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Title: PLANT LAYOUT FOR REHABILITATION CENTERS: A CASE STUDY AND GENERAL CONSIDERATIONS.

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This paper approaches the problem of arranging facilities and moving materials in a sheltered workshop, or rehabilitation center, employing handicapped people. Traditional plant layout and material handling principles, along with human engineering principles, are used for developing a layout for Open Door Incorporated, a sheltered workshop located in Corvallis, Oregon. Experience in developing this layout was used as a basis for postulating general criteria which should be considered in laying out any sheltered workshop. The study gives primary consideration to safety of workers, flexibility of operation, worker convenience and worker training. It was found that traditional plant layout principles required modifications and the human engineering factors played a critical role in the design.

PLANT LAYOUT FOR REHABILITATION CENTERS: A CASE STUDY AND GENERAL CONSIDERATIONS

by

JAYANT T. INGLE

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TABLE OF CONTENTS

LIST OF EXHIBITS

PLANT LAYOUT FOR REHABILITATION CENTERS: A CASE STUDY AND GENERAL CONSIDERATIONS

CHAPTER I

INTRODUCTION AND CHAPTER SUMMARY

In the following study, an attempt is made to determine general principles a designer should follow for making a plant layout for a rehabilitation center. According to the Department of Vocational Rehabilitation, U.S. Government; a rehabilitation center or Sheltered Workshop, is defined as follows:

> A rehabilitation center is a facility which is operated for the primary purpose of assisting the rehabilitation of disabled persons through an integrated program of medical, psychological, social and vocational evaluation and services under complete professional supervision and in the case of which the major portion of such evaluation and services is furnished within the facility.

The above definition indicates that these centers should assist the process of rehabilitation through vocational training. They should be planned considering the traditional layout principles; at the same time thought should be given to the fact that they employ handicapped people.

Traditional plant layout and human engineering principles can be stated as follows:

Plant Layout Principle: (Apple [1]) The planning and integrating of paths of component parts of a product should be done in such a way as to obtain the most effective and economic inter-relationships between men, equipment and movement of material.

Human Engineering Principle: (Meister [5]) Attention should be focused on the elements which influence the efficiency with which people can use equipment to accomplish the function of that equipment.

Ideally, therefore, the designer of plant and equipment should start from 'the man out.' He should begin with the man and his function in the system. In this respect there is nothing particularly unique about the plant layout design for a rehabilitation center. The layout should fulfill the requirements that are expected from any other layout. However, it is the departure from the conventional plant layout as applied to the rehabilitation environment on which this thesis focuses.

A pictorial representation of the above discussion is shown in Exhibit 1-1.

In this study, a plant layout was prepared for Open Door Incorporated; a rehabilitation center located in Corvallis, Oregon. After describing the center in Chapter II, the data-gathering phase of the study is presented in the third chapter. The analysis and design

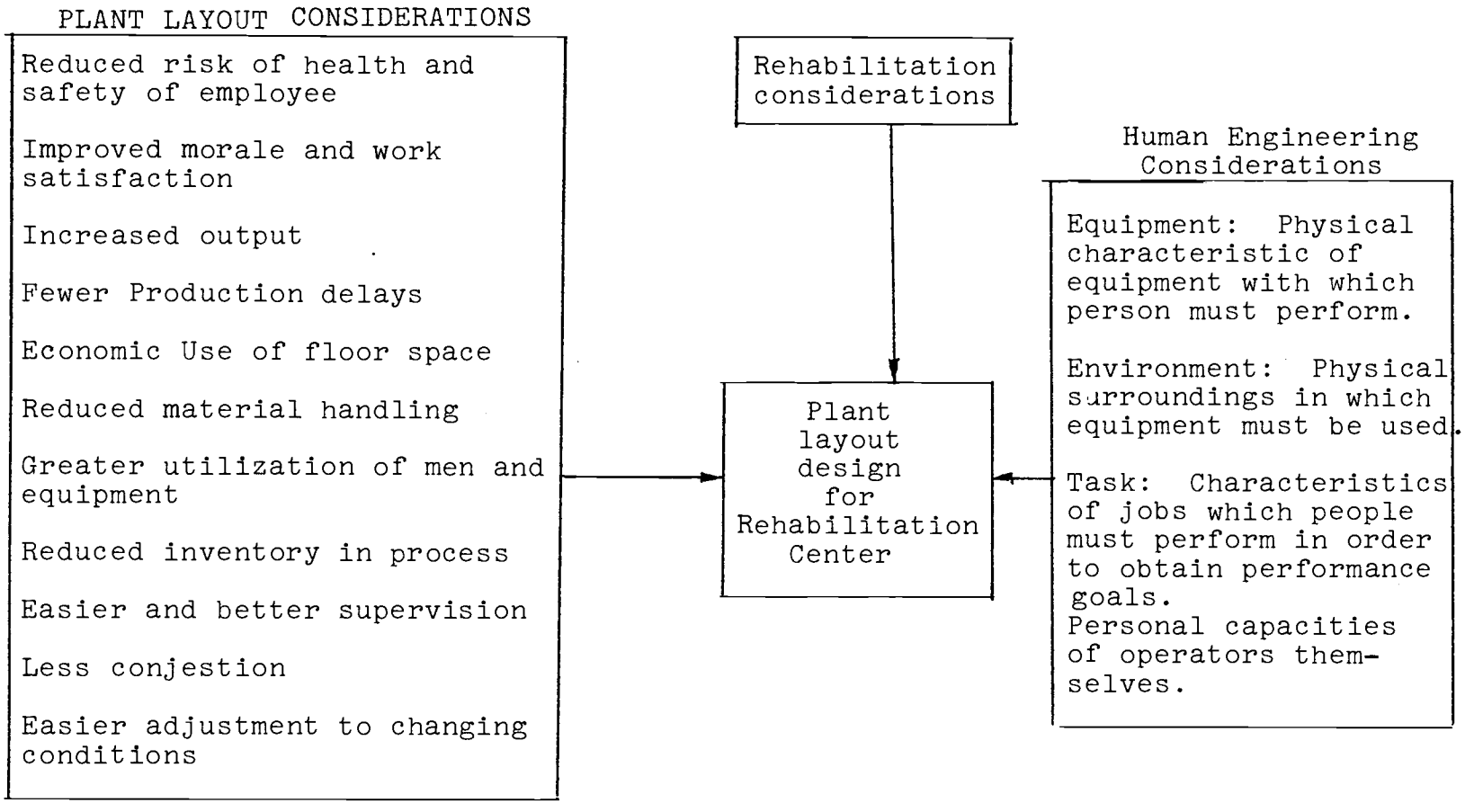


EXHIBIT 1-1

Pictorial Representation of Considerations for Plant Layout in Rehabilitation Center.

phase of the project are related in Chapter IV.

