1. SIGNALLING SCENARIOS

In this section different scenarios are described and compared. The Reference Case describes the minimum work that is required to merely maintain effective operation of the railway. The various scenarios have advantages and disadvantages from viewpoints of operations and size of investment required. They are as follows:

1. Reference case
2. Centralized traffic control (CTC)
3. Absolute permissive block (APB) system
4. Gradual approach leading to CTC
5. Proposed Progressive Modernization including OCS.

Due to the current state of the signalling equipment there is a need to enhance the ability of the S & T Workshop to recondition and make spare parts that are no longer available from the original suppliers. For the reference scenario, the workshop would be provided with three new lathes to replace the old ones and miscellaneous small tools to equip the artisans for the work. These measures should provide the ability to make necessary repairs and spare parts. Independent of the scenario selected, this workshop modernization work is necessary, but it would be modified to suit the system selected.

1.1. REFERENCE SCENARIO

This scenario is a program which includes:

- the replacement of the existing switch mechanism with a damped spring return mechanism at one end of each small line station,
- the replacement of existing semaphores with electric (colour light) signals, and
- the provision of an electric lever lock for each controlled signal.

The electric lever lock is an electromagnetic device providing an interface between mechanical equipment and electric signals.

This program is a "**minimum work solution**" designed to liberate equipment for spare parts (wires, cables, semaphores, switch point movements etc.) The parts thus obtained could be refurbished at the Atbara workshop to be re-used elsewhere as required. At the same time, this plan provides for newer and more reliable equipment.

The work involves replacement of the point mechanism at one end of each loop with a spring return mechanism and the semaphore signals with colour light signals on the existing lattice masts.

The mechanical interlocking is retained from Port Sudan to Khartoum. Some of the equipment replaced is re-used between Khartoum and Medani.

This would be a two year program. The replacement of ground lever frames between Medani and El Rahad has already been done with an English 2-wire system.

Nothing changes elsewhere.

Table 4.1 - REFERENCE SCENARIO Costs (U.S. $)

SUMMARY

Install Spring switch & electric signals at one end.
Retain mechanical interlocking from Port Sudan to Khartoum
Relocate equipment released to Khartoum-Medani, plus new locking
No change from Medani to El Rehad and beyond.

SMALL STATION SITE COSTS - ONE END		Qty	Unit cost	Total
Spring switch mechanism		1	$4,000	$4,000
Colour light signal heads		2	$700	$1,400
Lever locks		2	$2,500	$5,000
Batteries, solar power		1	$4,000	$4,000
Cable (lot)		1	$4,500	$4,500
Miscellaneous material		1	$2,000	$2,000
Total material				$20,900
Track work costs		1	$3,000	$3,000
Spare material 10%				$2,090
Transport & Miscellaneous 10%				$2,090
Installation 35%				$7,315
Site costs - 1 loop end				$35,395
PORT SUDAN TO KHARTOUM				
Loops - site costs		36	$35,395	$1,274,220
Engineering design		10%		$127,422
Supervision & initial maintenance		5%		$63,711
Training development & supervision		5%		$63,711
Equip workshop				$75,000
Total				$1,604,064
KHARTOUM TO MEDANI - SITE COSTS FOR ONE STATION				
Re-install released equipment plus new mechanical interlocking				
Control cabin		1	$4,000	
Interlocking equipment		1	$20,000	
Miscellaneous equipment		1	$2,000	
Transport & miscellaneous	5%		$2,200	
Installation	35%		$7,700	
Site costs			$35,900	
KHARTOUM TO MEDANI				
Loops - site costs		6	$35,900	$215,400
Engineering design		10%		$21,540
Supervision & initial maintenance		5%		$10,770
Training development & supervision		5%		$10,770
Total				$258,480
GRAND TOTAL				**$1,862,544**

1.2. CENTRALIZED TRAFFIC CONTROL

1.2.1. System description

Centralized traffic control (CTC) is the system most used in modern railroads. It provides full control of train movements by means of one or only a few dispatchers or controllers. CTC relies on the use of reliable telecommunications to provide controllers with good communications to train crews and maintenance-of-way crews. In addition, track circuits are usually extensively installed to make train locations known at all times. Train locations and maintenance crew locations are thus known to the controllers in real time allowing them to manage train movements with maximum safety and efficiency.

