ASSEMBLY LINE BALANCING TECHNIQUE APPLIED TO PATIENT TRAY ASSEMBLY

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CHAPTER 1

INTRODUCTION

Patient tray assembly in hospitals is a major component of the service sub-system. Stockdale (1) found that approximately twelve per cent of all labor time was spent assembling patient trays: whereas, data from Beach's (2) study indicated that nineteen per cent of all labor time was spent on this task. As labor costs continue to increase, efficiency in all areas of the foodservice department must also increase, especially in those areas requiring an intense amount of labor.

STATEMENT OF THE PROBLEM

At the present time, approximately 14.4 per cent of the production employees labor time is spent assembling patient trays at Arlington Memorial Hospital (AMH), a 320 bed general care facility. The assembly of patient trays at AMH (Appendix A) is accomplished by a centralized tray assembly procedure. Preliminary data from March, 1981, revealed an average of 235 trays were served at each meal. At that time, the number of trays per minute ranged from 2.11 to 4.11 at breakfast trayline and 2.81 to 4.57 for lunch and dinner traylines. Breakfast trayline required a trayline arrangement different from that of lunch and dinner trayline. Gagliano (8) estimated that a minimum of six trays per minute should be assembled in a conventional trayline assembly system.

Plans are currently being finalized for the addition of one hundred patient beds by December 1982 and a new foodservice facility. At the average rate of 3.5 trays per minute, and with no additional labor, approximately 51.2 labor hours or 20.6 per cent of the total labor hours per day would be spent in this operation assembling patient trays. The foodservice director's goal is for all patient tray assembly to be completed in one hour at each meal. When the trayline period exceeds one hour, the food becomes cold, the dietary employees become tired and edgy, and the schedule for nursing services is disrupted.

PURPOSE AND OBJECTIVES

The purpose of this study was to analyze the present patient trayline operation at AMH and offer recommendations for improving tray assembly productivity. The industrial technique of assembly line balancing was applied to the analysis of the trayline operation.

Specific objectives of the study were as follows:

1. To observe present patient trayline operations and identify causes of delays within the system which decreased trays per minute;

2. To calculate the trays per minute for breakfast trayline and lunch and dinner traylines for a one month period prior to application of the assembly line balancing technique;

3. To apply assembly line balancing techniques for breakfast trayline and lunch and dinner trayline;

4. To propose recommendations for the type of arrangement of

the trayline area for both the present and projected facilities which would require minimum capital investment.

CHAPTER 2

REVIEW OF LITERATURE

Limited published literature for improving efficiency on a hospital centralized tray assembly conveyor system was available. Four major categories of productivity improvement for trayline literature could be located. The first two categories were insulated service systems (3) and a computerized trayline (4, 5, 6, 7, 8, 9). Both of these systems were sold commercially and required extensive captial outlay.

The available literature discussing the insulated service system claimed the system increases efficiency, although no specific explanation for the increase was offered. Two different computerized assembly systems were available, an automated tray assembly line (4, 8, 9) and a system of food cassettes (5, 6, 7). In the automated tray assembly system, each patients' menu was transferred onto a punch card which was passed through a card reader at the beginning of the trayline. The patients' name, room number and selections were recorded in memory. As each tray approaches a station on the line, a light flashed to indicate the item and portion size required for that patient. This system eliminated the need for dietary employees to read each menu and reduced communication problems for non-English speaking employees.

The cassette system must be used with a cook-freeze production system. Individual servings were portioned, frozen and loaded into dispensing cassettes. At service time, the patients' selections

which were recorded on cards or in the computers memory, were read by the computer and dispensed from the appropriate cassette onto either a tray or a conveyor belt.

The third category of productivity improvement consisted of a variety of minor modifications to the tray assembly procedure. Modifications in menu design (10) was recommended to improve readability. Suggested revisions included color striping to define focal areas and to cluster information into a sequence of basic groups. Fankhauser (10) claimed such redesign of menus increased production by eleven per cent. The increase resulted because the operator could perceive sooner what was to be placed on upcoming trays. The use of color coded prepackaged condiments (11) increased accuracy of selection and made selection of condiments a one motion effort. The package colors match the color of the appropriate menus, for example, a blue menu for regular diets received a blue package which contained sugar, salt, and pepper.

Evaluation of the work area arrangement was recommended for efficient motion (12). Each person on the trayline should be able to reach with both hands, place two items on each tray using a single movement. Useless motion, such as dipping twice for one serving, should be eliminated through the use of serving utensils which accurately portion food items. There should also be a floater or runner assigned to retrieve items needed for the serving line.

The final minor modification involved determining cycle length of the conveyor system (13). The calculations on the following page

illustrate an example used to determine launch rate of new trays into the conveyor assembly system.

Example: Required output rate: 360 trays per hour

360 trays per hour = 6.0 trays per minute minimum acceptable output rate

Add: 15 per cent total delay facotr

6.0 x 100/85 = 7.1 trays per minute

7.1 trays per minute = 8.5 seconds per tray: 1 tray = 4 seconds (when trayline speed equals 15 tray lengths per minute.)

8.5/4.0 = 2.12 tray lengths

A new tray must start every 2.12 tray lengths (13).

Space was desired between trays to allow the operators time to read the menu and serve the appropriate product. When trays were spaced too closely, an operator who was unable to keep up, held trays back from the forward motion in order to complete his task. A holding area was recommended to allow trays to be removed from the line while mistakes were corrected.

Assembly line balancing was another method discussed in the literature for improving trayline efficiency. This included any means used to achieve balance between the work assignments of the work stations. McGary (14, 15, 16) developed a method for a hospital centralized food service based on industrial engineering studies (17, 18, 19). McGary's method required limited financial expenditure, limited equipment and could easily be accomplished manually. More recent studies by industrial engineers discussed the use of a computer in the

assembly line balancing procedure (20, 21, 22, 23, 24, 25, 26).

CHAPTER 3

PROCEDURE

The initial step in the procedure of increasing productivity consisted of identification of delays in the system which decrease trays per minute. This was accomplished through observation of the assembly process and identification of unequal work distribution between work stations and delays caused by operator failure.

The second step in the procedure was calculation of trays per minute for breakfast, lunch and dinner traylines. This data was calculated for a period of one month prior to initiating the stop watch time study to determine work unit time. A record of trays served at each meal as well as the length of service time required for service was recorded to determine trays per minute (Appendix B).

The assembly line balancing technique developed by McGary (14, 15, 16) was applied to the trayline system at AMH. Four of the seven delays identified could be eliminated through a balanced trayline. McGary's model was adapted from the Helgeson and Birnie (17) ranked positional weight technique for assembly line balancing. McGary altered only the procedure for determining cycle time. Constraint equations were added to prevent the use of a cycle time which would require tray assembly periods longer than a normal meal period (14). A glossary defining assembly line balancing terminology is included in Appendix C.

The procedure of balancing the assembly line consists of nine

steps.

Step 1: Preparation of Food and Accessory Item List

A list of food and accessory items that were placed on the meal trays was identified. Accessory items were listed separately if the item was placed directly on the tray or was combined with a food item on the assembly line, for example entree and dinner plate. If the food and accessory item were preassembled, only the food item was listed, for example salad or dessert. This distinction was made in order to identify items which required separate hand motions.

Steps 2 and 3: Combination of Food and Accessory Items into Work Units, Assignment of Numbers to Work Units, and Establishment of Work Unit Times

Work groups were developed based on the principles of motion economy and Helgeson and Birnies' criteria (17). Motion economy principles stressed the simultaneous motion of both hands during work (1). Helgeson and Birnies' criteria stated that work groups cannot be subdivided without additional motions (17). Consideration was also given to limitations of the physical layout of the trayline.

Work unit times were established by stop watch study. Initially, ten readings were recorded for each of thirty one trayline items. The number of additional readings required was determined following the equation: $\frac{R}{X}$

where: R = range of high time elemental value minus low time study elemental value
X = average time value of element for sample

The number of additional readings required (N') was determined by

locating the value of $\frac{R}{\bar{X}}$ and the corresponding number for ten samples in Barnes' Time and Motion (27) (Appendix D). A $\pm$ 10% Precision and a 95% Confidence level were desired. The average times were determined after the random readings were completed (Appendix E). The recommended number of readings could not be recorded for the diet entree and vegetables. A majority of the therapeutic diets were delivered to one nursing station which prevented a random time reading. Therapeutic diets represent less than fifteen per cent of the total meals served. The work units were then numbered consecutively, beginning with one.

Step 4: Development of a Precedence Graph

The precedence graph provided a visualization of the relationships between work units. This graph showed the logical sequence of work units while considering limitations of the system. In a conventional service system, where patient trays are assembled and delivered to the patients, hot foods are served at the last service station. Cold food items are served at the begining of the system. At AMH, the beverage station must be the last station before the checker due to the perminate placement of the coffee urn (Figure 1). Work unit one, the tray, received precedence over all other work units since the tray must be the first item introduced into the system.