The design consideration developed for this layout were used in the development of general principles for plant layout design in any Rehabilitation Center. These principles are explained in Chapter V. Other input to the development of these principles were obtained by consultation with the executives of the following Rehabilitation Centers:

Open Door Inc.; 550 SW 7th, Corvallis, OR 97330

Willamette Valley Rehabilitation Center, 4390 Santiam Hwy., Lebanon, OR 97355

Workshops Inc.; 212 Forest Ave., Fond Du Lac, WIS 54935

CHAPTER II

DESCRIPTION OF OPEN DOOR, INC.

Open Door Inc. is a sheltered workshop, established on February 21, 1964, at which time it served only mentally retarded people. At present 55 handicapped workers of all types are employed in the plant. The company is planning to expand to three times its present capacity within five years.

The goals of the company are rehabilitation of handicapped people, development of a public awareness of employment of the handicapped, and vocational training.

The primary means of financial support is by contracting with various companies. Typically, contract work involves wood working (manufacturing of pallets, stakes and hubs); rough and clean assembly (rough assembly includes buffing and polishing of telephones; clean assembly includes manufacturing of plastic parts, assembling cardboard crates and electronic component assembly); and warehousing (receiving material and equipment, packing and storing it, and shipping it out when ordered). All of the above operations are performed year round. The anticipated expansion will involve expansion of all the above departments.

The overall chain of command is shown in Exhibit 2-1. The production supervisor is responsible for safety and production from all departments. Every department has a foreman who is in turn responsible for the safety and production in his department. The leadman and the coreman are experienced workers, responsible for performing a particular machining operation. Trainees are the workers under training. They are used primarily for material handling and other simple non-hazardous operations.

A short description of the activities and the existing problems of each department are explained in the following paragraphs.

Wood Working Department

This department has an area of 5000 sq. ft. and an average of 36 workers. On the average, the raw material inventory is 6 truck loads. (One truck load has dimensions of 24' x 8' x 8'.) The average flow of raw material through the department is 6 truck loads per month. About 25 percent of the raw material becomes waste in the form of saw dust and chips. This raw material is in the form of boards of lumber 24' in length and of varying widths and thicknesses. It is stored outside the building. When needed, it is placed on a hand driven dolly and moved

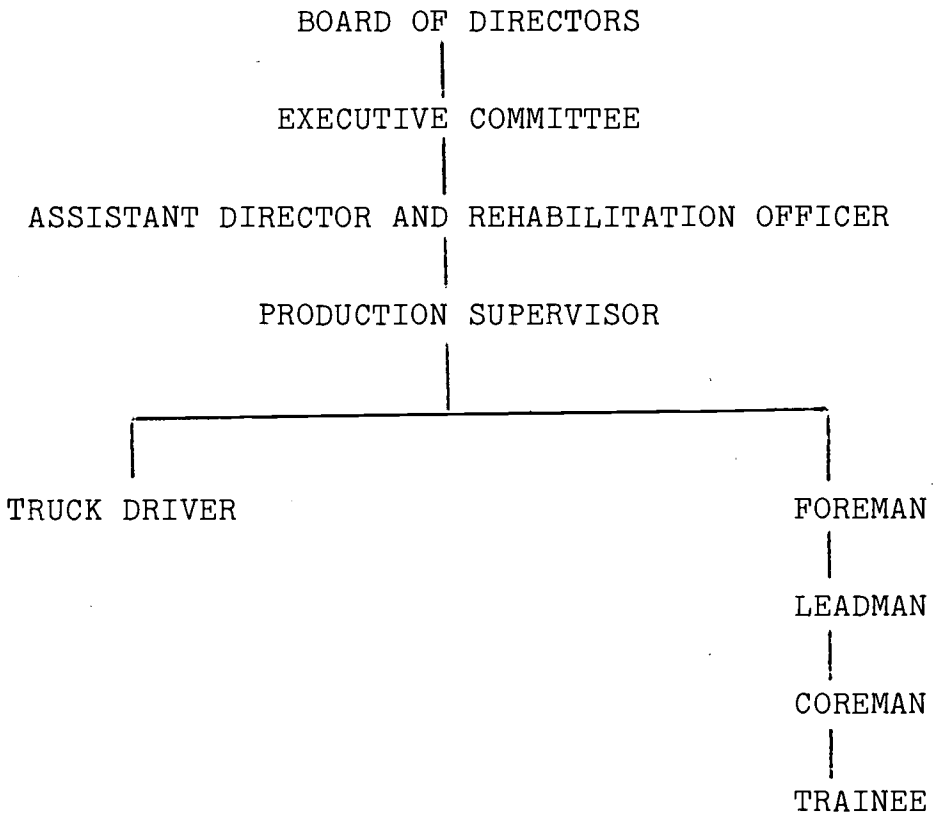


EXHIBIT 2-1

Chain of command in Open Door Incorporated.

to the work station by two workers. It takes 10 trips with a dolly to move one truck load.

Raw material is cut first on an XL ripping saw, after which it is cut to length on Irvington saws. It is then taken to sharpeners or table saws to make points on both ends. This is the sequence of operation for stakes, hubs and laths. The other primary product is pallets. The finished products are stored on 4' x 3' pallets and carried to storage by a fork lift truck.

Problems in woodworking can be summarized as follows. Due to unplanned expansion, space is inadequate. There is not enough storage space either for raw material or for finished products. They are usually stored outside the building - wherever space is available. There is not enough room available for in process inventory. Due to inadequate space, material handling is a constant problem. Raw material and in process inventory get piled up in the aisles. The foreman doesn't have an office near his department, so he has to walk through other departments frequently. Saw dust collection in the department is inadequate. There is no hopper. Saw dust is collected in wooden boxes. This takes place within the department; and so some saw dust is in the air.

Assembly Department

This department, employing an average of 25 workers, includes two sub-departments: rough assembly and clean assembly. The rough assembly department works on buffing, cleaning and polishing of telephones. The used telephones which comprise the raw material for the department, are stacked in cardboard boxes which can be moved by one person. Telephones are first machine-buffed, after which they are hand polished. The operations are intermittant; average inventory and volume fluctuate widely.

The clean assembly sub-department deals with electronic component assembly, manufacturing plastic washers and assembly of cardboard boxes. These activities can be considered as three separate assembly lines. Workers working on the different products work next to each other and there is usually a mixed line. All the material handling is strictly manual.

Problems in the assembly department can be explained as follows: Assembly has an area of 700 sq. ft., not including any storage. This makes the movement of the workers very difficult. The foreman does not have an office near the department to do his paperwork.

