesson1.html> . Accessed on June 2009
3. Rousseau, M: LOCOPROL: Low Cost satellite based train location system for Signaling and train Protection for Low density traffic railway lines – User Needs Analysis, Information Society Technologies, and 2002 July.
4. Signaling and train Protection for Low density traffic railway lines – User Needs Sub-System.
(<http://europe.eu.int/comm/transport/rail/interoperability/doc/ccs-tsi-enannex>. UIC, Implementing the European Train Control System ETCS: Opportunities for.
5. <http://www.tc.gc.ca/rafsafety/standards/tce17.htm>.
Accessed on November 2008.
6. http://en.wikipedia.org/wiki/Advanced_Train_Control_System.
Accessed on December 2008.
7. <http://en.sensorline-railway-application.htm>.
D Accessed on ecember 2008.
8. Railroad's traffic control systems by Frank W. Brian, Trains May 1, 2006, retrieved August 16, 2006. United States Recorders.
9. J. B.: The Great Western Railway Automatic Train Control, Categories: Rail technologies | Standards Commission, pp. 255-261.
10. A higher speed turnout, from Federal Railroad Administration, US Department of Transportation analysis, Information Society Technologies, 2002 July. B. Vincze, G. Tarnai: Development and Analysis of train brake curve calculation

11. Draft Technical Specification for Interoperability, Control-
Command and Signaling ERTMS/ETCS consortium:
Interoperability-related consolidation on TSI annex A European
Rail Corridors (version 31.12.03), 2003.
12. Information about the absolute block system on
www.signalbox.org Retrieved from
"http://en.wikipedia.org/wiki/British_absolute_block_signalling"
13. <http://www.wisegeek.com/what-is-a-microcontroller.htm> Accessed
on September 2009.
14. Prof. Dr Engineer Maged Nasr. University of Applied Engineering
& Science Karlst-SWEDEN.
15. <http://www.tech-faq.com/scada.shtml> Accessed on. September
2009.
16. <http://www.dpstele.com/white-papers/scada/page8.php>. Accessed
on September 2009.

Appendix (A)

The Code:-

```
Sub inilaize()
    Line1.Visible = True
    Line2.Visible = True
    Line3.Visible = True
    Line4.Visible = True
    Line5.Visible = True
    Line6.Visible = True
    Line7.Visible = True
    Line8.Visible = True
    Line9.Visible = True
    Line10.Visible = True
    Line11.Visible = True
    Line12.Visible = True
    Line13.Visible = True
    Line14.Visible = True
    Line25.Visible = True
    Line26.Visible = True
End Sub

Private Sub b_Click()
    Dim f As New About
    f.Show
End Sub

Private Sub cmd_Click()
    Dim i, m, n, M1, N1 As Long
    Inilaize
    '// State 1
    If cmbmove.ListIndex = 0 Then
        Line11.Visible = False
        Line12.Visible = False
        Line7.Visible = False
        Line8.Visible = False
    'Start
        m = 600 '345
        n = 225 '2400
        M1 = 10560
        N1 = 225
        Shape5.Left = m
        Shape5.Top = n
        Shape6.Left = M1
        Shape6.Top = N1
    'Goto switch 1
    Do
        If m > 1320 Or M1 < 10065 Then Exit Do
        If m <= 1320 Then
```

```

        m = m + 1
    End If
    If M1 >= 10065 Then
        M1 = M1 - 1
    End If
    Shape6.Left = M1
    Shape6.Top = N1
    Shape5.Left = m
    Shape5.Top = n
    i = 1
    Do While i <= 2000
        i = i + 1
    Loop
Loop
' cross switch 1 & cross switch 3
Do
    If n > 1050 Or N1 > 1050 Then Exit Do
    If M1 > 9325 Then
        M1 = M1 - 1
    End If
    Shape6.Left = M1
    If N1 <= 1050 Then
        N1 = N1 + 1
    End If
    Shape6.Top = N1
    If m < 2215 Then
        m = m + 1
    End If
    Shape5.Left = m
    If n <= 1050 Then
        n = n + 1
    End If
    Shape5.Top = n
    i = 1
    Do While i <= 2000
        i = i + 1
    Loop
Loop
Line3.Visible = False
Line4.Visible = False
Line1.Visible = False
Line2.Visible = False
"
M1 = 9325
N1 = 1085
Shape6.Left = M1
Shape6.Top = N1
m = 2115
n = 1050
Shape5.Left = m

