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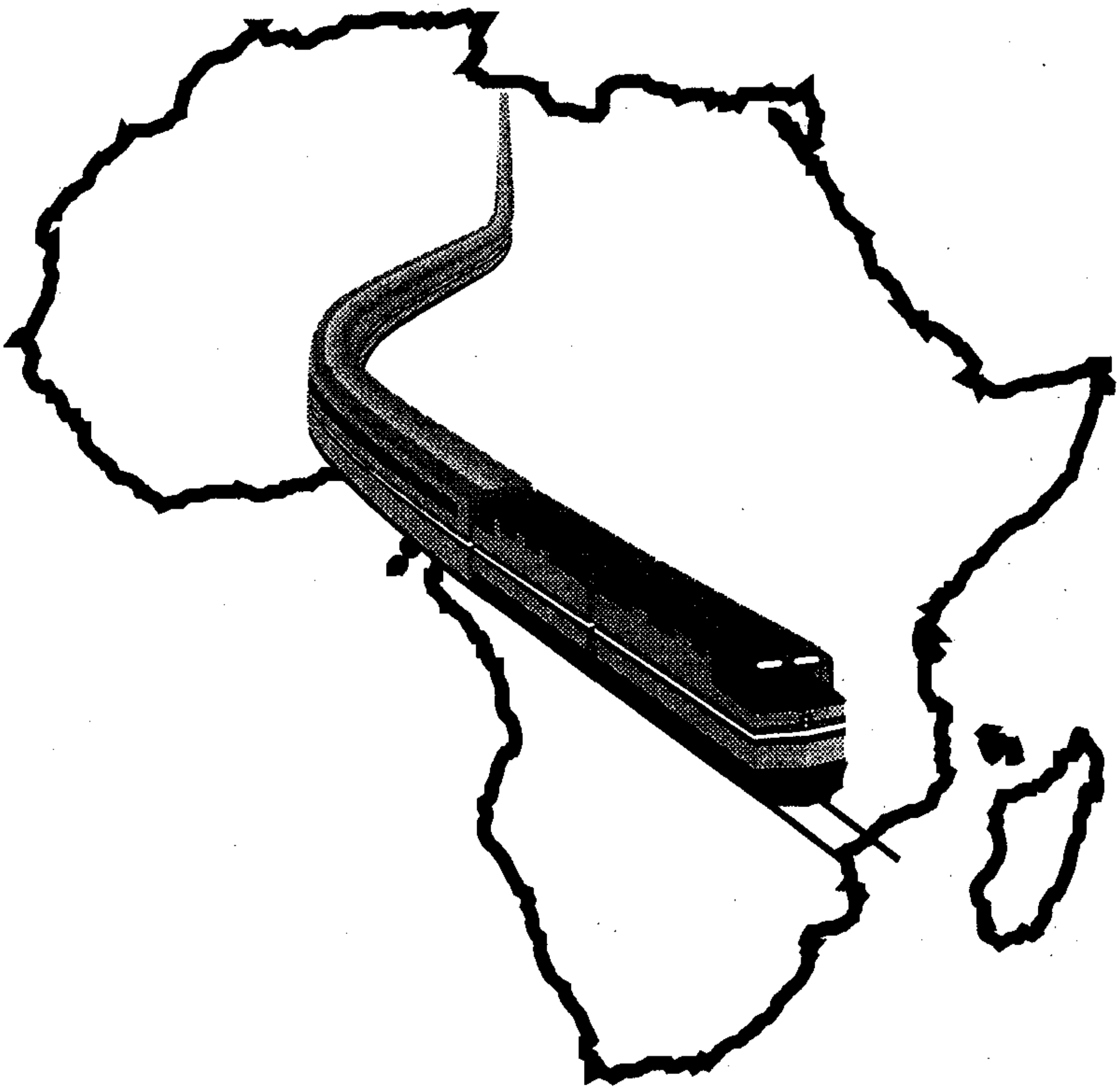

STRENGTHENING AND MODERNIZING AFRICAN RAILWAYS AND ROLLING STOCK

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STRENGTHENING AND MODERNIZING AFRICAN RAILWAYS AND ROLLING STOCK

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CONTENTS

I. INTRODUCTION

1. In the process of African economic development, railways and other modes of transport have an important role to play. Because of its great importance, the Heads of State and Government of African countries have classified "transport" as the third priority after agriculture and industry.

2. The establishment of a suitable and effective network structured around the complementarity of various modes is a condition sine qua non for the socio-economic development of Africa. There can be no doubt that without an integrated network the production and distribution process will become entirely ineffective.

3. The transport sector plays and should continue to play a key role in economic development. Given the demand for transport services, which results from several other socio-economic activities, its importance is universal and affects all sectors of economic activity.

4. With regard to rail transport, the general objectives to be achieved by the railway in each country of the continent are summarized below:

(a) Support to industrial and agricultural development at the country level by providing means of mass transport at minimum cost to communities and by ensuring the opening-up of hinterlands;

(b) Encouragement of the exploitation of agricultural and mining resources;

(c) Promote and maintain jobs and create new ones;

(d) Development of international railway cooperation, especially with neighbouring countries.

5. To play their part effectively, railways need to be rehabilitated, strengthened and modernized. This will mean extensive intervention assistance with regard to rails, related equipment and rolling stock which are currently dilapidated and are of obsolete design in many countries.

6. To face up to increasingly aggressive competition from other modes of transport, large-scale remedial action has yet to be undertaken in all areas of railway operations. To do this, first of all, such action must focus on strengthening, consolidating and modernizing the tracks and the installations.

7. The experience observed in several countries in the continent between 1979 and 1982 clearly illustrates that acquiring modern, high-performance rolling stock to be run on worn out, unstable lines is a dangerous and short-lived operation. The quick deterioration of such equipment, acquired at very high cost, is a negative result of this way of proceeding which ignores the destructiveness of a bad railway track. It will therefore be necessary to schedule programmes in a timely manner and to begin with the basics by formulating a realistic, coherent and integrated programme, taking into account all the factors which impinge on railway operations. "To put the cart before the horse" does not always seem appropriate since it remains undeniable that the two components are necessarily interdependent. Without a sound, stable and modern track, the rolling stock cannot perform effectively and without modern rolling stock, there can be no reliable railway operations.

8. It is within this context that ECA, as part of its development assistance to railways and rail transport in Africa, has conducted the present study with the aim of consolidating, strengthening and modernizing the railways and the rolling stock in the African railway systems.

II. THE HISTORY OF RAILWAY CONSTRUCTION IN AFRICA

9. The construction of railways in Africa was undertaken at the end of the nineteenth century, except for Egypt where the first railway line, Alexandria-Cairo, was inaugurated in 1853.

10. In most if not in all cases, the railway geometry selected was of the "narrow" type with a gauge of 1,000 or 1,067 mm. The stock used at the time was typified by low weight allowances and the type of rails used varied from 20 to 30 kg per linear metre. The platform for travel was generally built from metal sleepers of 27 to 39 kg, with or without tie plates and with 2 or 4 rail fastenings per sleeper. The materials used came from the surrounding environment. It should be noted that opting for the narrow track, light stock and the small radius of curves enabled considerable reduction of the costs of operations without notable effect on wagon capacity and train traffic at the time.

11. Today, operation of these lines is greatly handicapped by this characteristic, light-weight structure of the first tracks which were constructed to penetrate regions at the beginning of the century to meet specific requirements. The problems encountered are similar in most countries of the continent.

12. To illustrate what has been stated, we observe that in equatorial Africa, the first bite of a pickaxe for the Matadi-Kinshasa Railway was taken before 1890. In West Africa, the Dakar-St. Louis line was built between 1882 and 1885, the Kayes-Bamako line between 1881 and 1897, Otta-Lagos in Nigeria in 1897 and the Sekondji-Tarkwa in Ghana in 1901, to name just a few. A good number of other railways were established at the beginning of the twentieth century. It follows from the facts stated above that railways were built during the colonial period. A very heterogenous network has resulted, especially in the gauging of tracks without a logical development plan.

13. This handicap has seriously reduced reconversion possibilities for railway systems at a time when the competing modes are becoming well adapted to African conditions.

14. Today, economic expansion relies on rail transport which is especially adapted to mass transport of goods such as minerals as well as for servicing populated areas.

15. However, to achieve an integrated and operational system, it is necessary to make coherent long-term development plans, with part of operations promoting rail links with other networks.

16. Indeed, it is a general policy that transport systems should be designed to take the complementarity of transport modes into account.

17. To be efficient and competitive in such an environment, the railway has to be a reliable link, with consolidated and strengthened design structures, capable to fulfil the requirements of modern transport.

III. RAILWAY CONDITIONS IN THE SUBREGIONS OF THE CONTINENT

A. The Eastern and Southern African railways

18. In this subregion, railways may be divided into two groups. The first group includes the railway networks which are independent from each other. This refers to the railway lines in Kenya, the United Republic of Tanzania, Uganda, the Sudan and to the Djibouti-Ethiopian line.

19. The total route kilometre of this network is around 6,468 km. The second group built comprised those railways which are more or less integral units of a combined network. This includes the railways of Angola, Namibia, Botswana, Malawi, Mozambique, Zimbabwe and South Africa (as shown in table 1).

20. This combined network, which is characterized by a rail gauge of 1,067 mm and the laying of rails, with a 45-kg weight per linear metre on the main lines, directly or indirectly links 11 countries: South Africa, Namibia, Angola, Botswana, Malawi, Mozambique, the United Republic of Tanzania, Swaziland, Zaire, Zambia and Zimbabwe. Completion of the TAZARA line has made passenger and freight traffic possible between Dar-es-Salaam and all these countries and vice-versa.