Various types of inconveniences are present in this department. Some workers in this department have a tendency to stare at each other. This staring habit,

accompanied by the crowded condition, reduces the productivity of the department. The arrangement of the department causes difficulty in inspection of the quality of product. The foreman cannot reach every work-station easily.

Neptune Warehouse

This department stores material for Neptune Microfloc of Corvallis. Basic operations include receiving media and equipment; building containers or pallets for storage; storing the media and shipping it back as ordered by Neptune Microfloc. Media is building material in the form of gravel, granite, and sand. Thirty bags of media, 50 lbs. each, are stored per pallet.

The warehouse has an area of 2500 sq. ft. Typically, 5 workers work in the department. Media is brought to the department by rail while the equipment is delivered by truck. On the average, 75000 lbs. of media is received and shipped every month. It is neither possible to find the rate at which equipment is shipped to the warehouse nor can it be estimated. It depends totally on the external agency. On the average, there are 7 pieces of equipment in storage.

Several problems related to Neptune warehouse have been identified. Most of the floor space is covered by

material. The crates and containers are strictly wooden. There is not enough space in the department to manufacture them, so they are manufactured in the woodworking department. Woodworking is already crowded and the Neptune foreman has to spend a lot of time in moving between the departments. Since workers use pneumatic saws in manufacturing crates, it is important that the foreman is near his department. He does not have an office near his department from which he can supervise all the workers.

There is no aisle in the department. Previously there might have been an aisle but it is occupied by equipment in storage. Whenever material has to be shipped or stored, the aisle has to be cleared first. This causes unnecessary cost of using the fork lift truck. Lighting in the department is very poor. Since the material is stacked high on the pallets, the storing and unloading of the crates in bad light appears to be very hazardous.

General Plant Situation

As can be seen from the above description, problems in all the departments can be classified under the categories of space, material handling, safety, supervision and inconvenience. This study concentrates on these categories and an attempt is made to lay out the new plant in such a way as to minimize these problems.

In general, plant wide problems in Open Door Inc. can be summarized as follows:

The most important problem is conjestion. Conjestion can be considered with regard to workers, materials, and at the loading docks. Raw material and finished products are in the aisles and near loading docks. In-process inventory is stored between work stations and in aisles. This makes material handling extremely difficult. The majority of shipping is done by truck. There is no useable truck loading dock or ramp at the present plant.

Collection of saw dust is inadequate. It contaminates the finished products from assembly, necessitating rework. Office and wood-working are located near each other without a sufficient dust and noise barrier.

Poor working environment is another major problem in the present plant. Workers do not have a suitable place to eat lunch. They have to use outside premises or aisles as the lunch room. Wash rooms are inadequate and poorly lit. Since raw material is stored outside, some workers have to work outside the building. There is no shelter from rain or snow. Workers come back inside the plant if it rains heavily. This aggrevates the already crowded condition.

This chapter has explained the problems and difficulties within the individual departments and of the overall plant. To allocate appropriate space and arrange facilities in the new plant, material flow and space requirement information is necessary. This data collection is explained in the next chapter.

CHAPTER III

MATERIAL FLOW AND SPACE REQUIREMENTS FOR OPEN DOOR INC.

Traditionally the most important consideration in the layout design is material flow. Efforts to develop a quantitative model to represent flow of material can pay off since such flows and their associated costs can be estimated. Many of the other critical factors (e.g., ease of inspection) are not so readily measurable but nonetheless must be considered in the design.

The approach taken here is (i) to develop a quantitative model of the costs of the material flows and (ii) to use this model as input to a larger qualitative model in which all major factors affected by facility layout are accounted for. The quantitative representation is called a From-to-Chart which reflects flow costs based on flow activity volume, wages and hourly machine operating costs. The qualitative considerations are formalized in an Activity Relationship Chart, in which the relative importance of the distance between each pair of activities in the plant is rated. The two models are now developed.

Development of the From-To-Chart

The entry in the From-To-Chart can be expressed as

$ / Unit time / Unit Distance

For manual labor this entry would take the form

(wages/hour) (no. of trips/month) / (speed of travel)

For machine labor, the entry would appear as

(machine operating cost) (frequency of travel) / (speed of travel)

Typically, the cost of moving material between two departments include both wages of the driver and the cost of running the material handling equipment. The number of trips per month represents average number of trips, a fork lift truck makes between two departments. To get these figures, the foreman of each department was instructed to keep a record of trips he made between each department for a period of one week. These figures were adjusted to one month. The average speed of material handling equipment was found to be 4 miles per hour. The from-to chart calculations include only material movements; information flow and personnel flow are not quantified. Departments having relevant flows are the main office, Neptune warehouse, wood working, raw material storage, finished products storage, waste storage, wash rooms, lunch room and shipping and receiving.

Material moved consists of raw material, in-process inventory, finished products or scrap. Material handling in the assembly area is strictly manual. The workers

are paid only an average of $3.50 per day. From to chart entries for the assembly area were calculated but were found to be negligible and have been omitted in the chart. In fact, the only significant entries from a material handling point of view were between wood working, Neptune and the storage area.

Calculation of the entries is shown in Exhibit 3-1.

There is substantial information flow between the departments. In the present plant, the foreman usually walks to the main office frequently. However, it is not a good idea to keep the main office near the plant due to the discomfort of saw dust and noise. It is therefore suggested that an intercom system be installed in the offices of the foreman and the main office. This will enable the foreman to get the information quickly and without leaving his department.

Facilities like wash rooms and lunch rooms are included in the from to chart to indicate that there is a flow of personnel between them. It was deemed unnecessary to measure this flow. The wood working department employees the largest number of people, so the wash rooms should be placed near the wood working department to reduce the movement of workers.

The from-to chart is shown in Exhibit 3-2. This chart is used as an input to activity relationship chart,

Movement activity (from dept/ to dept.)	Cost of moving raw material	Number of trips made per month	Speed of travel miles/hr	From-to chart entry
Raw material (raw material storage/wood-working)	$7.50/hr	12	4	22.5
Waste disposal (woodworking/ waste storage)	$7.50/hr	22	4	41.25
Finished pro-duct (wood-working/ finished pro-ducts)	$7.50/hr	44	4	82.5
Raw material (rail ramp/ Neptune)	$7.50/hr	40	4	75
Useable scrap (Neptune/ woodworking)	$7.50/hr	30	4	56.25
Waste Disposal (Neptune/waste storage)	$7.50/hr	22	4	41.25
Finished pro-duct (Neptune/ truck ramp)	$7.50/hr	60	4	112.5

EXHIBIT 3-1

Calculation of Entries for the From-To Chart

From / To	Main Office	Neptune	Woodwork	Raw material storage	Finished product storage	Waste storage	Wash room	Lunch room	Receiving	Shipping
Main Office										
Neptune			56¼	75*		41¼				112½
Wood Working					82½	41¼				
Raw Material Storage			22½							
Finished products Storage										
Waste storage										
Wash rooms										
Lunch rooms										
Receiving		75								
Shipping										

* The dimensions of each entry are dollars/mile/month. Only economically significant entries are included.