In this scenario a CTC signal system would replace the present method of train control, however it differs from a fully centralized system in that it makes minimum use of track circuits. Track circuits would be installed only at passing stations and not along the entire distance separating stations. In addition, further economy is achieved through the installation of only one major equipment housing rather than two, as sidings are relatively short. The CTC scenario presented here can thus be termed "economical".

One controller at Atbara, would be responsible for all train movements between Khartoum and Port Sudan. Stationmasters would no longer be required at each crossing loop, except for commercial or other reasons, nor would tokens be delivered to the drivers. The present mechanical interlocking at each end of the loop would be replaced. Mechanical signals and points mechanisms would be replaced by electric signals and electric machines. Signals at adjoining loops would be electrically interconnected so that if one signal displayed a proceed aspect the opposing signal could not. The driver would rely on the signals for permission to proceed.

The location of all trains and other information would be shown at the Central Controller Office (CCO) on a display board. The information would be updated as the train passed the end of each loop. The controller would have the ability to activate the points and clear the signals remotely and would decide which train should be held at a loop or be allowed to proceed. The safety of the train would be ensured by the signal system.

An important component of the cost of this system is the need for an extremely reliable communication link between the train controller and each station, as this link will be used for the control of all train movements and for communications with trains along the line. This is largely provided for in the communications estimates.

Track circuits are provided only through the loops from distant signal to distant signal. A method of proving that the train is complete has been provided by incorporation of a check-in/check out system and also a method of interconnecting the adjacent loops.

1.2.2. Advantages and disadvantages

The benefits of this system are the reduced cost of eliminating

1) stationmasters,
2) delays in the exchange of the tokens, and
3) unreliability and delays due to the mechanical interlocking.

The drawback is that the system must be installed over a significant portion of the line before any benefits can be realized. This includes replacing all the signals and installing points machines. The substantial investment required is therefore a major disadvantage.

1.2.3. System Costs

CTC system costs are presented next page.

Table 4.2 - CTC costs (U.S. $)

SUMMARY

Install electric signals & switch at each end, with electric interlocking
CTC supervsion from a Central Controller's Office
Suitable for short passing loops (e.g. less than 1 km)
Track circuits are installed only where required

	Qty	Unit cost	Total	
SITE COSTS - ONE STATION				
Switch machines	2	$15,200	$30,400	
Signals	4	$2,200	$8,800	
Signals (additional aspects)	4	$3,500	$14,000	
Main housing, wired complete	1	$45,000	$45,000	
Other housing, wired complete	3	$3,000	$9,000	
Power (batteries, solar power)	2	$4,000	$8,000	
Power for track circuits	4	$2,800	$11,200	
Cable (lot)	1	$35,000	$35,000	
Miscellaneous material	1	$20,000	$20,000	
Emergency control panel	1	$1,500	$1,500	
Insulated rail joints	24	$350	$8,400	
Total material			$181,400	
Track work costs switches	2	$3,000	$6,000	
Track work, track circuits (km.)	5	$105,000	$525,000	
Spare material 10%			$18,140	
Transport & Miscellaneous 10%			$18,140	
Installation 35%			$63,490	
Site costs - 1 loop			$812,170	
PORT SUDAN TO KHARTOUM				
Loops: small station costs	28	$812,170	$22,740,760	
medium station costs	5	$1,218,255	$6,091,275	(15
large station costs	3	$1,624,340	$4,873,020	(20
Control office complete	1	$500,000	$500,000	
Total			$34,205,055	
Engineering design		5%	$1,710,253	
Supervision: Inst'n & initial mtce		5%	$1,710,253	
Training: Development, supervision		5%	$1,710,253	
Total Port Sudan to Khartoum			$39,335,813	
Total Khartoum to Medani (first section)			$258,480	
GRAND TOTAL			**$39,594,293**	

1.3. ABSOLUTE PERMISSIVE BLOCK

1.3.1. System description

An Absolute Permissive Block (APB) signal system allows trains to follow one another into the same block but ensures that opposing trains can not enter the same block. It thus provides full safety based on extensive use of track circuits throughout i.e. in between stations as well as in the passing loops at the stations.

