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STRENGTHENING THE TECHNICAL AND MANAGERIAL CAPACITIES  
OF THE CARPENTRY COOPERATIVES IN MUKALLA AND SEIYUN

SM/PDY/87/005

THE REPUBLIC OF YEMEN

Technical report: Training Manual on Plant Layout\*

Prepared for the Government of the Republic of Yemen  
by the United Nations Industrial Development Organization  
acting as executing agency for the United Nations Development Programme

Based on the work of: Radmilo Malis  
Expert in Furniture and Joinery Production

Backstopping officer: Antoine V. Bassili  
Agro-based Industries Branch

United Nations Industrial Development Organization  
Vienna

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## INTRODUCTION

This training manual is one of a series prepared by a UNIDO expert while serving as Chief Technical Adviser on a UNDP financed and UNIDO executed project in the Republic of Yemen, to strengthen the Technical and Managerial Capacities of the Carpentry Cooperatives in Mukalla and Seiyun (project No. SM/PDY/87/005).

The entire scope of the training envisaged to be given, with the intended audience for each topic is given in Annex I.

The syllabus, namely the topics, the duration of lectures (theory) and practical work and the level of competence attained after completion of the course on this topic is given in Annex II.

### 1. Plant layout

Plant layout is a general arrangement of production, including placement of equipment and working areas, planning internal transport and the factory building, and providing optimal conditions for the manufacturing process. The design of a plant layout represents the integration of various aspects of the production system. Besides the technological aspects of the system, plant layout implies a great deal about the organization of work. It is an expression of the entire socio-technical system designed to produce certain products. This manual is aimed at training the technical staff of the Cooperatives on how to compile some basic facts and principles when making minor rearrangements within their existing workshops, or for planning new production sections.

### 2. Objects of plant layout

The nature of the product and details of its design have a decisive influence on the design of the plant layout. Working methods and processes, their operating sequence, the selection of the machines and the appropriate location of different sections are also objectives of plant layout. Also, the entire industrial infrastructure: electrical installations, compressed air, dust extraction, waste disposal and general layout of the factory area must be considered as an integral component of the plant layout design.

Special attention must be paid to the flow of materials in order to minimize distances and to avoid moving of materials against the processing flow.

Work safety is an obligatory requirement which has to be respected and incorporated in the plant layout.

### 3. Starting points for plant layout

The starting points for plant layout are information on:

- present and projected production programme.
- type and construction of products and material used.
- desired quality.
- desired production capacity.

The production programme should meet some requirements, such as:

- An adequate volume that permits a reasonable utilization of equipment.

- Stable product demand,
- Product standardization,
- Interchangeability of parts, and
- Continuous raw material supply.

The types and construction of products and materials used predetermine the technological operations and the technological characteristics of the machinery.

The desired quality level must be assured by including it in the technological requirements regarding the processing method and the accuracy of the equipment.

Where the product is relatively homogenous, such as doors, windows, chairs etc., a number of units can be used to determine capacity. Where the products are not homogenous, however, tons of products or any sort of physical units related to inputs and outputs can be used to express capacity.

#### 4. Special characteristics of production of the furniture and joinery industries.

The main raw materials used in the production of furniture and joinery are solid wood and wood based panels (plywood, blockboard, particle board and fibreboard - including MDF). All these materials are voluminous and a great deal of wood waste, chips and dust have to be removed during processing. Enough space for the work in process and for transportation aisles must be foreseen on the factory floor. The following additional characteristics of the furniture industry affect planning the layout:

- the range of products manufactured is usually large,
- the production series tend to be rather small,
- the life cycle of most designs is short.

In the joinery industry, the range of products is considerably smaller than in the furniture industry. Although product sizes of windows and doors are variable, many products are standardized, so that production of components in bigger series is possible.

Flexibility of production is desirable in particular in the manufacture of furniture.

#### 5. Arrangements of production

There are two basic layout patterns: process (or method) oriented layout, and product oriented layout.