EXHIBIT 3-2

From-To chart for the departments of Open Door Inc.

which is explained in the development of a quantitative model.

Development of Activity Relationship Chart

As can be observed, there are not many entries in the from to chart. The logical thing to do is to keep the departments with significant interactions as close together as possible. This can be a little misleading. Although there is a large information flow between the main office and wood-working, it is not advisible to keep these departments near each other. Such considerations are reflected in an activity relationship chart. The plant layout is more activity oriented than flow oriented. Thus, material flow is only one of the many considerations in designing department arrangements.

The Activity Relationship chart is displayed in Exhibit 3-3. The letters A, E, I, O and U are used to indicate the importance of closeness between two departments. They have the following standard meanings:

A - Closeness absolutely essential

E - Closeness extremely desirable

I - Closeness important

O - Ordinary closeness

U - Closeness undesirable

The following are the reasons chosen for the closeness values in the chart.

1) Ease of supervision - The only way to keep the plant free from accidents and keep production at a steady pace is by good supervision. The foreman is responsible for the safety of his department. His office should be located such that he can supervise all the workers easily.

2) Use of same personnel - When the workers are shared by two departments, it is necessary to keep these departments closer to each other. This is essential so as to reduce the time of movement and again for ease of supervision.

3) Flow of material - If there is a material movement between two departments, keeping them together will reduce time and hence cost of movement.

4) Ease of waste removal - Waste material makes it hard to work around the work stations. It therefore should be easily transported to the waste storage.

5) Unpleasant working conditions - This refers to cold, noise, dust and odors. Presence of these factors, especially near offices, should be avoided.

6) Transportation facilities - Departments involved in shipping and receiving of large volumes of material should be placed near the loading docks.

7) Flow of information - There should be good information flow between main office, production

supervisor and foremen. Similar flow also should exist between foremen and his staff.

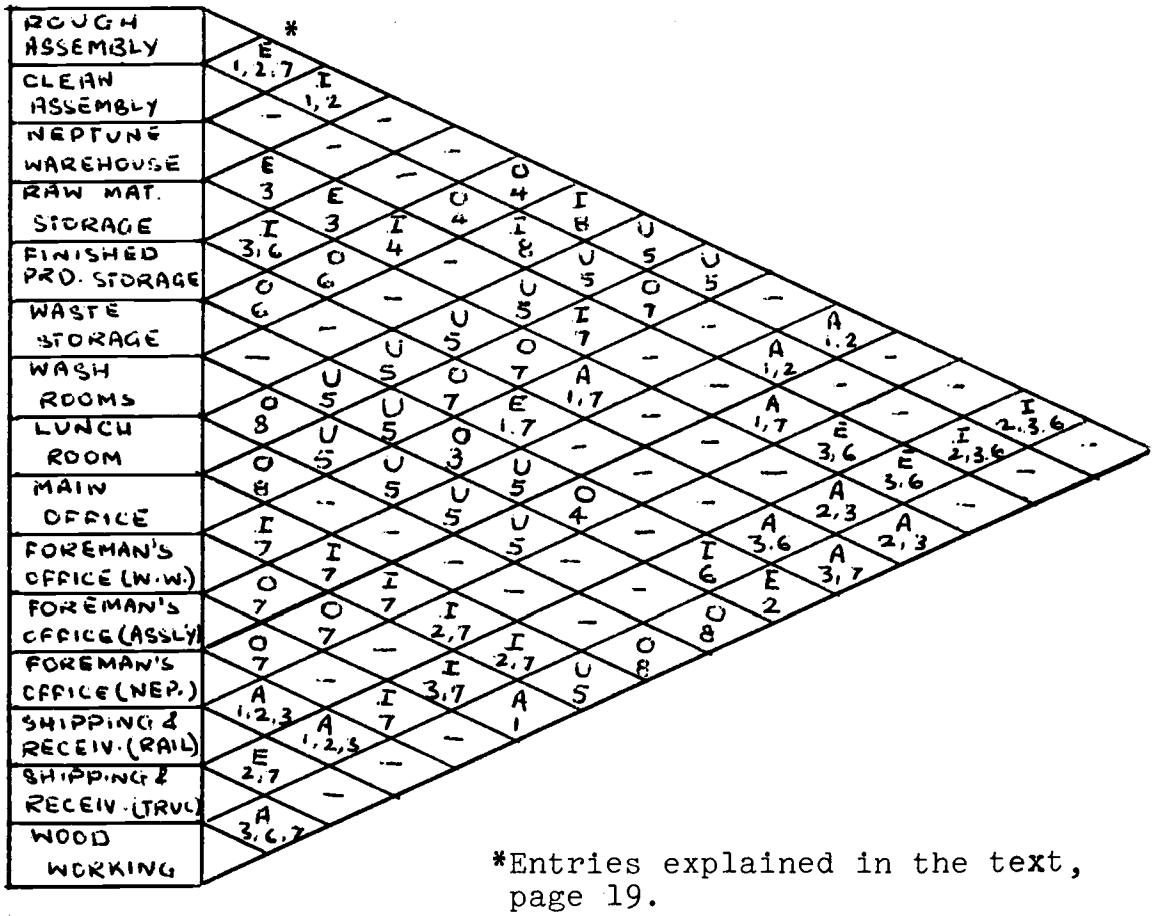
8) Flow of personnel - The facilities like wash rooms where the flow of personnel is high, have to be located near highly populated departments.

Space requirement

Another important factor in layout design is the space requirements for various departments. As it is, all the departments are very crowded; hence, realistic calculation of space for each department is necessary. Likewise, storage space for both raw material and finished products must be adequate. Requirements were estimated by consulting with the Production Supervisor.

The raw material inventory for both wood working and Neptune is a maximum of 10 truck loads. As the dimensions of material are fairly large, viz. 24'x8'x8' it it not possible to stack two truck loads vertically. The maximum in-process inventory between XL and Irvington saws was found to be 7 pallets each of size 3' x 4'. Finished products inventory is as low as 3 pallets in winter and it is as high as 20 pallets in summer.

Storage is not a major problem for Neptune material. Raw material is stored along with the raw material used for making stakes and pallets.



*Entries explained in the text, page 19.

EXHIBIT 3-3

Activity Relationship Chart for the Departments in Open Door Inc.