21. The combined network is technically capable of meeting the needs of Southern African countries and the fact that TAZARA was constructed with the same track gauge should facilitate linkage of this network with that of East Africa.

22. It is nevertheless important to note that passenger traffic is not sufficiently developed in this subregion where rail transport is often oriented towards the transport of freight and minerals. Efforts should therefore be made to promote such passenger transport. To ensure such promotion, tracks have to be rehabilitated, as well as telecommunications and signalling installations, rolling stock and special action has to be initiated in the area of personnel training and refresher courses. In the east of the continent, the railways of Kenya, the United Republic of Tanzania and Uganda should reestablish passenger transport services which existed before the collapse of the Eastern African Railways Corporation and agree on the means of regulating inter-network operations. Freight transport by rail should be developed further to handle the movement of the bulky freight over long distances. This would allow restrictions on the axle loads of trucks and so protect the line against early deterioration, particularly where both transport functions exist.

23. It is also important to stress that although linked by a uniform metric track, the railways of Kenya, the United Republic of Tanzania and Uganda have no direct link with TAZARA which links up with the combined networks of Southern Africa. In view of this situation, arrangements should be made to carry out a study on the lines and the ways of resolving the problem of passing from a gauge of 1,000 mm to one of 1,065 mm. These days, considering technological progress, the difference in gauges no longer handicaps border crossings. Several solutions have been studied and implemented in European countries for facilitating inter-State traffic.

24. In various studies conducted, the Union of African Railways (UAR) has recommended that only rolling stock making up international trains should be subjected to standards for international traffic between networks of different gauges. Given the fact that in sub-Saharan Africa only two gauges of 1,000 and 1,065 mm are used for international traffic, linkages are from now on possible between the two large systems of Southern and Eastern Africa. The rest requires the political resolve that should underline the action required for infrastructural development and the choices to be made for the physical, economic and social integration of the African continent.

Table 1. Rail network, gauge and braking system

Railway	Network km	Rail (kg/m)	Gauge (mm)	Breaking system	Axle load (tonnes)
Angola	2,776	45	1,067	Vacuum	12.5-18
Botswana	627	45	1,067	"	12.5-18
Ethiopia-Djibouti	1,088	30	1,000	"	12.5-18
Kenya	2,653	45	1,000	Air	12.5-18
Malawi	863	45	1,067	Vacuum	12.5-18
Madagascar	873	30	1,000	"	12.5-18
Mozambique	3,600	40	1,067	"	12.5-18
N.R.Z	3,374	45	1,067	Air	12.5-18
Namibia	2,338	45	1,067	Vacuum	12.5-18
Swaziland	240	48	1,067	"	12.5-18
Tanzania	2,580	25/27	1,000	Air	12.5-18
TAZARA	2,060	45	1,067	Vacuum	12.5-18
Uganda	1,235	40	1,000	Air	12.5-18
Zambia	1,274	45	1,067	Vacuum and air	12.5-18
SATS	22,891	45	1,067	Vacuum	12.5-18

Source: "Consultant, Country Profiles"

B. The Central African railways

25. The four railways of this subregion, namely the Congo-Océan Railway, the National Corporation of Cameroon, the railways of Zaire (SNCZ and CFMK) and the Trans-Gabonese Railways are not inter-connected and, moreover, have three different gauges (1,000, 1,065 and 1,435 mm) respectively. In this subregion, the railway may be considered as modern, some of them having recently undergone heavy works of realignment, modernization and other recent repairs.

26. Generally, such railways play an important role not only in the region to which they belong but also for the two land-locked countries, the Central African Republic and Chad.

27. The existing route kilometre in the subregion are divided as follows: Congo-Océan, 515 km; National Railway Corporation of Cameroon, 1,245 km; the National Railway Company of Zaire, 5,280 km; the Matadi-Kinshasa Railway, 3,668 km; and the Trans-Gabonese Railways, 635 km.

28. Given the lack of linkages within the subregion, there is hardly any inter-network cooperation in operation.

29. Except for Gabon's railway and the sections realigned and already covered by other railway networks, programmes must be formulated and implemented for rehabilitating, consolidating and modernizing tracks, installations, rolling stock and network operations. In this regard, great efforts have been made in Cameroon to upgrade the railway to conditions which could enable it to follow a positive development trend despite the constraints of its environment and the competition from other transport modes.

C. The North African railways

30. These railways are formed by the networks of Morocco, Algeria, Tunisia, the Libyan Arab Jamahiriya, Egypt and the Sudan.

31. All the North African countries except the Libya Arab Jamahiriya have well-structured rail networks. The railways in Maghreb countries are in good condition with regard to track, rolling stock, electrification, passenger services, fares and rates and terminals. The Libyan network is linked neither to the Tunisian network nor to that of Egypt. Similarly, the Egyptian network is not linked to that of the Sudanese. Nevertheless, there is a railway line between Cairo and Aswan Dam and another between Khartoum and Wadi Halfa, but there is no direct link between these two networks. We note that the railways in the Maghreb (Morocco, Algeria and Tunisia) are interconnected.

32. Given the level of railway development in this subregion compared to networks south of the Sahara except for South Africa and its immediate neighbours, it is an opportune time to intensify efforts to develop this mode of transport. To this end, the various networks of the subregion are briefly described in the subsequent paragraphs.

33. The whole Algerian network totals 3,760 km of which 1,253 km are of metric track. The north-south line parallel to the Tunisian border (Annaba-Djebel Ouk) is almost completely electrified at 3 kv continuous (up to Tebessa for the trunk line and mining outposts).

34. The programmes for modernizing and constructing new lines enables the doubling of certain tracks in order to obtain smoother traffic and to extend the railway to other zones to open them up.

35. The Moroccan railway is a large homogenous system with a normal track close to 1,800 km in length, of which almost half is electrified at 3 kv continuous and more than 13 per cent has double track. This is the case with the Casablanca-Rabat line. Among the achievements of recent years, it was convenient to develop the new electrified line to come fully into service and to reconnect the Casablanca-Marrakech line to the Atlantic port of Jorf Lasfar.

36. The Tunisian network, with a length of 2,145 km, is formed by two separate sections, a normal track running north of Tunis which is connected to the Algerian network and the other, a metric track running south and comprising two gauges. Extension of the track up to the Libyan border is planned.

37. The Egyptian railway network, which is almost 5,000 km in length, serves the geographic, demographic and economic reality of the country with a dense system of lines in the Nile Delta, a trunk line which runs beside the river as far as southern Aswan and two branches which run into the desert, one to the north along the coast up to the Libyan border and the other to the centre, towards the Baharia Oasis.

38. The Sudanese network is one of the most important in Africa, with lines close to 4,800 km long offering effective passenger transport in the country, but road transport competition severely affects the freight traffic. This rail network is considered to be the backbone of the whole transport system and is the principal transport mode in the territory of the Sudan.

39. The programmes of action instituted in recent years have encouraged rehabilitation, strengthening and modernization of infrastructure and equipment and acquisition of high-performance rolling stock. The rehabilitation programmes to be pursued should enable the railways in the North African subregion to play a more significant role in the conveyance of freight and traffic by rail, thus promoting the increased efficiency of the entire system.

D. The West African railways

40. West African railways are formed by 12 national networks in Benin, the Niger, Burkina Faso, Côte d'Ivore, Ghana, Guinea, Liberia, Mali, Mauritania, Nigeria, Senegal, Sierra Leone and Togo. Three of these networks are railways conveying minerals, in Liberia, Mauritania and Sierra Leone.

41. Mauritania, although a part of West Africa, is treated as North African in railway development programmes. This country has a minerals railway 689 km long with a normal track (1,435 mm). Heavy- weight trains of 11,000 tons net use this network, pulled by diesel electric locomotives of 2,500 to 3,000 horse power, in multiple units.

42. From the point of view of the physical integration of the subregion, only five networks covering six countries serve the subregion (Benin-Niger, Burkina Faso, Côte d'Ivoire, Mali and Senegal). Formerly, the interconnected networks were the only inter-State networks (Abidjan-Niger and Dakar-Niger).

43. The fact that these railway lines are not interconnected and extended into the interior of certain land-locked countries constitutes inter alia, one of the obstacles which helps to maintain the external trade dependency of the States in the subregion vis-à-vis industrialized countries.

44. Almost all the railway infrastructure of West Africa was built at the beginning of the century. With only a few exceptions, the tracks are worn out from old age, lack of maintenance and unsuitable design that is ill-adapted to efficient and modern rail operations. Major shortcomings are listed as follows:

(a) The ballasting of tracks is generally insufficient;

(b) Curves are too numerous and of a small radius on certain sections of routes; and

(c) The number of sleepers per kilometre and the weight of the rails are also low since they date from a time when the average axle load hardly went above 14 tons.

45. Important tracks are still equipped with rails of 20 kg weight to the linear metre. Operations have been suspended and some of these lines are threatened with suspension in the short term (for example, the coastal routes of OCBN and of Togo).

46. Rolling stock is varied and is often advanced in age. Supply of spare parts is made difficult due to financial problems with the treasury and with the multiple sources of origin of the stock.

47. As already mentioned in the earlier paragraphs, the problems posed by differences in rail gauges have already found solutions, for example, in France and Spain for TALGO trains; in North Africa, the Algerian network is made up of lines with different gauges. This network has 3,155 km of track to the gauge of 1,435 mm and 1,138 km of track to the gauge of 1,000 mm.

