

Designing of Computer Aided Visual System for Workstations Layout Planning Based on Efficiency Criteria

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Abstract

Layout planning in industrial plants means planning the location of all machines, utilities, workers, workstations, and department...Etc. five basic types of layout, fixed-position, cellar, process, product & hybrid. This research study Product layout problem through study problem of arranging number of machines, workers, workstations on a production line in way achieves uniform materials flow, this problem is known as single row facility layout, this problem is very difficult to be solved in fact. The aim of the research is to designs and builds computer aided visual planning system to study product layout problem, helps the management in layout planning process and in decision making about the workstations arrangement based on efficiency criteria. The suggested planning system was built by Auto lisp language and display the system outputs on computer screen in two ways visual diagram (workstation time-workstation number), calculated outputs (actual cycle time, workstations number, efficiency actual daily production rate) .the suggested system was applied on lawn mower production line gets from reference to show the sequence of system working, inputs & visual outputs, so the system will study all possible workstations layout. Current workstations arrangement consists of series four workstations& line Efficiency=81.82%, the efficiency can improve & increases to 90% by re-arranges the workstations& distributes the total work in five serial workstations.

Keywords: Layout planning ,product layout, Production line, Single line, Efficiency.

تصميم نظام مرئي معان بالحاسوب لتخطيط ترتيب محطات العمل باعتتماد معيار الكفاءة

الخلاصة

ان تخطيط مواقع العمل في المنشآت الصناعية، يهتم بتخطيط ترتيب محطات العمل من مكائن وعمال ومعدات بشكل يودي الى تحقيق اهداف الشركة، ويمكن تمييز خمسة انواع رئيسية لتخطيط ترتيب محطات العمل تعتمد على نوع تدفق الانتاج هي : -ترتيب على اساس ثبات موقع العمل، ترتيب على اساس خلايا عمل، ترتيب على اساس العملية، الترتيب الهجين (المختلط). ترتيب على اساس المنتج. في هذا البحث تم دراسة مشكلة تخطيط ترتيب محطات العمل على اساس المنتج ويقصد بها مشكلة ترتيب محطات العمل من مكائن وعمال ومعدات بشكل خطي لتحقيق تدفق منتظم للمواد، عمليا تعتبر هذه مشكلة معقدة. في هذا البحث تم تصميم وبناء نظام مرئي معان بالحاسوب لتخطيط ترتيب محطات خط الانتاج الاحادي بالاعتماد على معيار كفاءة الخط الانتاجي في اختيار الترتيب الافضل لمحطات عمل الخط الانتاجي. تم استخدام لغة (Auto lisp) لامكانيات هذه اللغة ومرونتها، مخرجات النظام تعرض على شاشة الحاسبة بشكلين مخطط مرئي (مخطط اوقات المحطات - عدد المحطات) ومخرجات حسابية تمثل حساب وقت دورة الانتاج الفعلية كفاءة الخط الانتاجي، عدد المحطات ومعدل الانتاج الفعلي اليومي، على شاشة الحاسبة على شكلين مخطط ومخرجات حسابية توضح تسلسل خطوات الحل. تم تطبيق النظام المقترح على منتج صناعي لتوضيح طريقة وتسلسل عمل النظام المقترح لتخطيط ترتيب محطات العمل ونوع المدخلات والمخرجات، ولهذا الغرض استخدم الباحث خط انتاج حصادة الحشيش كمثال لدراسة الترتيبات الممكنة للمحطات لاختيار الترتيب الافضل لمحطات العمل الذي يحقق اعلى كفاءة عمل للخط الانتاجي، الترتيب الحالي هو اربع محطات عمل متسلسله بكفاءة عمل لمحطات خط الانتاج =81.82% يمكن تحسينها باستخدام النظام المقترح، حيث وجد امكانية رفع كفاءة عمل الخط الانتاجي الى 90%. عن طريق اقتراح اعادة ترتيب محطات الخط الانتاجي وتوزيع محتوى العمل الكلي في خمس محطات عمل .