In process layouts, all machines or processes of the same generic type are grouped together forming machine centres or departments that are technologically specialized. This is a widely used arrangement in the furniture and joinery industries. In it the machines are grouped according to their working or manufacturing methods. For example, wood sawing, planing and thicknessing, mortising and tenoning, profiling, routing and drilling, panel sizing, veneer trimming and joining, veneering, panel processing, sanding finishing and so on. Each group is specialized in a certain operation regardless of the type of products being processed. Transportation between successive manufacturing stages calls for the use of various means of

transport (pallets, conveyors etc.), and the existence of intermediary storage areas within the factory.

The product-oriented arrangement is used for the large-scale mass production of standardized products. Production is carried out in automated production lines consisting of automated machines that are connected among themselves by automated transportation conveyors. The modern furniture and joinery factory usually combines these two types of arrangements, combining separate multi purpose machines with automated production lines. This arrangement is more flexible than the product-oriented arrangement.

The advantages of the process-oriented arrangement are lower investments and higher flexibility; and the advantages of the product oriented arrangement are higher productivity and lower production cost per unit.

#### 6. Production capacities

The capacity of a machine line may be estimated on the basis of the number of available hours per machine per year and the given production programme or cubic metres of wood per year processed on individual machines. The most reliable method to calculate the required machine hours per year is the machine operation chart (see fig. 1).

MACHINE OR WORKING STATION	PART 1	PART 2	PART 3	PART...
Cross-cut saw	12	16	14	
Edging saw	18		19	
Bandsaw		32		
Surface planer	15	18	18	
Thickness planer	12	14		
Double blade trim saw		12	14	
Single end tenoner	22			
Chain mortiser		16		
Slotting machine		29		
Preassembling station				
Spindle moulder	28	31	26	
Router			32	
Horizontal drilller				
Vertical drilller	14			
Edge sander	28	22		
Horizontal belt sander	32	30	28	

The sum of all the time needed for a single machine to process all the parts in the production programme is the required capacity for that machine. The available time of one machine should be calculated based on the number of

working hours of that machine per year. The number of machines required for a certain capacity is determined by dividing the total time required by the available time on one machine.

In stating the capacities it is important to recognize that two factors reduce equipment utilization below the ideal levels:

- The plant's efficiency factor, and
- The scrap factor.

The factory's efficiency factor takes into account organizational losses due to scheduling delays, machine breakdowns, preventive maintenance, absenteeism, tardiness etc. This factor ranges generally from 0.5 to 0.95, depending on the quality of the organization of production and on the maintenance of equipment (see Fig. 2). The scrap factor recognizes that some productive time is required to produce rejected, unusable products, due to bad quality. Thus in planning the capacity we must take into account this loss of capacity by multiplying the time available on a machine by all the corrective factors.

