CHAPTER 5

DEVELOPMENT OF MATHEMATICAL MODEL FOR LEAN KITTING ASSEMBLY

5.1 INTRODUCTION

In this chapter, the study focuses on development of model for lean kitting assembly of a two wheeler assembly process which considers the allocation of components among various assembly work stations to show the advantages of lean kitting against line side assembly. Kitting is initiated well in advance of actual production to prepare and deliver the kit on time. This work focuses design of lean kitting system against line side assembly process in terms of operator distance traveled, floor space required per work station, work in process inventory per day and operator walking time per day. Hence, a mathematical model is developed to quantify the above said criteria for both line side and lean kitting assembly.

5.2 DESCRIPTIVE MODEL FOR LINE SIDE AND LEAN KITTING ASSEMBLY

Based on the literature, it is clear that lean kitting has lot of advantages in a manufacturing environment. So, developing a mathematical model for lean kitting assembly is very much essential for any plant engaging assembly in a multi product single conveyor environment.
5.2.1 Important Definitions

i) Component: It may be a manufactured or purchased part and it is a single piece of object.

ii) Subassembly: It is a collection of two or more components or collection of one or more sub assembly.

iii) Final assembly: It is the result of series of assembly with sub assemblies. It never requires further processing.

iv) Kit: It is a specific collection of components and/or subassemblies for doing one assembly operation.

v) Kit container: It is a container which collects kits for doing specific assembly operation.

vi) Kit Trolley: It is used for transferring kit container from kitting area to assembly line.

5.2.2 Material Flow in a Kitting Assembly

The components and subassemblies received from the vendors are stored in the storage area. From store some components are sent for components preparation and remaining components are directly sent to kitting area. After preparing kits, some kits may be stored in kit storage and remaining kits sent to production line for carrying out assembly processes. After the components are assembled, they either are taken to storage area as subassemblies or left the system as end product as shown in Figure 5.1.
5.2.3 Assumptions made in the Model

1. Same part family with varying dimension is assumed as different component.
2. Number of kits = Demand per day.
3. Demand = Number of change over.
4. All the area of individual work stations are equal.
5. All the components are consumed uniformly.
6. All the component containers have equal storage capacity.
7. Work stations do not share components in a kit.

Based on the assumptions made, a model has been developed to calculate distance travelled per day, floor space required per workstation, WIP
inventory per day and operator walking time per day for both line side and lean kitting assembly.

5.3 MODEL FOR LINE SIDE ASSEMBLY

Mathematical model for line side assembly is given below.

1. Number of replenishment per day per component \((N_R)\)
   \[ N_R = \frac{NCO}{CC} \]  \hspace{1cm} (5.1)

2. Distance travelled from store to workstation for all replenishments per day \((DT)_L = N_R \times D_{sw}\)
   \[ (5.2) \]

3. Floor space required per work station \((A_w)\)
   \[ A_w = \{N_w \cdot (A_w + (A_{cc} \times N_{cc})}\)  \hspace{1cm} (5.3)

4. Average work-in-process inventory per replenishments
   \((AWIPI)_L = N_w(\frac{1}{2} \times N_{cc} \times CC)\)
   \[ (5.4) \]

5. Work-in-process inventory per day \((WIPI)_d\)
   \[ = \{(AWIPI)_L \times N_R\} \]  \hspace{1cm} (5.5)

6. Operator walking time per assembly \((WT)_L\)
   \[ = \text{Direct observation} \]  \hspace{1cm} (5.6)

7. Operator walking time per day for all assembly \((WT)_{ld}\)
   \[ = NCO \times (WT)_L \]  \hspace{1cm} (5.7)

5.4 MODEL FOR LEAN KITTING ASSEMBLY

Mathematical model for lean kitting assembly is given below.

1. Total Number of kit container supplied from kitting area per day \((KCS)_k = \frac{N_k}{K_{cc}} = \frac{NCO}{K_{cc}}\)
   \[ (5.8) \]
2. Number of replenishments per day \( (N_R)_k = \frac{(KCS)_k}{K_{tc}} \) \( (5.9) \)

Number of kit per replenishment \( N_{kR} = \frac{N_{CO}}{(N_R)_k} \) \( (5.10) \)

3. Distance travelled from kitting area to workstation for all replenishment per day \( (DT)_k = (N_R)_k \times (D_{sw})_k \) \( (5.11) \)

4. Floor space required per workstation

\( (A_w)_k = \{N_w(A_w+(A_k \times N_k))\} \) \( (5.12) \)

\( N_k = 1 \) when kits are stacked;

\( N_k = N_{k}, \) when the kits are kept adjacent to each other.