1- Introduction

The layout decision is an important strategically for any organization to stay competitive in the present era; it is the physical configuration of department, workstations & equipment in the entire conversion process. It is the spatial arrangement of physical resources used to produce the product or service [1][2]. The right layout for an organization improves productivity, quality of the product & the delivery rates [3], wrong layout lead to over-long or confused flow patterns, inventory in process, idle time, long process time, inflexible operations, unpredictable flow high cost, the costs of producing & delivering product depend on the layout decisions. The type of layout most suitable to any organization is a function of the operations the organization performs .the operation function in any organization can be either intermittent or continuous [4][5]. Intermittent operations deal with made-to-order products, low product volume, general purpose equipment, labour-intensive operations, interrupted product flow, frequent schedule changes large product mix. Continuous operations deal with standardized products made to store inventory, high product volume, special purpose equipment, capital-intensive operations continuous product flow & small product mix. Objectives of manufacturing layouts are [6][7]: -

- 1- Provide enough production capacity.
- 2- Reduce materials handling cost.
- 3- Allow space for production machines.
- 4- Allow high labor, machine, and space utilization productivity.
- 5- Provide for volume & product flexibility.
- 6- Achieve objectives with least capital investment.

Many kinds of layouts depending on the types of workflow they entail. These kinds are [8][9]:

1- Process layout: -functional layout or some time called job shop, it designed to accommodate variety in product designs process steps, it used general-purpose

machine that can be changed over rapidly to new operations for different product designs, machines arranged according to the type of process being performed, example to the Process layout machining the parts which go into air craft engines.

2- Cellular layout: in this layout, machines are grouped into cells to produce a single parts family, the cells function somewhat like a product layout island within a larger job shop or process layout

3- Hybrid layout: -this layout combination of layout types, the departments are arranged according to the types of processes but the products flow through on a product layout, aircraft manufacturing example to Hybrid layout.

4-Fixed-position layout: -in this layout, the product location a fixed position & transports workers, materials, machines & subcontractors to and from the product, it used when a product is very bulky, large, heavy or fragile, example to Fixed-position layout shipbuilding, heavy machinery.

5- Product layout: - Product layout often called production lines or assembly lines, it designed to accommodate only a few product design & it used specialized machines that are setup once to perform a specific operation for along period of time on one product, automobiles assembly line example to Product layout. Table (1) shows the relationship between process types and basic layout types.

Product layout concern with “what to place where”, locations are frequently decided upon and then work tasks are allocated to each workstation, for example, it may decided that four workstations are needed to make computer case, the decided is then which of the tasks that go into making the cases should be allocated to each of the four workstations. This decision is called the line balancing decision, other product layout decisions are [10]: -

- What cycle time is needed?
- How many workstations are needed?
- How should the task time variation be dealt with?

- How should the layout be balanced?
- How should the workstations be arranged?

In this research, the researcher designing visual planning system for single production line to arrange workstations of the line in way helps the managements in decision-making about the workstations arrangement layout based on efficiency criteria.

2- Product layout

Companies normally use a repetitive flow process, when the production of all products requires the same tasks in the same sequence, the system physically designed so that the tasks are performed at workstations arranged in sequential order according to the flow of the product, this spatial arrangement called product layout. The basic problem in product layout is assure uniform material flow along the production line by planning&arranges the workstations layout in way lead to Max. Efficiency, Min. works in process inventory & Min. idle time.

Product layout often called production line or assembly line, Production line are an important class of manufacturing systems, it consists a series of workstations arranged so that the product moves from one station to the next, and at each location portion of the total work is performed on it. The slowest station determines the production rate of the line. The workstations are arranged into one long line or into a series of connected line segments . A production line classify in two types these are: -

- Manufacturing line builds components on a series of machines
- Assembly line puts the fabricated parts together at a series of workstations [11].

Each production stage is dependent on prior stages so that the production time must be equalized for all stages by balancing the production line to assure smooth production flow [12] The production of product requires several, possibly thousands of distinct tasks to be performed by workers or machines. Many

factors can causes variation in task times, some of the more common reasons are [13]:

1-human variation: because workers are human, fatigue, sneezes, sickness & interruptions can all cause variation in work times.