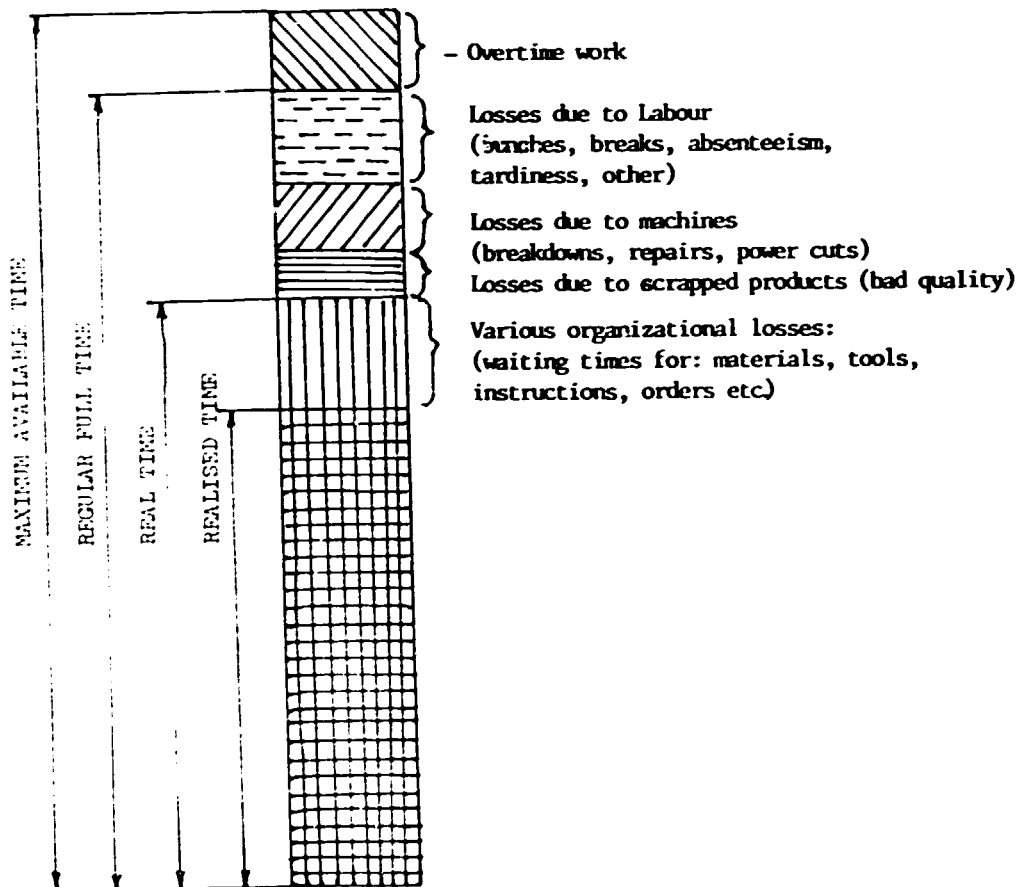


Fig. 2: Calculation of a plant's capacity.

Data of average capacities of woodworking machines can be used for indicative purposes, but it must be recognized that it is less accurate. For example: When processing solid wood parts for furniture and joinery, and when working one shift, experience has indicated that the following volumes of wood can be processed on individual machines:

MACHINES	CAPACITY (CUBIC METRES/YEAR)
Crosscut saw	2300
Rip saw (manual feeding)	1400-1900
Rip saw (chain feeding)	2300
Surface planer	1400
Thickness planer	2500
Four sided moulder	2300-4700
Vertical spindle moulder	700-1400
Router	2300
Chain mortiser	1400-1900
Horizontal narrow belt sander	1900-2800

This data varies according to the species of wood and the dimensions of the components (parts) that are produced.

#### 7. Means and facilities for plant layout

In order to design a plant layout, the following means and facilities should be provided:

- Internal standardization of:
  - products,
  - materials,
  - working methods,
  - means of transport,
  - work benches etc.
- Operation process chart (see fig. 3)
- Machine operation chart (see fig. 1)
- Material flow charts (see Fig. 4)
- Scale models of machines (see fig. 5)

Internal standards are used to determine distances between machines, floor area requirements for pallets, organization of working areas, and the position of the machines.

The operational process chart shows the sequences of operations in the production flow. The machine operation chart is used for calculating the capacities of single machines and the production line as a whole. The material flow chart is used to minimize cost of internal transport of materials and parts.

Scale models, cut of cardboard or made in form of wooden three-dimensional scale models, can help to minimize the preparation of layout drawings at the stage of searching for the optimal positioning of equipment and for a better visual presentation of the plant layout.