As explained in Chapter I, material for assembly is stored in an attic. It is estimated that the storage space for assembly should be 700 sq. ft. This space will be utilized for storing raw material, finished products and extra containers.

The factors considered in this chapter are considered heavily in the layout design presented in the next chapter.

CHAPTER IV

A PROPOSED PLANT LAYOUT FOR OPEN DOOR INC.

Development and justification for the layout of individual departments as well as the arrangement of the overall plant is presented in this chapter. The reader should refer to Exhibit 4-1 as he reads this chapter.

The woodworking department handles the largest volume of material. It is therefore desirable that the material should not be subjected to any unnecessary movement. This is achieved in the proposed layout. Raw material is brought into the department from the raw material storage and finished products are stored at the opposite end. A maximum raw material inventory of ten truck loads is provided for (a truck load has dimensions of 24' x 8' x 8'). The material is moved to work stations by dollies in the present plant. This method is not efficient. It is proposed that a conveyor be used for moving raw material to the XL saw. This will avoid any accumulation of material in front of the XL saw.

In the present plant, raw material is stored on pallets or on the ground where ever space is available. Another method is suggested here. Dollies should be

fabricated for storing one truck-load. When the raw material is received, it should be stored on these dollies. Whenever needed, one of these dollies can be pulled out and taken to the head of a simple roller conveyor. There is another roller placed between the conveyor and the dolley, so that the material handler does not actually have to completely lift the boards. He just has to slide them over this roller. It is also suggested that there should be a suitable shelter where the material handler feeds the material to the conveyor since this work is performed outside the building. Another roller conveyor should be placed directly above the XL saw. The cutting of any board on XL is not complete in one pass through the saw. The uncut portion of the board has to be fed back to the XL saw. This portion can be slid back over this conveyor.

The woodworking department, excluding raw material storage, has an area of 150' x 47'. It is anticipated that in the near future two more Irvington saws will be acquired. Enough space is provided for this expansion. Many times two different products are manufactured in the department at the same time. For this purpose two separate blocks of space are provided. After cutting on the Irvington, material to be used for pallet making can be moved backwards, as shown in Exhibit 4-1. The

Production Supervisor's office is placed near the Irvington saws. The foreman's office is placed near the sharpeners. Sharpeners are the saws for making points to the stakes. It is suggested that these offices should be placed five feet above the ground level, so that the whole department can be supervised easily. Between the Irvingtons and the sharpeners, a space of 15' is provided for in-process storage.

The width of the main aisles is 15'. To the side of the main aisles is provided a sub-aisle 3' in width. This aisle is strictly to be used by pedestrians, workers in wheel chairs or on crutches. This will help in keeping material handling unobstructed and will hold down accidents. Yellow lines should be painted on the floor indicating the main aisles. The sub-aisles should also be painted yellow and with stripes.

It is suggested that there be truck ramps for loading and unloading at three locations. Neptune receives media from rail cars but it is shipped back by truck. All the receiving and shipping in woodworking is done by truck. One ramp should therefore be placed near the raw material storage. A second ramp should be placed near the finished product storage; and the third near the Neptune warehouse. There are no such ramps at the present plant. A capacity of three ramps may seem to be excess at pre-

sent, but in the future, when the volume of activity increases, the ramps will provide for easy handling of material. It is suggested that a hopper be installed near the woodworking department to remove saw dust and chips.

In the assembly department, a storage area of 1320 sq. ft. is provided. A special type of bench should be fabricated for this department. Such a bench is shown in Exhibit 4-2. This bench is designed according to the Human Engineering principles of ease of working and maximum work area that can be utilized by any worker with ease (McCormick[4]). The worker will be seated in the circular notch. Such an arrangement is extremely useful for the movement of material. As explained in Chapter I, all the material movement in the assembly is manual. It is suggested that the arrangement of the work station be in a U-shape, as shown in Exhibit 4-1. The product will start at one end and will be completed at the other end. In-process inventory will be stored on the benches between each pair of workers. Such an arrangement will also provide enough room for the foreman to observe individual workers and check the quality of product without disturbing the flow of material on the line. All the benches should be separately fabricated. This may seem costly; but it has very important implication. An important problem frequently faced by this department is the change

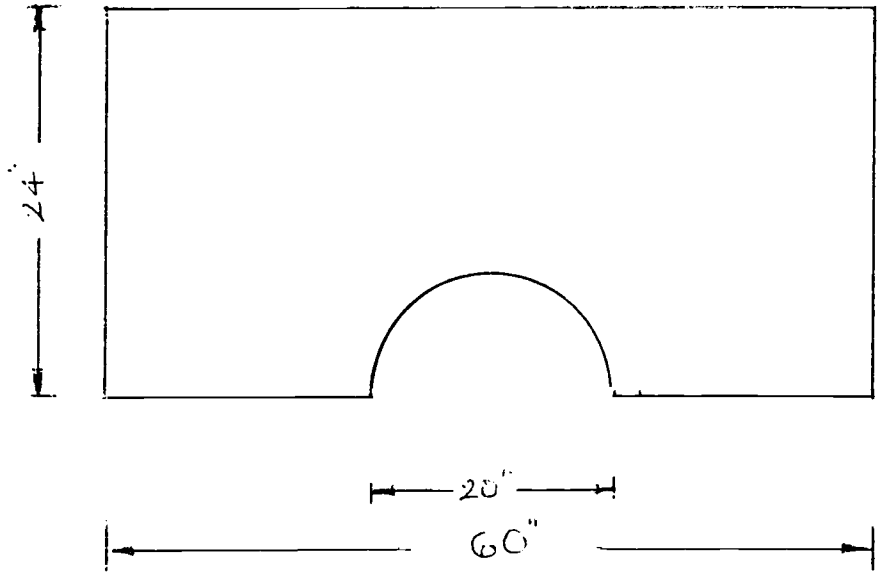


EXHIBIT 4-2

Working table to be used in the assembly area

of product mix. The foreman has difficulty changing the layout to accommodate any new product. Individual benches will help in solving this problem. The foreman can move smaller benches more easily to make changes, either to make more room or make more production lines.

It was explained in Chapter I that the major problem in the assembly department is some of the workers have a tendency to stare at each other. The foreman and the Rehabilitation officer have suggested that a good way to train these workers is by keeping them separated from other workers. This is accomplished by the proposed layout.

This department does not use any material moving equipment. Therefore aisle width of 6' is sufficient. Individual workers can be seated on the other side of the aisle (cf. Exhibit 4-1). This will enable the foreman to supervise all the department with ease and also assure a steady production pace.