2- variation in materials: even small variation in materials can cause variation in work times such as the threading on a bolt or the amount of lubricant on a part

3-material shortage: shortage will increase the processing times& it cause when components are not delivered to the workstations on time.

4- defective: -Corrective actions to the component defectives will spend times.

5-mechanical failure: this cause when machines or tools break through the production time, considerable delay variation affect processing times.

6-lot size differences: in batch flow system, differences in both product type &batch size can cause variation in processing time.

3- Production line type

Production lines classify in three types, these are [14][15]:

1 -Single-model line: single production line as shown in fig (2) Produces only one type and there is no variation in the model and the tasks performed at each station are the same on all product units.

2 -Multi-model lines: This line as shown in fig (3) used for production of two or more products. Each model produced in batches on the line, workstations are setup to produce the desired quantity of the first model, Then the station are reconfigured to produce the desired quantity of the next model. These result in down time (lost production time) on a batch model line. The models made on the line are usually similar and the tasks to make them are similar, differences exist among models so that a different sequence of tasks is usually required and tools. One model may take more total time than another.

3 -Mixed-model lines: This line is also used for the production of more

than two models as shown in fig (4). But various models are intermixed on the line, several different models produced simultaneously rather than batches. In addition, this type use where there is soft variety in the products made on the line [16].

4- Line efficiency

Efficiency represents positive achievement in line utilization and key representation of economic performance. The efficiency or % balance of a line is the percentage of available workstations time that is used productively, in this research efficiency of the single production line computed by [17]:-

$$\text{Line Efficiency (E) (\%)} = \frac{\sum ti}{M * C.t.} \dots(1)$$

Where: -

E= line Efficiency.

ti=task time, where i=1,2,3,...m

m= tasks number.

$\sum ti$ =the total work time required to make a unit of product (at all workstations).

C.t.=cycle time.

M= actual workstations number on the production line.

T=Total production time.

Differential in workstations time, workstations idle time &WIP inventory will affect on the efficiency of the line.

System 5- the suggested layout planning

The system was designs and builds for easing the process of workstations layout planning for single line to study all possible arrangements and choice the right arrangement based on efficiency criteria. The system inputs are task number, task time, tasks requirements, and task type. The layout planning steps display on the computer screen in visual way shows workstations layout solutions. Layout solution means the way of workstations arrangement in the production line. The system designed by Auto lisp language& represents the outputs in two ways: -

1-Visual diagram represents the workstations time diagram where stations time& stations number are represents in two axes (X, Y), the (X) axis represents the number of stations and (Y) axis represents of the stations time in form of a Block, the Block height from (X) axis represents the amount of station time.

2- Calculate outputs represents: - Actual cycle time, where: -

Actual cycle time (C.T)= previous actual cycle time+Min.ti (Min.)..... (2)

• Calculate the Total task time of product Where: -

Totaltasktime= $\sum ti$ (Min.)..... (3)

Calculate the line Efficiency, Line Efficiency (E)(%)= $\sum ti/M * C.T.$ (4)

• Calculate the Actual daily production rate (Pact) where: -

Actual production rate=1/ C.T (60*60*T)(Unit/day(5)

• Actual workstations number (m).

The layout planning system arranges workstations based on the variable value of the actual cycle time& based on loop, this loop start from at first depends on Max.ti = first actual cycle time.

And then the planning system continuous arranges the workstations by using this rule:-

Currently actual cycle time = the previous actual cycle time+Min.ti.....(6)

The system displays all possible workstations arrangement on computer screen& finally choice the right workstations layout based on workstations efficiency criteria. Fig (5) show flowchart of layout planning system.