48. For many years now, UAR which is a specialized OAU institution, has also come up with solutions of convenience in various African subregions.

49. The problems which interconnection could pose were also studied during the second UAR symposium held at Blantyre, Malawi, in 1981.

50. The size of the existing pools of rolling stock in African networks shows the importance of the industry. Given the high costs of acquiring stock, spare parts and fuel, development of the African railway industry should be intensified.

1. The physical characteristics of tracks and other infrastructure

(a) Infrastructure

51. In West Africa as in many other subregions, the infrastructure is generally very old despite the renovation and rehabilitation efforts observed in some networks. **The typical parameters concerned are:**

(a) **The track layouts:** typical layouts are very restricted with regard to the traffic recorded in these times. In some networks, the frequency with which slopes occur and the low radius of curves are very pronounced. Gradients more than 10 per 1,000 and a curve radius lower than 500 m makes track layout difficult and forms constraints which must be removed for achieving interconnected network operations;

(b) **Cross sections and platforms**: platform lengths vary from 4.5 to 6 m. Due to lack of maintenance and bad weather, embankments are eroded over time.

52. Ballast is insufficient on several lines (under 800 litres per linear metre)

(b) Construction works

53. Most of the engineering construction works were done before the Second World War and have 14-ton axle loads. The obsolete state of some of these structures is today a constraint to be removed in order to have a modern railway operating. Moreover, it has become necessary to adjust railway lines to the traffic requirements. To this end, engineering structures should therefore be strengthened to bear axle loads of at least 20 tons.

(c) The superstructures

54. The tracks in the subregion are generally equipped with old rails which are very hard, but their age is beginning to weaken them. Almost 14 per cent of the route kilometre of the network is still equipped with rails weighing 20 to 25 kg per linear metre. Within the context of rehabilitation programmes, such rails have to be replaced. Difficulties in getting supplies and/or financing slow down the renovation and rehabilitation process of tracks. In fact, the age of some sections and the poor adaptation of some sections for modern operations are some of the handicaps for correct maintenance of old lines. This is also the case with the sleepers and the number of sleepers per kilometre.

55. It is noticed that only 30 per cent of lines are equipped with 1,500 sleepers per kilometre. Under such conditions, modernizing the existing network can be done through gradual increase of the number of sleepers and substitution of old rails for heavier ones. This would encourage strengthening of a homogeneous overall subregional network.

56. Use of long-railed track should become generalized, especially where this serves to reduce the maintenance costs of the track and the rolling stock, to increase the safety factor for traffic.

57. Comfort will be increased by the use of soldered long-rails to replace worn-out rails on around 80 per cent of the length of existing tracks. Tables 2 and 6 provide some data on subregional networks.

2. Signalling and telecommunications

58. The safety of single track train traffic is currently ensured by:

(a) Automatic systems;

(b) Manually operated systems; and

(c) Regulation systems.

(a) Automatic systems

59. Automatic systems such as "Bloc automatique lumineux" (BAL) or the axle-load computing bloc have very high-performance capacity with regard to railway lines. The cost of installations, operations and maintenance are high and cannot be justified except with high levels of traffic.

(b) Manually operated systems

60. These systems of operations are less costly than automatic systems but their installation is also very expensive. It is necessary to deploy a worker for each post of the bloc, in order to guarantee the functioning of the equipment.

(c) Regulation systems

61. The regulation systems are based on the respect which the agent responsible for safety has for very precise regulation. Various formulae are used in railway networks. Such installations are suitable for low levels of traffic.

62. To ensure safe train traffic, a reliable, large-capacity telecommunications network is necessary, to monitor train position and composition, because the engineers must be in permanent contact with the construction work sites on the track for various aspects of production and operations for better management of rolling stocks and for urgent intervention assistance as needed, etc.. Considerable progress has been made with the new telecommunications equipment. It is important for safety and for smooth train traffic that obsolete installations be replaced with modern equipment.

3. Assistance requirements resulting from the conditions of railway installations

63. Given the current state of deterioration of most African railways, which varies in degree from one country to another, stress should be placed on the priority of rehabilitating, consolidating and modernizing existing railways and services in order to achieve the guaranteed safety of freight and passenger transport under the conditions set by the competitive environment. It is the chief priority on which the managers and supervisory authorities of railway enterprises should focus.

64. Rehabilitation, consolidation and modernization should therefore be the main aim of the programmes to be established on the basis of inter-network consultations on equipment (track, rolling stock, telecommunications, etc.) which have the same standards and specifications in certain areas. It should be possible to bring the impact of mass into play and to profit from substantial economies of scale through bulk purchasing of space parts and through specialized maintenance and production workshops within the context of collectivizing existing capacities and making investments complementary. Given the concern about technical cooperation, the railways should establish catalogues of parts that are produced or can be produced locally and they should distribute the documents on classifications which were formulated for this purpose. The existing facilities in each railway network should be identified as well as examining the possibilities of sharing the equipment from industrial production workshops developed in the countries of the subregion.

IV. CONSOLIDATION AND MODERNIZATION OF RAIL TRACKS AND RELATED EQUIPMENT

65. With regard to rail tracks, two areas of development seem promising at this time. These areas are as follows:

(a) Increased speeds, which essentially depend on the state of the tracks and vehicle performance would enable net improvement of commercial services for both passengers and freight;

(b) Modernization of the superstructure through systematic use of soldered long-rails and, if the case arises, use of modern materials such as concrete sleepers or elastic rail fastenings lead to significant reduction in maintenance costs.

Table 2. Tractive network stock

Network	Motive stock		Horse power (hp)		Average age (years)	Availability rate %
	Type	Number	Unit	Total		
SICF	CC2200GM	11	2,250	24,750	18	59/69
	BBB/800CEM	6	1,800	10,800		16
	Autorails					
	ZE200CIMT	8	950	7,600	12	68/33
	Manoeuvre	20				
	AA90	1	350	350	22	
	AA100	11	450	4,950	13	52
	BB150	5	750	3,750	11	
	BB160	3	750	2,250	9	
SCFB	Locomotives	12				
	CC2200GM	11	2,250	24,750	18	
	BBB/800CEM	1	1,650	1,650	20	72
	Autorails					-
	ZE200	6	950	5,700	12	-
	Manoeuvre	17	-	8,900	12	-
						18
SNCS	Locomotives	27		42,164		76
	BB1100	3	1,050	3,150	25 to 33	84
	BB1200	3	1,100	3,300	19 to 20	77
	BB1600	10	1,450	14,500	8 to 15	82
	CC2000	2	1,700	3,400	5	84
	CC1700	3	1,546	4,638	9	65
	CC2400	6	2,196	13,176	5 to 13	66
	Autorails	5		3,950		65
	ZE120	2	550	1,100	22	55
	ZE140	3	950	2,850	5	72
	Manoeuvre	15	-	6,142		53

Source: Study on railway interconnections in West Africa, ECO/TCTD/ECOWAS/13/92

Table 2. (Cont'd)

Network	Motive stock		Horse power (hp)		Average age (years)	Availability rate %
	Type	Number	Unit	Total		
CFT	Locomotives	8		9,555		47.09
	BB500	1	800	800	36	
	BB800	2	730 and 925	1,655	34	51.35
	BB1200	1	1,200	1,200	19	41.91
	BB1100(TH)	1	1,100	1,100	28	7.12
	CC1600	3	1,600	4,800	13	59.31
	Autorails	3		2,500	30	18.21
	ZE130	2	550	1,100	34	
	ZE150	1	950	950	24	
	Manoeuvres	7		2,060	31	50
	Moyse	4	350	1,400	35	
	Gmeinder	2	180	360	27	
	CEM	1	300	300	24	
OCBN	Locomotives	20		1,900		
	BB500	8	800	6,400	30	
	BB600	12	1,050	12,600	15	Out of
	Autorails	4	950	3,800	12	service
	Manoeuvre	9		3,750		
	CFM	2	300	600	13 and 25	
	CEM	4	450	1,800	13 and 25	
	Moyse	3	450	1,350	12	
RCFM	Locomotives	28		46,390		54.13
	BB500	1	850	850	38	71.7
	BB800	4	1,000	4,000	20	52.47
	BB1100	4	1,050	4,200	23	52.00
	CC1600	6	1,650 and 1,720	10,040	12	39.86
	CC2400	3	2,100	6,300	14	23.47
	CC2200	10	2,100	21,000	6	71.39
	Autorails	7		2,900		2.58
	ZE150	2	950	1,900	15	3.84
	ZE110	5	200	1,000	3	2.08
	Manoeuvre		400			
	AA40	1		400	15	

Source: Study on railway interconnections in West Africa, ECO/TCTD/ECOWAS/13/92.