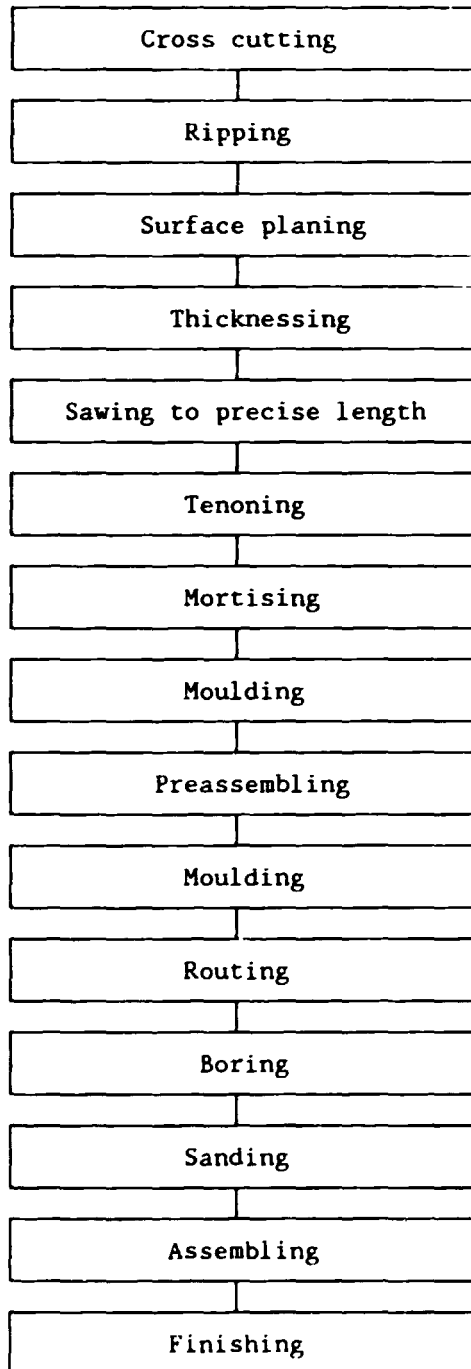
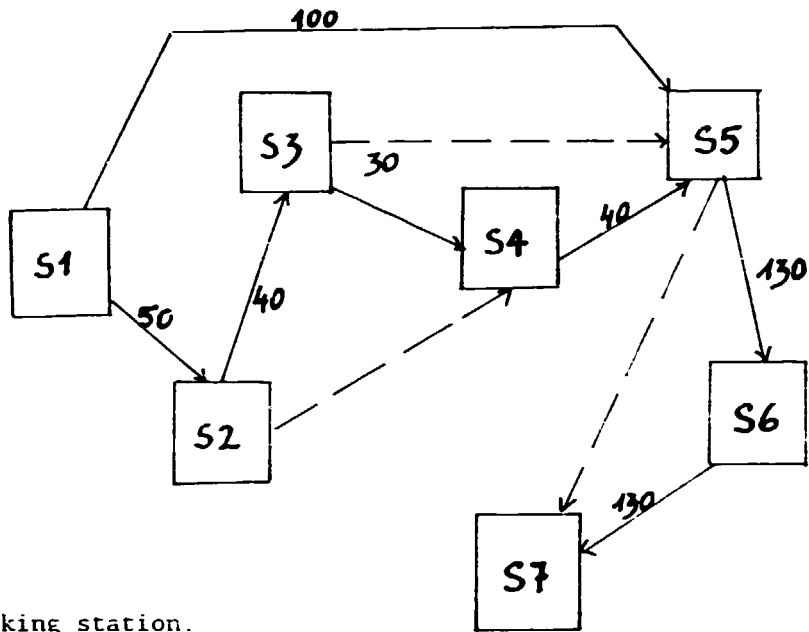


Fig. 3: Operation process chart for the production of joinery.



S1-S7 Working station.  
 ——— Main transportation route.  
 - - - - Possible transportation route.  
 (numbers show the quantity of material to be moved during the period observed.)