```

```

Shape5.Top = n
Do
  If M1 < 7065 And m > 3960 Then Exit Do
  If M1 >= 7065 Then
    M1 = M1 - 1
  End If
  Shape6.Left = M1
  Shape6.Top = N1
  If m <= 3960 Then
    m = m + 1
  End If
  Shape5.Left = m
  Shape5.Top = n
  i = 1
  Do While i <= 2000
    i = i + 1
  Loop
Loop
"cross switch 2
M1 = 7065
N1 = 1085
"
m = 3960
n = 1050
Do
  If N1 < 225 And m > 6105 Then Exit Do
  If M1 >= 6225 Then
    M1 = M1 - 1
  End If
  If N1 >= 225 Then
    N1 = N1 - 1
  End If
  Shape6.Left = M1
  Shape6.Top = N1
  If m <= 6105 Then
    m = m + 1
  End If
  Shape5.Left = m
  Shape5.Top = n
  i = 1
  Do While i <= 2000
    i = i + 1
  Loop
Loop
"
Line5.Visible = False
Line6.Visible = False
Line3.Visible = True
Line4.Visible = True
"

```

```

Line7.Visible = True
Line8.Visible = True
Line9.Visible = False
Line10.Visible = False
'station 1 to 2
m = 6105
n = 1050
M1 = 6300
N1 = 225
Do '3825
    If m > 10590 And M1 < 5550 Then Exit Do
    If m <= 10590 Then
        m = m + 1
    End If
    If M1 >= 5550 Then
        M1 = M1 - 1
    End If
    Shape5.Left = m
    Shape5.Top = n
    Shape6.Left = M1
    Shape6.Top = N1
    i = 1
    Do While i <= 2000
        i = i + 1
    Loop
Loop
' // State 2
ElseIf cmbmove.ListIndex = 1 Then
    Line11.Visible = False
    Line12.Visible = False
    "
    Line7.Visible = False
    Line8.Visible = False
'Start
m = 600 '345
n = 225 '2400
"
M1 = 10560
N1 = 225
"
Shape5.Left = m
Shape5.Top = n
Shape6.Left = M1
Shape6.Top = N1
'Goto switch 1
Do
    If m > 1320 Or M1 < 10065 Then Exit Do
    If m <= 1320 Then
        m = m + 1
    End If

```

```

    If M1 >= 10065 Then
        M1 = M1 - 1
    End If
    Shape6.Left = M1
    Shape6.Top = N1
    Shape5.Left = m
    Shape5.Top = n
    i = 1
    Do While i <= 2000
        i = i + 1
    Loop
Loop
' cross switch 1 & cross switch 3
Do
    If n > 1050 Or N1 > 1050 Then Exit Do
    If M1 > 9325 Then
        M1 = M1 - 1
    End If
    Shape6.Left = M1
    If N1 <= 1050 Then
        N1 = N1 + 1
    End If
    Shape6.Top = N1
    If m < 2215 Then
        m = m + 1
    End If
    Shape5.Left = m
    If n <= 1050 Then
        n = n + 1
    End If
    Shape5.Top = n
    i = 1
    Do While i <= 2000
        i = i + 1
    Loop
Loop

Line5.Visible = False
Line6.Visible = False
Line25.Visible = False
Line26.Visible = False
"

M1 = 9325
N1 = 1085
Shape6.Left = M1
Shape6.Top = N1
m = 2115
n = 1050
Shape5.Left = m
Shape5.Top = n