APB is generally less expensive than CTC as there is no remote control and power switching equipment. In the case of SRC however, the CTC version proposed in scenario 2, does not require the full line to be equipped with track circuits whereas this APB scenario uses track circuit throughout so as to illustrate the high costs of such devices.

The stationmasters are required and remain to authorize train movements but can now use a line clear on the verbal authority of other stationmasters. In an APB signal system, stationmasters must be able to communicate by voice with more stationmasters than in the token block system in which voice communication is limited to adjacent stationmasters. Several trains may now enter a block between stations thus increasing efficiency of train movements.

In addition, if the controller can communicate with the stationmasters, he can decide the best location for trains to cross and advise the stationmasters accordingly.

Normally, trains would meet at stations without any need to reposition the spring switches. The spring switches could be manually operated, however, to allow a train to pass another travelling in the same direction.

1.3.2. Advantages and disadvantages

The main benefit of the system is a decrease in train running times over the line. Customer satisfaction will improve particularly as a result of the controller coordinating the stationmasters to give priority to trains handling time sensitive traffic. The system will also allow a faster recovery from line blockages through the system's ability to "fleet" trains safely.

The high cost of the system is a result of the need to provide continuous track circuits throughout and a three wire circuit to reflect the occupancy of these track circuits and so control the aspects of the signals. As in the CTC solution, investment is high and are unlikely to be offset by gains resulting from an increase in commercial speed.

1.3.3. System costs

The cost of the system covers:

1) the provision of three line wires between stations to interconnect the loops,
2) the replacement of the mechanical signals with electric signals,
3) the replacement of the mechanical interlocking switches with hand operated switches,
4) the provision of continuous track circuits to detect the presence of the train between stations, and
5) track work required for installation of reliable track circuits.

These system costs are presented on the page.

A note of caution is necessary here. The cost of track work for installation of reliable track circuits had been estimated as $ 105,000 per km. This unit cost was used in both CTC and APB scenarios. Depending on the accuracy of this unit cost, the ultimate costs of the CTC and APB scenarios could vary widely. Nevertheless, it is clear that track circuit installation has a major influence on the outcome. SRC track experts should review this cost item.

Table 4.3 - APB Costs (U.S. $)

SUMMARY

Install electric signals with hand operated switch at each end.
Track circuits are installed throughout the rail line

	Qty	Unit cost	Total	
SITE COSTS - EACH SMALL STATION				
Hand operated switches	2	$1,500	$3,000	
Switch point detectors	2	$1,500	$3,000	
Signals	8	$2,200	$17,600	
Signals (additional aspects)	2	$3,500	$7,000	
Main housing, wired complete	2	$10,000	$20,000	
Other housing, wired complete	3	$6,000	$18,000	
Power (batteries and solar)	5	$4,000	$20,000	
Power for track circuits	5	$2,800	$14,000	
Cable (lot)	1	$15,000	$15,000	
Miscellaneous material	1	$20,000	$20,000	
Insulated rail joints	24	$350	$8,400	
Total material			$137,600	
Track work costs switches	2	$3,000	$6,000	
Track work, track circuits (km.)	21	$105,000	$2,205,000	
Spare material 10%			$13,760	
Transport & Miscellaneous 10%			$13,760	
Installation 35%			$48,160	
Site costs - 1 loop			$2,424,280	
PORT SUDAN TO KHARTOUM				
Loops: small st'n costs	28	$2,424,280	$67,879,840	
medium st'n costs	5	$3,636,420	$18,182,100	(150% of small)
large st'n costs	3	$4,848,560	$14,545,680	(200% of small)
Total			$100,607,620	
Engineering design	5%		$5,030,381	
Supervision & initial maintenance	5%		$5,030,381	
Training development & supervision	5%		$5,030,381	
Port Sudan to Khartoum			$115,698,763	
Khartoum to Medani (first section)			$258,480	
GRAND TOTAL			**$115,957,243**	

1.4. A GRADUAL APPROACH LEADING TO CTC

Note: *This scenario previously included loop lengthening as a way to cope with longer trains resulting from traffic increase. SRC has already decided not to lengthen loops and reference to lengthening of loops has been deleted.*

1.4.1. Overall description

This scenario proposes a number of sequential steps: changes to the signals equipment similar to those outlined in the Reference Scenario; elimination of mechanical interlocking; replacement of the token block system (two steps) and finally installation of a central supervisory system for controlling train movements. Each of these forms the object of a subproject.