Table 3. <u>Trailer stock</u>

Networks	Passenger stock		Freight stock			Total personnel
	Coaches and trailers	Wagons	Covered	Platforms, tipcarts, hoppers	Tanks	
SICF	62	18	342	132	176	730
SCFB	66		200	125		301
SNCS	94	11	433	315	24	377
CFT	32		55	182	36	305
OCBN	45		122	98	47	312
RCFM	41	11	226	186	44	478
S/Total	340	40	1,378	1,008	327	3,093

Source: Study on railway interconnections in West Africa ECO/TCTD/ECOWAS/13/92

Table 4. Networks track equipment

Networks	Rail route kilometre								Total
	30 kg/m	22 kg/m	25 kg/m	26 kg/m	30 kg/m	32 kg/m	36 kg/m	36 kg/m	
SICF	-	-	-	50	293	-	297	-	640
SCFB	-	-	-	-	487	30	-	-	317
ONCPG	-	-	450	-	137	-	65	291	953
SNCS	-	-	121	59.3	2,144	-	510.8	-	905.5
RCFM	-	-	58	-	575.4	-	8	-	641.4
OCBN	-	203	-	30	334	-	12	-	579
CFT	141	-	-	267	-	13	71	-	35
OTP	-	-	-	-	-	-	35	-	
SNIM	-	-	-	-	-	-	-	690	690
NRC*	-	-	-	-	-	-	-	-	3,523
GR*	-	-	-	-	-	-	-	-	925
Sierra Leone	-	-	-	-	-	-		80	80
Liberia	-	-	-	-	-	-		493	493
Total	141	203	639	406	-			1,554	10,473.9

Source: Study on railway interconnections in West Africa, ECO/TCTD/ECOWAS/13/92.

* Information not available

Table 5. State of track ballasting

Networks	Normal ballasting 800 km	Average ballasting	Poor ballasting	Very little ballasting	No ballasting	Total route kilometre
SICF	462	178	0	0	0	640
SCFB	0	517	0	0	0	517
ONCFG + Mines	282		174	460	37	953
SNCS	534	73.3	80	218	0	905.5
RCFM	212.4	161	244	24	0	641.4
CFT	0	237	74	117	64	492
OCBN	165	223	22	0	169	579
SNIM	690	0	0	0	0	690
OTP	35	0	0	0	0	35
NCR	634	943	875	1,071	0	(3,523)
GRH	276	67	240	342	0	(925)
Sierra Leone	80	-	-	-	-	(80)
Liberia	493	-	-	-	-	(493)
TOTAL	3,863	2,399.5	1,717	2,232	270	10,474
Percentage	36.9	22.9	16.4	21.3	2.5	100

Source: Study on railway interconnections in West Africa, ECO/TCTD/ECOWAS/13/92.

Table 6. <u>Equipment and components of ECOWAS railway networks (1990)</u>

etworks	Countries	Area (Km²)	Population 10^6	Route km Gauge (mm)			Motor equipment		Trailers		Average no. of personnel	Rail traffic						
				1,435	1,06 7	1,00 0	Locos/ locotrac	Rail/ cars	Coaches	Wagons		Pass. (10^6)	% 90/89	Pass. (10^6)	% 90/8 9	Tonnes (10^6)	Tonnes/km (10^6)	% 90/89
CF	Cote d"Ivoire	322,462	12.7	-	-	640	36	8	62	846	2,625	0.926,492		199.266	-2.86	0.4,876	272.10	-5.88
FB	Burkina Faso	274,200	9	-	-	517	29	6	66	325	-	0.522	-29	6		0.3,327	106.234	-0.88
CS	Senegal	196,722	7.2	-	-	906	42	5	-	984	2,239	4,997.64	+79	182.994	+28	3.264,26 5	612.104	+14
FM	Mali	1,240,192	9.4	-	-	641	28	7	59	2,625	2,625	0.929,961	+7.9	196.982	+6.9	0.43,519	241	-8.7
+ OTP	Togo	56,785	3.5	-	-	527	16	2	32	-	-	0.397,995	-35.64	24,826	-39.7 7	0.098	6.499	-10.448
C	Nigeria	923,768	88.5	-	3,52 3	-												
H	Ghana	238,537	15	-	925													
	Benin	112,622	4.8	-	-	579	23	4	45	1,857	1,857	0.943.972	-7	97.1	-9.9	0.34	244.8	-1.6
BN	Niger	126,700	7.2															
NIM	Mauritania	1,030,700	2	690	-	-												
ICFG	Guinea	245,857	6.9	291		662												
CMC				(14)														
	*Liberia	111,369	2.5	348	145													
ng Min- Co.Ltd				(78)														
tional n Co. d.				,	(145)													

Networks	Countries	Area (Km²)	Population 10^6	Route km Gauge (mm)			Motor equipment		Trailers		Average no. of personnel	Rail traffic						
				1,435	1,067	1,000	Locos/ locotrac	Rail/ cars	Coaches	Wagons		Pass. (10^6)	% 90/89	Pass. (10^6)	% 90/89	Tonnes (10^6)	Tonnes/km (10^6)	% 90/89
**LAMCO JV Operating Co.				(270)														
	*Sierra Leone	71,740	4.1	80														
	Cape Verde	4,003	0.38	-	-	-												
	Gambia	11,295	0.86	-	-	-												
	Guinea Bissau	36,125	0.99	-	-	-												
		6,143,407	175,030	1,409	4,593													
					10,474													
				13.4 %	43.9 %	42.7 %												

Source: Study on railway interconnection in West Africa, ECO/TCTD/ECOWAS/13/92.

(*) 1991 data
* Mining railways
** LAMCO: Liberian American-Swedish Mineral Company (The mine was closed down in March 1977)
(1) The Conakry Mines Company (14 km - 1993/1966 Koloum mines)

A. Factors influencing track quality

1. Vehicle performance; impact on metric-track layout

66. Information about the on-track performance of railway vehicles aims at fulfilling the three complementary objectives of safety, comfort and economy.

2. The origin of transverse pull

67. In terms of the track and its layout, the transverse pull by the vehicles has three distinct origins:

(a) The almost static pull due to lack of gradient, or more precisely, due to non-compensated centrifugal acceleration, that is, on a theoretical track;

(b) Risks due to weak spots in the layout when compared to the theoretically ideal track; and

(c) Eventually, the risks arising from the specific phenomena of railway dynamics, such as the instability of the bogie trucks.

68. With regard to this transverse pull on the whole of the track and which depends very strongly on the speed of traffic, particularly over faulty sections, the track chassis opposes this well-known lateral resistance which depends on the friction conditions of the sleepers loaded on the ballast.

69. It is important to note that the performance of a bogie truck on track is not stable except when its speed is lower than a certain level called critical speed, which strongly depends on:

(a) The equivalent conicity of wheel/rail contact;

(b) The bogie's wheel base;

(c) The size and rigidity of the bogie; and

(d) The gauge of contact points.

3. Low-speed traffic

70. At low speeds, on curves with a tight, cramped radius and a steep vertical slant, the most important phenomena, from the point of view of vehicle performance, are produced from the load on the steering wheel. The relation of the transverse pull of this wheel on the rail to the vertical slant becomes too great and exceeds the acceptable limit for the friction conditions between two surfaces in contact. Of course, the wagon's own rigidity and an awkward track are unfavourable factors.

71. In general, the characteristic wheel contours used by metric-track networks are the slope of the tread of the rail at about 1/20 to 1/40 with an angle of 700 at the side of the flanged wheel.

72. In such situations, the limited conditions for derailment of the steering wheel of a vehicle remains the same, that is, $Y/Q \leq Y/Q$ (lim) with a value of 1.2 for axle wagons, rising to 1.8 for bogie wagons.

73. Furthermore, the efforts to steer the outside wheel strongly depend on the friction coefficient observed for the inside wheel on the same axle, which does not depend on the gauge. The laws of variation of the wheel/rail transverse pull on the steering wheel will be identical for the same vehicle on metric or normal track. Because of this, the main criterion applicable both on metric and normal tracks is restriction of the acceptable load on the steering wheel to a suitable level, for curves and for rigid wagons.

74. It is important to recall the conditions to be met for train traffic. Those which are influenced by the geometry of track layout are mainly:

(a) Safety against derailment;

(b) Passenger comfort; and

(c) Equipment fatigue (track and rolling stock).

75. Vehicles operating around curves are affected by two types of pull:

(a) A vertical pull due to the action of gravity; and

(b) A centrifugal force, perpendicular to the axis of the track, which is proportional to the square of the speed and inversely proportional to the radius of the curve.

76. If the result of these two forces is not perpendicular to the track layout, there is a transverse component in the layout.

77. The significance of this component is a function of the speed and of the difference between the outside speed of the rails (large radius) and the inside speed (small radius). This difference between the two is called vertical slant.

78. The result of this centrifugal force, if it is not perpendicular to the track layout, is lack of vertical slant when it is directed towards the outside of the curve and excess vertical slant when it is directed towards the inside of the curve.

79. Between the alignments and the full curve, or between two curves of different radii, parabolic connections have been made, for which the length of the radius and the vertical slant vary proportionally.

4. Trends in loads and speeds

80. In fact, one of the characteristics of a railway is that it is a very strongly concentrated mode of transport, that is, any increase in the load permitted on the track, or any increase in speed to a specific limit generates increased productivity.

81. General trends have seen axle loads evolve towards the current level of 20 to 25 tons and even more for minerals transport and, during the same periods, have seen speeds increased to the recently recorded levels of more than 515 km/h in Europe.

5. Comfort conditions

82. In terms of comfort, there are generally two major considerations for transverse faces:

(a) The transverse acceleration of the body in relation to its almost static section due to insufficient or excess vertical slant, with full acceleration, carry some risks due to faults in the track, mainly lack of vertical slant;

(b) The variation speed of the almost static section of the transverse acceleration of the body which in fact is a characteristic of the track.

83. It is therefore acknowledged that lack of vertical slant should be minimized in respect of the given physiological factor of non-compensated transverse acceleration (generally, 1.5 m/s^2 is admissible).

84. From the point of view of comfort, vertical slant partly compensates for the centrifugal acceleration of fast trains.