Step 5: Transposing Precedence Relationships to a Precedence Matrix

The precedence matrix was used to determine positional weights in step six. The definitions for the numbers used in the precedence

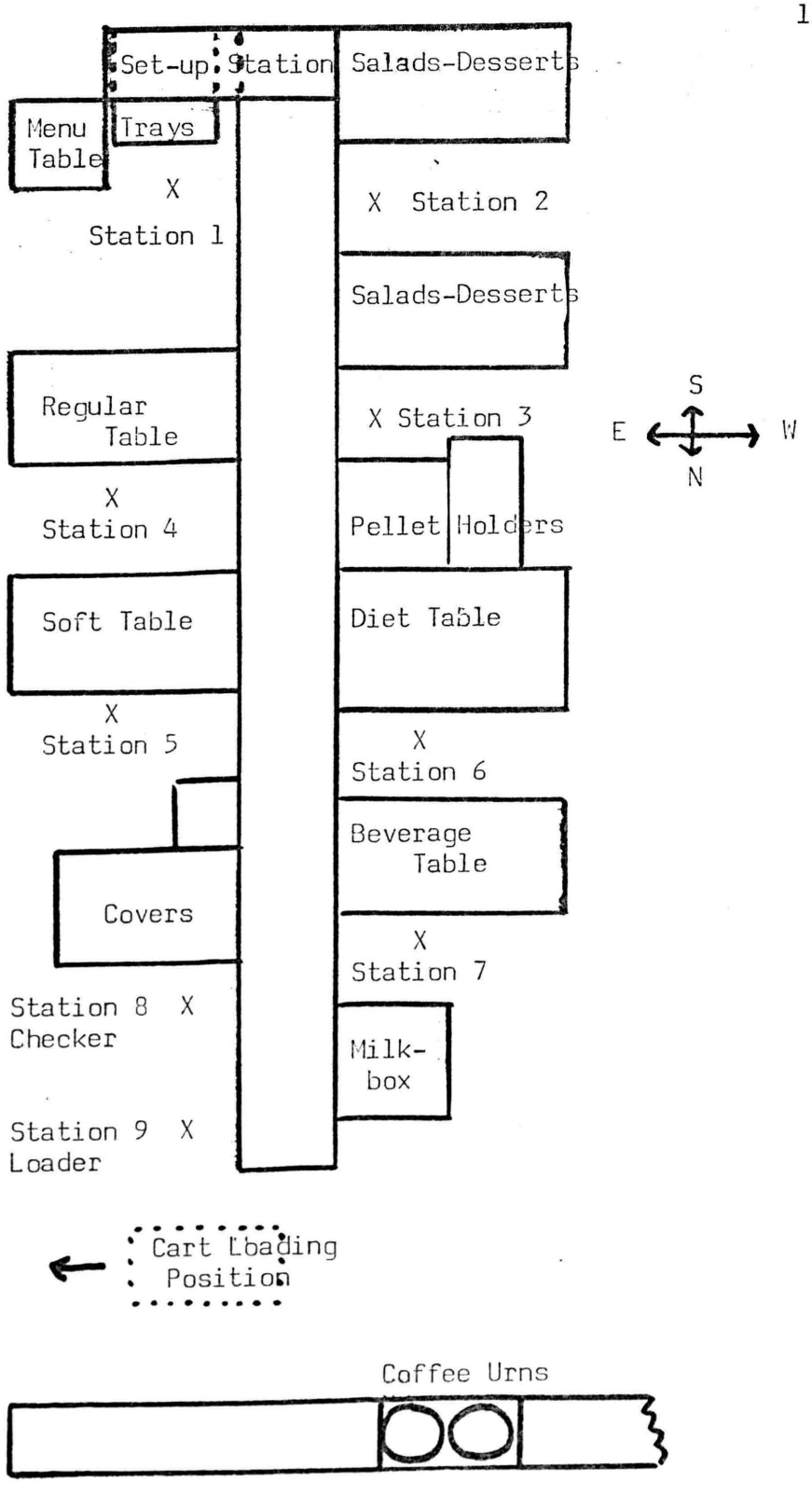


Figure 1: Trayline Layout of Present Facility

matrix are:

1. Must precede = +1
2. Must not precede = -1
3. Makes no difference as to precedence = 0

The precedence graph developed in step 4 was used to visualize precedence of work units in this step.

Step 6 and 7: Calculation of Positional Weights and Ranking of the Work Units

To calculate positional weights, the time values for each work unit and all work units which must follow as shown by the precedence matrix, were summed. The work units were then ranked from highest to lowest positional weight, and immediate precedence work units were noted.

Step 8: Determination of Cycle Time

Cycle time was determined and controlled so that all trays were served within a specified period of time. Cycle time was expressed as:

$$30 \leq \frac{U_H T}{1} \leq 80, \qquad C = U_H$$

where: U_H = Highest work unit time, minutes

T = Average number of trays assembled

X = Number of conveyors

30 = Minimum assembly time, minutes

80 = Maximum assembly time, minutes

C = Cycle time, minutes

For an average tray count of 235, 40 minutes were considered ideal (5.875 trays per minute).

Step 9: Assignment of Work Units to Work Stations

McGary's (14) steps for assignment of work units to work stations were as follows:

> In the assignment of work units to work stations, ranked work units begining with the one with the highest positional weight are successively assigned to the first work station until either:
>
> 1. Unassigned work station time is zero and cumulative work station time is equal to cycle time or
> 2. Any subsequent work unit assignment would cause the cumulative work station time to be greater than cycle time.
>
> Work units are rejected which would either:
>
> 1. Cause the cumulative work station time to be greater than cycle time, or are
> 2. Considered technically unfeasible for assignment to the work station due to work units already assigned.
>
> Rejected work units are considered in sequence prior to continuing the attempt to assign other work units according to positonal weights. The same procedure is followed until all work units have been assigned to a work station (14).

The observations noted during data collection and the actual data were used to develop the recommended layout for the present facility. The work unit assignments made in step nine determined the work station content. Spacing of work stations along the trayline was based on earlier observation of delays in the system.

CHAPTER 4

RESULTS AND DISCUSSION

The average trays per minute for breakfast, lunch and dinner traylines was calculated for a period of one month prior to initiation of the stop watch study. The average trays per minute for August 1981 was slightly higher than the average for March 1981 when the preliminary data was collected. However, the results, an average of 3.65 trays per minute, was still below the desired standard of six trays per minute (Appendix B).

Trays move through a centralized assembly system in one of two ways: manual, where the trays are moved manually from one station to the next either on rollers or a flat surface, or secondly, by a mechanized conveyor belt. Since the conveyor belt system of tray movement required fewer work motions, it is generally considered the superior system (14). The system at AMH was manual. The new facility will be equiped with a thirty five foot mechanized conveyor system.

Because the present trayline required manual movement of the trays from one station to another, provision of space between the trays was not possible. For this reason, the recommendation for determining launch rate (13) could not be applied to the assembly system at AMH at the present time. The calculations on the following page show the required launch rate for the new facility.

Required output rate: 335 trays per hour

335 trays per hour = 5.58 trays per minute acceptable output

Add: 15 per cent total delay factor

5.85 x 100/85 = 6.56 trays per minute

6.56 trays per minute = 9.15 seconds per tray

Because the specifications for the trayline and trays were not available, only the launch rate was determined. The space available between trays will have to be determined following the procedure on page six at a later date. Based on the above calculations, a new tray must be introduced into the system every 9.15 seconds

RESULTS OF ASSEMBLY LINE BALANCING

The assembly line balancing technique developed by McGary (14, 15, 16) was applied to the trayline system at AMH. The results of this nine step procedure are presented in the following discussion, tables and figures.

Step 1: Preparation of Food and Accessory Item List

Tables one and two contain the list of food and accessory items placed on the meal trays. These lists were developed to distinguish items and accessories which required separate hand motions when moved to the tray.

Steps 2 and 3: Combination of Food and Accessory Items into Work Units, Assignment of Numbers to Work Units, and Establishment of Work Unit Times

Tables 3 and 4 list the work units, work unit times and work unit numbers. Work units were developed based on principles of mo-

Table 1: Food and Accessory Item List - Breakfast

Basic Accessory Items

Tray and cover
Menu in holder
Napkin
Silverware (knife, fork, spoon in plastic bag)
Salt
Pepper
Sugar
Sugar Substitute
Salt Substitute
Pellet
Lid Cover
Straw

Food Items	Accessory Items for Food Assembly
Dry Cereal	Bowl
Jello	
Fruit	
Bread	
Oleo	
Jelly	
Entree and accompaniments	Plate
Broth	Cup and lid
Hot Cereal	Bowl and lid
Milk	
Juice	
Carbonated Beverage	Cup
Coffee	Cup
Hot Water	Cup
Creamer	
Tea Bag	
Decaffeinated Coffee (Individual)	
Melba Toast	
Crackers	

Table 2: Food and Accessory Item List - Lunch and Dinner

Basic Accessory Items

Tray and cover
Menu in holder
Napkin
Silverware (knife, fork, spoon in plastic bag)
Salt
Pepper
Sugar
Sugar Substitute
Salt Substitute
Pellet
Lid Cover
Straw

Food Items	Accessory Items for Food Assembly
Broth	Cup and lid
Soup	Bowl and lid
Crackers	
Melba Toast	
Entree and accompaniments	Plate
Bread	
Oleo	
Dessert	
Salad	
Milk	
Coffee	Cup
Hot Water	Cup
Tea bag	
Decaffeinated Coffee (Individual)	
Iced Tea	
Juice	
Ice Cream	
Jello	
Carbonated Beverage	Cup

tion economy (1, 17). Work unit times were determined from stop watch studies (Appendix D). The work units were numbered consecutively, begining with one.