6.Practical application of the system

The system was applied at single production line at McMurray Machine Company on lawn mowers production line. This example gets from reference [18] for showing the sequence of system working for planning the workstations layout &also shows the system inputs &outputs. The

researcher choice lawn mower product to planning workstations layout of the line in way leads to produce this product in Max. efficiency & productivity. The sequence, task description & lawn mower tasks time are shown in table (1) & fig (6). Current workstations arrangement as shown in Fig (7), shows the line layout consist of four series workstations, where efficiency of line = 81.82%, actual cycle time = 3.4min and actual daily production rate = 98 unite/day.

The planning layout system test and study all possible workstations layout based on the rule (6) to choice the workstations layout that achieves max. Efficiency. Table (3) shows calculated outputs for all possible workstations layout, so this table shows max. efficiency was achieves when the lawn mower tasks arranges in (5) workstations as shown in fig (8), where the efficiency increases = 90%, Actual daily production rate (line productivity) was increase to 135 unite/day & actual cycle time was decrease to 2.4min. Table (2) & Fig (9) shows the workstations arrangement way & tasks for every workstation. Fig (10) Efficiency for all possible Workstations layout arrangement.

7- Conclusions

- 1- Workstations number do not affect on the line efficiency in increase or decrease.
- 2- Right tasks arrangement way in workstations leads to right layout, where increases efficiency of the line
- 3- Minimizes the workstations time differential will increases the line efficiency.
- 4- using Computer Aided Visual System for Workstations Layout Planning easy the process of testing and studying all possible

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layout to lead to choice the right layout based on efficiency Criteria.

5- Right Workstations layout also will affect on the productivity of the line.

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Table (1) Tasks required to assembly a21-inch rear bagger rotary lawn mower (18)

Seq.	Task description	Tasktime (sec.)	Task requirements
1	Stamp out mower body	40	Worker+mashine
2	Stamp out mower handle	50	Worker+mashine
3	Bolt engine to mower body	55	Worker
4	Attach back stop to mower body	30	Worker+mashine
5	Attach left wheels and handle latch	65	Worker
6	Attach right wheels and handle latch	65	Worker
7	Attach grass bag collar	30	Worker+mashine
8	Attach blade	25	Worker+mashine
9	Attach throttle cable to engine	35	Worker
10	Attach control bar cable to engine	50	Worker
11	Insert spark plug	20	Worker
12	Attach control bar to handle	30	Worker
13	Attach handle to mower	20	Worker
14	Attach throttle cable to handle	50	Worker
15	Attach control bar cable to control bar	45	Worker+mashine
16	Test mower	50	Worker
17	Pack mower	60	Worker

Table (2) calculation outputs for all possible workstations arrangement

Seq.	Workstations Number	Efficiency%	Actual cycle time (min)	Actual Daily production rate (unit/day)
1	15	73.85%	1.05	333
2	12	70.59%	1.25	254
3	9	80%	1.4	216
4	7	79.12%	2.1	166
5	5	90%	2.4	135
6	5	77%	3.05	117
7	4	81.82%	3.4	98
8	4	70.59%	4.15	85
9	4	65.45%	4.35	79
10	3	71.64%	5.35	65
11	3	66.67%	6.0	60
12	3	60.76%	6.35	55
13	3	51.61%	7.45	45
14	3	46.6%	8.35	42
15	2	63.72%	9.25	38
16	2	59.02%	10.1	36
17	1	100%	12.0	30