Fig. 4: Material flow chart

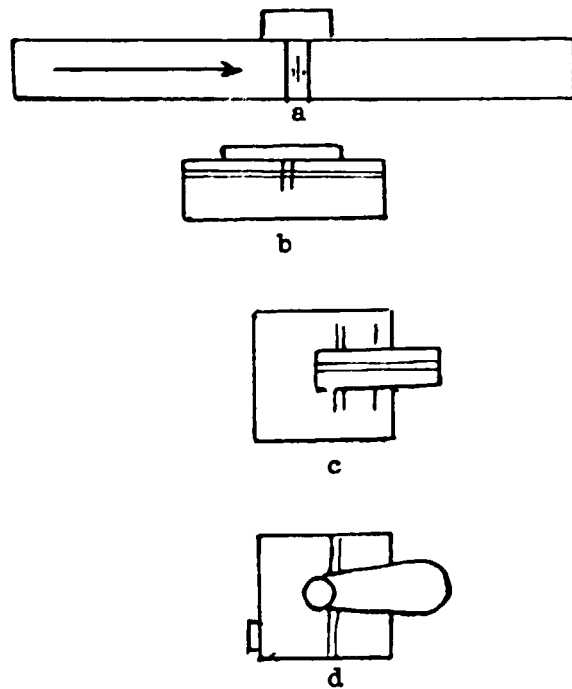


Fig. 5: Two-dimensional scale models.

- |                           |                   |
|---------------------------|-------------------|
| a: cross-cut circular saw | b: surface planer |
| c: narrow bandsaw         | d: router         |

## 8. Production flow

The production flow shows the direction of movement of materials and parts, from the entry of raw materials until the storage of finished products.

The most common production flow forms are (see fig. 6):

- a- straight line flow,
- b- L-shaped flow,
- c- U-shaped flow, and
- d- zig-zag flow.

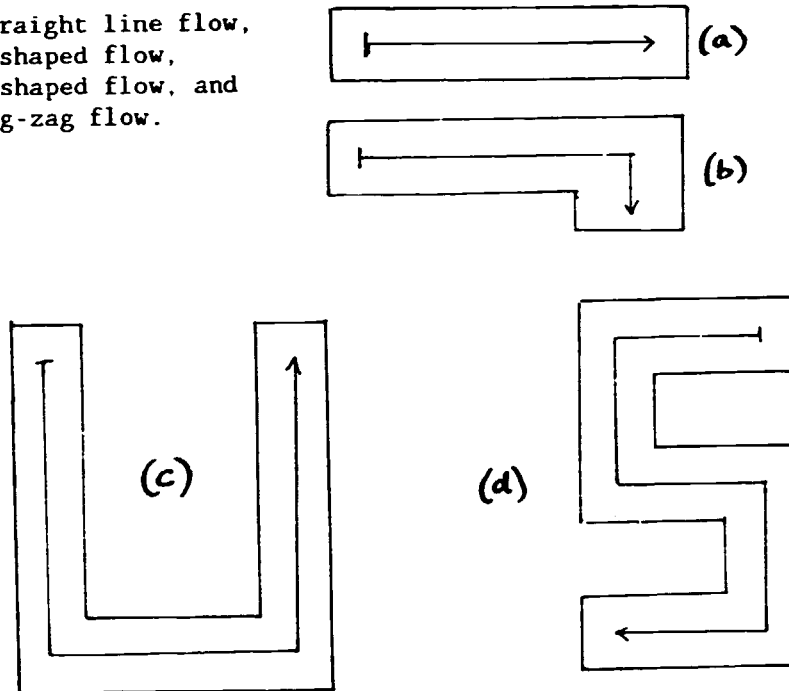


Fig. 6: Some production flow patterns.

Before deciding on the production flow, one should take into consideration the following factors:

- the nature of the process,
- the possibility of future expansion of the buildings,
- the access to the main transport aisles.
- the position with respect to the existing infrastructural facilities, etc.

## 9. Plant layout

The plant layout of a new factory should be based on the process and not on the factory's building. In other words, the factory building must fit to the finished process and not vice versa.

Before the final drawings are prepared it is advisable to use millimetric graph paper fixed on a plywood board. The construction details, which impose limits (walls, columns, doors etc.) should be drawn on to this paper. This becomes the plan.

Buy using scale models, cut from coloured cardboard, storage areas, working areas, transport aisles, machines and other equipment are positioned on the plan.

By using pins it is easy to change the position of equipment during the design of the layout.

