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UNITED NATIONS INDUSTRIAL
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EXPLORATORY MISSION TO ASSESS THE POTENTIAL
FOR MODULAR LOW-COST PREFABRICATED
WOODEN BRIDGES
RP/SUD/77/003
SUDAN

Prepared for the Government of the Sudan
by the United Nations Industrial Development Organization

Based on the work of Harald Erichsen, consultant
in timber engineering

id.77-3275

Explanatory notes

References to dollars (\$) are to United States dollars, unless otherwise stated.

The monetary unit in the Sudan is the Sudanese pound (LSd). During the period covered by the report, the value of the LSd in relation to the United States dollar was \$US 1 = LSd 0.3976.

The following exchange rates are used in the conversion of country currencies to United States dollars:

<u>Country</u>	<u>Currency</u>	<u>Exchange rate in March 1977</u>
Costa Rica	colón (¢)	8.57
Kenya	shilling (KSh)	8.31
Uganda	shilling (USh)	8.31

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

References to "tons" are to metric tons, unless otherwise specified.

The following abbreviations of organizations are used in this document:

FAO	Food and Agriculture Organization of the United Nations
NCR	Norwegian Church Relief
UNDP	United Nations Development Programme

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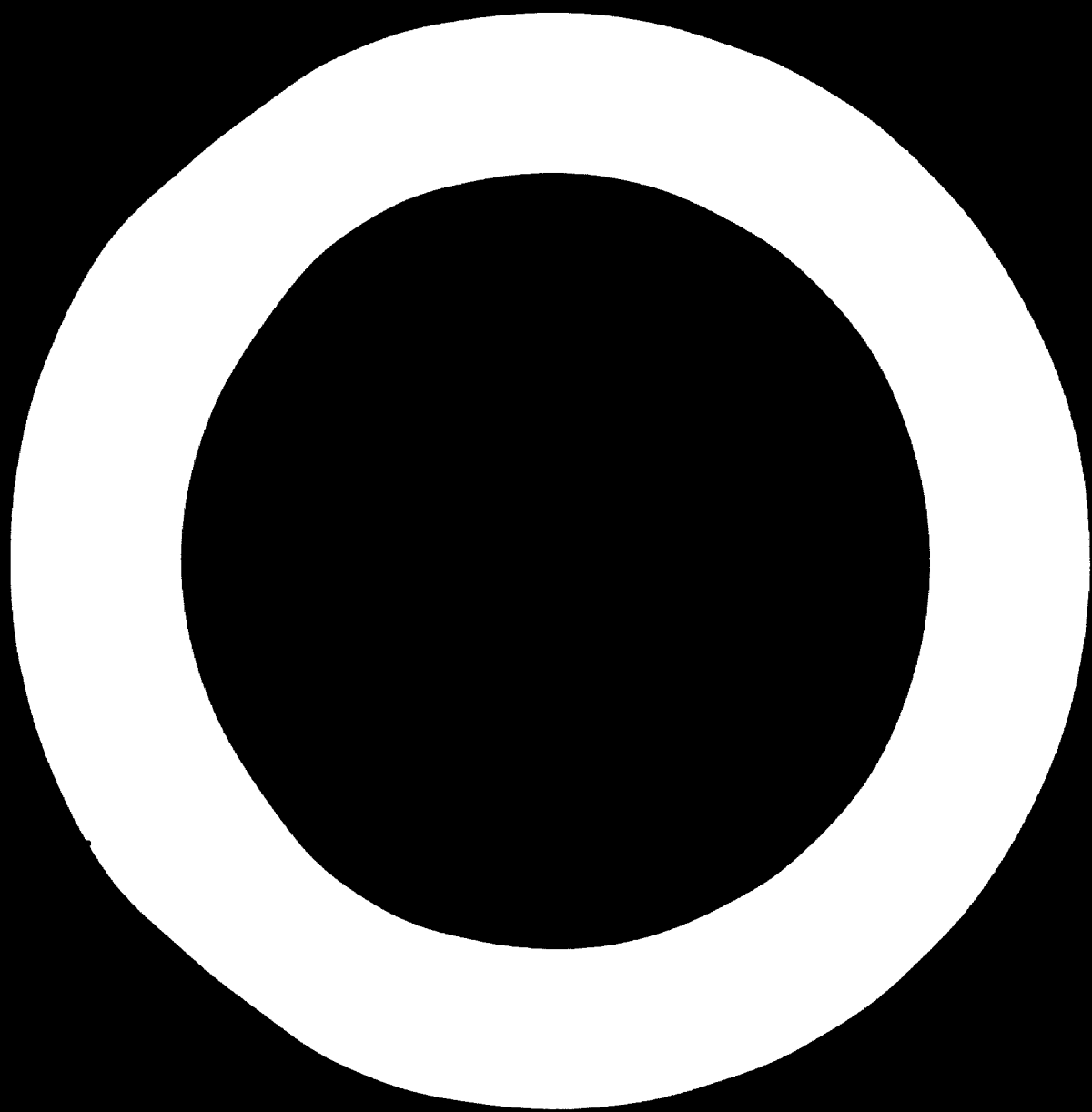
ABSTRACT