85. However, it should be emphasized that the degree of almost static transverse acceleration that is permissible varies greatly in terms of the geometric quality of the track, both in terms of layout and slant. The relative riskiness of strong accelerations additional to those which accompany significant transverse pull reduces the impression of comfort at the rate of non-compensated acceleration (almost static).

86. Upgrading the geometric quality of the track is increasingly achieved by means of surveying railcars which are able to do spectral analysis of track faults using electronic equipment.

6. Fatigue criteria

87. These are mainly associated with vertical loads, which affect the constraints imposed by the infrastructure. As with as transverse pull, these include:

(a) A quasi-static section essentially due to the load balance between wheels of the same axle when going around a curve; and

(b) Risky load dynamics due to faults in the track.

B. Consequences of the impact of track layout parameters

88. Consideration of these various criteria of safety, comfort and equipment fatigue introduces a number of relationships between track layout parameters and gauging which may be summarized as follows:

(a) The comfort criteria imposed by vertical slant, lack or excess of vertical slant and their speeds of variation, with limitations inversely proportional to the gauge and the geometric quality of the same track; and

(b) The criteria for safety and for equipment requests imposed on the other hand, through vertical slant, its lack or excess, and its variation in adjustments inversely proportional to the square of the gauge.

89. It is well understood that this collection of rules, to which must be added the classic rules relating to the longitudinal section (radius of curves and slope adjustment), should be adapted to each line. The choice of vertical slant especially for track layout is often difficult and should be made only after a preliminary study which takes all the following factors into account:

(a) Maximum potential speed as a function of track layout parameters;

(b) Future division into sections of homogeneous speeds;

(c) Identified gradients which restrict the use of rolling stock; and

(d) The combination of types of traffic.

90. Additionally, in order to homogenize the impression of comfort, large sections of lines should select constant vertical slant coefficients (ratio of slant to track curvature).

91. Increasing speeds on the existing lines or construction of new lines should take such rules into account because they determine the optimum yield from railway operations.

C. Modernization of the superstructure

92. Whether achieved through large operations for full renovation or through maintenance replacements, modernization of track superstructure has been carried out through three complementary techniques:

(a) Welded long-rails;

(b) Elastic rail fastenings; and

(c) Concrete sleepers.

93. These techniques have major advantages for lateral track resistance, as well as for the very great adaptability of different types of fastenings and rails.

94. The first two techniques go together and result in so much maintenance savings that they should be rapidly introduced where possible.

D. Use of welded long-rails

95. Given the positive experience of several networks which have laid welded rails, there is no need here to review the functions and the special characteristics of this type of layout.

96. It is only important to stress that a study of the conditions for laying welded long rails should be conducted in each particular case, by examining separately the stability conditions offered by deconsolidated and consolidated tracks. It is very difficult to give general rules applicable to a wide range of climatic conditions, without being too restrictive consequently.

97. Description of a very general nature cannot be given except for the stability conditions of consolidated tracks, in terms of the minimum radius of track layout. Such descriptions should be systematically completed by a study of consolidated track stability as a function of the climatic conditions affecting the whole.

98. The two aspects of layout and outfitting potential clearly show that the track made of welded long-rails is capable of high performance when desirable technical improvements are introduced.

99. Certainly, there are often unfavourable economic conditions which slow down such modernization. The recent choice made by some networks clearly shows that higher speeds are currently a priority. In this regard, it is important to cite the experience of the 105 km/h "inter-city" train traffic of the National Railway Corporation of Cameroon on the Douala-Yaounde route and before this performance, the successful attempt at 160 km/h on the 300 km-long Abidjan-Bouaké route after the metric-track renovation work undertaken on this network at the end of the 1970s.

E. Earthworks and construction of track infrastructure

100. For a long time, earth-moving works were carried out with low resources and, especially, without heavy-duty compacting rollers. Furthermore, the need to fix maximum transport distances led to an almost systematic reusage of excavated earth packed into embankments, although such soils were unsuitable for the purpose. Finally, the ignorance of conditions for transferring wheel loads to the platform did not allow proper appreciation of the thicknesses of the foundation layers, including the ballast, which has caused more or less serious long-term miscalculations: subsidence of embankments, piling up of mud on the track, poor levelling etc., all of which are very costly to overtime.

101. The new methods developed for construction of new railway lines allow for improvement of old structures through renovations and other important works on the railway line.

102. It is important to recall at this stage that UAR is looking into the problem of methods used for intervention activity on tracks and, in 1986, mandated the Trans-Gabonese Railway Office (OCTRA) to carry out a survey of the various types of railway platforms existing in Africa. Thus, information exists on the characteristics of African platforms.

F. New tracks

1. Earthworks

103. It is recommended that earthworks should be carried out with the help of heavy earth-moving equipment, such as mechanical diggers, trucks, etc., the heavy-duty nature of which enables the removal of soils unsuitable for constructing embankments or higher layers from the dumped excavated earth and their replacement with quality soils which may be found at a reasonable distance from the given site. The soils from the displaced earth should be packed in thin, compact layers at 95 per cent of the ONP (Optimum Normal Proctor).

104. The higher part of the dumped soil or the embankment is compacted at 95 per cent OMP (Optimum Modified Proctor). This layer, in the form of sloping a roof, is thickened to 50 cm in the case of dumped earth and loose soils and to 30 cm in the case of processed soils or rocky terrain. From the ONP and OMP definitions, it would appear that if the water retention in the soil used is too high, there must be sufficient drainage to remove it or it should be treated with lime.

105. The various compacting rollers can be used under the following conditions:

(a) Smooth-tyred rollers : Not very efficient on any terrain;

(b) Sheep-foot rollers : Clays and clay sands, as is the case with laterite

(c) Vibrating rollers : All soils, especially sands.

2. Soil classification

106. With regard to soil classifications, the holding qualities of the soils that are essential for laying foundation strata are defined by their geotechnical characteristics. The International Union of Railways (IRU) index 719 classifies soil into four categories: S0, S1, S2 and S3, with rocks playing a special role in category S3. In these four categories, S0 soils are completely unsuitable for earthworks. They should be systematically removed to avoid the danger of serious miscalculations and be replaced by safe soils.

3. Construction of foundation layers

107. Going down from the part lower than the sleepers, to the platform and its foundation strata, the following layers are encountered.

108. The ballast plays a triple role that of drainage, acting as a check on the dynamics of friction of elements against one another, and serving as a facility for re-establishing required levels by mechanical filling. Hardness and resistance to abrasion are characteristic of the Los Angeles and Deval prototype. The coefficient of the resulting overall hardness should be 17 to 20 for sections higher than 10 cm and 14 to 16 for the lower stratum. These dimensions are in the 25/50 mm range.

109. The sub-layers protect the platform against erosion from the ballast and help with load distribution. They include sub-ballasting and foundation layers. The gravel sub-layer of ballast which usually measures 0/30 is therefore one of continuous granulometry. It is compacted at 100 per cent OMP or 103 per cent ONP. The foundation layer which is not present in suitable soils and which enables movement of not only work-site engines but also earthmoving engines, is of graded gravel and is increasingly compacted at 95 per cent OMP or 100 per cent ONP.

110. Eventually an anti-contaminating layer avoids the mounting of the platform ends on the sub-layer. Such a layer may be replaced by a synthetic sheet or in some cases even by a geotextile or a geomembrane.

4. Thickness of sub-layers

111. In calculating sub-layer measurements, thickness is a function of the type of platform, which may be classified as PF1, PF2 or PF3. Table 7 sets out the type of platforms as a function of the soil used in the shaped and formation layer which can be of the same soil as the soil in the foundation or may be a higher quality type of soil. This table moreover shows the thickness of layers occurring in various cases as well as the thickness of principle E of foundation layers placed between the platform and the underside of the sleepers. The definitive thickness is determined by the formula $e(m) = E - a + b - c + d$ in the case of the standard gauge of 1,435 mm. For the metric track, it is recommended that the simplified formula $e = E + 0.10$ be used which is valid for loads not exceeding an axle load of 20 tonnes. At this stage, attention must be drawn to the fact that any errors in determining the thickhesses of layers are not correctable except at prohibitive cost.

G. Platforms

112. Application of the recommendations and standards set out in the previous paragraphs regarding construction of new lines or major works on existing platform structures shows that:

(a) Given the nature of foundation layers, the ballast is always crushed (generally 25 to 50 or 25 to 65) in accordance with the IRU recommendation (0 - 25 or 0 - 31.5);

(b) With regard to the thickness of foundation layers, table 8 below shows the thickness of the ballast layer for various networks and, when this is known, the total thickness of the foundation layers. On the basis of tonnage and axle load, table 8 also gives information about the thicknesses recommended by IRU. This involves minimum thicknesses (maintenance coefficient k = 1) in theoretical application on a platform of average PF2 quality. It is quite evident that this recommendation, if the case arises, should be adapted to the actual quality of the foundation terrain, the age of the network and the importance allocated to maintenance works;

(c) Cleaning of the platform should also receive special care. The transverse slope of the platform is generally between 3 and 5 per cent in Africa (narrow platform) compared to the 4 to 6 per cent recommended by IRU for tracks of 1,435 mm gauge.

H. Summary

113. It is recommended that the work authorities controlling the construction of new tracks and the consolidation of old ones or implementing major engineering works should take into account the new data which are compatible with IRU standards or a compromise close to the old structures.