The technical process must be homogeneous. So if the factory will produce both solid wood and panel components it should be divided into two distinct lines:

- a solid wood processing line, and
- a panel processing line.

Within each of these lines some machines are common, and one of each should be placed in each section of the workshop. This depends either on a similar function or working principles or on some other factors such as: waste removal, dust exhaust etc.

When positioning the machines a lot of extra floor area is needed around the machine for pallet loads, for handling workpieces, for moving the parts of the machines (feed tables etc.), for tool cabinets, storage of jigs, waste boxes, as well as for easy access to the machine for maintenance. It is not enough to position the machine, but it is also necessary to organize the working areas appropriately.

In the manufacture of furniture and joinery internal transport costs represent a significant proportion of production costs. The components are usually transported on pallets, using hand-operated hydraulic lift trucks. This is the most flexible method of transport in series production. Belt conveyors or dead roller ways can only be used to a limited extent, because of the great variety of items produced.

Storage areas are needed between the different phases of manufacture.

Transport must, to the extent possible, be in one way only, avoiding crossings and transport in the direction opposite to the process flow.

The electric installations and pipe network (compressed air pipeline, or dust extraction pipes) should be positioned above the machines and equipment to facilitate later modifications.

An example of the plant layout for a factory producing joinery and carcass furniture products, in Mukalla, has been designed and included in the project's technical report.

#### 10. The factory's building

Modern factory buildings for the furniture and joinery industries should be designed to meet the following basic requirements:

- They should all be on one level.
- They should be rectangular in form.
- Natural illumination is desirable, but electric illumination is of decisive importance.

- Partition walls should be avoided except in the surface finishing area.
- Columns should be avoided whenever possible.
- The number of corners should be kept to a minimum.
- Future expansions must be taken into consideration.
- The factory floor must be resistant to abrasion by the wheels of hand lift trucks.
- The doors must be big enough to allow the passage of maximum size loads, and easy to open or close.
- Safety must be taken into consideration in all details of a plant's layout.

11. Factory area

In planning a factory's area, the following details must be taken into consideration:

- The form and position of the factory building should permit future expansions.
- Different sections must be located at appropriate places in order to minimize transport distances for the major materials. An analysis of the relative importance of the location of various departments is done through a "Proximity chart" (shown in Fig. 7).
- Providing office space for the production management staff and the factory's administration.
- Organizing a traffic plan within the factory area for the movement of people, materials and products.
- From the ecological and psychological points of view the factory area must be planned so that people like their working surroundings and that it makes them feel happy and motivated to work.

Lumber yard	4																			
Storage of materials		1																		
Machining			1																	
Assembling				2																
Surface finishing					2															
Upholstering						1														
Glass cutting							1													
Toilets								1												
Tool sharpening									1											
Maintenance office										1										
Production office											1									
Storage of finished products												1								

- Key:
- 1 - Important for the departments to be located close to each other.
  - 2 - Preferable for the departments to be located close to each other.
  - 3 - Less important for the departments to be located close to each other.
  - 4 - Departments should not be in proximity.

Fig. 7: Analysis of the location of various departments.

## ANNEX I

## TRAINING PROGRAMME FOR FURNITURE AND JOINERY PRODUCTION

This training programme is designed to achieve the objectives and outputs of the project entitled "Strengthening the Technical and Managerial Capacities of the Carpentry Cooperatives in Mukalla and Seiyun" (project No. SM/PDY/87/005).