This is the report of the United Nations Industrial Development Organization (UNIDO) project "Exploratory Mission to Assess the Potential for Modular Low-Cost Prefabricated Wooden Bridges" (RP/SUD/77/003).

The demand for low-cost modular timber bridges (Collins type) in the Southern Sudan is found to be comparatively low. The parties that showed interest in the design have their own excellent facilities and skilled personnel. The Government showed little interest in this kind of bridge and qualified counterparts do not seem to be available in the Southern Sudan.

A study on the availability of the raw materials shows that every component of the bridge has to be imported.

It is recommended, therefore, that a UNIDO bridge project not be started in the present circumstances, but instead that the sawmilling operations should be improved in the Southern Sudan, wood preservation should be introduced, the wood-drying facilities and techniques should be improved and wooden school furniture should be produced.



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INTRODUCTION

A UNIDO technical assistance project in Kenya has developed a low-cost prefabricated modular timber bridge. It was felt that this system would also be applicable to the Southern Sudan. In order to assess local conditions and requirements, UNIDO initiated a project "Exploratory Mission to Assess the Potential for Modular Low-Cost Prefabricated Wooden Bridges" (RP/SUD/77/003). The consultant was sent to the Sudan for one month (March 1977); his duties were:

- (a) To determine the need for such bridges;
- (b) To identify sources for raw materials;
- (c) To identify the potential wood species;
- (d) To determine the availability of other materials, such as steel plates, bolts, rods etc.;
- (e) To identify the workshops where the prototype bridges could be produced.

I. FINDINGS

A. Demand for modular timber bridges (Collins type) in the Southern Sudan

The demand for modular timber bridges is found to be smaller than originally expected. This is mainly because the Regional Ministry of Communication and Transport does not intend to use timber bridges on main roads. The remaining feeder roads are not under the responsibility of a central ministry, but are taken care of by the local district offices. The actual road-building programmes on feeder roads are carried out by international or foreign organizations in the different areas of the Southern Sudan, partly in combination with other development projects.

The following demand for bridges with spans of 9-30 m could be assessed:

Torit area	12	Norwegian Church Relief (NCR)
Loka/Jei area	15	German Forestry Team/Project Development Unit, World Bank
Wau area	30	Food and Agriculture Organization of the United Nations (FAO)
Total	57	

It can be assumed that the demand will rise after a successful introduction of the Collins type bridge and parallel with an expanding road-building programme for feeder roads. On the other hand, part of this demand will certainly be satisfied with other bridge concepts such as:

Simple steel trusses with wooden decks for small spans of 3-12 m

Low-cost reinforced concrete bridges for 12-m spans (or multiples of 12 m) as designed by Messrs. Kocks, consulting on behalf of German Caritas/GTZ in Maridi

Bailey bridges for spans of 25 m and up.

B. Workshop facilities

There are excellent workshop facilities available in the Southern Sudan, which would be suitable for the construction of Collins type bridges. Only in a few cases would additional equipment have to be purchased.

These facilities are:

<u>Workshop</u>	<u>Location</u>
NCR	Torit
German Forestry Team	Loka
German Caritas/GTZ	Maridi
United Nations Development Programme (UNDP)	Jambio and Wau
FAO	Wau/Pongo Aweil

All these workshops have skilled expatriate personnel and Sudanese counterparts. Welding and drilling equipment is available and most workshops have earth-moving equipment and experience in concrete constructions, to build embankments and foundations.