The readings for carbonated beverages, broth, soup, jello, ice cream, diet entrees and diet vegetables were not included in the list of work units. The ideal balance of the assembly line should be determined for a majority of the trays served (regular and soft diets). Recommendations for the service of these items was considered in the final proposal of the system layout.

Step 4: Development of a Precedence Graph

The precedence graphs in Figures 2 and 3 were developed to visualize the relationship between work units.

Step 5: Transposing Precedence Relationships to a Precedence Matrix

Based on the precedence graph developed in step 4, the precedence matrix was established to determine positional weight in step 6. Figures 4 and 5 illustrate the precedence matrices for breakfast, lunch and dinner.

Steps 6 and 7: Calculation of Positional Weights and Ranking of the Work Units

After positional weights were determined based on the precedence matrix, the work units were ranked from highest to lowest positional weight. The immediate precedence work unit was noted. Tables 5 and 6 present the results of this step.

Step 8: Determination of Cycle Time

Cycle time was determined and controlled so that all trays were

Table 3: Work Units, Work Unit Numbers, and Work Unit Times
Breakfast

Work Unit #	Work Units	Work Unit Time in Minutes
1	Tray with cover	0.021
2	Menu in holder	0.016
3	Napkin, silverware	0.037
4	Condiments	0.022
5	Special Items - teabags, creamer, decaffeinated coffee, melba toast, crackers	0.019
6	Jelly, oleo	0.028
7	Fruit	0.034
8	Dry Cereal	0.023
9	Pellet	0.033
10	Regular plate	0.105
11	Hot cereal or broth	0.112
12	Juice	0.030
13	Coffee or hot water, cup	0.032
14	Milk, straw	0.044
15	Checker	0.084
16	Loader	0.048

Table 4: Work Units, Work Unit Numbers, and Work Unit Times-Lunch and Dinner

Work Unit #	Work Units	Work Unit Time in Minutes
1	Tray with cover	0.021
2	Menu in holder	0.016
3	Napkin, silverware	0.037
4	Condiments	0.022
5	Special items - teabags, creamer, decaffeinated coffee, melba toast, crackers	0.019
6	Pellet	0.033
7	Bread, oleo	0.026
8	Dessert, salad	0.064
9	Regular plate	0.141
10	Soft plate	0.175
11	Milk, straw	0.044
12	Juice	0.030
13	Coffee or hot water, cup	0.032
14	Iced tea	0.019
15	Checker	0.084
16	Loader	0.048

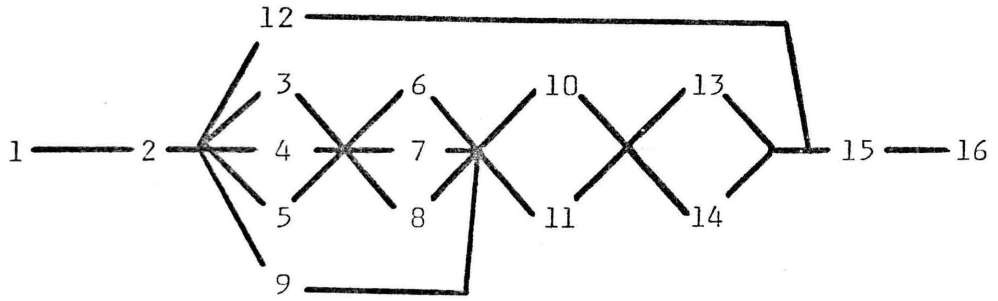


Figure 2: Precedence Graph - Breakfast Trayline

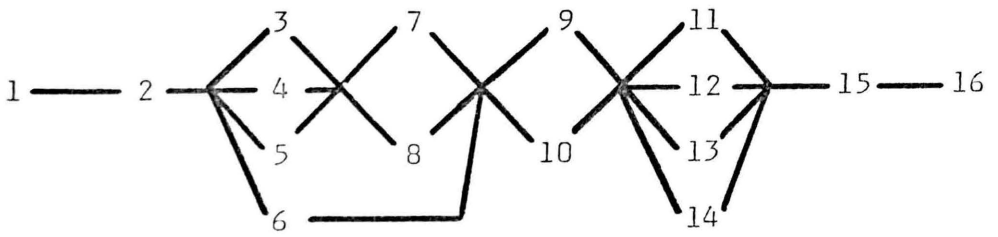


Figure 3: Precedence Graph - Lunch and Dinner Trayline

Work Unit Time	Work Unit #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.021	1	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
0.016	2	-1	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
0.037	3	-1	-1	0	0	0	+1	+1	+1	0	+1	+1	0	+1	+1	+1	+1
0.022	4	-1	-1	0	0	0	+1	+1	+1	0	+1	+1	0	+1	+1	+1	+1
0.019	5	-1	-1	0	0	0	+1	+1	+1	0	+1	+1	0	+1	+1	+1	+1
0.028	6	-1	-1	-1	-1	-1	0	0	0	0	+1	+1	0	+1	+1	+1	+1
0.034	7	-1	-1	-1	-1	-1	0	0	0	0	+1	+1	0	+1	+1	+1	+1
0.023	8	-1	-1	-1	-1	-1	0	0	0	0	+1	+1	0	+1	+1	+1	+1
0.033	9	-1	-1	0	0	0	0	0	0	0	+1	+1	0	+1	+1	+1	+1
0.105	10	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	+1	+1	+1	+1
0.112	11	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	+1	+1	+1	+1
0.030	12	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	+1	+1
0.032	13	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	+1	+1
0.044	14	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	+1	+1
0.084	15	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	+1
0.048	16	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0

Figure 4: Precedence Matrix - Breakfast Trayline

Work Unit Time	Work Unit #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.021	1	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
0.016	2	-1	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
0.037	3	-1	-1	0	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
0.022	4	-1	-1	0	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
0.019	5	-1	-1	0	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
0.033	6	-1	-1	0	0	0	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1
0.026	7	-1	-1	-1	-1	-1	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1
0.064	8	-1	-1	-1	-1	-1	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1
0.141	9	-1	-1	-1	-1	-1	-1	-1	-1	0	0	+1	+1	+1	+1	+1	+1
0.175	10	-1	-1	-1	-1	-1	-1	-1	-1	0	0	+1	+1	+1	+1	+1	+1
0.044	11	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	+1	+1
0.030	12	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	+1	+1
0.032	13	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	+1	+1
0.019	14	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	+1	+1
0.084	15	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	+1
0.048	16	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	0

Figure 5: Precedence Matrix - Lunch and Dinner Trayline

Table 5: Positional Weights, Ranked and Unranked - Breakfast

Work Unit	Unranked Positional Weight	Immediate Precedence	Work Unit	Ranked Positional Weight	Immediate Precedence
1	.688	-	1	.688	-
2	.667	1	2	.667	1
3	.547	2	3	.547	2
4	.532	2	4	.532	2
5	.529	2	5	.529	2
6	.453	2	7	.459	3,4,5
7	.459	3,4,5	9	.458	2
8	.448	3,4,5	6	.453	2
9	.458	2	8	.448	3,4,5
10	.313	7,8,9	11	.320	7,8,9
11	.320	7,8,9	10	.313	7,8,9
12	.162	2	14	.176	10,11
13	.164	10,11	13	.164	10,11
14	.176	10,11	12	.162	2
15	.132	12,13,14	15	.132	12,13,14
16	.048	15	16	.048	15

Table 6: Positional Weights, Ranked and Unranked - Lunch and Dinner

Work Unit	Unranked Positional Weight	Immediate Precedence	Work Unit	Ranked Positional Weight	Immediate Precedence
1	.811	-	1	.811	-
2	.790	1	2	.790	1
3	.700	2	3	.700	2
4	.685	2	4	.685	2
5	.682	2	5	.682	2
6	.606	2	8	.637	3,4,5
7	.599	3,4,5	6	.606	2
8	.637	3,4,5	7	.599	3,4,5
9	.398	6,7,8	10	.432	6,7,8
10	.432	6,7,8	9	.398	6,7,8
11	.176	9,10	11	.176	9,10
12	.162	9,10	13	.164	9,10
13	.164	9,10	12	.162	9,10
14	.151	9,10	14	.151	9,10
15	.132	11,12,13,14	15	.132	11,12,13,14
16	.048	15	15	.048	15

served within a specified period of time. Cycle time was expressed as: $30 \leq \frac{U_H T}{1} \leq 80, \quad C = U_H$

where: U_H = Highest work unit time, minutes

T = Average number of trays assembled

X = Number of conveyors

30 = Minimum assembly time, minutes

80 = Maximum assembly time, minutes

C = Cycle time, minutes

For an average tray count of 235, 40 minutes was considered ideal (5.875 trays per minute).

Breakfast: $30 \leq \frac{0.112\ (235)}{1} \leq 80, \quad C = U_H$

$30 \leq 26.32 \leq 80, \quad C \neq U_H$

Lunch and Dinner: $30 \leq \frac{0.175\ (235)}{1} \leq 80, \quad C = U_H$

$30 \leq 41.125 \leq 80, \quad C \neq U_H$

When the highest work unit time multiplied by the average number of trays was less than thirty minutes, as in the case of the breakfast trayline, cycle time must be increased.