```

```

Do
  If M1 < 7065 And m > 3960 Then Exit Do
  If M1 >= 7065 Then
    M1 = M1 - 1
  End If
  Shape6.Left = M1
  Shape6.Top = N1
  If m <= 3960 Then
    m = m + 1
  End If
  Shape5.Left = m
  Shape5.Top = n
  i = 1
  Do While i <= 2000
    i = i + 1
  Loop
Loop

"cross switch 2
M1 = 7065
N1 = 1085
"

m = 3960
n = 1050
Do
  If n < 225 And M1 > 4905 Then Exit Do
  If M1 >= 4905 Then
    M1 = M1 - 1
  End If
  Shape6.Left = M1
  Shape6.Top = N1
  If m <= 4815 Then
    m = m + 1
  End If
  If n >= 225 Then
    n = n - 1
  End If
  Shape5.Left = m
  Shape5.Top = n
  i = 1
  Do While i <= 2000
    i = i + 1
  Loop
Loop

"

Line2.Visible = False
Line1.Visible = False
Line25.Visible = True
Line26.Visible = True

```

```

"
Line11.Visible = True
Line12.Visible = True
Line13.Visible = False
Line14.Visible = False
'station 1 to 2
m = 4815
n = 225
M1 = 4905
N1 = 1085
Do '3825
    If m > 5535 And M1 < 600 Then Exit Do
    If m <= 5535 Then
        m = m + 1
    End If
    If M1 >= 600 Then
        M1 = M1 - 1
    End If
    Shape5.Left = m
    Shape5.Top = n
    Shape6.Left = M1
    Shape6.Top = N1
    i = 1
    Do While i <= 2000
        i = i + 1
    Loop
Loop
' // State3
ElseIf cmbmove.ListIndex = 2 Then
    Line11.Visible = False
    Line12.Visible = False
    "
    Line7.Visible = False
    Line8.Visible = False
'Start
m = 600 '345
n = 225 '2400
"
M1 = 10560
N1 = 225
"
Shape5.Left = m
Shape5.Top = n
Shape6.Left = M1
Shape6.Top = N1
'Goto switch 1
Do
    If m > 1320 Or M1 < 10065 Then Exit Do
    If m <= 1320 Then
        m = m + 1

```

```

End If
If M1 >= 10065 Then
    M1 = M1 - 1
End If
Shape6.Left = M1
Shape6.Top = N1
Shape5.Left = m
Shape5.Top = n
i = 1
Do While i <= 2000
    i = i + 1
Loop
Loop
' cross switch 1 & cross switch 3
Do
    If n > 1050 Or N1 > 1050 Then Exit Do
    If M1 > 9325 Then
        M1 = M1 - 1
    End If
    Shape6.Left = M1
    If N1 <= 1050 Then
        N1 = N1 + 1
    End If
    Shape6.Top = N1
    If m < 2215 Then
        m = m + 1
    End If
    Shape5.Left = m
    If n <= 1050 Then
        n = n + 1
    End If
    Shape5.Top = n
    i = 1
    Do While i <= 2000
        i = i + 1
    Loop
Loop

Line5.Visible = False
Line6.Visible = False
Line25.Visible = False
Line26.Visible = False
"

M1 = 9325
N1 = 1085
Shape6.Left = M1
Shape6.Top = N1
m = 2115
n = 1050
Shape5.Left = m

```

```

Shape5.Top = n
Do
  If M1 < 7065 And m > 3960 Then Exit Do
  If M1 >= 7065 Then
    M1 = M1 - 1
  End If
  Shape6.Left = M1
  Shape6.Top = N1
  If m <= 3960 Then
    m = m + 1
  End If
  Shape5.Left = m
  Shape5.Top = n
  i = 1
  Do While i <= 2000
    i = i + 1
  Loop
Loop