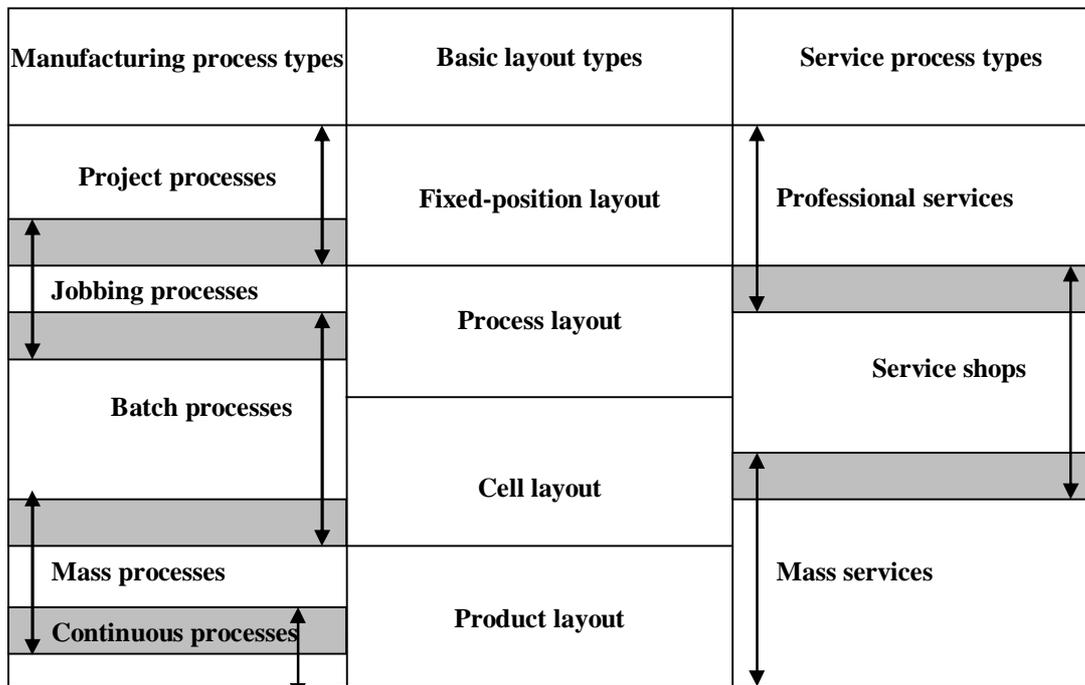


Figure (1) the relationship between process types and basic layout types (10).