5. Average work in process inventory per replenishment

\( (AWIPI)_{kR} = \frac{1}{2} \times N_w \times (N_{kR} \times NC_k) \) \( (5.13) \)

6. Work-in-process inventory per day

\( (WIPI)_{kd} = (AWIPI)_{kR} \times (N_R)_k \) \( (5.14) \)

7. Operator walking time per assembly \( (WT)_k \)

= Direct observation \( (5.15) \)

8. Operator walking time per day for all assembly

\( (WT)_{Kd} = N_k \times (WT)_k \) \( (5.16) \)

5.5 DATA FOR NUMERICAL ILLUSTRATIONS

5.5.1 Data for Cylinder Head Sub Assembly

i) Number of change over (NCO) = 160 Nos.

ii) Container capacity (CC) = 30 Nos.
iii) Number of individual components in end product (n) = 18 Nos.

iv) Number of workstations (N_w) = 2 Nos.

v) Area of workstations (A_w) = 1.2 \times 0.61 = 0.732(m^2)

vi) Area of component containers (A_{cc}) = 0.22\times0.15 = 0.033(m^2)

vii) Number of component containers (N_{cc}) = 35 Nos.

viii) Operator walking time per assembly (WT)_L = 26 Sec

ix) Distance between store and workstation (D_{sw}) = 27 (m)

Similarly the data for lean kitting assembly is given below. Prototype model of kits are prepared (Refer: Appendix.1) and relevant data are obtained as follows:

i) Area of kit (A_k) = 0.22\times0.18=0.0396 (m^2)

ii) Number of kits (N_k) = 160 Nos.

iii) Number of components per kit, (NC_k) = 18 Nos.

iv) Distance to pick a kit (kd) = 1 (m)

v) Kit container capacity (K_{cc}) = 10 Kits

vi) Kit trolley capacity (K_{tc}) = 4 kit containers

vii) Distance between kitting area and workstation (D_{sw})_k = 9 (m)

viii) Operator walking time per assembly (WT)_k = 4 Sec
5.5.2 Data for Timing Cover Sub Assembly

i) Number of change over (NCO) = 160 Nos.

ii) Container capacity (CC) = 20 Nos.

iii) Number of individual components in end product (n) = 15 Nos.

iv) Number of workstations ($N_w$) = 2 Nos

v) Area of workstations ($A_w$) = 1.2 x 0.6 = 0.72 (m$^2$)

vi) Area of component containers ($A_{cc}$) = 0.22 x 0.15 = 0.033 (m$^2$)

vii) Number of component containers ($N_{cc}$) = 27 Nos.

viii) Operator walking time per assembly ($WT_L$) = 26 Sec

ix) Distance between store and workstation ($D_{sw}$) = 27 (m)

Similarly the data for lean kitting assembly is given below.
Prototype model of kits are prepared and relevant data are obtained as follows:

i) Area of kit ($A_k$) = 0.19 x 0.16 = 0.0304 (m$^2$)

ii) Number of kits ($N_k$) = 160 Nos.

iii) Number of components per kit ($NC_k$) = 15 Nos.

iv) Distance to pick a kit (kd) = 1 (m)

v) Kit container capacity ($K_{CC}$) = 11 Kits

vi) Kit trolley capacity ($K_{tc}$) = 4 kit containers
vii) Distance between kitting area and workstation \((D_{sw})_k\) = 10 (m)

viii) Operator walking time per assembly \((WT)_k\) = 4 Sec

5.5.3 Data for E-Start Sub Assembly

i) Number of change over (NCO) = 60 Nos.

ii) Container capacity (CC) = 10 Nos.

iii) Number of individual components in end product (n) = 12 Nos.