Neptune has a designated area of 4400 sq. ft. One wall is used for storing media. Equipment will be stored along the other wall. The aisle is 15' in width with a pedestrian aisle adjacent to it. Neptune does most of its crate manufacturing in the woodworking area. This should be avoided in the future. Am empty block of space has been left open for crate manufacturing as wood assembly.

In the present plant, initial cutting is done by the XL saw. The Open Door executives have not decided whether to install a new XL saw in Neptune to perform this initial cutting or to use the saw in woodworking and bring cut pieces to Neptune for assembly of crates. As explained in Chapter I, the XL saw can cut enough material for 8 Irvington saws. It has been decided by the executives that the new plant will have 6 Irvington saws. The spare capacity of XL can then be used for Neptune. In the future, when woodworking expands, Neptune might need an additional saw. Enough space is provided in the layout for this expansion.

The main office and lunch room are secondary considerations. Location of these facilities can be arranged after the selection of site. (When this study was conducted, Open Door Inc. was interested in a particular plant site at which office and lunch room were already constructed.)

In the latter part of this study, it is indicated that there should be a training facility in the Rehabilitation Center to train workers about different jobs. The exact location of this center and its arrangement is a secondary consideration, to be ascertained after deciding upon the site.

Flow diagrams of material handling operation for the existing plant are provided in the Appendix 1-A and 1-B. Flow diagram for the proposed layout is provided in Appendix 1-C. These flow diagrams should help in understanding the simplicity in material handling and smoothness in material flow in the proposed layout.

This industry handles a large volume of lumber. Hence, an adequate fire protection system is essential. Fire caused by lumber is grouped under Class A fire by State Accident Insurance. It is suggested by State Accident Insurance Fund that water type fire extinguishers are satisfactory against such fires. There is electrical equipment in the plant so it might be better to use carbon dioxide type extinguishers instead. These extinguishers should, of course, be easily accessible. Care should be taken that no material be stacked in front of them at any time. If the water type fire extinguisher is used, it should not be any larger than 3 gallons capacity. Any heavier extinguisher is very hard to carry and operate. The Accident Prevention Manual [10] has suggested the following requirements.

> At least one unit for each 2500 sq. ft. of floor area plus additional units as required by the inspection department having justification. Units located within 50' of persons required to use them.

One such unit should be located between XL and Irvington saws, and another located between Irvington and sharpeners. A similar extinguisher should be provided in assembly and Neptune. It is also important that the employees do not panic in case of fire hazard and that they know what procedure to follow. This can only be emphasized by fire drills. It is therefore suggested that fire drills be conducted in the plant. This will help workers in case of an emergency. Lighting standards for the plant are shown in Exhibit 4-3. The plant should comply with them.

The plant layout and related considerations have been discussed in this chapter. In the next chapter, an attempt is made to provide general guideline which a designer should follow while preparing a plant layout for any Rehabilitation Center.

Situation or task	Recommended illumination, fc
Assembly:	
Rough easy seeing	30
Rough difficult seeing	50
Medium	100
Fine	500
Extra fine	1000
Machine shops:	
Rough bench and machine work	50
Medium bench and machine work	100
Fine bench and machine work	500
Extra-fine bench and machine work, grinding -- fine work	1000
Storage rooms or warehouses: inactive	5
Offices:	
Cartography, designing, detailed drafting	200
Accounting, bookkeeping, etc.	150
Regular office work	100
Cooridor, elevators, stairways	20
Residences:	
Kitchen, sink area	70
Kitchen, range and work surfaces	50

EXHIBIT 4-3

Illumination Standards Recommended by the IES for Several Selected Types of Situations and Tasks
(McCormick [4])

CHAPTER V

GENERALIZED GUIDELINE FOR PLANT LAYOUT FOR REHABILITATION CENTERS

In the introduction to this thesis, it was explained that the planning of a Rehabilitation Center should be done considering both plant layout principles and human engineering principles. Safety of workers, accommodation of widely varying product mix and total job load, worker morale, worker convenience and training of workers, essential criteria in any plant, are at least as critical for a Rehabilitation Center.

Much work (Soden [9], Kessler [4]) has been done on planning of rehabilitation centers and efficient methods of rehabilitation; but comparatively little has been recorded reflecting the use of plant layout principles in rehabilitation centers. The following pages explain guidelines to be followed related to the above mentioned criteria.

Safety of Workers: Plant layout and work place safety relate directly to worker's safety. Industrial accidents vary from a small cut to perhaps amputation of limbs. To find the causes of these accidents and try to minimize their occurence will therefore be an important factor in the designing of a layout.

A study was made of the accidents which occured during the period January 1, 1972 to December 31, 1972. The data was made available by the State Accident Insurance Fund, Salem, Oregon. Exhibit 5-1 shows the classes, occurances and the cost of these accidents. Referring to Exhibit 5-1 the 'Internal Injuries' class covers bone fractures, chest injuries and abdominal injuries like hernia. 'Special type of Injuries' include gas poisoning, skin irritation, eye injuries due to foreign bodies and injuries induced by electric shocks. The 'Sprains' category includes sprains and strains during material handling. The majority of these injuries happen to the workers' backs. Sometimes workers are not able to tell how the injury occured. These injuries are accounted for under 'Unclassified'.

The accidents have the following likely causes:

1. Carelessness of workers
2. Hazardous machinery
3. Conjested aisles and workplaces
4. Faulty material handling
5. Improper storing methods

These causes are now examined to develop guidelines for layout design.

I. Carelessness of workers: The term 'carelessness' is used here as the workers' negligence regarding their

superior's orders. Many times workers do not obey their foreman. Some workers, especially mentally retarded persons cannot determine whether their action is harmful or not. The best way to avoid accidents due to such carelessness is by good supervision.

A layout should therefore make it possible for the foreman to supervise every worker from his office with ease. Elevated observation posts should be installed in the plant. The departmental foreman's office should be placed on a platform at least 5 feet above the floor. This can give him good visibility over the department.

The foreman should be able to reach every worker if he observes any hazardous act. The aisle should be clean and wide. The author suggests that a portion of the main aisles be reserved for pedestrians and workers in wheel chairs or on crutches. This space should be painted yellow and the pedestrians should be taught to walk between this space. The ratio of management to workers should be high to facilitate good supervision and safety. A ratio between 1:5 to 1:8 is found to be satisfactory by the executives of rehabilitation centers.

II. Hazardous machinery: Accidents due to the machinery are typically cuts and punctures. To avoid them, covers and guards should be provided on cutting and rotating parts. Many times parts are held in hands while some

operation like cutting or drilling is being done on the part. This practice should be minimized and jigs or fixtures should be provided. Lighting near the working areas is also an important factor. Adequate lighting must be provided at the work stations. To avoid eye injuries, the use of protective goggles must be made compulsory for workers in wood working departments.