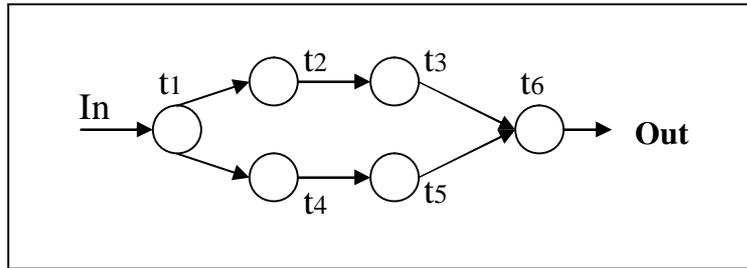


Figure (2) Single Production Line

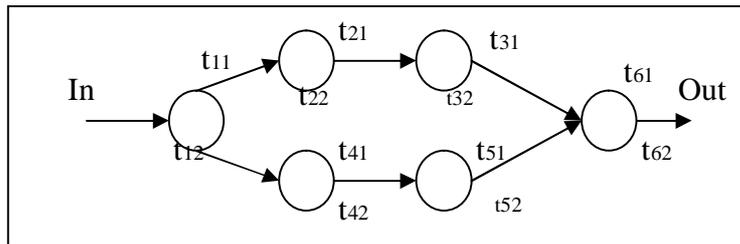


Figure (3) Multi Production Line

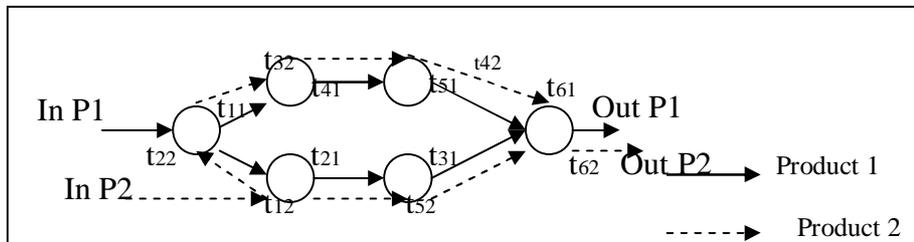


Figure (4) Mixed Production Line

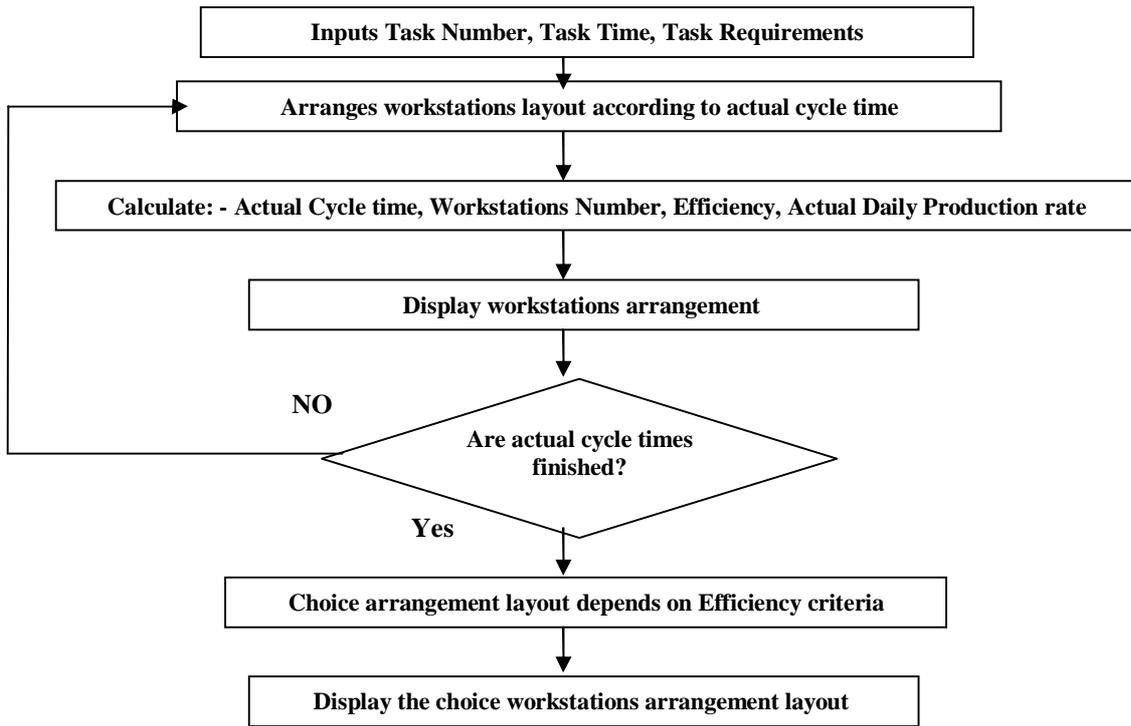