Ultimately, this "gradual approach" could lead to a centralized traffic control but the scenario proposed here excludes a "full" CTC as the cost was already judged prohibitive in the second scenario.

1.4.2. Replacement of signals and switches

Rather than using the existing signals, new colour light signals and a spring return mechanism for the points will be provided as in the Reference Scenario. This means that trains can only enter the loop from the end where the mechanical interlocker is located. With the current train density this should not be not a burden. The signals will be the colour light type, controlled from the existing cabin and electric lever locks would be included.

1.4.2.1. Advantages and disadvantages

Resulting benefits include the elimination of the slow running approaching one end of the loop, although the train will still lose time exchanging the token. Spare parts will also be freed up for re-use elsewhere as in the Reference case.

1.4.2.2. System costs

The costs include:

1) provision of signals, a spring switch and electric lever lock
2) track work necessary for switch replacement

Costs are presented in a table 4.4 (Step 1). It is reminded that costs are the same as for the Reference scenario.

1.4.3. Elimination of mechanical interlocking

1.4.3.1. Description of the work

The next step is by far the most costly and consists of replacement of the mechanical interlocking at the other end of the loop. However, the work can be performed at stations one at a time, on a priority basis. Completion of all consecutive steps in a particular area would permit going to following steps for that area. For instance, interlocking devices at busy stations where a significant number of wagons are loaded need not be replaced at this time as they are very expensive and there will be sufficient spare parts to maintain them and a stationmaster to operate them.

Mechanical interlocking equipment will be replaced by electric switching devices and electric colour signals installed. This will control both ends of the loop (i.e. including the end with the spring switch and signals installed in the first step.

1.4.3.2. Advantages and disadvantages

As previously discussed the supply of spare parts to maintain the interlocking is no longer available from the supplier and there is no local supplier. If the mechanical signals are replaced, maintenance will be simplified and safety and reliability improved. There will be a significant improvement in train performance, such as for example a reduction in the running time of trains as the need to slow down at the distant signal will be eliminated.

Removal of mechanical interlocking will permit easier modernization of track layouts to meet traffic needs.

1.4.3.3. System cost

The major drawback of this step is the cost involved. As stated, of the various steps included in this gradual approach, it is by far the most expensive, but can be carried out selectively over time.

Costs are presented in table 4.4 (Step 2).

1.4.4. **Replacement of the token block** (Steps 3 and 4)

1.4.4.1. Description of the work (Step 3)

When step 2 work at pairs of adjacent stations has been completed, delays at the loops due to the exchange of the tokens may now be eliminated by removing the token blocks and running train movements in a tokenless mode. All signals within the area of these stations are under the control of the station master. The locomotive driver will only receive authority to proceed from the display of a proceed aspect on a starter signal which the stationmaster will control.

New tokenless block machines will be installed and connected to the signal control circuits which enables the station master to operate the signal lights safely in that block.

1.4.4.2. Advantages and disadvantages

The provision of a tokenless block system will eliminate the delay at a station inherent in the current operating system. The benefit is the increased average train speeds and the elimination of the maintenance of the old token block instruments.

Note that it may be possible to bypass step 3 if telecommunication links are available when it comes the time to implement tokenless operation.

1.4.4.3. System costs

Costs are presented in table 4.4 (Step 3).

1.4.4.4. Description of the work (Step 4)

With good telecommunication links between stations, it will be possible to eliminate the tokenless block machines and directly interconnect the opposite "block" signals so that only one can be cleared at a time. This is really what is termed "traffic locking". An automatic check-in and check-out system will be installed (in lieu of full track circuits such as provided in the APB scenario).

1.4.4.5. Advantages and disadvantages

This step is necessary before proceeding to step 5.