This is expressed as: $U_H T \leq 30, \quad C_L = U_H, \quad C_H = \frac{30}{T}$

and

$C_L \leq C \leq C_H$

where: U_H = Highest work unit time, minutes

T = Average number of trays assembled

30 = Minimum time, minutes

C_L = Lower limits of cycle time, minutes

C_H = Upper limits of cycle time, minutes

C = Cycle time, minutes

When: $U_H = 0.112$

$T = 235$

$U_H T = 0.112 \times 235$

$= 26.32$

$C_H = \frac{30}{235}$

$= .128$

Therefore: $0.112 \leq C \leq 0.128$

The cycle time for the breakfast trayline may range from 0.112 to 0.128 minutes as indicated above.

Step 9: Assignment of Work Units to Work Stations

McGary's (14) procedure for assignment of work units to work stations was followed. Tables 7 and 8 present the results of this procedure.

RECOMMENDATIONS FOR IMPROVED TRAYLINE EFFICIENCY

McGary (14) identified ten common delays found in assembly systems. Seven of the ten delays listed by McGary (14) were identified within the assembly system at AMH. Table 9 lists the delays as well as observations noted.

TABLE 7
ASSIGNMENT OF WORK UNITS TO WORK STATIONS
CYCLE TIME 0.128 MINUTES

BREAKFAST

	WORK UNIT NO.	POSITIONAL WEIGHT	IMMEDIATE PRECEDENCE	WORK UNIT TIME	CUMULATIVE STATION TIME	UNASSIGNED STATION TIME	ASSIGNMENT TECH. FEASIBLE	NOTATION
Station 1	1	.688	-	0.021	0.021	0.107	Yes	Assigned
	2	.667	1	0.016	0.037	0.091	Yes	Assigned
	3	.547	2	0.037	0.074	0.054	Yes	Assigned
	4	.532	2	0.022	0.096	0.032	Yes	Assigned
	5	.529	2	0.019	0.115	0.013	Yes	Assigned
	All other work units rejected, work unit times greater than 0.013							
Station 2	7	.459	3,4,5	0.034	0.034	0.094	Yes	Assigned
	9	.458	2	0.033	0.067	0.061	Yes	Assigned
	6	.453	2	0.028	0.095	0.033	Yes	Assigned
	8	.448	3,4,5	0.023	0.118	0.010	Yes	Assigned
	All other work units rejected, work unit times greater than 0.010							
Station 3	11	.320	7,8,9	0.112	0.112	0.016	Yes	Assigned
	All other work units rejected, work unit times greater than 0.016							
Station 4	10	.313	7,8,9	0.105	0.105	0.023	Yes	Assigned
	All other work units rejected, work unit times greater than 0.023							
Station 5	14	.176	10,11	0.044	0.044	0.084	Yes	Assigned
	13	.164	10,11	0.032	0.076	0.052	Yes	Assigned
	12	.162	2	0.030	0.106	0.022	Yes	Assigned
	15	.132	12,13,14	0.084	0.190		No	Rejected
Station 6	15	.132	12,13,14	0.084	0.084	0.044	Yes	Assigned
	16	.048	15	0.048	0.132		No	Rejected
Station 7	16	.048	15	0.048	0.048	0.080	Yes	Assigned

TABLE 8
ASSIGNMENT OF WORK UNITS TO WORK STATIONS
CYCLE TIME 0.175 MINUTES

LUNCH AND DINNER

	WORK UNIT NO.	POSITIONAL WEIGHT	IMMEDIATE PRECEDENCE	WORK UNIT TIME	CUMULATIVE STATION TIME	UNASSIGNED STATION TIME	ASSIGNMENT TECH. FEASIBLE	NOTATION
Station 1	1	.881	-	0.021	0.021	0.154	Yes	Assigned
	2	.790	1	0.016	0.037	0.138	Yes	Assigned
	3	.700	2	0.037	0.074	0.101	Yes	Assigned
	4	.685	2	0.022	0.096	0.079	Yes	Assigned
	5	.682	2	0.019	0.115	0.060	Yes	Assigned
	8	.637	3,4,5	0.064	0.179		No	Rejected
	6	.606	2	0.033	0.148	0.027	Yes	Assigned
	7	.599	3,4,5	0.026	0.174	0.001	No	Rejected
Station 2	8	.637	3,4,5	0.064	0.064	0.111	Yes	Assigned
	7	.599	3,4,5	0.026	0.090	0.085	Yes	Assigned
	10	.432	6,7,8	0.175	0.265		No	Rejected
Station 3	10	.432	6,7,8	0.175	0.175	0.0	Yes	Assigned
Station 4	9	.398	6,7,8	0.141	0.141	0.034	Yes	Assigned
	11	.176	9,10	0.040	0.181		No	Rejected
Station 5	11	.176	9,10	0.040	0.040	0.135	Yes	Assigned
	13	.164	9,10	0.032	0.072	0.103	Yes	Assigned
	12	.162	9,10	0.030	0.102	0.073	Yes	Assigned
	14	.151	9,10	0.019	0.121	0.054	Yes	Assigned
	15	.132	11,12,13,14	0.084	0.205		No	Rejected
Station 6	15	.132	11,12,13,14	0.084	0.084	0.091	Yes	Assigned
	16	.048	15	0.048	0.132	0.043	No	Rejected
Station 7	16	.048	15	0.048	0.048	0.127	Yes	Assigned

Table 9: Common Delays in Trayline Assembly Systems Noted at Arlington Memorial Hospital

Types of Delays	Observations
Work station layout not conducive to motion economy	The necessity for operators at the salad-dessert station to walk in order to reach some items
Unequal work distribution between work stations	Range of one to fifteen food or accessory items handled at different stations
	Variability in operator pace among work stations
Work station content greater than cycle time	Location of salad-dessert station to close to set-up station
High frequency of missed or incorrect items, often with concentration at a specific work station	Possibility of inappropriate operator assignment at some work stations
Operators responsible for replenishment of own supplies	Lack of specified runner
	Inaccuracy of initial supply
Necessity for operators to hold trays back from forward progress	Operators unable to complete work station tasks before trays are moved past station
Supervisors serving as checker and subsituting for the cart loader during short periods of when the latter is engaged in other activities	Lack of a runner to assist checker
	Delayed return of loader from delivering food carts to nursing floors.

Modification of menu design was recommended to improve readability (10). The menu design should cluster the information required by each work station into one specific area. The current menu design required the operator at the salad-dessert and the beverage stations to look in two separate places on the menu to complete the work of their stations. The menus should also be color coded to match the color coded condiment packages.

The color coded condiment packages (11) are commercially available. Five combinations of condiments would meet the needs of a majority of the diets at AMH: regular, soft-bland, sodium controlled, sugar controlled and sodium-sugar controlled. At the set-up station, the operator could select the appropriate color condiment package which would match the menu, for example, blue menus for regular diets, blue condiment packages which contain sugar, salt and pepper.

The current system required the set-up operator to select either a packaged or individual condiments. The checker must then locate and check three or more individual condiment packages for all trays other than for regular diets. At the present time, coded packages were available for regular diets although the menus were not color coded. Although this system is more expensive than the use of individual condiments, the packaged condiments are recommended for increasing speed and accuracy.

Attention should be given to the loss of productivity due to wasted motion. Consideration should be given to eliminating the numerous minor

unnecessary motions which when repeated add up to a great loss of productive time. The use of the prepackaged condiments reduced the process of selecting condiments to one motion. Condiment packages are also available which include a napkin and straw, further reducing the number of motions required for assembly of each tray. An additional benefit associated with these packages is increased sanitation standards since the straw, condiments and napkin are not directly handled.

The appropriate size of serving utensils should be used. Service of brother currently required the operator to fill a six ounce ladle twice to fill a twelve ounce cup. If a serving size of larger than six ounces is desired, a ladle of the appropriate size should be used by the operator.

The process of portioning eggs for therapeutic diets should be reviewed from the standpoint of motion economy. In this case, the serving size of seventy grams of scrambled eggs is approximately portioned by one number 16 scoop. A number 16 scoop portions sixty five to seventy five grams of scrambled eggs. Variation results due to the degree which the individual operator packs eggs into the scoop during portioning. The use of a scale would be required for portion sizes which are not multiples of seventy grams.

During observations, the operator dipped a scoop of eggs and patiently removed or added to the serving until exactly seventy grams was portioned. Such degree of accuracy was time consuming and not necessary for a majority of the patients. Few patients at AMH have

ever required strict protein controlled diets for renal failure. However, the clinical dietitian would need to make a judgement concerning the acceptable variance of portion sizes.

The arrangement of the individual work stations was directly related to the efficiency of motion at each work station. The arrangement of the salad-dessert and of the beverage station was usually left to the operator. There was a standard arrangement of all the other stations. Consequently, some operators arranged their stations carefully, and others simply placed the products randomly in no given order at their work stations. Figure 6 details a proposed arrangement for the salad-dessert station for the present facility.