iv) Number of workstations \((N_w)\) = 1 No

v) Area of workstations \((A_w)\) = 1.2 x 0.6 = 0.72 (m²)

vi) Area of component containers \((A_{cc})\) = 0.22 x .15 = 0.033 (m²)

vii) Number of component containers \((N_{cc})\) = 12 Nos.

viii) Operator walking time per assembly \((WT)_L\) = 26 Sec

ix) Distance between store and workstation \((D_{sw})\) = 22 (m)

Similarly the data for lean kitting assembly is given below.
Prototype model of kits are prepared and relevant data are obtained as follows:

i) Area of kit \((A_k)\) = 0.25 x 0.15=0.0375(m²)

ii) Number of kits \((N_k)\) = 60 Nos.

iii) Number of components per kit \((NC_k)\) = 9 Nos.
iv) Distance to pick a kit (kd) = 1 (m)

v) Kit container capacity (K_{CC}) = 8 Kits

vi) Kit trolley capacity (K_{tc}) = 2 kit containers

vii) Distance between kitting area and workstation (D_{sw}) = 8 (m)

viii) Operator walking time per assembly (WT) = 4 Sec

5.5.4 Data for Carburetor sub assembly

i) Number of change over (NCO) = 160 Nos.

ii) Container capacity (CC) = 50 Nos.

iii) Number of individual components in end product (n) = 7 Nos.

iv) Number of workstations (N_{w}) = 1 No.

v) Area of workstations (A_{w}) = 1.2 \times 0.6 = 0.72\, (m^2)

vi) Area of component containers (A_{cc}) = 0.22 \times 0.15 = 0.033 \, (m^2)

vii) Number of component container (N_{cc}) = 7 Nos.

viii) Operator walking time per assembly (WT) = 26 Sec

ix) Distance between store and workstation (D_{sw}) = 22 (m)

Similarly the data for lean kitting assembly is given below. Prototype model of kits are prepared and relevant data are obtained as follows:
i) Area of kit \((A_k)\) = 0.076 x 0.062
  = 0.004712 (m\(^2\))

ii) Number of kits \((N_k)\) = 160 Nos.

iii) Number of components per kit \((N_{C_k})\) = 5 Nos.

iv) Distance to pick a kit \((kd)\) = 1 (m)

v) Kit container capacity \((K_{CC})\) = 16 Kits

vi) Kit trolley capacity \((K_{tc})\) = 4 kit containers

vii) Distance between kitting area and workstation \((D_{sw})_k\) = 8 (m)

viii) Operator walking time per assembly \((WT)_k\) = 4 Sec

5.5.5 Data for Decompressor sub assembly

i) Number of change over \((N_{CO})\) = 100 Nos.

ii) Container capacity \((CC)\) = 20 Nos.

iii) Number of individual components in end product \((n)\) = 12 Nos.

iv) Number of workstations \((N_w)\) = 1 No

v) Area of workstations \((A_w)\) = 1.2 x 0.6 = 0.72(m\(^2\))

vi) Area of component containers \((A_{cc})\) = 0.22 x .15 = 0.033(m\(^2\))

vii) Number of component container \((N_{cc})\) = 12 Nos.

viii) Operator walking time per assembly \((WT)_L\) = 26 Sec

ix) Distance between store and workstation \((D_{sw})\) = 32 (m)
Similarly data for lean kitting assembly is given below. Prototype model of kits are prepared and relevant data are obtained as follows:

i) Area of kit \( A_k \) \[= 0.9 \times 0.75 = 0.675 \text{ (m}^2\)\]

ii) Number of kits \( N_k \) \[= 100 \text{ Nos.}\]

iii) Number of components per kit \( N_{C_k} \) \[= 8 \text{ Nos.}\]

iv) Distance to pick a kit \( k_d \) \[= 1 \text{ (m)}\]

v) Kit container capacity \( K_{CC} \) \[= 16 \text{ Kits}\]

vi) Kit trolley capacity \( K_{tc} \) \[= 3 \text{ kit containers}\]

vii) Distance between kitting area and workstation \( D_{sw} \) \[= 10 \text{ (m)}\]

viii) Operator walking time per assembly \( WT_k \) \[= 4 \text{ Sec}\]

5.6 SUMMARY

In this chapter, a descriptive model for both line side and lean kitting assembly is developed. Also, data required for performing numerical illustration for all the five sub assemblies are furnished.