Figure (5) Flow Chart of layout planning System

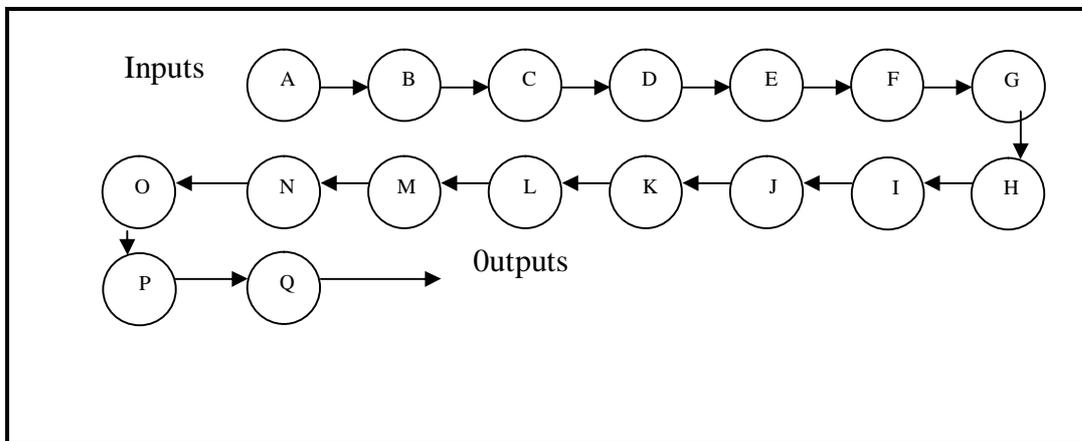


Figure (6) lawn mower tasks sequence

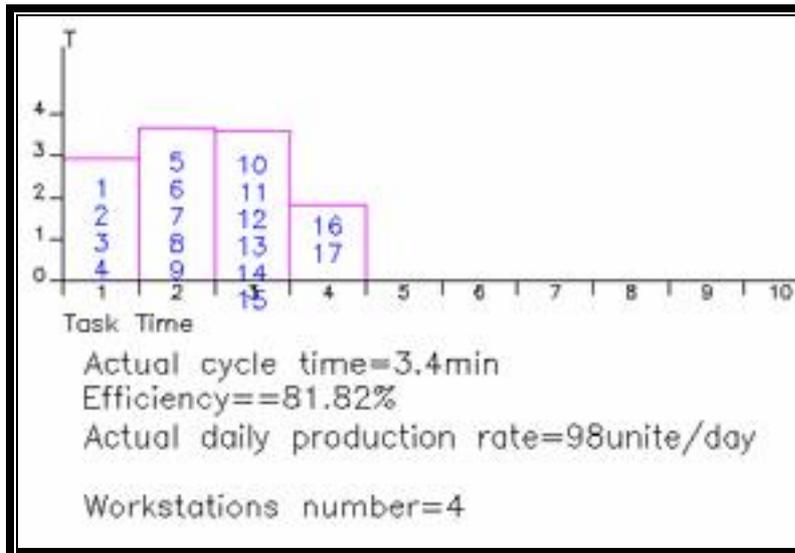


Figure (7) current arrangement layout

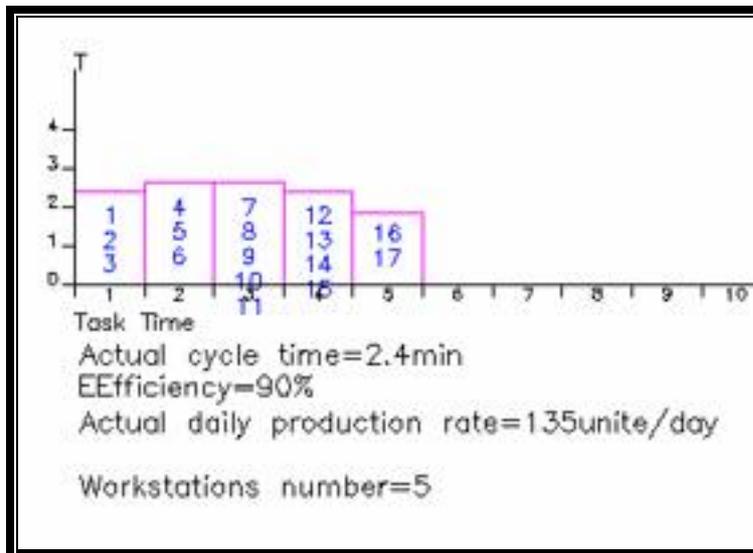


Figure (8) workstations arrangement layout, Efficiency=90%