III. Conjested aisles and work places: When the aisles get conjested by material piling up, accidents are bound to happen either by workers colliding with material handling equipment or against material piles.

The aisles therefore should be clean and wide. For material handling generally accepted dimensions of aisles are shown in Exhibit 5-2. It may be wise to leave 1' to 2' extra width, since some workers walk in a staggering way, or are in wheelchairs.

Regarding the work place area, Woodson [8] recommends that at least 65 to 100 sq. ft. should be available per worker. Such a general space allocation system does not account for the varying space requirements of different work activities. A lot of space may be wasted in such allocation. Space allocation should be made dependent upon the activities involved at the work station.

IV. Faulty material handling: This refers primarily to overuse of manual material handling. Injuries categorized under 'sprains' are frequently found to be due to manual material handling. The injuries are usually in the form of back sprains resulting from lifting excessive loads.

Excessive manual handling should be reduced. A table showing the maximum limits of lifting loads is shown in Exhibit 5-3. This table should be modified for handicapped workers. The use of containers with easy to hold handles should be considered when manual handling is necessary.

Another aspect of material handling is of course automatic machinery such as conveyors. This is considered under 'worker training' below.

V. Improper storing methods: In most operations, it has been found that the work-in-process inventory and finished products are piled in the aisle or on the floor, creating an obvious potential danger. Containers or pallets should be used for stacking material. This not only enhances safety, but makes it easier to move material by hand jacks or a fork lift truck.

Some factories provide additional storage on elevated levels. Such a practice is dangerous as the workers can fall off the stairs or the ladder while carrying material. Use of staircases should be avoided;

ramps should be used whenever possible.

The above guidelines should be very useful in reducing accidents. It must be emphasized that safety is more critical in rehabilitation than in normal plants. The normal worker can think faster and avoid some accidents. Such is not the case with handicapped workers. Hence, safety should be given even more consideration than in the conventional plant.

Accommodation of widely varying product mix and total job load

Rehabilitation centers experience frequent changes in product mix. Flexibility is the ability of handling changes in product mix and also in overall production. The layout therefore should be flexible enough to accommodate different jobs. The equipment should be general purpose and should serve a variety of uses.

Another factor is the volume of material. If the volume increases suddenly, the operation should not be disturbed. Extra space should be available if the volume increases. Permanent walls should not be installed within the plant. If there is a change in the sequence of operations, the machines may need to be moved. The equipment should be portable. Electrical wiring and saw dust collecting pipes should be designed with flexibility.

Very long production lines should be avoided. Handicapped workers are generally found to be good workers; but one cannot rely on their working pace. This varying pace may pile up inventory along the line. A process layout therefore should be strongly considered in planning the equipment.

Worker morale

In any plant, worker morale is an important factor. The success of the organization is dependent upon worker morale and their interest in their work. This factor is equally important in the rehabilitation centers. It is observed that when accidents happen the workers are hesitant to work. The above guidelines will reduce accidents; workers will take interest in their work.

Worker convenience

Especially since the workers are handicapped, it is necessary that the environment should be pleasing. They should enjoy working in the plant. Air suction should be used to collect sawdust and keep the air clean. Some workers are required to work outside the plant. A shelter should be provided for protection against the rain and snow.

Some workers do not like a noisy environment. Such workers should not be forced to work near noisy work stations. Work should be assigned according to his capacity, ability and affinity towards that work.

Rehabilitation centers should be constructed such that it is possible that supervision be done by a foreman in a wheel-chair. The bathrooms and doors should be adequately designed for use by the handicapped.

Training of workers

A rehabilitation center should be provided with a training center. As explained previously, under 'safety of worker', many accidents occur due to insufficient knowledge about how to do particular work. The workers sprain their backs while moving material because they use their back muscles instead of the leg muscles. The training center can teach them the correct way of doing work. The workers can be taught to use only the pedestrains' aisle while working, etc. This can help substantially in reducing accidents and also in rehabilitating workers.

Most of the workers that work in rehabilitation centers have never worked before. Material handling is therefore one of the safe jobs they can do. Automation is tending to restrict employment in jobs with

low skills. Rehabilitation centers are designed to create jobs for the handicapped. Excessive automation should therefore be avoided. The simple jobs like material handling actually help in rehabilitation. When he learns to do this job, he is taught to be a machine operator. Hence, the jobs which can be done more effectively with automatic machines in practice may justifibly be done manually in rehabilitation centers.

A summary of the above discussion has been prepared as a guideline for a designer to use while preparing a plant layout. This is shown in Exhibit 5-4.

The above rules will have the following payoffs:

a) Insurance premiums can be substantially reduced. As the accident frequency decreases, insurance will reduce automatically.

b) Once the workshop shows good progress, communities will take more interest in these workshops. Grants and other facilities will increase. Such grants are very small at the present.

c) The most important pay-off is increased productivity of workers. The workers will work with interest. This will help in the process of rehabilitation. The most important product of the rehabilitation center is people.

	Type of Injury	Number of Occurance	Total Cost $	Cause
1	Cut	42	11,260.50	1. Carelessness of workers 2. Hazardous machinery 3. Faulty material handling
2	Bruise	26	5,351.00	1. Carelessness of workers 2. Conjested aisles 3. Improper storing method
3	Sprain	32	73,144.00	1. Improper storing method 2. Faulty material handling
4	Puncture	15	889.00	1. Carelessness of workers 2. Hazardous machinery
5	Internal Injury	14	38,995.00	1. Carelessness of workers 2. Improper storing method 3. Faulty material handling
6	Special Type of Injuries	27	4,458.00	
7	Unclassi-fied	2	71.00	

EXHIBIT 5-1

Accident Analysis for accidents in Oregon Rehabilitation Centers, 1972

For personnel only (2 persons to pass)	30 inches
For two wheel hand-trucks (no passing)	30 inches
For 2000 lb. fork lift truck	8-10 feet
For 4000 lb. fork lift truck	10-12 feet
For 6000 lb. fort lift truck	12-14 feet

EXHIBIT 5-2

Recommended aisle widths in the plant.
(Apple [1])

	Height lifted from floor (ft.)	Maximum weight lifted by 5th percentile Men (Lb.)
1	1	142
2	2	139
3	3	77
4	4	55
5	5	36

EXHIBIT 5-3

Maximum weight that can be lifted to various heights. (Damon [2])

1. All the work stations should be easily accessible and visible by the foreman.
2. Elevated observation posts should be installed in the plant.
3. Span of control of the supervisor should be small.
4. Long production lines should be avoided. Process layout is preferable in a rehabilitation center.
5. Use of jigs or fixtures, where appropriate, should be made compulsory. The jigs or fixtures themselves should not be hazardous.
6. Protective goggles and hard hats must be used by all the workers working near machines. Machine operators should not wear loose clothing. Industrial shoes should be made available to the workers.
7. Separate aisles should be provided for pedestrians and workers in wheel chairs or on crutches.
8. A compromise should be obtained between manual and automatic handling. Automation opposes objectives of rehabilitation except where safety or excessive cost is involved.
9. Steps should be replaced by ramps. Ramps should be covered with non-slippery material.
10. Saw dust collection should be efficient and portable.
11. Numerous electrical outlets should be available to avoid lengthy cords.
12. Loading docks should be designed so that manual loading and unloading can be done if needed.
13. At conjested points, vehicle traffic should be closely controlled. This implies installing stop signs at conjested points and painted cross-walks.
14. The lighting in the plant should be variable to help in doing several jobs concurrently.