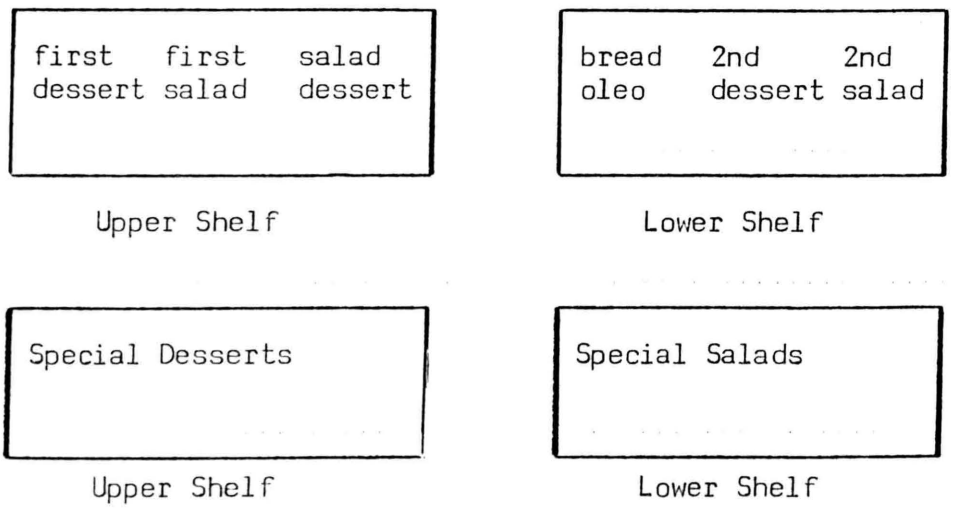


Figure 6: Proposed Arrangement for Salad-Dessert Station - Current Facility

The operator at this station should select the appropriate dessert and salad and with one motion, move the salad and dessert to the tray. The first dessert and salad appearing on the menu should be placed on the upper shelf in order to be easily reached. The dessert should be placed closest to the line, so the left hand places the dessert at the lower left hand portion as the operator views the tray. As the patient views the tray, the desserts are placed in the upper right hand portion of the tray. The desserts for the therapeutic diets are placed on the upper shelf of the second cart for the same reason.

This arrangement should reduce the need for the operator to move their feet when preparing most of the trays. Ideally, the salads and desserts should be stored on a vertical rack. The current tables require that the items be spread over a large area. This arrangement makes it necessary for the operator to move around within the work station. Two vertical racks, one for salads, one for desserts, would allow all products to be placed within easy reach of the average operator.

The arrangement of the beverage station is not as important as the preliminary tasks which should be performed during the preparation period prior to service times. The carbonated beverages and any canned fruit juices should be removed from the plastic holders and boxes. When left until after the trayline begins, delays occur. If straws are dispensed at this station, the box of straws should be placed on the milk box so that the milk and straw are selected and moved to the pa-

tient tray in one motion. Finally, the coffee cup, with handle, should be placed on top of the coffee container. This practice is usually followed, but when the cups are separated, an extra motion is required.

One of the common delays identified by McGary (14) was work stations positioned too close to the set-up or starter station. The salad-dessert station must wait for the starter to complete each tray set-up before the salad-dessert operator could read the patient's menu and fill the salad and dessert order. The same delay occurs between the beverage operator and the checker. The proposed layout for the present facility (figure 7) was designed to consider these delays.

Delay occured when items are not available as needed. This inaccuracy of the initial supply pointed out the need to analyze the system of forecasting production which was beyond the scope of this study. However, an area should be available for the checker to place trays which must be corrected. In the current system, trays which were missing items were either left on the trayline, bringing the system to a halt, or placed on the cart with the menu upside down. Leaving the trays out in view but off the trayline would eliminate the problem of the cart being delivered before the missing item was placed on the tray and the menu turned over. The loader did not always check to see that all menus were right side up, indicating all trays were complete. A cart could be used for the tray holding space in the present facility where space is limited, while something more permanent would be required in the new facility.

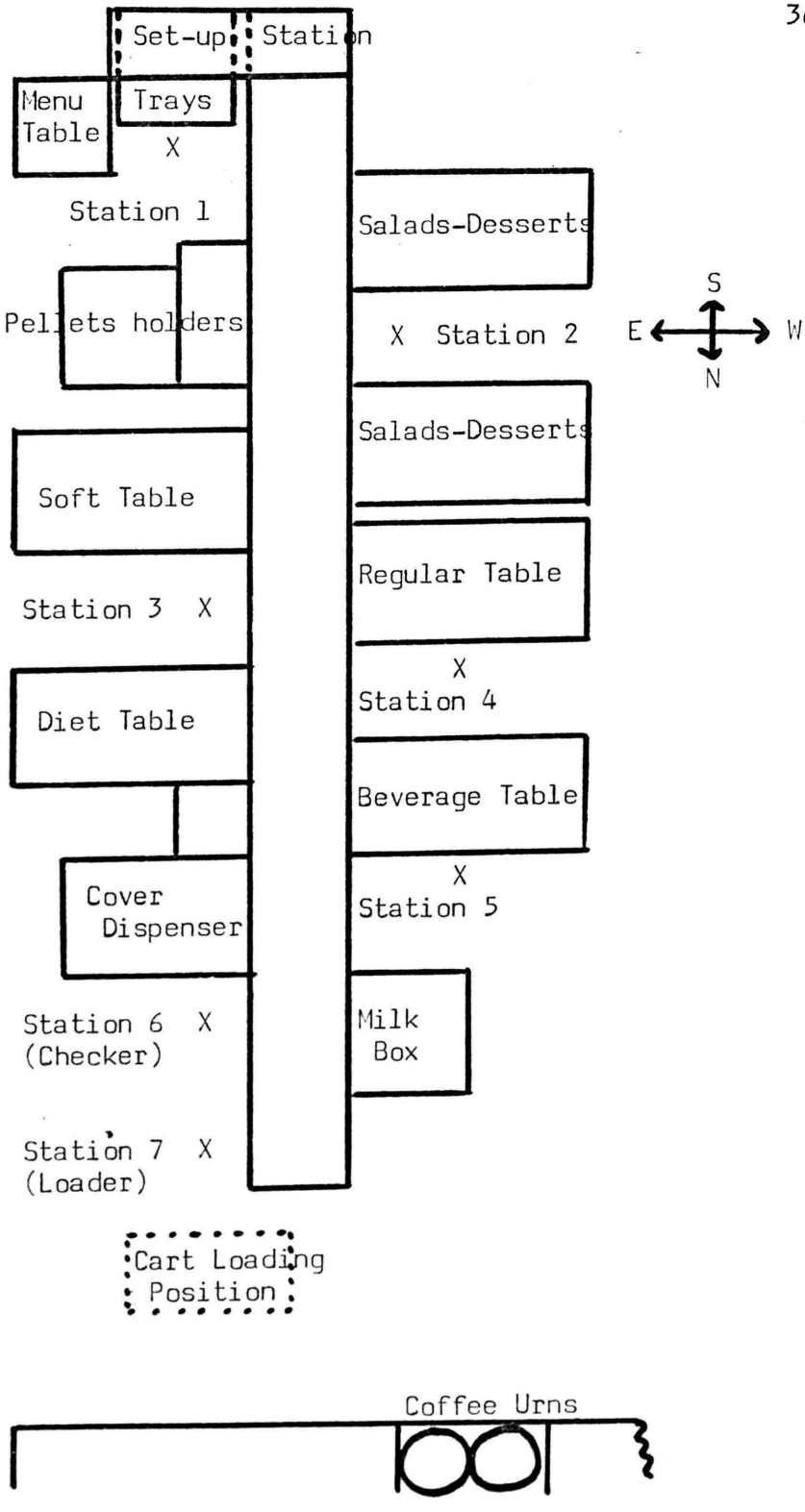


Figure 7: Proposed Layout for Present Facility

Figure 7 illustrates the proposed layout for the present facility which reflects the results of the assembly line balancing procedure. As a result of this procedure, two positions were eliminated on the trayline for lunch and dinner. The diet entrees and vegetables were assigned to work station 3 after the assembly line balancing procedure was completed. Since the majority of therapeutic diets are delivered to one nursing station, the therapeutic menu items could not be grouped with the rest of the entrees or vegetables. The assembly line balancing procedure should be used to determine the ideal design for the majority of patient trays. For the same reason, carbonated beverages, broth, soup, jello and ice cream were assigned to work stations after the assembly line balancing procedure was completed.

One of the operators eliminated by this arrangement can now be designated as a permanent floater or runner. This operator would be responsible for replenishment of the salads and desserts, retrieving and racking menus for the set-up station, obtaining coffee and hot water as required and taking missing items to the checker. The checker should be in control of the trayline, that is, the operator should notify the checker of their needs and the checker should then direct the runner to the area of need. No operator should leave their station once the trayline begins. The runner will also be responsible to assist the operator at the soft table prepare the therapeutic diets. Most of these diets are delivered to the last nursing station served.

The second operator eliminated by this proposed arrangement can be

assigned cleaning during lunch or the position may be assigned to a part time employee who is scheduled to arrive at work after the lunch trayline. The current lunch trayline system required three full time evening employees for operation. During dinner trayline, the second operator eliminated was a salad maker. The position description could be altered in order that this employee is dismissed at an earlier time or additional cleaning duties could be assigned.