System costs

Costs are presented in table 4.4 (Step 4)

1.4.5. Step 5: Provide centralized control

1.4.5.1. Description of the work

The last step consists of providing a central control system and establishing the new operational procedures to be used under the simplified form of CTC. At this point, trains are operating under a CTC system very similar to the one in the CTC scenario.

1.4.5.2. Advantage and disadvantages

Step 5 completes the system by providing the benefits of centralized control over traffic and operation for that part of the railway network. It can be implemented only when the preceeding steps have been completed for a number of stations (e.g. 5 or 6). Other stations will be added on to the system progressively.

1.4.5.3. System Costs

Costs are presented in table 4.4 (Step 5) covering Port Sudan to Khartoum. The bulk of this cost is during the initial implementation of the first five or six stations.

1.4.5.4. Comments

This phased approach is obviously more complicated and costly. It turns out to be more expensive than the CTC Scenario 2.

The advantage is that expenditures are spread over a number of years.

Table 4.4 - Gradual Approach Costs (U.S. $)

SUMMARY

STEP 1 - same as Reference Scenario (see table 4.1)
Install spring switch & electric signals at one end of each loop

Port Sudan to Khartoum (36 stations)	$1,604,064
Khartoum to Medani (6 stations)	$258,480

STEP 2
Replace the mechanical interlocking with electric, with a power switch and electric signals. This would also control signals at the spring switch end.

	Qty	Unit cost	Total	
SITE COSTS - ONE STATION				
Switch machine	1	$15,200	$15,200	
Signals	2	$2,200	$4,400	
Signals	4	$3,500	$14,000	
Housing, wired complete	1	$25,000	$25,000	
Other housing complete	3	$3,000	$9,000	
Power (batteries, solar power)	2	$4,000	$8,000	
Power for track circuits	4	$2,800	$11,200	
Cable (lot)	1	$30,000	$30,000	
Miscellaneous material	1	$15,000	$15,000	
Local control panel	1	$2,500	$2,500	
Insulated rail joints	24	$350	$8,400	
Total material			$131,800	
Track work costs switches	1	$3,000	$3,000	
Track work, track circuits	5	$105,000	$525,000	
Spare material 10%			$13,180	
Transport & Miscellaneous 10%			$13,180	
Installation 35%			$46,130	
Site costs - 1 loop			$732,290	
PORT SUDAN TO KHARTOUM				
Loops: small station costs	28	$732,290	$20,504,120	
medium station costs	5	$1,098,435	$5,492,175	(150% of small)
large station costs	3	$1,464,580	$4,393,740	(200% of small)
Total			$30,390,035	
Engineering design		5%	$1,519,502	
Supervision: Inst'n & initial mtce		5%	$1,519,502	
Training: Development, supervision		5%	$1,519,502	
Total electric interlocking			$34,948,540	

Interlocking is controlled by Station Masters
Not track circuited between stations.

Table 4.4 - Gradual Approach Costs (U.S. $) - continued

STEP 3.

Provide tokenless block operation. At this point all signals for station and block are controlled by Station Master. This entails two (2) tokenless block machines per block, ie., per pair of stations. The machines would be interconnected with the controls for the station departure signals.

Tokenless block equipment	2	$9,100	$18,200
Spare material 10%			$1,820
Transport & Miscellaneous 10%			$1,820
Installation 35%			$6,370
Site costs - 1 block			$28,210
PORT SUDAN TO KHARTOUM			
Blocks	37	$28,210	$1,043,770
Engineering design	5%		$52,189
Supervision: Inst'n & initial mtce	5%		$52,189
Training: Development, supervision	5%		$52,189
Total tokenless block			$1,200,336

STEP 4

With solid direct communication between stations, it will be possible to eliminate the tokenless block machines and directly interconnect the opposing "block" signals so that only one can be cleared at a time ("traffic locking"). (Depending on timing it may be possible to avoid step 3.) A check-in/check-out system is needed in lieu of the full track circuits provided in scenario 3 (APB). These features are necessary for future CTC.

SITE COSTS - ONE BLOCK			
Additional circuits	2	$2,000	$4,000
Check-in/check-out system	1	$25,000	$25,000

Note: Certain basic work was included in step 2.