114. Scattered throughout the subregions of the continent, some intensive activities are under-way or planned for the rehabilitation of railways, for carrying greater loads at higher speeds, while offering safety and comfort. Achievement of these objectives requires rehabilitation, strengthening and modernization of the infrastructure of existing tracks. Since various approaches and methods have been used by some railway networks which have attained significant results in this area, it is therefore important to make a choice on the basis of environmental considerations and on the basic of scenarios leading to improved cost/quality advantages. To fix small-radius curves given the importance of the works and the costs incurred, the time spent on a route and the constraints inherent to network operations have to be taken into account. The interventions should be programmed in stages over time on the basis of the advantages flowing from improvement of rail transport, which faces stiff competition from other transport modes.

115. Considering each country's experiences in this area, inter-network connections would be very useful in the programme for strengthening and modernizing African railways.

116. Decision-makers should not lose sight of the fact that, within the context of reliable rail operations, the rail-track is the most essential factor on which all others are based and without which progress (increased loads, speeds, comfort and safety) cannot be achieved. Engineering works for upgrading the track, including heavy construction and telecommunications and signalling systems for smooth train traffic should therefore be top priorities among the activities to be carried out for strengthening and modernizing African railways.

117. To carry out such strengthening and modernization for upgrading and promoting rail transport, it is important to remember the specific features which are basic to the structural design of a railway track and which are summarized below:

(a) The railway track economically performs the dual functions of vertical and lateral steering of the vehicles, that is, the mechanical system which controls the vehicle on a fixed trajectory. As in all controlled systems, the contacts thus created emanate from the forces reciprocally applied to the track and to the vehicle; and

Table 7. Determination of minimal thicknesses of foundation structure
(IRU groups found under index IRU 714)

Quality of supporting soil	Layers		Platform carrying capacity	E(m)
	Quality	Thickness		
QS1 "Bad" soils	QSI		P1	0.7 + geotextile
	Fine soil mixed with:	0.30	P2	0.55 + geotextile
	QS2	0.55	P2	0.55 + geotextile
	QS3	0.40	P2	0.55
	QS3	0.60	P3	0.45
QS2 "Average" soils	QS2	-	P2	0.55 + geotextile
	QS3	0.40	P3	0.45
QS3 "Good" soils	QS3	-	P3	0.45

Parameters a, b, c, d have the following values;
Values of "a":
0 for the lines of groups IRU 1 and 2 or lines to V > 200km/h
0.05 m for the lines of groups IRU 3
0.10 m for the lines of groups IRU 4, 5, 6 as well as "7, 8, 9" with passengers
0.15 m for the lines of groups "7, 8, 9", without passengers
Values of "b":
0 for wooden sleepers of length L (b and L are expressed in metres, b may be negative if L > 2.50 m)
Values of "c":
0 for a normal size (except for "c" which may be equal + 0.05 m or 0.10m for the lines of group IRU 7, 8, 9 SV or for the service tracks in categories B and C).
Values of "d":
0 when the maximum nominal axle load for trailer cars is <200 kN
0.05 m when load is 225 kN
0.12 m when load is 250 kN
0.35 m when load is 300 kN

Source: General Survey of Railways, 1988.

Table 8. Layer thicknesses compared to IRU recommendations

Network	Tonnage			Foundation thickness		Recommendation IRU		Observation
	Journ.	Axle	Gr. IRU	Ballast	Total	Ballast	Total	
SNIM (Mauritania)	300,000	25	15	25	20	40	Firm sub-layer	
OCTRA (Gabon)	250,000	25	15	35	15	39	Gravel sub-layer	
CFA (Angola-Moçamedes)	21,400	18	20		15	36		
RNCFC (Cameroon)	15,000	20	15	30	15	36	Grave sub-layer	
CFCO (Congo)	11,000	20	20	50	15	35	Firm sub-layer	
RCFS (Senegal)	8,700	17	34	44	15	35	Compacted sand sub-layer	
OCBN (Benin-Niger)	1,500	17	25	40	10	33		
CFE (Djibouti-Ethiopia)	1,400	17	10	10	10	33		
SNCFT			30	30				
Marrakech-La-youne			25	80			Firm sub-layer	
CFM (Mali)			28	35				
NRZ (Zimbabwe)			25					
TAZARA (Zambia-Tanzania)			25	25				
RCFT (Togo)			27	27				

Source: General Survey of Railways, 1988.

(b) Under the influence of these forces for maintenance of full mechanical capacities the optimum working levels of the various components forming the transmission chain of these forces on the soil, sound functioning of the track remains at any moment, for every component, lower than the set limit for rupturing (or of fatigue) of the equipment constituting a given component.

118. A railway line is functioning well when the constraints imposed by rail/wheel contact are transmitted after considerable reduction, to the holding soil, both for its spatial and temporary weakening in cases of shock, by absorbing the forces through the elasticity and flexibility of various elements, especially the ballast.

119. In addition to holding capacity and suspension may be added the function of steering carried out jointly with the first two factors by the conicity of the wheels.

120. The effect of reducing the forces on track structure is remarkable. In fact, the railway track weakens on the order of 1,000 of the working rates of materials between the steel of the surface of rail heads (sometimes collapsing under load levels) and the holding soil.

I. Recommendations for consolidation of tracks and related installations

121. Railway strengthening activities carried out within the context of consolidation and modernization require the establishment of a national and subregional master plan with the goal of facilitating programme coordination of various railway systems. Such a master plan would have the advantage of taking into account the scheduled programmes of all major developments planned for the railways of the continent. To prepare this plan, each railway network should provide its national programme which should then be included in the subregional programme. The facilities of the General Secretariat of UAR should be made available (to subregional vice-presidents to upgrade the skill levels in the subregion and to the General Secretariat for the region) to facilitate information activities, harmonization, monitoring of inter-network exchanges and coordination of the future possibilities for pooling existing capacities for programme implementation.

122. Establishment of such a programme should be preceded by identification of the weak spots in the rail networks in each country, in order to determine which zones are critical and the level of priority to accord to various forms of intervention for development.

123. As mentioned in the previous chapters dealing with the state of railway tracks, consolidation activities in some zones should focus on infrastructural priorities and, in other zones, on the superstructure, to meet the immediate need for train traffic safety. It should be the same for engineering structures, most of which date back to the beginning of the African railway industry.

124. On the basis of the expressed needs of networks, it is necessary to identify the availability of equipment in the various countries and their inventories compiled in terms of joint action for their maintenance in a state of operation and their future use on the basis of location or transfer contracts by neighbouring networks.

125. To this end, feasibility studies were conducted to determine the viability and the profitability of such operations. Parts of the equipment were identified which required rehabilitation at reasonable cost, and others reserved for replacement through acquisition of fresh equipment from the civil engineering office for the works to be undertaken. It should be pointed out at this stage that the railway networks which have carried out major works over time are equipped for such activities and have equipment which could be of service to other networks. All possible solutions should be examined for reducing investment costs as much as possible. Thus, priority should be given to acquisition of rails, sleepers, rail fastenings, small machinery and machinery not available in the subregion for performance and control of the works. It will be necessary, in certain specific situations,

to study the modalities for transporting equipment from one non-interconnected network to another and to compare the costs in terms of improved use of the meagre resources at the disposal of railways.

126. In the same context, available skills should be used at lower cost, since such skills are backed by solid experience in the area of major track realignment and construction works.

127. To carry out the works planned over time, the networks should organize for encouragement of group purchasing in order to profit from economies of scale.

128. Indeed, much equipment could be acquired through group purchasing to maximize the benefits of economies of scale. Workshops could be specialized by subregion for repair and rehabilitation of small equipment at reasonable cost. Equipment exchanges and standardized spare parts could also be objectives.

129. Since action for upgrading infrastructure involves much construction, on the basis of the constraints inherent to the operations and to the country's environment, it is important that the cost of realignment activities and the impact of time savings recorded in the zones concerned should be studied so as to establish the ranking of priorities for programme performance.

130. Consolidation and modernization works should be done with welded long rails as much as possible, with a 45 kg weight per linear metre used in the networks serving Southern Africa within the perspective of future unification of African railway networks.

131. Several solutions exist with regard to methods for development activities. It is up to each network to select those which have been tested and which are economical but also meet the standards and can guarantee safety of the train traffic.

V. STRENGTHENING AND MODERNIZATION OF ROLLING STOCK

A. Trends in rolling-stock design

132. The range of rolling stock available includes tractive equipment (locomotives, locotractors) and trailer equipment (passenger coaches and freight wagons).

133. The first rolling stock was constructed at the dawn of the railway era worldwide. Such equipment was constructed with light-weight characteristics which met the operational requirements of the time. They were designed for traffic on tracks also built with light carrying capacities. In Africa, the gauge used by railways for the first penetration tracks was narrow. In the subregion of the continent, this ranges from 0.55 to 1,067 mm. The rolling stock was constructed accordingly. Thus, wagons of the period hardly went above 10-tonne loads.

134. As time passed, changes gradually occurred in the design of railway equipment. The development of tractive equipment and trailer equipment occurred in stages. Steam locomotives were developed ranging from small-, medium- and large-engine capacities. Trailer equipment evolved from the wagon design with reduced body dimensions to wagons with much greater capacity and equipped with bogies instead of axles. The characteristics of materials used also became increasingly sophisticated. Gradually, from generation to generation, railway rolling stock has grown from the simple designs of the end of the nineteenth century to the complex technology involved today in the manufacture of modern rolling stock.

135. For tractive equipment, the steam locomotives of the last generation were replaced by diesel locomotives, and later electric ones in some African countries. The introduction of diesel engines in Africa, which made their appearance a little before the Second World War, reached its peak around 1950.