At the breakfast trayline, the same number of work stations remained as before the assembly line balancing procedure. Two employees and a supervisor are available to act as a runner, however the position descriptions should clarify the required duties for these employees. The kitchen production supervisor must be available throughout the trayline period to keep all operators at their stations and to assist the checker. On weekend days, the kitchen supervisor will have to act as the runner due to a reduced number of employees scheduled for work.

There is one disadvantage to the proposed layout for the present facility. Both of the hot food service stations require restocking of food items throughout the tray assembly period. The two hot food tables which required restocking were located on the east side of the trayline, close to the cooks' unit, in the original layout (Figure 1). In the proposed layout, the regular table would be located on the west side of the trayline, requiring additional movement to restock this table. This disadvantage will be outweighed by the reduction in the number of operators on the assembly line, and the assignment of one employee as a runner.

The architectural blueprint for the trayline assembly area for the new facility is shown in Appendix F. The trayline for the new facility will be thirty five feet in length, ten feet longer than the current trayline. This additional length will allow more space between work stations, which in turn allows each operator a full cycle to complete each station's tasks. The results of the assembly line balancing technique can not be applied to the layout of the new facility since there will be several additional menu items, including a bread station. An additional study will need to be performed once the new facility is constructed, and after operations have been underway for several months, allowing for adjustment to the new facility. During this period of adjustment, the proposed layout for the present facility could be adjusted to the new facility.

CHAPTER 5

SUMMARY AND CONCLUSION

The purpose of this study was to analyze the tray assembly system at Arlington Memorial Hospital, and propose recommendations for improving the productivity. Observation of the assembly system identified seven types of delays within the system. The procedure of assembly line balancing was applied to this system in order to make recommendations for improving four of the seven delays identified. Other recommendations were offered on the basis of the review of literature. The recommendations were made for both the current facility and the new facility to be completed in December 1982. At this time, the recommendations have not been initiated.

The model of assembly line balancing designed by McGary (14, 15, 16) for a centralized assembly system would be appropriate for use in many facilities. Tray assembly must occur on a centralized tray assembly line, however, the production system may vary, including conventional, cook-freeze, and cook-chill production systems. The model could be used to measure efficiency and productivity of the service system in addition to serving as a tool for redesign of an existing facility or design of a new facility.

RECOMMENDATIONS FOR FUTURE STUDY

After these recommendations have been initiated, an evaluation of the procedure should be made. Efficiency could be measured from the

number of trays served per minute. A rate of six trays per minute is desired. Reevaluation of the system should be made if this rate has not been reached after the initial period of adjustment.

An additional study based on McGary's (14) model of assembly line balancing should be conducted once the new facility is open. There are many differences between the present and new facilities, therefore the results of this balance study can not be applied to the design of the new facility. This evaluation should occur once a daily routine has been established after the move to the new facility.

APPENDIX A

Arlington MEMORIAL HOSPITAL Foundation, Inc.

274-5581 ★ 800 W. RANDOL MILL ROAD

Arlington, Texas 76012

May 20, 1981

Dr. Robert Pawlowski
Dean of Graduate Studies
Texas Woman's University
Denton, Texas

Dear Dr. Pawlowski:

This letter is to advise you that Nancy S. Wise has my permission to conduct her graduate research study in the Dietary Department of Arlington Memorial Hospital. I understand that she will be conducting an assembly line balancing study for the purpose of increasing the speed of the tray assembly process.

Sincerely,

Rex C. McRae
Administrator

RCMcR:me

APPENDIX B

Times on the Trayline - August 1981

Breakfast

Date	Count	Time	Trays/Minute
1	255	78 min.	3.27
2	231	70 min.	3.30
3	239	58 min.	4.12
4	242	64 min.	3.78
5	237	65 min.	3.65
6	228	65 min.	3.51
7	235	58 min.	4.05
8	250	65 min.	3.85
9	230	60 min.	3.83
10	209	55 min.	3.80
11	219	60 min.	3.65
12	214	55 min.	3.89
13	219	55 min.	3.98
14	222	55 min.	4.04
15	209	60 min.	3.48
16	207	55 min.	3.76
17	196	45 min.	4.35
18			
19	230	63 min.	3.65
20	228	70 min.	3.26
21	209	56 min.	3.73
22	216	50 min.	4.32
23	195	50 min.	3.90
24	194	60 min.	3.23
25	209	60 min.	3.48
26	209	45 min.	4.64
27	220	55 min.	4.00
28			
29	224	54 min.	4.15
30	166	50 min.	3.32
31	203	53 min.	3.83

Average trays served: 219

Average trays/minute: 3.76

Range of trays served per minute:

2.83 (August 9) to 4.64 (August 26)

Times on the Trayline - August 1981

Date	Lunch Count	Time	Trays/ Minute	Dinner Count	Time	Trays/ Minute
1	248	75 min.	3.31	222	58 min.	3.83
2	225	58 min.	3.88	254	68 min.	3.74
3	236	60 min.	3.93	257	70 min.	3.67
4	244	80 min.	3.05	256	62 min.	4.13
5	232	69 min.	3.36	237	65 min.	3.65
6	224	65 min.	3.45	242	70 min.	3.46
7	233	63 min.	3.70	241	50 min.	4.82
8	242	65 min.	3.72	225	70 min.	3.21
9	222	65 min.	3.42	240	58 min.	4.14
10	211	65 min.	3.25	233	65 min.	3.58
11	215	65 min.	3.31	238	58 min.	4.10
12	212	58 min.	3.65	234	58 min.	4.03
13	211	58 min.	3.64	236	63 min.	3.75
14	209	57 min.	3.67	211	55 min.	3.84
15	222	59 min.	3.76	200	54 min.	3.70
16	214	70 min.	3.06	216	58 min.	3.72
17	202	65 min.	3.11	200	80 min.	2.50
18				247	80 min.	3.09
19	232	60 min.	3.86	247	70 min.	3.53
20	220	55 min.	4.00	220	60 min.	3.67
21	206	65 min.	3.17	206	55 min.	3.75
22	210	68 min.	3.09	180	46 min.	3.91
23	192	47 min.	4.08	228	60 min.	3.80
24	186	62 min.	3.00	226	71 min.	3.18
25	209	60 min.	3.48	226	60 min.	3.76
26	214	60 min.	3.56	236	75 min.	3.14
27	231	62 min.	3.73	254	60 min.	4.23
28						
29	220	60 min.	3.67	214	55 min.	3.89
30	198	54 min.	3.67	228	49 min.	4.65
31	198	48 min.	4.13	216	55 min.	3.93

Average trays served: 218 Lunch
229 Dinner

Average trays/minute: 3.61

Range of trays served per minute:

2.5 (August 17) to 4.65 (August 30)

APPENDIX C

Glossary

McGary (14) assembled the following list of terms and definitions used in assembly line balancing literature.

Assembly line- an arrangement of areas where material moves continuously at a uniform rate through a series of balanced operations which enable simultaneous performance as the work progresses toward completion along a fairly direct path.

Assembly line balancing- any means used to acheive balance between the work assignments of the work stations.

Balance delay- The amount of idle time on the assembly line due to imperfect division of work between work stations. It is the ratio between the total idle time and the total time a product spends in moving from the beginning to the end of the assembly line. The term slack time is used interchangeably with balance delay time.

Centralized tray assembly conveyor system- The whole complex of interacting physical and human resources, equipment, materials, capital, space, time and manpower necessary to assemble patient trays along a mechanized conveyor belt to the desired state of output.

Checker- The operator at the last work station on a centralized tray assembly line who is responsible for checking the food and beverage items on a tray against a printed patients' menu, and who takes necessary action to insure that items on the tray correspond to the patient's menu and that specfic quality standards are maintained.

Conveyor belt- A moving flexible belt used to transport materials.

Cycle time- The amount of time each unit of a product is normally available for an operator in the performance of an assigned task.

Fixed rate launching- Introduction of the initial part of a product, that is, the hospital trays, into an assembly system at required intervals.

Float- An operator not assigned to any specific work station who is responsible for obtaining items missed from trays and replenishing food and accessory items at all work stations.

Mixed Model Assembly- A variety of models of the same general product which typically requires divergent amounts of work, are intermixed on an assembly line, and result in uneven distribution of work and variations in the work load of individual stations.

Operator- An individual assigned to a work station on an assembly line who performs assigned tasks upon the unit of a product as they are conveyed past his work station during progressive assembly.

Precedence relationship- A description of the ordering in which work units must be performed in an assembly operation.

Set-up work station- The initial work station at which preliminary assembly operations are performed, most of which takes precedence over the work activities of the other stations. In a centralized tray assembly conveyor system, the station work includes such activities as placing tray cover, silver, napkin, and condiments on a tray, and then placing the tray on the assembly conveyor belt (launching the tray into the assembly system).

Station work content time- The time necessary to perform the work content of a given work station, also known as operation time.

Total work content- The aggregate amount of work of all the work stations or total assembly.

Total work content time- The time required to perform the total work content, the work activities of all the work stations in the assembly system.

Variable rate launching- Introduction of the initial part of the product into an assembly system at variable intervals.

Work unit- Groupings of work which cannot be subdivided on the assembly line without paying a penalty in extra motions.