EXHIBIT 5-4

Guideline for developing plant layout in rehabilitation centers.

The guidelines developed in this study may be difficult to comply with as most rehabilitation centers are very tight financially. It would be quite expensive to implement all the suggestions. However, if implemented, the improved condition would contribute substantially to a safer and more pleasant environment and the resulting atmosphere would surely assist rehabilitation efforts. Since all the suggestions probably cannot be instituted due to financial constraint, rehabilitation officer must face the difficult task of selecting which ones to fund. This question, the trade-off between pay-offs and the cost of modification is the most demanding aspect of management.

This study has been confined to the development of principles of design for laying out productive facilities with the handicapped workers in mind. Extensions of such an applied study would most likely fall into one of the following categories: (1) Plant layout design for a plant which is operated by workers with special characteristics, (2) Other problems associated with the design of operational system in which the handicapped employee is present, (3) Scientific analysis of some of the fundamental relationships observed in this study; and (4) Additional case studies of the type made herein.

Layout design, may for example, involve special conditions if the work force is composed of: the elderly, the incarcerated, persons with particular physical, social or medical constraints. Santa's workshop is staffed with elves; the Amish shun the use of machinery. Cultural variations heavily affect plant design in developing countries.

Every phase of operational systems design is potentially affected by the presence of the handicapped. The economics of equipment use depends on altered productivities. Make-or-buy decisions must be based on training as well as traditional economic considerations. Labor standards, production schedules and product pricing are all tied up to revised efficiencies.

On a more fundamental level, the design parameters of material handling equipment might be related to the handicapped workers' safety, productivity and training. Learning curves could be developed for various tasks performed by these workers. Design of non - production areas such as rest rooms should be based on criteria which result from basic research on the capabilities and limitations of this class of production individuals.

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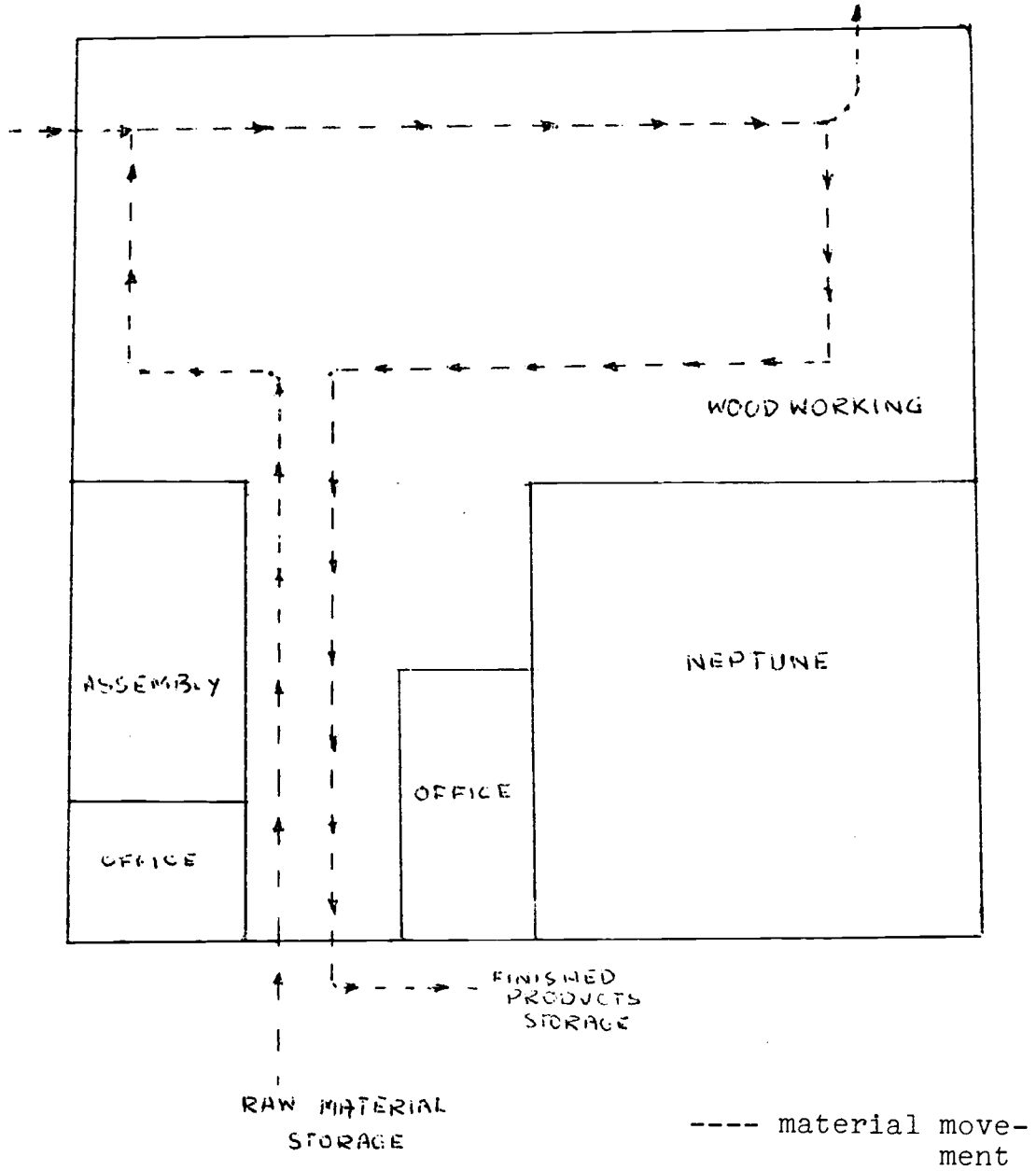
APPENDICES

APPENDIX 1-A. Flow Diagram for wood working.



APPENDIX 1-B. Flow Diagram for Neptune.