C. Raw materials

Steel parts

The Collins design requires mild steel plates of the following thicknesses: 6 mm ($\frac{1}{4}$ in.), 9 mm ($\frac{3}{8}$ in.) and 12 mm ($\frac{1}{2}$ in.) The plates usually come in sheets of 3 ft x 4 ft (244 cm x 122 cm). They have to be imported. In Khartoum only 6-mm material was found to be available and the supply was said to be irregular. Considering also the transport costs to the Southern Sudan and the sometimes excessive transport times of up to three months, as well as the irregularity of the transport facilities, the logical conclusion is to import the metal sheets by truck from Kenya. Transport time from Nairobi to Juba is 1-3 weeks.

The same applies to all the other necessary steel parts that are not locally produced such as bolts, nails, and round steel bars.

Timber

The table shows the timber species, which are found to be suitable for the construction of Collins type bridges. These species occur in the various forest areas of the Southern Sudan.

Timber species suitable for Collins type bridge construction

Botanical name	Strength group (Collins)	For truss construction			For deck construction			Available dimensions			Remarks
		Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	
<i>Azelia africana</i>	S 3	x			x			x			1, 4
<i>Albizia alymeri</i>			x			x			x		
<i>Burkea africana</i>	S 2	x			x				x		1, 4
<i>Celtis soyauxii</i>	S 4		x			x			x		3, 4
<i>Chlorophora excelsa</i>	S 5	x			x			x			1
<i>Cordia africana</i>		x				x				x	1
<i>Cupressus spp.</i>	S 6	x	x			x		x			3
<i>Erythrophleum guineense</i>			x			x		x			1, 4
<i>Khaya grandifolia</i>	S 4	x				x		x			2
<i>Khaya senegalensis</i>	S 4	x				x		x			2
<i>Isoberlinia doka</i>			x			x			x		2, 4
<i>Olea hochstetteri</i>	S 3		x			x			x		2
<i>Ocotea usambarensis</i>			x			x			x		2, 4
<i>Podocarpus spp.</i>	S 5		x			x			x		3
<i>Prosopis africana</i>	S 3	x				x			x		1
<i>Pygeum africanum</i>			x			x			x		2
<i>Tectona grandis</i>			x			x				x	2, 5
<i>Terminalia glaucenscens</i>			x			x			x		2, 4

Key to remarks: 1. Durable species, no treatment necessary.

2. Normally durable species but treatment preferable (dipping, spraying or brushing with creosote or similar product).

3. Non-durable species, pressure treatment necessary with an adequate product against fungus and insect/termite attack.

4. Hardwood, predrilling of nail holes necessary to avoid splitting.

5. Plantation timber of good quality but small dimensions. The timber derives from the regular thinning of the plantations and is only 20-30 years old (1977). Ideal for furniture production.

Note: Only good grade timber without any sapwood may be used.

Considering the actual availability and the present lack of any treatment plant, preference is given to:

<u>Khaya senegalensis</u>	}	for the construction of the panels (trusses)
<u>Khaya grandifolia</u>		
<u>Isoberlinia doka</u>		for the decking

The total sawmill capacity in the Southern Sudan is about 7,000 m³ per year, but the actual output is only about 3,000 m³ per year. This is because most sawmills work with very old equipment and suffer losses of up to 15 working days per month because of breakdowns and lack of spare parts.

The timber produced is immediately absorbed by the local market (government requirements) or sent to Khartoum. It is, usually, of poor quality, because it is not allowed to dry properly and because the non-durable species are not treated.

This situation leads to the conviction that the timber necessary for the construction of Collins type bridges would also have to be imported from Kenya in order to secure a regular supply of sufficiently good grade timber.

D. Costs and cost comparisons

Steel prices

Khartoum (Ministry of Works store):

Mild steel^{1/} sheets (imported):

	<u>LSD</u>
3 ft x 4 ft x $\frac{1}{4}$ in.	16 (1975 price)
3 ft x 4 ft x $\frac{5}{8}$ in.	46

Plus 15% tax (for government sector only; the private sector has to pay higher taxes). Average steel price per kg: LSD 0.140 (\$0.35) per kg.

Kenya (UNIDO Bridge Project):

Mild steel price per kg: KSh 4 (\$0.49)

	<u>KSh/kg</u>
Mild steel plates, ready made for use on Collins type bridges (including welding and drilling)	10
Bolts (specially made)	14
Nails	5
Round steel bars	4

^{1/} Weight: 7.35 g/cm³.