APPENDIX D

RESULTS OF STOP WATCH STUDY - IN SECONDS

Tray and cover	1.6	2.0	2.2	2.0	1.8	2.2	1.4	2.6	1.4	1.8
	2.2	3.6	2.0	3.0	2.8	2.6	2.4	2.0	1.6	1.6
	1.8	2.0	1.8	1.4	1.8	1.6	2.0			
Menu in holder	1.0	1.0	1.4	0.8	2.4	2.2	1.8	1.6	1.4	1.4
	0.8	1.4	1.4	1.4	2.2	2.6	2.2	2.0	1.2	2.0
	2.0	2.0	2.0	2.0	1.2	1.2	1.0	1.2	1.0	1.2
	1.0	1.6	1.2	1.0	1.8	1.2	1.4	1.4	1.8	2.4
	1.8	2.0	1.2	2.4	2.0	2.4	1.4	2.0	1.6	1.2
	1.6	1.4	2.8							
Napkin	1.0	2.2	2.0	2.8	1.0	1.4	2.6	1.6	2.8	1.4
	1.4	1.6	1.4	1.4	1.6	1.4	1.8	1.8	1.2	2.4
	2.0	2.2	1.8	2.0	1.4	1.8	1.8	2.0	1.4	1.6
	1.6	2.0	1.2	2.2	1.8	1.8	1.2	1.4	1.2	1.4
	1.4	1.4	2.0	1.8	2.8	1.2	1.8	1.2	2.4	1.4
	1.6	1.8	2.0							
Silverware	1.4	1.4	2.6	2.0	3.8	2.0	2.0	1.6	1.6	2.6
	2.0	1.8	1.6	1.8	2.2	2.0	3.6	1.8	1.8	2.4
	2.8	2.4	1.4	2.0	3.8	2.2	2.2	1.6	1.8	1.6
	1.4	1.4	1.2	2.0	1.6	1.6	1.4	1.8	1.4	2.4
	2.0	1.6	1.4	2.6	1.8	2.8	2.4	1.6	2.0	1.4
	1.6	2.2	1.8							
Special items	1.0	2.4	2.4	2.0	2.0	1.6	1.8	2.8	2.2	2.4
	2.8	1.0	1.2	1.0	2.8	2.8	1.6	1.2	1.2	2.4
	1.0	2.6	2.2	2.0	1.0	1.0	4.0	1.2	2.6	2.0
	2.0	1.8	2.4	3.2	1.8	2.4	1.6	2.4	2.0	1.2
	2.0	2.2								
Condiments	1.4	1.2	2.2	218	2.2	2.2	3.2	4.0	1.4	1.8
	2.0	1.2	1.8	1.8	3.4	4.0	4.0	4.0	1.4	3.4
	1.0	1.6	1.2	2.6	2.2	1.2	1.2	1.6	3.8	2.2
	2.4	2.0	1.2	1.4	2.0	2.4	1.2	1.2	3.0	2.0
	4.6	2.0	2.0	2.2	1.8	3.6	2.2	1.4	2.2	2.0
	1.8	1.4	1.2	1.4	2.2					
Jello	2.0	1.6	1.4	2.0	2.0	2.0	2.0	2.8	2.0	2.8
	2.8	2.8	2.0	1.8	2.6	2.2	1.8	2.6	2.0	2.2
	2.0	1.8	1.4	2.0	1.8	2.6	2.4	2.0	2.4	2.4
Bread & Oleo	2.2	3.8	2.0	2.6	3.0	2.6	3.0	2.8	2.6	3.0
	3.0	2.4	3.8	2.2	2.0	2.8	2.8	3.2	3.2	3.6
	2.2	2.0	3.0	3.2	2.8	2.4	3.0	2.4		

Pellet	1.4	1.4	2.4	3.8	2.8	4.0	2.6	4.8	4.2	2.6
	2.6	2.8	2.0	2.8	3.2	4.0	3.8	2.4	2.6	5.8
	2.8	1.6	2.6	4.0	5.0	2.8	5.8	3.4	3.2	2.8
	3.4	3.4	2.6	2.2	3.4	4.6	4.2	3.4	4.2	4.8
	4.4	2.2	2.2	3.4	4.0	3.2	3.4	2.6	3.2	3.8
	3.6	4.0	4.0							
Milk and straw	4.0	5.8	3.4	6.2	2.6	1.4	7.2	7.0	5.2	6.8
	4.2	2.8	5.2	3.2	3.6	5.8	6.8	4.2	8.4	3.6
	3.4	2.2	2.6	2.8	4.8	3.8	8.0	2.2	2.0	2.8
	5.0	4.4	6.8	4.4	6.0	4.2	6.0	7.2	5.2	3.6
	2.6	3.6	4.0	5.8	4.2	6.6	4.6	4.2	6.8	4.8
	3.8	2.8	2.2	2.4						
Juice	2.0	4.0	2.0	2.2	2.4	2.4	2.8	2.0	2.0	2.4
	3.2	2.4	2.6	4.2	3.2	2.0	7.0	3.6	2.6	3.4
	3.0	4.0	3.0	3.8	2.0	1.8	2.2	3.4	6.0	2.4
	2.4	3.8	3.6	1.8	2.4	3.8	4.2	2.4	3.2	
Carbonated beverage & cup	2.2	3.6	4.4	5.8	3.4	3.6	4.8	7.0	2.0	4.2
	4.2	5.2	3.8	7.2	4.0	3.2	7.0	4.8	3.8	4.4
	8.6	3.0	2.4	4.0	3.2	4.2	3.2	4.2	2.0	4.8
	4.8	5.2	4.6	4.2	6.8	7.0	4.4	2.8	5.2	4.8
	3.2	2.0	3.2	3.6	2.4	4.4	5.2	5.4	6.0	5.0
	4.4	2.2	2.6	5.2	3.4					
Coffee or hot water	2.6	2.8	3.0	3.6	4.6	1.6	1.2	2.8	2.6	4.2
	2.6	2.0	5.0	3.4	3.8	2.0	2.8	2.8	5.8	2.2
	2.4	4.2	2.8	2.4	1.6	2.8	2.0	4.2	2.2	3.8
	3.8	2.0	3.0	2.0	3.4	3.4	3.4	6.0	2.8	4.0
	5.4	3.2	3.6	3.8	3.4	3.0	2.0	3.6	4.0	2.2
	2.4	2.0	3.8							
Checker	8.2	8.8	6.4	9.0	14.2	8.2	7.8	11.0	14.0	7.2
	5.4	4.4	7.0	4.6	7.8	8.8	10.0	10.2	12.6	4.6
	2.4	4.6	10.6	4.0	10.6	6.8	7.2	4.0	11.0	10.2
	4.4	10.2	14.6	10.6	9.2	7.6	12.8	8.4	8.2	
Loader	5.4	3.8	6.0	3.0	3.0	4.8	8.0	4.8	4.6	6.4
	4.4	5.2	4.8	5.2	3.4	3.0	7.4	5.0	6.0	5.6
	4.0	3.6	5.0	5.2	3.4	4.2	5.4	3.6	4.6	4.8
	3.6	8.8	4.8	4.0	5.0	6.6	9.4	5.6	5.2	5.2
	4.4	3.8	4.4	4.8	4.2	3.6	4.2	3.0	3.4	4.2
	4.0	4.2	7.0	5.2						
Broth	9.2	7.0	10.8	9.4	10.8	11.6	16.0	10.2	10.0	14.8
	7.2	11.8	12.6	8.8	12.6	14.2	10.0	9.6	10.2	12.2
	9.4	10.2	10.4	11.0	10.2	11.8	9.2	9.2	7.8	14.2
	9.8	12.4	16.8	9.2	13.4	12.2	14.2	14.4	12.0	