After visiting all the production units of these Cooperatives, (the three units of the Coastal Strip Carpentry Cooperative and the four units of the Carpentry Cooperative, Seiyun), and after studying the present state of their production, it has been concluded that a thorough training of operators and managerial staff is a prerequisite for all improvement. Due to this conclusion, the training programme prepared and proposed hereunder is more comprehensive, and the training activities are more numerous than originally planned in the project document. It has been designed to meet the specific requirements of the cooperatives which are on the point of transiting from handicraft to industrial production. The topics for the training courses selected are:

COURSE NUMBER	TITLE OF COURSE	DESIGNED FOR:
1.	Production systems and types of production in the wood processing industry.	Management staff of the Cooperatives and their production units.
2.	Furniture products, classification, standards, design and construction	Production Department staff
3.	Joinery products, classification, standards, design and construction	Production Department staff
4.	Product development in the secondary wood processing industry	Staff of the production and sales departments.
5.	Organization and planning of production	Production planning staff.
6.	Work allocation and control of production	Production planning staff, supervisors and foremen.
7.	Planning, cost accounting, pricing, cost control and optimization of a product line	Accountants, salesmen and staff of the production department.
8.	Inventory control and purchasing techniques	Purchasing unit's staff and staff of the production department concerned with material planning.
9.	Basic elements of marketing	Management, sales and production department staff.
10.	Modern industrial production management	Managerial staff.
11.	Information and documentation systems in the secondary wood processing industry	Managerial staff, top and middle management of the cooperatives.
12.	Plant layout	Staff of the production department and production supervisors.

COURSE NUMBER	TITLE OF COURSE	DESIGNED FOR:
13.	Wood, affiliated products and other materials used in the production of furniture and joinery	The technical department's staff, supervisors, foremen and operators.
14.	Wood seasoning and preparation	The technical department's staff and people working in the timber yard.
15.	Crosscutting and trimming of sawwood	Operators of crosscutting and ripping machines, and foremen in the wood cutting area.
16.	Panel sizing.	Operators of panel sizing machines and their foremen.
17.	Veneering and laminating surfaces and edges of wood based panels.	Operators laminating surfaces and edges of panel furniture components.
18.	Surface planing and thicknessing of components	Operators of surface planers/jointers and thicknessers and their foremen.
19.	Tenoning, mortising and drilling	Operators of tenoning, mortising and drilling machines and their foremen.
20.	Moulding and routing	Operators of moulding and routing machines and their foremen.
21.	Sanding and surface finishing.	Operators of sanding and surface finishing machines and their foremen.
22.	Preassembling, assembling and packaging.	Assemblers, packagers and their foremen.
23.	Managing of quality and quality control	Managerial staff at all levels, foremen and quality controllers.
24.	Jigs, templates and fixtures in the secondary wood processing industry.	Production department's staff.
25.	Tool sharpening, maintenance and managing.	Tool sharpeners and persons in charge of ordering tools.
26.	Internal transport, receiving and storage of materials and shipping of products.	Persons working in storage and internal transport services.
27.	Maintenance of equipment	Maintenance personnel.
28.	Safety measures in the secondary wood processing industries.	Foremen and supervisors in workshops.
29.	Motivation of employees	Managerial staff at all levels.
30.	Innovation and development techniques and methods.	Managerial and production department staff

## PURPOSE AND METHOD OF TRAINING

Training of employees is an integral part of production in modern industrial enterprises. Technical and technological developments offer new technical means and new production methods which make human work easier, safer and more productive. To be able to utilize such advancement, people working in industry have to learn and to train in order to achieve new knowledge and skills necessary for handling modern equipment and processes.

In developing countries, such training has decisive importance for the better utilization of new production techniques and for mastering new technological processes. To avoid unnecessary mistakes and gain indispensable skills, training courses are the most suitable way, because, in a short time, people can learn the best way of performing their duties in production.

The output of these training courses should be knowledge acquired by workers who will increase their abilities for effective production. To achieve this, the training method will rest on three steps as follows:

1. The lecturer will explain a new method.
2. The lecturer will demonstrate the new method.
3. The trainee will perform the new method under the lecturer's supervision.

Short manuals written in a simple language, understandable to the workers, will be prepared by lecturers for each course, translated into Arabic and distributed to the trainees. All graphs, tables and formulas will be adjusted to the level understandable to the people to be trained.

Theoretical teaching will be conducted in a classroom and its duration will be adapted to the minimum of theory which has to be known for a certain job. This part of the training will be performed by the CTA, other experts in the project and by United Nations Volunteers assigned to the project.