Timber prices

The prices for timber of following dimensions: 2 in. x 10 in., 2 in. x 8 in., 2 in. x 6 in., 2 in. x 4 in. are:

	<u>Per m³</u>	<u>\$/m³</u>
Southern Sudan	LSd 60	150
Kenya	KSh 1,100	135
Uganda	USH 1,800	220
Costa Rica	¢ 1,000	117

To the above prices 20% should be added for purchasing timber cut to size in order to avoid excessive waste of timber (up to 40%).

Timber prices in the Southern Sudan have been set by the Government. They do not represent the actual market price. The production cost of timber is considerably higher than the sales price (in some cases more than twice this price), mainly owing to the antiquated and inefficient sawmill operations. The comparatively small private sector pays for timber a "black market price" of up to LSd 120 per m³.

Timber price per m³ of imported timber in Juba is KSh 2,580 (\$315).^{2/} This price includes all taxes and handling and transport charges from Nairobi to Juba. The timber (East African camphorwood - Ocotea usambarensis and cypress - Cupressus spp.) is "cut to size" and pressure treated.

Transport costs (Transexpo/Interfreight Juba)

By truck from Nairobi, Kenya, to:

	<u>KSh/ton</u>	<u>\$/ton</u>
Juba	930	115
Maridi	1,400	170
Wau	1,750	215

The above prices include the border tax of KSh 90/ton. For bulky items (e.g., prefabricated bridge panels, ready made steel plates etc.) a transport surcharge of about 30% will have to be added. The prices do not include handling charges and Sudanese taxes.

^{2/} FAO Ferrocement Boat Project, Juba.

Comparative costs for various construction of
Collins type modular timber bridges

Costa Rica (pilot bridge):

Pilot bridge in Santa Cruz with handrails, total span: 30 m; consisting of 2 spans of 15 m each with a concrete pillar in the middle, 4 trusses, 2 embankments, roadwork surface.

Total costs per running metre: ₡ 180,000 (\$700)

Kenya (UNIDO Bridge Project):

	<u>Per running metre</u>	
	<u>KSh</u>	<u>£</u>
15 m span, 4 trusses (including embankments and roadwork)	41,000	335
9 m span, 2 trusses (excluding embankments and roadwork)	14,000	190
12 m span, 4 trusses (excluding embankments and roadwork)	26,000	265
24 m span, 6 trusses (excluding embankments and roadwork)	73,000	370

Southern Sudan (Juba):

The following cost calculation for a typical Collins type bridge is based on the previous findings. The prices do not include labour costs for assembly and erection, costs for constructing the embankments and roadworks and eventual local taxes (it is assumed that the material can be imported duty free).

Collins type modular timber bridge:

Span 12 m
Width 3.80 m
Number of trusses 4
Loading H 20

	<u>Dollars</u>
(a) Complete bridge of treated, prefabricated panels including all metal parts, bolts, nails and chords, ready for erection	3,200 ^{a/}
Estimated profit (30%)	1,000
Transport Nairobi - Juba (7 tons, bulky, including all handling charges)	<u>1,200</u>
Total	<u>5,400</u>
Cost per running metre	450

^{a/} This is fabrication at cost price for the Ministry of Natural Resources, (Forest Department) in Kenya.

	<u>Tons</u>	<u>Dollars</u>
(b) Timber (8.5 m ³), treated, cut to size, dimensions: 2 in. x 10 in., 2 in. x 8 in., 2 in. x 6 in., 2 in. x 4 in. (not included: drillholes, retreatment of fresh cuts and holes)	5.235	1,400
Mild steel sheets of 8 ft x 4 ft, thickness: 1/4 in., 3/8 in., 1/2 in. (to be cut, welded and drilled according to plans)	1.4	700
Nails (100 mm and 150 mm)	0.135	90
Bolts (specially made, ready for use)	0.080	140
Round steel bars ϕ 12 mm, 38 mm, 50 mm (to be cut to length and welded in place)	<u>0.150</u>	<u>80</u>
Total	7.0	2,410
Transport Nairobi - Juba (7 tons, including handling charges)		<u>890</u>
Total		3,300
Cost per running metre		275
	<u>LSd</u>	
Embankments (estimated costs according to experience in Kenya and Costa Rica, including all materials and labour)	160	400 for each side
Estimated labour costs for assembly and erection (10 workers, 1 foreman, 15 days)	200	500

Costs for a conventional concrete bridge of the same width are estimated by the Ministry of Communications and Transport, Roads and Bridges Public Corporation at LSd 800 (\$2,000) per running metre.