Soup	8.2	17.0	13.0	12.6	14.0	14.4	11.0	10.0	17.0	8.0
	7.6	10.2	11.0	14.2	11.8	11.2	14.8	7.4	14.2	17.6
	7.4	9.0	12.4	10.8	13.0	14.0	11.8	12.6	11.2	19.6
	9.6									
Dry cereal	2.0	1.4	1.4	3.8	4.6	4.6	3.2	4.2	2.0	2.0
	2.0	2.4	2.0	2.2	2.4	2.6	2.2	1.8	1.8	4.2
	1.6	2.6	2.4	2.0	3.4	2.4	2.8	2.8	2.0	1.4
	1.6	2.0	2.4	2.0	2.0	1.8	1.8	1.6	1.8	1.6
	1.4	1.4	1.8	1.6	212	1.8	1.6	2.0	2.6	2.0
	2.4	3.6	2.2							
Breakfast fruit	4.0	3.8	3.2	4.6	2.6	3.4	3.4	3.2	3.6	2.8
	3.2	3.2	4.8	3.6	3.4	4.6	2.4	2.8	4.8	2.6
	2.0	2.6								
Jelly & oleo	1.4	1.6	3.2	2.4	2.0	3.6	2.0	2.4	2.8	2.0
	2.4	2.2	3.4	2.8	3.2	2.8	1.8	1.2	3.4	2.0
	4.6	2.2	2.8	3.2	3.4	2.4	3.8	4.2	1.4	2.4
	2.4	4.0	4.0	3.2	2.0	2.8	2.6	3.0	2.6	4.2
	2.8	3.4	3.4	2.6	4.0	4.2	3.4	2.2		
Regular plate (breakfast)	7.8	12.0	10.2	18.6	14.4	10.6	10.2	11.6	10.2	10.0
	9.2	12.0	11.4	13.2	9.8	12.2	9.0	7.6	6.6	8.0
	9.6	11.0	8.4	11.8	15.0	10.2	7.2	10.2	12.8	11.4
	9.6	12.2	12.2	10.2	10.2	10.8	11.6	8.4	11.6	8.0
	9.6	8.6	10.6	8.6	9.8	10.4				
Diet plate	26.8	20.2	18.8	20.4	10.0	21.0	11.6	14.2	23.4	25.8
	28.4	24.0	10.4	13.8	22.8	14.6	19.6	14.0	20.0	12.2
	23.0	18.2	24.2	36.4	18.4	19.2	15.4	25.2	13.6	17.2
	16.0	11.2	17.2	18.2	25.0	24.6	14.2	20.8	23.6	24.2
	16.6	27.4	20.2							
Hot cereal	5.4	5.2	12.0	5.8	8.0	7.2	10.0	9.8	12.0	7.2
	9.8	11.0	7.0	12.2	14.6	9.0	7.2	8.8	8.0	10.0
	6.6	10.8	7.8	11.0	11.4	9.8	7.0	8.0	9.6	13.2
	9.0	12.6	14.0	6.2	12.2	10.2	17.0	8.2	7.2	
Salads	3.4	2.0	3.0	2.4	2.2	2.2	2.4	3.2	3.8	3.2
	5.8	3.0	2.2	2.8	3.8	4.0	2.8	3.0	3.4	3.2
	3.6	10.2	3.0	3.6	4.2	2.8	2.6	2.0	3.0	
Desserts	3.4	2.2	2.0	3.0	2.2	2.2	2.4	3.2	3.8	3.2
	5.8	2.4	3.0	2.2	2.6	2.6	2.8	3.0	8.2	2.8
	2.6	2.8	2.0	2.4	2.4	3.6	4.2	2.8	3.2	
Regular plate	13.0	12.0	17.2	9.0	11.0	17.0	16.8	17.0	13.2	16.2
	16.2	14.2	12.2	14.0	14.0	9.2	10.0	19.4	16.4	17.4
	17.6	10.4	13.0	11.2						

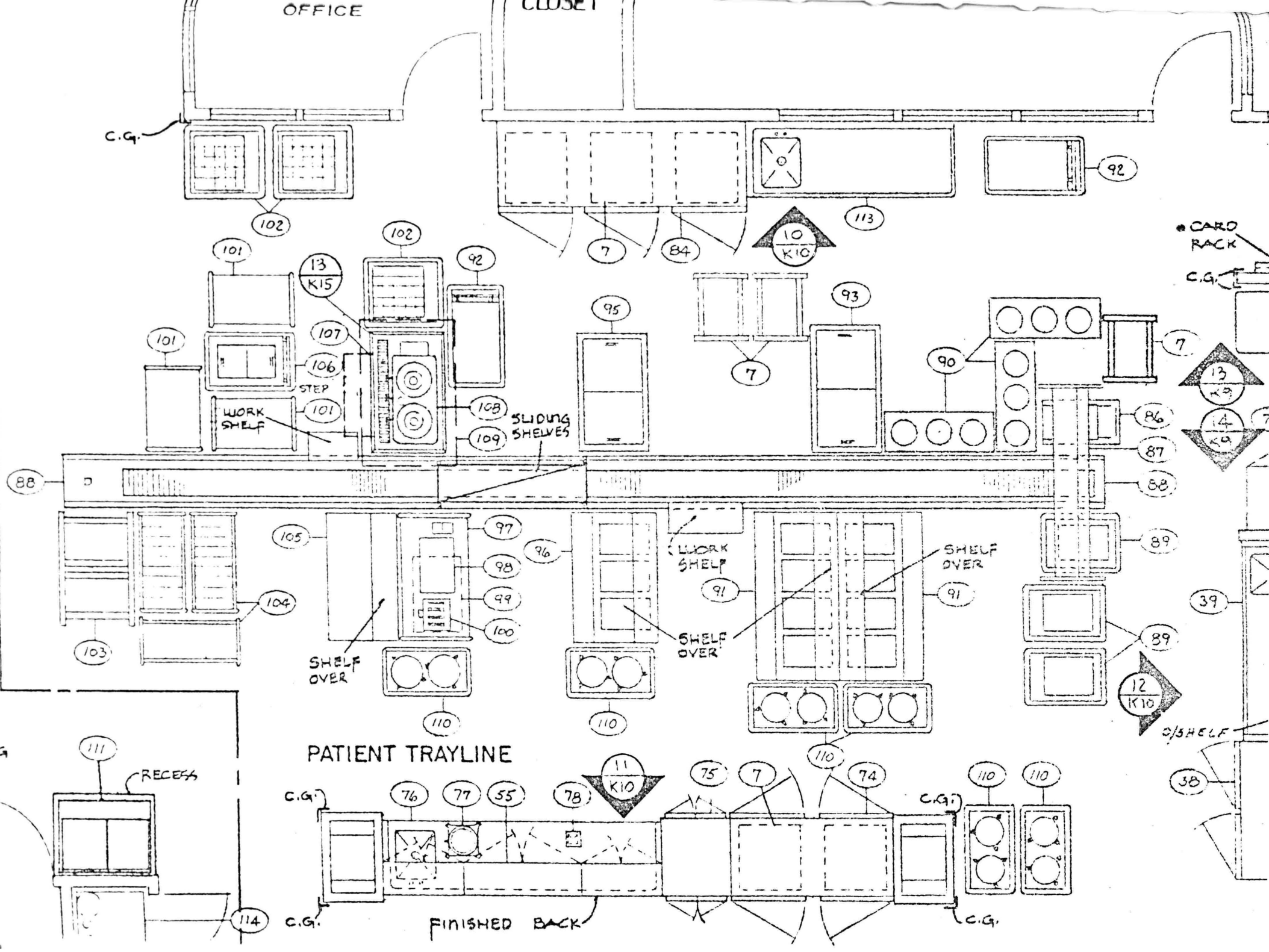
Soft plate (lunch and dinner)	16.4	18.6	12.0	20.8	14.6	12.8	16.0	14.0	16.8	22.4
	20.2	25.8	12.0	15.2	16.0	12.4	12.0	22.0	19.6	23.0
	14.0	15.0	14.6	19.0	17.6	21.6	27.2			
Diet entree	29.0	27.2	41.2	17.6	29.6	61.0	19.6	50.0	33.8	27.2
	23.8	25.6	16.0	13.4	35.0	28.2				
Diet vegetables	55.0	29.6	16.0	29.5	23.2	22.8	14.0	36.0	7.0	15.0
	15.4	9.2	20.4	22.6	17.6					
Iced tea	2.4	2.0	2.0	1.0	1.4	1.6	1.2	1.8	1.8	2.6
	2.6	1.8	1.6	1.8	2.4	2.0	1.8	1.8	1.4	2.2
	2.0	2.0	1.8	1.6	2.2	1.8	1.4	1.6	1.0	3.8
	1.8	1.0	3.4	2.8	2.2	1.6	1.6	1.8	1.8	2.0
	1.8	1.8	2.2							
Ice cream	1.8	4.2	2.4	2.8	2.0	3.2	2.4	2.0	2.4	2.4
	4.0	2.8	5.0	4.0	3.0	2.8	2.0	2.8	2.0	4.2
	2.0	2.0	1.8	1.8	2.2	2.8	2.2	2.8	3.4	1.4
	2.0	1.8	2.0	2.0	1.6	2.4	2.0	1.6	2.2	3.6
	4.6	5.0	4.8	2.2	4.3	3.8				

APPENDIX E

Work Unit Content Times (in Minutes)

Tray	0.021	Hot cereal	0.095
Menu in holder	0.016	Soup	0.122
Napkin	0.017	Salads	0.033
Silverware	0.020	Desserts	0.031
Special Items- Tea bags, Melba toast, Crackers, Creamer, Decaf. Coffee	0.019	Regular Plate Lunch and Dinner	0.141
Condiments	0.022	Soft Plate Lunch and Dinner	0.175
Jello	0.021	Diet Entree	0.299
Pellet	0.033	Diet Vegetable	0.222
Bread and oleo	0.026	Ice Tea	0.019
Milk and straw	0.044	Ice Cream	0.027
Juice	0.030		
Carbonated Beverage, Cup	0.043		
Coffee or hot water	0.032		
Checker	0.084		
Loader	0.048		
Broth	0.112		
Dry Cereal	0.023		
Breakfast fruit	0.034		
Jelly and oleo	0.028		
Regular Breakfast plate	0.105		

APPENDIX F


OFFICE
CLOSET
C.G.
102
101
13
K15
107
106
STEP
WORK SHELF
101
108
109
SLIDING SHELVES
102
92
95
7
84
10
K10
113
92
93
7
90
7
13
K9
14
K9
CARD RACK
C.G.
86
87
88
88
89
89
12
K10
39
38
C/SHELF
105
97
98
99
100
96
WORK SHELF
91
SHELF OVER
91
SHELF OVER
104
103
SHELF OVER
110
110
110
PATIENT TRAYLINE
111
RECESS
114
C.G.
76
77
55
78
11
K10
75
7
74
110
110
C.G.
C.G.
C.G.
FINISHED BACK

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