The practical part of the training will be organized at the work areas of the respective production operations. This part of the training will be carried out jointly by the experts and the UN Volunteers. The working area must be organized in a proper way, including the prepared production documents, tools, jigs, gauges, protective devices, pallets, materials and everything that is necessary for safe, productive and good quality work. The lectures should explain and show how to check a machine, tools, jigs, and in the case of wrong adjustment, how to correct them and how to prepare correctly all that is needed for the production operation.

The lecturer will show the correct way of performing the operation and supervise the performance of the trainees until he concludes that their work is fully acceptable and that the quality of the products is satisfactory. The counterparts with higher skills and experience will also be engaged to train less qualified labourers and to supervise their practical work.

Most of the training courses conducted for the Coastal Strip Carpentry Cooperative will be repeated for the Carpentry Cooperative in Seiyun, while in some cases the trainees from Seiyun will be invited to come to Mukalla. Persons from the production units outside of Mukalla and Seiyun will be travelling to these two places. Some of the practical training could and should be carried out in the satellite units by the UN volunteers.



### SELECTION OF TRAINEES

Trainees will be selected by the counterpart, according to their jobs and to the topics of the training programme. Besides workers who will directly perform particular production operations, all other people concerned with certain aspects of the production, such as: foremen, supervisors, management staff, maintenance personnel, etc. can be included in the training. The list of trainees is an integral part of the training programme and it determines the number of copies of the training manuals to be prepared and distributed for each course.

### TIMING OF TRAINING COURSES

The training courses will be prepared and conducted mostly during the experts' missions, and those to be conducted by the volunteers will be scheduled in between those missions. The priority should be given to the courses which are a prerequisite for the better understanding of other topics.

The timetable of all courses is a part of this programme, though the exact schedule can be changed depending on the timing of the future missions by the experts.

Some of the courses are intentionally foreseen for the last mission, hoping that by that time the workshops will be the missing equipment, which is indispensable for a proper training of the operators.

### SYLLABI OF COURSES

This programme contains syllabi of all courses planned to be conducted during the project execution. The courses are broken down into topics, and, for each topic, the training duration, both theoretical and practical, and the level of competence to be reached are given.

The selection of topics and the required level of competence is aimed to reach a minimum knowledge needed for successful manufacturing of furniture and joinery products in a medium-scale factory.

Each course has its number and topics are subdivided into a decimal classification following the numbers of the courses.

Once all the training courses are completed the training material can be compiled into a printed handbook to be used throughout the country.

## ANNEX 11

## SYLLABUS OF THE COURSE ON PLANT LAYOUT

This course is foreseen for the staff of the production department and production supervisors.

STAGE	TOPICS	TRAINING TIME (hours)		LEVEL OF COMPETENCE TO BE REACHED
		THEORY	PRACTICE	
12-1	Introduction	0.25	--	Understanding the purpose of the course.
12-2	Objective of a plant layout.	0.25	--	Understanding which factors have to be taken into consideration.
12-3	Starting points for a plant layout.	0.25	--	Knowing about necessary information for planning a layout.
12-4	Special characteristics of production in the furniture and joinery industries.	0.5	--	Knowing about special characteristics of secondary wood processing to be taken into consideration.
12-5	Arrangement for production.	0.25	--	Understanding various principles of arranging production capacities.
12-6	Production capacity.	0.50	--	Knowing about the average capacities of basic woodworking machines.
12-7	Means and facilities for plant layout.	0.5	2	Knowing about means and facilities needed for planning the layout of a plant.
12-8	Production flow.	0.50	--	Being able to select an appropriate production flow.
12-9	Plant layout.	2	8	Ability to design a simple plant layout.
12-10	The factory building.	0.50	--	Knowing about major characteristics of a modern factory building in the furniture and joinery industries.
12-11	The factory area.	0.5	--	Knowing about requirements for the production areas.
	TOTAL	6	10	