```

"cross switch 2

M1 = 7065

N1 = 1085

"

m = 3960

n = 1050

```

Do
  If n < 225 And M1 > 4905 Then Exit Do
  If M1 >= 4905 Then
    M1 = M1 - 1
  End If
  Shape6.Left = M1
  Shape6.Top = N1
  If m <= 4815 Then
    m = m + 1
  End If
  If n >= 225 Then
    n = n - 1
  End If
  Shape5.Left = m
  Shape5.Top = n
  i = 1
  Do While i <= 1000
    i = i + 1
  Loop
Loop

```

Loop
'station 1 to 2

m = 4815

n = 225

M1 = 4905

N1 = 1085

```

Do '3825
    If m > 5535 And M1 > 5360 Then Exit Do
    If m <= 5535 Then
        m = m + 1
    End If
    If M1 <= 5535 Then
        M1 = M1 + 1
    End If
    Shape5.Left = m
    Shape5.Top = n
    Shape6.Left = M1
    Shape6.Top = N1
    i = 1
    Do While i <= 2000
        i = i + 1
    Loop
Loop
Else
    MsgBox ("Please Choose The Route First")
End If
End Sub

Private Sub Command1_Click()
Unload Me
End Sub

Private Sub Command2_Click()
    inilaize
    Shape5.Top = 105
    Shape5.Left = 465
    Shape6.Top = 105
    Shape6.Left = 10425
End Sub

Private Sub h_Click()
    Dim f As New Help
    f.Show
End Sub

```

Appendix (B)

Table. (2.1) Functional grouping of train control systems (without ETCS)

Functional type	Systems and countries
Auxiliary systems	PZB/INDUSI (Austria, Germany, Romania, Serbia, Croatia, Slovenia), EVM (Hungary), LS (Czech Republic, Slovakia), Crocodile (France, Belgium, Luxemburg), SHP (Poland), BACC (Italy), AWS/TPWS (Great Britain), ATB (Netherlands), ASFA (Spain)
Cab signaling systems	LZB (Austria, Germany, Spain), TVM (France, Belgium, Great Britain), TBL (Great Britain), SELCAB (Great Britain), ZUB 123 (Denmark)

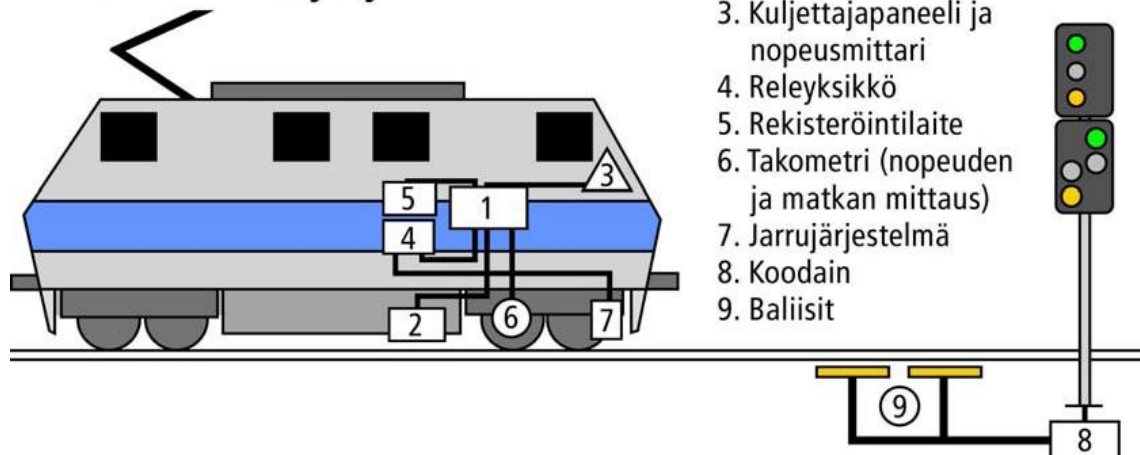
**Table (2.2) Grouping of train control systems by transmission type
(without ETCS)**