Total material	$29,000
Spare material 10%	$2,900
Transport & Miscellaneous 10%	$2,900
Installation 35%	$10,150
Site costs - 1 block	$44,950

Table 4.4 - Gradual Approach Costs (U.S. $) - continued

PORT SUDAN TO KHARTOUM		37	$44,950	$1,663,150	
Blocks					
Engineering design	10%			$166,315	
Supervision: Inst'n & initial mtce		5%		$83,158	
Training: Development, supervision		5%		$83,158	
Total traffic locking				$1,995,780	

STEP 5

This consists of designing and providing a central control system establishing the new procedures used with CTC, connecting to the communications circuits, etc. Corresponding communication and control equipment is needed at each station.

SITE COSTS - ONE STATION				
Comms & control equipment	1	$5,000	$5,000	
Spare material 10%			$500	
Transport & Miscellaneous 10%			$500	
Installation 35%			$1,750	
Site costs - 1 loop			$7,750	
PORT SUDAN TO KHARTOUM				
Loops: small station costs	28	$7,750	$217,000	
medium station costs	5	$11,625	$58,125	(150% of small)
large station costs	3	$15,500	$46,500	(200% of small)
Control office complete	1	$500,000	$500,000	
Total			$821,625	
Engineering design		25%	$164,325	
Supervision: Inst'n & initial mtce		10%	$82,163	
Training: Development, supervision		10%	$82,163	
Total supervisory control for CTC			$1,150,275	

TOTAL PROJECT

Step 1 - reference case	**$1,862,544**
Step 2	**$34,948,540**
Step 3	
Step 4	**$1,200,336**
Step 5	**$1,995,780**
	$1,150,275
GRAND TOTAL	**$41,157,475**

1.5. PROGRESSIVE MODERNIZATION

This scenario is a program which includes:

- removal of mechanical leverframes, semaphore signals, etc.,
- installation of 2 new electric entry signals and 4 new starter signals,
- replacement of existing switch mechanisms with trailable or spring mechanisms at both ends of each station,
- establishing a computer aided Occupancy Control System (OCS) at the CCO,
- development and implementation of new rules and procedures.

1.5.1. Description of the work

A full description of the system is given in Chapter 5. Essentially it entails removal of all existing signal equipment and installation of more modern and much simpler equipment.

In some ways, this scenario is similar to the reference scenario in that it frees up equipment for spare parts (wires, cables, semaphores, switch point movements etc.) The parts thus obtained could be refurbished if required at the existing Atbara workshop and re-used elsewhere. Similarly, it replaces existing equipment with simpler and more reliable equipment. The major difference is that the operating concept provides the flexibility for future changes and upgrading as traffic requirements dictate.

Simultaneous with this equipment simplification is a change from the token block system to a tokenless method of operation. This is made possible by the improved and more reliable voice communications resulting from the telecommunications upgrade projects. The token block machines will be removed and a set of rules and procedures established for the new tokenless method of moving trains. Trains will no longer have to stop although moderate speed restrictions will be necessary at the approach to, and through, the stations. The change to a more disciplined approach to running train movements through rules and procedures, using "voice" authorizations is significant and will require SRC management to train its personnel in order to successfully adapt to the new system.

1.5.2. Advantages and disadvantages

The major advantages of this scenario are the simplicity and lower investment required. It modernizes the method of traffic control and permits further improvements in future, as described in Chapter 5. It is emphasized that this will control train movements as well as maintenance-of-way crews occupying track for repair or other work.

The major drawback, if it is one, is a change in operational procedures. The system is heavily reliant upon a good telecommunications system.

This type of OCS of system is presently used by CP Rail in Canada and many other world class railways. It has proven extremely successful and reliable. This scenario also has the advantage of being economically viable throughout the SRC system.

1.5.3. System Costs

System costs are presented in table 4.5.

The costs shown are for what is considered to be a minimum but extremely viable system. Many variations are possible, some of which can be had for little or no cost by incorporating special provisions in the operating rules as they are being developed. For some locations, additional signal facilities will be needed at extra cost. However, in each case the costs must be justified by the expected benefits. All of these special situations can be identified in the planning stages. Further additions can be made later as new traffic requirements develop.