136. The trailer equipment (wagons and passenger coaches) has also undergone extensive design modifications. Several generations of rolling stock have been put on the rail transport market. Following the partition of Africa by the colonial powers in 1885, the types of equipment differed from one region to another and from one country to another. Thus, rolling stock originating from the old metropoles can be found on the African continent and includes equipment which helped to construct the railways and the rolling stock. The beginning of this diversity goes back therefore to this period and, a century later, Africa faces serious problems in consolidating installations and in standardizing and normalizing the parts and the units forming its rolling stock.

137. As mentioned earlier, the fleets of African rolling stock are an incongruous mixture and are obsolete for the most part.

138. To meet the requirements of reliable transport, there has to be reform of the image of obsolete equipment which spoils the reputation of the stock as well as rehabilitation of wagons and coaches, after carrying out an intensive study. On the basis of profitability calculations it should be determined which wagons and coaches may enter this category and then a programme for acquisition of equipment should be prepared, given the adequacy of the stock for traffic requirements.

139. It is the same with tractive equipment (locomotives and locotractors) whose life expectancies are different from those of trailer equipment. For this category of equipment, there exists the possibility of using medium-powered locomotives for carrying out manoeuvre operations and serving branch lines. Here also a profitability study should be conducted to determine the viability of operations and the status of spareparts supply for equipment more than 20 years old poses serious problems.

B. Areas of intervention for strengthening and modernizing rolling stock

140. In the previous chapters we have clearly associated equipment maintenance and design considering the interdependence of these two aspects.

1. Tractive equipment

141. For this type of equipment, given its complexity, consolidation and modernization very often requires the help of the manufacturer. The study carried out before attempting the intervention should be jointly done by the management of the railway network and the manufacturer who has supplied the equipment. On the basis of the results of the study and of the advantages flowing from the operations conducted, while taking into account investment levels and the number of machines forming the fleet, the decision should be taken on the basis of all the parameters acting on, or influencing, the life expectancy of the equipment and on its maintenance.

142. Consequently, it is important that formulation of rehabilitation and modernization programmes should carry out a survey of networks using the same rolling stock in the subregions. It will thus be possible to minimize the cost of intervention by organizing group purchasing of parts and units required for operations. Similarly, the studies carried out in the subregion could be useful to others. Workshops should be specialized for certain subregional operations within the framework of pooling existing capacities.

2. Trailer equipment

143. As with tractive equipment, nothing should be done unless a serious study is first carried out to determine the profitability of the projected action.

144. Although wagon construction does not require sophisticated technology, it is still important to compare rehabilitation costs with those of new acquisitions and to take into account the maintenance

constraints over time for old equipment. To guide decision-making, only profitability calculations which take all factors into consideration are relevant.

145. In many railway networks, maintenance schedules have not been respected. This has resulted in a situation where many wagons and passenger coaches remain parked and unused for several seasons. Such equipment, if it is to be rehabilitated, consolidated and modernized, should receive extensive attention focusing on all the elements of safety, especially the equipment for running the train and for braking. For many wagons, consolidation and modernization should consider conversion from vacuum brakes to compressed air brakes which are more efficient and reliable. Bogie chassis frames should be strengthened and solidified to resist the stress of the track. The material used in construction of the axles and the rails should be suitable for this category of parts and should meet the safety standards imposed by use of such material.

146. When there are interventions, the need for commercial services should be considered for specialization of certain equipment and future modification of their design, with the aim of adapting them to certain types of transport. After consolidation, strengthening and modernization operations, activities should focus on achieving an adequate fleet of vehicles.

147. To this end, inter-network cooperation is necessary, especially for the interconnected network where the possibility exists for forming equipment pools that are able to ensure regulation of traffic using central points located in various parts of the networks.

148. For passenger coaches, modernizing activities should go beyond simple technical aspects. They should aim at comfort in all its forms (interior furnishings of the compartments, seats, sound-proofing, public address system, air conditioning for some types of coaches, lighting, conveniences provided, etc.). The mechanisms for running the vehicle should be of solid design and should be equipped with a good suspension and maintained in operational conditions at commercial speeds suitable for customer requirements. As much as possible, progress achieved in the construction of equipment for other modes of transport should also be considered.

149. In carrying out the consolidation and modernization operations, maintenance requirements should be constantly borne in mind in order to maintain the quality of renovated equipment. As already mentioned in the previous chapters, without the maintenance which guarantees quality and standards, modernization efforts will not achieve the desired objective. Given the importance of this objective which, unfortunately, is not always well understood, a chapter in the present study has been devoted to this subject. This is also the case with the supply of spare parts necessary for repairs and maintenance throughout the life of the equipment.

C. Rolling stock designs and maintenance

150. Future maintenance of equipment with a very long life and a high unit value should receive very careful attention. Indeed, maintenance requirements should already have been taken into account at the design stage.

151. The inescapable costs of labour and the real difficulty of finding qualified personnel are only two of the reasons for stressing the problem of maintenance.

152. Indeed, the actual cost of maintenance expenditure on railway equipment may be estimated at an amount at least four times the cost of initial investment. It is therefore important that the new equipment meet the desired level of performance and, above all, be aimed at raising overall network productivity.

D. Programme of operations

1. Influential parameters

153. The basic conditions of network operations which are characterized by the gauge of the track, the geometry of curves and the structural dimensions of rolling stock often seem obvious, but the "state of the track" and maintenance policy have a significant impact not always clearly perceived in the design of bogies and suspensions. A piece of equipment may be running with a worn-out suspension over a good track. Depreciation of the equipment calls for more sophisticated suspensions aimed at reducing the fatigue of non-suspended elements. The speed of traffic is also of great significance and it is important to take this into account.

2. Unification

154. The resolve to unify the technical arrangements between networks offering different services or built at different times (universality) is due to the fact that the cost of spare parts and the time required for training maintenance personnel in new techniques have to be considered, forcing a search for technical solutions tested over a relatively long time, in order to draw the full benefit.

155. In this regard, the services operated are likely to be more "conservative" than the technicians who are always on the lookout for progress in performance or even simply the elegance of solutions.

156. Technical progress for railway equipment cannot be achieved continuously, but rather by gradual "steps up a ladder" sufficiently spread over time.

157. Within this objective, clarification of operational theories so as not to create equipment specific only to the state of the market at a given time is a difficult task, but strict attention to this is indispensable for making future management of stock economical.

158. Whatever railway network is involved, such "universality" should be possible for passenger and freight trailer equipment aimed at satisfying a necessarily multi-faceted commercial demand. The constituent parts of such equipment (bogies, body structure, braking equipment, doors, etc.) can nevertheless be standardized. The savings on spare parts, tools and personnel orientation are often inadequately computed in the selection process.

3. Equipment reliability

159. Once the programme is established and the operational environment is set, maximum equipment reliability has to be sought. Such reliability is achieved by using all or part of the following methods:

(a) Solutions widely known or carefully tested. Innovation is always very attractive, sometimes profitable to the performance plan but rarely implemented. Intellectual rigour applied to any new product may be viewed with suspicion but it is only the wisdom of the operator;

(b) Not testing a piece of equipment to the limits of its capacity: this is difficult to avoid when financing constraints and service requirements are considered, but it is an essential condition that helps prolong the life of the equipment;

(c) Wise placement of useful redundant items but avoidance of costly sophisticated ones.

160. To take past experience into account, the factors affecting organizational arrangements or work methods are dealt with in the chapters which follow.

E. Technical specifications

161. General technical specifications aim at setting, as their name implies, collective standards of performance for all the equipment. In addition to a handbook of legal clauses, such specifications provide some of the technical clauses valid for all equipment in a network. Here again, this very desirable unification of requirements is not easy to achieve without effort. If care is not taken, wagon wheels could be (wrongly) a different size from the wheels of passenger coaches.

F. The working group

162. To effectively determine whether to acquire new or to transform old equipment, it is useful to bring together a project team in charge of detailing the constraints and the objectives which the equipment has to meet.

163. Commercial services for coaches, wagons and services using motive equipment in establishing the tractive equipment programme or the modalities of operations need attention. The participation of maintenance technicians enriches the ideas of those responsible for the use of the new equipment. They bring field experience and by "looking out" for problems, they can avoid action contrary to the maintenance policy.

164. A number of costly modifications will be avoided in the future. Moreover, since the choices have been made collectively, no one can claim to have been excluded.

G. Use of physical properties

165. When using materials, choice has to be made between the materials to be used in making the equipment and in the manufacturing of the parts and units for the railway equipment. As is easy to point out, some interdependence and interaction exist between the railway track and the rolling stock. It is because of this state of affairs that any study on the railway track necessarily has to consider various limitations of the rolling stock and vice-versa.

166. This is the case for example with monobloc wheels. They are able to avoid slippages and retiming of the solid tyres, which is always difficult and can run at high speed in safety. It is true that the existence of a large number of curves with a small radius poses problems due specifically to rapid wear of the flanged tyres.

167. When choosing materials, it should constantly be taken into account that the life expectancy of railway equipment is of the order of 25 to 30 years for locomotives and 35 to 40 years for wagons. The structures should be able to hold up to a certain amount of service without needing heavy repairs for a number of years. Fatigue-resistance calculations for this purpose allow correct sizing of the constituent parts and it is necessary to ensure that corrosion does not destroy what official studies carried out have taken the greatest care to calculate.