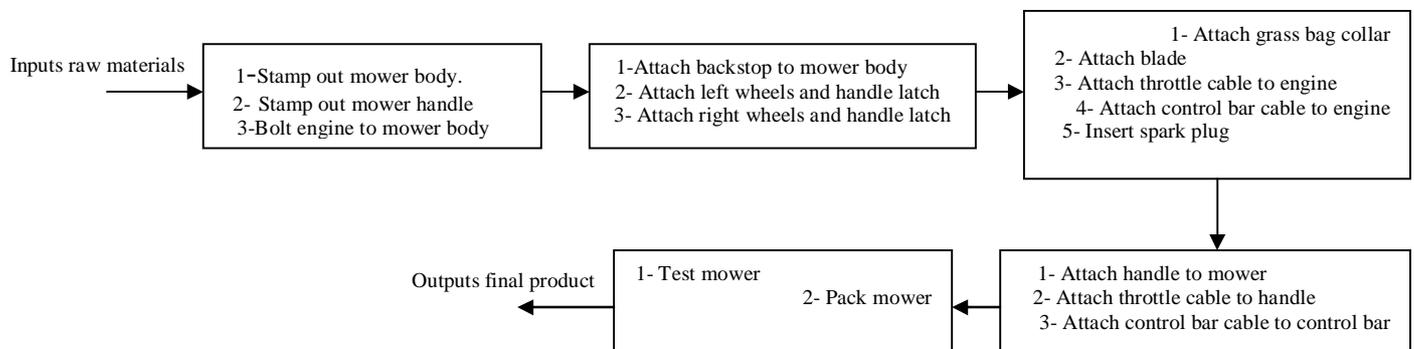


Figure (9) Suggested workstations arrangement layout, Efficiency=90%, Workstations Number=5

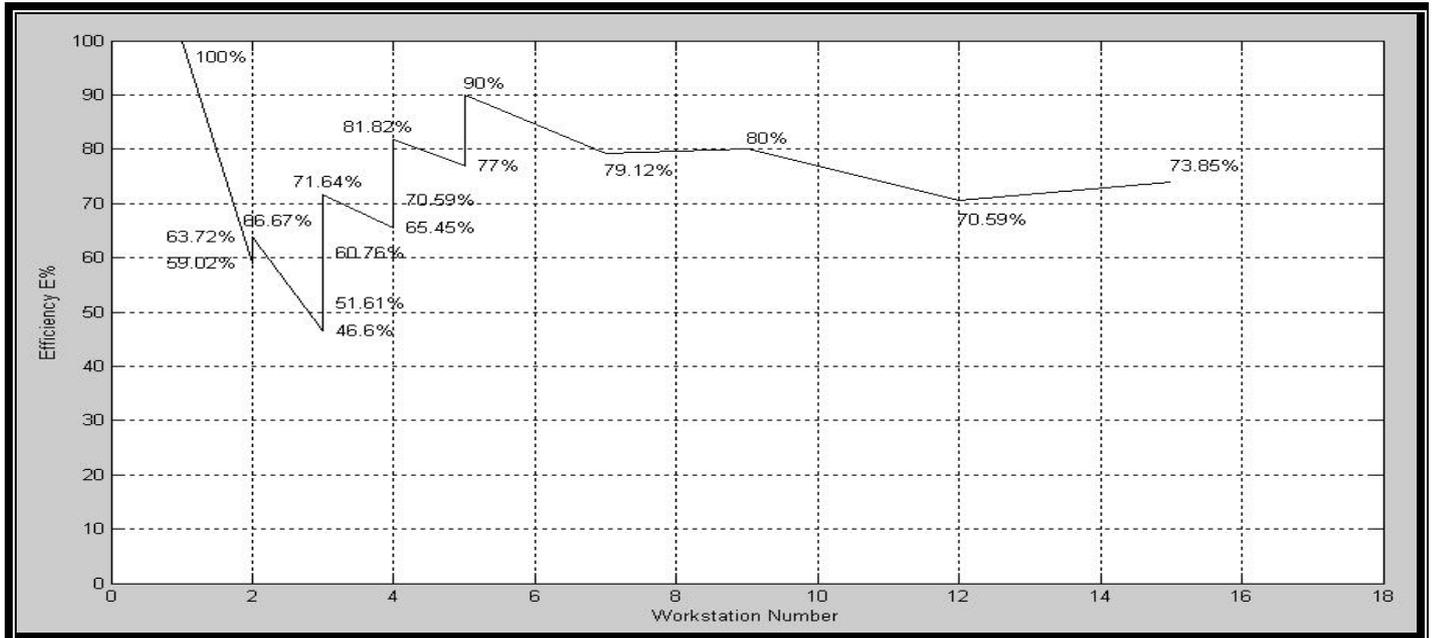


Figure (10) Efficiency for all possible Workstations layout arrangements