II. CONCLUSIONS AND RECOMMENDATIONS

The demand for low-cost modular timber bridges (Collins type) in the Southern Sudan is existent only in areas where international or foreign organizations are working and are taking care of the feeder road system. These organizations operate well equipped workshops and have the necessary facilities available to construct and assemble Collins type bridges. They have qualified expatriate personnel (engineers) and their Sudanese counterparts and would not need a special United Nations bridge project to fulfill their present demand in low-cost bridges.

The Government (Regional Ministry of Communication and Transport) shows little interest in low-cost modular timber bridges, because it does not intend to use them on main roads.

Qualified counterparts cannot be provided for an eventual United Nations bridge-building project. The raw material situation is not in favour of such a project, since, in the present situation, every part of the bridge, even the timber, has to be imported and paid for in foreign currency.

Considering the previously mentioned facts, it is not recommended to start a United Nations project for low-cost modular timber bridges (Collins type) in the Southern Sudan at this stage. Instead it is proposed to initiate the following actions:

1. Provide the complete set of plans with the manual for the construction of Collins type low-cost modular timber bridges and a list of the Sudanese timbers found to be suitable for the construction to the following institutions:

Regional Ministry for Communication and Transport, Juba
Norwegian Church Relief, Torit
Project Development Unit, Jee/World Bank, Juba
German Caritas, Maridi
FAO, Wau

The last four organizations have shown interest in the design and are perfectly capable of constructing and erecting the bridges according to their needs.

2. Provide, if necessary, short term (1-2 weeks) technical assistance through the existing United Nations bridge-building project in Nairobi, Kenya.

3. Provide United Nations technical assistance in order to improve the sawmill operations in the Southern Sudan. This assistance should be given in close co-operation with the Regional Ministry of Forestry, which is interested in such a project and would provide qualified counterparts. In particular it is recommended to totally replace the sawmill in Gilo, Imatong by a small but modern sawmill (pilot sawmill).

The main forest areas of the Southern Sudan are:

The Imatong mountains and Lotti Forest Reserve (3 sawmills, Gilo, Katire, Kalisoni)

The Loka/Jei/Kagelu area (3 sawmills, Kagelu, Loka, Nuni)

The Jambio area (1 sawmill, Nzara)

The Wau area (5 sawmills, two of which were visited: Wau Sawmill Training Center, and Pongo Aweil)

Taking into consideration the present forestry situation and the existing reforestation programme, it does not appear desirable to install more sawmills at this time. Instead, the existing ones should be improved or replaced in order to increase their timber production, to improve the quality of the timber and to advise local trainees on modern sawmilling techniques.

The Gilo sawmill has a special importance. It is located in an area that consists mainly of coniferous plantation forest (the only one in the Southern Sudan). This coniferous forest could provide the country with excellent construction timber. The existing mill is in a very poor shape. Based on a defective locomobile steam engine (which suffers constant breakdowns), the mill produced in 1976 a monthly average of only about 10 m³ timber. The sawmill employs 75 workers, including those responsible for felling and hauling.

The recommended new sawmill should be laid out specially for coniferous wood (not for tropical hardwoods). It should have a monthly capacity of about 50 m³ and should have a diesel/electric power source. The equipment should include a frame saw line and a parallel line with a circular saw. It would also be necessary to provide a treatment plant (ideally for pressure treatment, but at least with facilities for dip-preservation) and to improve the already existing air drying facilities and techniques.

An expatriate United Nations sawmilling expert should be provided for two years minimum. He should be able to plan the layout of the machines and organize and supervise the erection of the new mill. He should work closely

with the management of the Katire and Kalisoni sawmills and give technical advice whenever needed (e.g. "saw-doctoring" a new band-saw that might shortly be installed in Katire). He should also give lectures on wood preservation, drying techniques and grading.

Such a sawmill co-operation with skilled expatriate help, together with a balanced reforestation programme could turn the Imatong Lotti Forest Reserve into a highly productive timber supplying area.