Transmission type	Systems and countries
Electro-mechanic (galvanic) contact	Crocodile (France, Belgium, Luxemburg), AWS/TPWS (Great Britain)
Conventional inductive contact	PZB/INDUSI (Austria, Germany, Romania, Serbia, Croatia, Slovenia), EVM (Hungary), LS (Czech Republic, Slovakia), SHP (Poland), BACC (Italy), ATB (Netherlands), LZB (Austria, Germany, Spain), TVM (France, Belgium, Great Britain)
Transponder contact	ZUB 121/122/123 (Germany, Switzerland, Denmark, Bulgaria, Spain), Ebicab (Sweden, Portugal, Finland, Norway) KVB (France)
Wireless link	FFB (Germany), FZB (Germany)

Appendix (C)

Automatic train protection

Junien automaattinen kulunvalvontajärjestelmä



Appendix (D)

CTI Electronics

These are the computer requirements needed to operate the CTI system:

- An IBM-PC or compatible computer

- 640K conventional memory

- DOS 3.0 or later

- CGA, EGA, or VGA color monitor

- One serial (COM) port

- Mouse (recommended, but not required)

The CTI system is completely "gauge independent." It is currently in use with all model railroad gauges from Z through G. (There are even a number of live steam railroads using it for their signaling operations!!!)

Both AC and DC operated trains can be controlled using CTI .

you prefer to control your motive power using Digital Command Control, CTI's software provides full support for the systems from all major manufacturers of PC-controllable DCC equipment. In this case, too, operation can be fully computer-controlled. (See the question on DCC compatibility below for more details.)

The Train Brain's sensor ports themselves are completely independent of any underlying detection mechanism. They are fully compatible with all common forms of train detection including magnetic, infrared, photocells, and current detection sensors. The Train Brain's sensor ports incorporate a digital noise rejection filter to prevent noise-induced false alarms. In addition they provide a variety of detector-specific filtering mechanisms for use with each type of sensor (e.g. switch bounce rejection for magnetic sensors, car-gap rejection for IR, and

intermittent contact (dirty track) compensation for current detection sensors).

CTI system compatible with DCC One of the major advantages of our control software is that it supports the integration of command control with our cost effective discrete control and sensing modules.

One of the big drawbacks of digital command control is that it has no sensing capability. Thus, automated operation simply isn't possible. That problem is solved by CTI's control software. Your command control hardware and the CTI system can now be joined, working in tandem as a seamless, integrated system. Your command control system can respond automatically to CTI's sensors, and work in partnership with CTI's affordable control modules. Command control owners can use their DCC system to do what it does best - run trains, while using CTI to cost-effectively control switches, signals, sound, etc. - the entire integrated system operated automatically by CTI's powerful control software.

When we designed the Signalman, we realized there was a nearly endless variety of signaling products on the market. Trouble-free, 100% compatibility with all commercial signal hardware was a top priority in the Signalman's design.

Electrically speaking, all signaling hardware falls into one of 4 categories:

- Incandescent lamp-based signals

- Common-anode LED-based signals

- Common-cathode LED-based signals

- Bipolar LED-based signals

In contrast to the profusion of fixed-function signal control products on the market, we designed the Signalman to specifically exploit the flexibility that's available only through computer control. Rather than build complex fixed-function signaling logic using expensive, "hard-

wired" electronic circuitry, with the Signalman, all signaling decisions are centralized, and performed much more affordably, under computer control (just like on real railroads) by CTI's powerful control software.

Most of our users incorporated CTI into their existing model railroads. In fact, in most cases, adding computer control capability will not even require removal of your existing manual wiring. It can simply be wired in parallel with your present wiring, giving you the ability to switch back and forth between manual and automated control.

To make it easy to check out what CTI can do on your layout, we've packaged everything you'll need to get started in model railroad computer control into the "CTI Starter Kit". It contains our control software, a Train-Brain PC board, sensors, our users guide, power supply, and interface cables. That's everything you'll need to try out a wide variety of real-world applications of CTI on your own railroad. [17]