1.5.4. Simpler Scenario

A simpler version of the above scenario is possible and only includes 2 entry signals. This table of unit costs for this scenario is preserved here for future use if required by SRC.

Table 4.5 - Progressive Modernization with OCS : Costs (U.S.$)

SUMMARY

Requires reliable voice communications between CCO and all stations
Basic OCS costs are for Steps 1, 2, 3, and 5. Step 4 is optional and may be carried out at selected stations only.
Signalling estimate assumes a spring switch at each end of the loop
There are no track circuits
When secure radio voice or data circuits are available, operation can be converted to radio OCS on the Khartoum - El Rahad section
For items marked *, it is assumed that some or all fabrication could be in Sudan
Costs of large stations are not included - see Chapter 5, Section 5.5

SITE COSTS FOR SMALL STATION	Qty	Unit Cost	Total	
Spring switch mechanisms	2	4,000	8,000	
Signals (average cost) *	6	3,000	18,000	
Switch point detectors	2	1,500	3,000	
Station limit approach signs *	2	200	400	
Control panel *	1	1,000	1,000	
Control equipment (per end)	2	3,000	6,000	
Power equipment (per end)	2	5,000	10,000	
Cable (lot)	1	12,000	12,000	
Equipment housings *	2	500	1,000	
Miscellaneous	1	4,000	4,000	
Total equipment			63,400	
Track work costs switches	2	3,000	6,000	
Spare material 10%			6,340	
Transport & Miscellaneous 10%			6,340	
Installation 35%			22,190	
Site costs - 1 loop			104,270	
PORT SUDAN TO KHARTOUM				
Loops: small station costs	28	104,270	2,919,560	
Loops: medium station costs	5	156,405	782,025	(150% of small)
OCS Costs				
CCO: Computer hardware	2	10,000	20,000	
Software development	1	115,000	115,000	
Voice recorder	2	10,000	20,000	
Other	2	10,000	20,000	
Total			3,876,585	
Engineering design		5%	193,829	
Development: Operating procedures		5%	193,829	
Supervision: Inst'n & initial mtce		5%	193,829	
Training: Development, supervision		5%	193,829	
Total			4,651,902	

Table 4.5 - Progressive Modernization with OCS : Costs (U.S.$) (cont'd)

KHARTOUM TO KOSTI				
Loops: small station costs	12	104,270	1,251,240	
Loops: medium station costs	3	156,405	469,215	(150% of small)
CCO: Computer hardware	1	10,000	10,000	
Software development	1	15,000	15,000	
Voice recorder	1	10,000	10,000	
Other	1	10,000	10,000	
Total			1,765,455	
Engineering design	5%		88,273	
Development: Operating procedures	5%		88,273	
Supervision: Inst'n & initial mtce	5%		88,273	
Training: Development, supervision	5%		88,273	
Total			2,118,546	
KOSTI TO BABANOUSA				
Loops: small station costs	12	104,270	1,251,240	
Loops: medium station costs	4	156,405	625,620	(150% of small)
CCO: Computer hardware	1	10,000	10,000	
Software development	1	15,000	15,000	
Voice recorder	1	10,000	10,000	
Other	1	10,000	10,000	
Total			1,921,860	
Engineering design	5%		96,093	
Development: Operating procedures	5%		96,093	
Supervision: Inst'n & initial mtce	5%		96,093	
Training: Development, supervision	5%		96,093	
Total			2,306,232	
TOTAL PROJECT				
Port Sudan to Khartoum			4,651,902	
Khartoum to Kosti			2,118,546	
Kosti to Babanousa			2,306,232	
GRAND TOTAL			**9,076,680**	

Table 4.5a - Simpler Progressive Modernization (OCS) Costs (U.S. $)

SUMMARY

Requires reliable voice communications between CCO and all stations
There is minimal initial cost. No (or few) track circuits.
When communications are secure, initiate voice block control using simple signals and indicators
Trailable or spring (optional) switches could be used
When secure radio data circuits are available, operation can be converted to electronic radio block for the Khartoum - El Rahad section