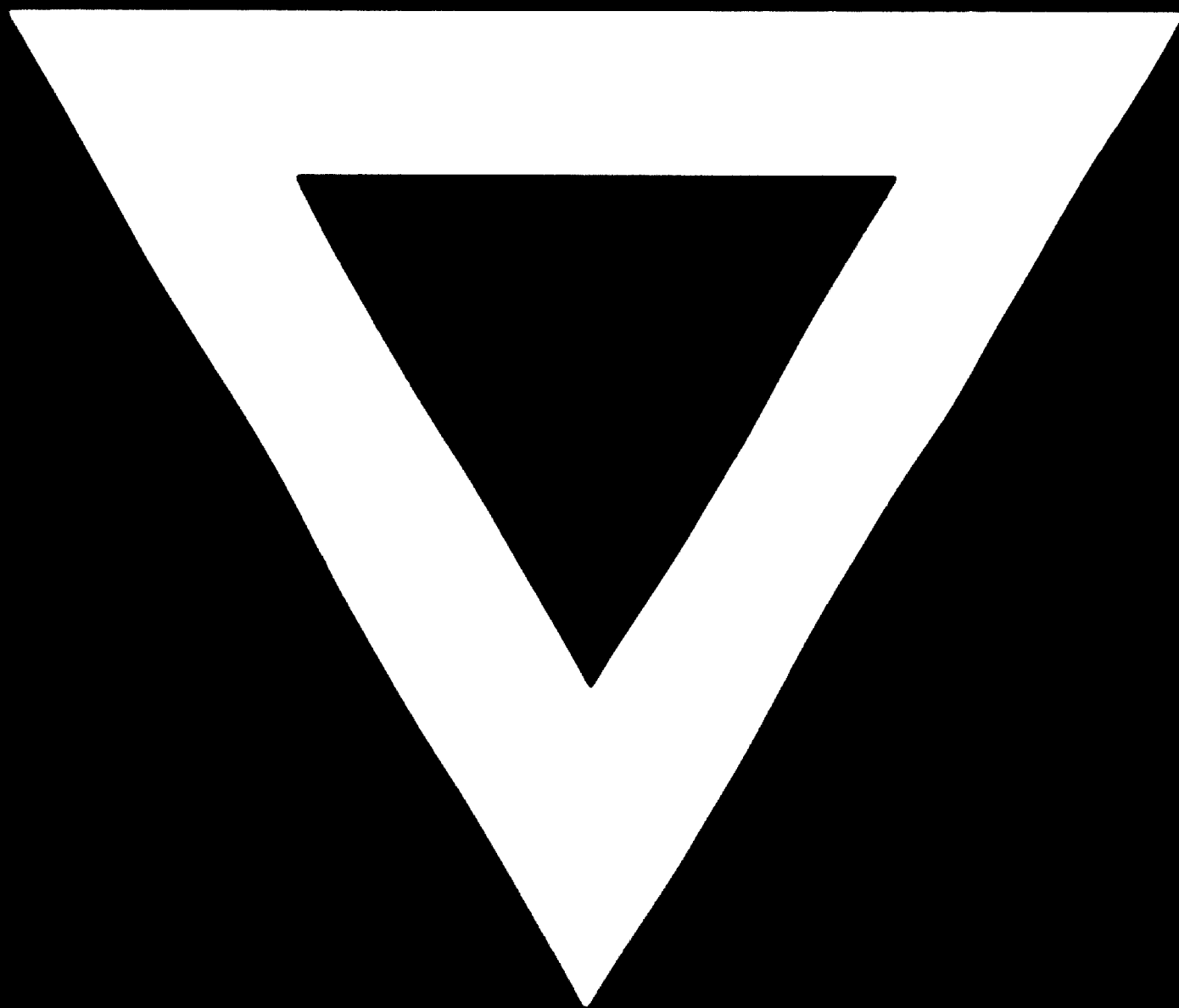
4. Provide United Nations technical assistance in designing and producing school furniture. This could ideally be carried out in co-operation with the existing German/Sudanese Carpentry Workshop in Juba. The workshop is centrally located, well built and fitted with a variety of modern machines. A school furniture production line can easily be added to it.

The workshop operates presently under the guidance of an expatriate carpentry expert with 25 trainees. The timber supply (mainly teak, Tectona grandis, from the Kagelu plantations) and the timber transport to Juba is secured by the operations of the German Forestry Team in Kagelu and Loka.

An expatriate expert should be provided for one year to specialize in the production of school furniture. This assistance is badly needed especially since it is planning to establish about 30 new school centres in the Southern Sudan.



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