168. The experience drawn from the large amounts of equipment in service that are made with light frames and alloys should help to improve various designs for overall systems. As a result, requirements for rolling stock construction cost a great deal of the investment, but they are indispensable to guaranteeing both the longevity of the structures and their reduced maintenance needs.

169. The objective of 30 years' life expectancy for a piece of equipment, without any major structural repairs and of ten years between two coats of paint, for example, are possible from now on in certain climates.

170. Everything should therefore be done to ensure the construction of equipment that is both solid and reliable for railway operations. An overall perspective of stock utilization should prevail over

short-term financial interests. General revisions for routes now totalling over a million kilometres, only take a few days, yet arrangements can be made to get sub-systems ready to roll and to have qualified staff.

H. Achievement of quality interventions

171. Achievement of quality interventions depend on the actions taken by management personnel. Based on observation of the situation and taking into account the experience of "on-site personnel" who set indisputable criteria, the working documents (inspection files, repairs files, work inventories) prepared in this way can win the support of the person carrying out the tasks. Then, the latter may be able to take full responsibility for the work entrusted to him. The stakes deserve to be considered because whatever the value of maintenance regulations, it is obvious that the determining factor for obtaining a high level of quality is based on the state of the art of implementation itself.

172. Ultimately, it is the person carrying out the work who thoroughly knows the true standards of quality. In addition, the actions taken by managers should deploy personnel in the optimum conditions possible with regard to equipment and also in terms of the psychological motivation for accomplishing the task.

173. To achieve this, interest and participation have to be revived. In particular:

(a) As far as possible, the employee himself has to set out the nature of his task, perform it and finally ensure its quality. In general, this means assigning all the tasks requiring job expertise and control to the employee who will perform them from the beginning;

(b) The employee himself should participate in task definition, that is, definition of the area to which he will apply his skills and carry out his duties.

174. The support of project management and staff may be added to the initiatives identified above because the preceding activities cannot be properly developed except to the extent where it is possible to have the support of a control base and high quality personnel, that is, who are competent, efficient and motivated.

I. The results

175. The results to be achieved rely on the means of quality control and the costs of maintenance.

176. Maintenance costs should be permanently monitored by the various employees by means of criteria and ratios which fulfil the following objectives:

(a) To have a mass of data enabling continuous objective comparison at any moment for comparable establishments and, in time, for the same establishment;

(b) To compile and summarize the parameters for guiding the actions of the personnel responsible;

(c) To draw from the accounting system not only the prices of products but also the management results in the different sectors of responsibility.

177. Quality criteria are expressed in terms of rate of reliability, rate of availability or rate of immobilization.

178. The management ratios concern both service operations (freight rates, for example) and the results of maintenance (for example, cost of maintenance per km/vehicle).

179. Improvement of management results basically rests on effective improvement of organization. The leaders of institutions should unceasingly seek all possible progress in this area. After this, the institutions themselves should continuously verify that the objectives which have been assigned are achievable or should measure the gaps in relation to such objectives, in order to take timely corrective action.

VI. EQUIPMENT/SUPPLIES MANAGEMENT

A. Importance of supplies in equipment management

180. A railway enterprise is a very complex organization in comparison with other modes of transport. A railway has to construct and maintain considerable infrastructure representing the following much-needed capital investment:

(a) A network of tracks;

(b) Locomotives;

(c) Passenger coaches and freight wagons;

(d) Signalling and telecommunications equipment; and

(e) Station buildings, etc.

181. The efficient use of such installations has a direct influence on the capacity of the railway to perform its duties with regard to the economy of the country and its own financial stability. Effective use of such capital investments, whether the track network, locomotives or even trailer equipment, depend very much on the rapid and timely availability of materials, spare parts and accessories.

182. The modernization of railway equipment has made this job even more difficult and costly.

183. Today, the number of component pieces in a locomotive is in the order of 10,000 different parts, the great majority of which have to be imported. This means long delays and uncertain supplies.

184. One cannot therefore talk about strengthening and modernizing railways and rolling stock without considering this very important factor of availability of supplies, which is an element influencing the level of performance of various programmes for the railway track, signalling system, telecommunications, the rolling stock and related equipment.

185. Effective control of this aspect depends to a large extent on equipment availability which, in turn, impacts on transport capacity and reliability of operations.

B. Stock management

1. The need for stock management

186. A railway has to stock spare parts and whole units in its warehouses to meet the needs of maintenance and repair units for locomotives and trailer equipment, when necessary.

187. When the parts and the units are manufactured in the workshops, the warehouses should also stock raw materials and tools. Similarly, stocks of parts and materials are necessary for supplying maintenance yards or the track, the signalling system or other fixed installation. Maintenance efficiency and the resulting equipment availability depend on high-level maintenance of stocks, in order

to have the necessary articles in the time desired, to the specification wanted and also at lower cost. This implies that the needs have to be forecasted and the orders for the parts should be placed in sufficient time so that the equipment can arrive before available stocks are exhausted. This is done through the interplay of systems and procedures for ordering supplies which must be followed up automatically by warehouse personnel. There are two basic systems used for supplies replenishment, namely the "minimums and maximums" stock system and the periodic stock-control system.

188. In most networks, one or the other of the two systems mentioned above or a combination of both are used. At the present time, the procedures are better organized and more effective due to technological progress and development of computerized programmes for stock management.

2. Purchase of parts and units for diesel locomotives

189. Diesel locomotives are a costly investment. It is therefore wise to use them as efficiently as possible. This depends first of all on the quality of maintenance, which affects the technical availability of stock for traffic runs and also on the operational use made of available motive power by operations management. The quality of maintenance is a direct result of the timely availability of necessary parts and units which should be stocked in the warehouses.

190. To avoid often costly improvizations, it is useful to prepare a list of articles classified as vital, including the parts which are the most frequently used for maintenance, both because these parts are scarce and because they are subjected to very frequent faults. Technical availability of locomotives very much depends on these vital articles and, consequently, it is very useful for management to review their stock situation very frequently and take suitable corrective measures.

C. Standardization and restriction of the number of models

191. In standardization, the first step is to prepare a convenient system of classification and a catalogue giving the description of the articles and the reference to plans, designs and specifications.

192. Establishment of such a classification or catalogue, whatever it may be called, would help to speed up identification of such articles as well as of those which cannot be standardized and for which the file index could be removed when the stock is exhausted.

193. In addition, an assessment of the value of stock should also be frequently carried out. This requires a critical assessment of each important article in the inventory by function and by the possibility of removing it from the inventory or replacing it with an article of less unit value but providing the same technical service.

194. Further cost-reduction possibilities should also be examined for using a raw material of corresponding quality but which is less costly, and so forth.

D. The need for a coordination body and the role it should play

195. The areas which should be monitored and managed by UAR include standardization of rolling stock, data collection and dissemination about supply sources and possibilities of group purchasing of elected articles.

196. The advantages of group purchasing, for example, are numerous. Among these advantages may be mentioned wider competition in terms of best prices and supply time frames, new supply sources, etc. In the special case of African railways which use locomotives with similar and sometimes identical characteristics and same types of trailer stock and miscellaneous equipment, bulk purchasing of selected articles and equipment would lead to substantial savings. Following such procedures would also encourage greater standardization.

197. Finally, let us note that the items which are of a type easily managed through bulk purchasing are rails, sleepers, track apparatus, rail fastenings, small machinery and trailer equipment components.

198. The assembly parts for the locomotives used in most sections of a railway network could also be ordered through the same procedure, to the benefit of railway administration and potential equipment suppliers.

199. From the preceding, it follows that the area of "supplies" constitutes a multiple function on which all factors associated with railway operations closely depend.

200. Without effective control in this area, it is not possible to carry out programmes in good time and in a satisfactory manner. Such programmes include rehabilitation, strengthening and modernization or deal with the daily management of a railway network.

VII. CONCLUSIONS

201. Within the context of railway development and promotion of rail transport in Africa and to strengthen the contribution of the railway to meet the continent's economic development, it is obvious that actions need to be taken for rehabilitating, strengthening and modernizing rail infrastructure and equipment, given the state of depreciation of some railway tracks and the obsolescence of rolling stock.

202. In this regard, the present study, which was carried out on the basis of a review of various parameters which have handicapped rail transport development, is able to offer suggestions and recommendations with regard to renovation of various components required for African railway networks. In the face of competition from other modes of transport, the objective is to make the railway competitive, reliable, able to carry heavier loads and support higher speeds for train traffic, as required by customers and by the environment.

203. Taking such environmental considerations into account, experience has shown that it is not enough to take extensive action for consolidating and modernizing the track and equipment. It is also very important to find ways and means to ensure proper maintenance in order to secure sound functioning over time. It is to take this concern into account that the maintenance aspects associated with equipment design and construction have been dealt with in this study.

204. In this period of financial difficulties afflicting most African railway systems, it is important that once strengthening and modernization programmes are carried out, arrangements set out should be instituted at all levels in order to avoid early deterioration of tracks and equipment. In most cases such depreciation, unfortunately, is often due to the absence or poor adaptation of maintenance methods, not forgetting lack of available resources.

205. To achieve a successful railway enterprise, the managers responsible should always make use of the range of resources at their disposal, in closely linking the two objectives of design and maintenance. These should be based on the safety offered by a solid and stable railway track and by the high-performance of rolling stock designed and constructed in accordance with the standards set for the material and to meet the operational requirements of safety, speed, regularity and comfort.

206. It is only at this price that the goals of consolidation and modernization of African railways will be achieved, thus providing this mode of transport with the enabling conditions required for contributing effectively to the process of physical integration and the socio-economic development of Africa.