	Qty	Unit cost	Total	
SITE COSTS FOR SMALL STATION				
Hand-operated switch stand	2	$1,500	$3,000	
Trailable switch mechanism	1	$4,000	$4,000	
Switch point position detector	2	$1,000	$2,000	
Station Entry Signal	2	$2,000	$4,000	
Block entry indicator	2	$1,000	$2,000	
Station limit approach sign	2	$200	$400	
Combined control panel	1	$600	$600	
Control equipment	2	$3,000	$6,000	
Power equipment per end	2	$4,000	$8,000	
Cable (lot)	1	$12,000	$12,000	
Equipment housing	2	$300	$600	
Miscellaneous	1	$3,000	$3,000	
Total for equipment			$45,600	
Track work for switch	1	$3,000	$3,000	
Spare material 10%			$4,560	
Transport & Miscellaneous 10%			$4,560	
Installation 35%			$15,960	
Site costs - 1 loop			$73,680	
PORT SUDAN TO KHARTOUM				
Loops: small station costs	28	$73,680	$2,063,040	
medium station costs	5	$110,520	$552,600	(150% of small)
large station costs	3	$147,360	$442,080	(200% of small)
CCO: Computer hardware	1	$10,000	$10,000	
Software development	1	$100,000	$100,000	
Voice recorder	1	$10,000	$10,000	
Other	1	$10,000	$10,000	
Total			$3,187,720	
Engineering design		5%	$159,386	
Development: Operating procedures		5%	$159,386	
Supervision: Inst'n & initial mtce		5%	$159,386	
Training: Development, supervision		5%	$159,386	
Total			$3,825,264	

Table 4.5a - Simpler Progressive Modernization (OCS) Costs (U.S. $) - continued

KHARTOUM TO KOSTI				
Loops: small station costs	12	$73,680	$884,160	
Loops: medium station costs	3	$110,520	$331,560	(150% of small)
CCO: Computer hardware	1	$10,000	$10,000	
Software development	1	$15,000	$15,000	
Voice recorder	1	$10,000	$10,000	
Other	1	$10,000	$10,000	
Total			$1,260,720	
Engineering design	5%		$63,036	
Development: Operating procedures	5%		$63,036	
Supervision: Inst'n & initial maint'ce	5%		$63,036	
Training: Development, supervision	5%		$63,036	
Total			$1,512,864	
KOSTI TO BABANOUSA				
Loops: small station costs	12	$73,680	$884,160	
Loops: medium station costs	4	$110,520	$442,080	(150% of small)
CCO: Computer hardware	1	$10,000	$10,000	
Software development	1	$15,000	$15,000	
Voice recorder	1	$10,000	$10,000	
Other	1	$10,000	$10,000	
Total			$1,371,240	
Engineering design	5%		$68,562	
Development: Operating procedures	5%		$68,562	
Supervision: Inst'n & initial mtce	5%		$68,562	
Training: Development, supervision	5%		$68,562	
Total			$1,645,488	
TOTAL PROJECT				
Port Sudan to Khartoum			$3,825,264	
Khartoum to Kosti			$1,512,864	
Kosti to Babanousa			$1,645,488	
GRAND TOTAL			**$6,983,616**	

1.6. SUMMARY

Five scenarios have been presented here. They are summarized below together with their costs and one or two major elements highlighting each scenario.

SCENARIO	COST (MILLIONS U.S. $)	HIGHLIGHTS
1. Reference	$1.86	Minimum work required to keep signalling systems operating.
2. CTC	$39.59	Simple centralized traffic control with track circuits at station areas only.
3. APB	$115.96	Requires track circuits throughout the line.
4. Gradual Approach	$41.16	Phased in approach in five steps.
5. Progressive modernization	$9.08	Modernized signals and switches in all stations combined with computer assisted control (OCS). This is also a gradual approach in terms of implementation.
5a. OCS with Simpler Version of Signals/Switches	$6.99	Simplified signalling system based on reliable communications and rules and procedures.

Based on the above, CANARAIL recommends Scenario 5 but suggests that SRC review its approach on signalling and traffic control again prior to undertaking detailed implementation in order that expenditures may by optimized.