Production Planning and Control of Assembly Process for the High Tech Products

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Abstract-Global competition, marvelous achievement in technology and quick fix solutions compels manufacturers to use standard techniques in production settings. The presented work is related to the planning and control assembly process for high tech products. The assembly line has been balanced using heuristics approaches of largest candidate rule, kilbridge and wester method and ranked positional weights. After initial analysis, three algorithms give the same balanced efficiency and balance delay. The simulation routines have been written in software; model verified and validated spreadsheet and discussion with case company. Significant performance parameters have been evaluated and effects on the responses have been established and prioritized according to their importance. It has been observed that setup time comes out to be the most sensitive parameter followed by quality level and process time at global level, while total production, cycle time and average delay in queue identified important at local level. The utilization of the resources is the least sensitive parameter found in the company. It is recommended to use temporary storage buffers, fixed launching sequence in different models, keeping less than six percentage losses (quality related) and balanced efficiency by implementing line balancing techniques.

Keywords-Assembly process, Cycle time, High tech manufacturing, Manufacturing simulation, Setup time reduction

I. INTRODUCTION

For customer's satisfaction, the competition of improving the productivity with high level of quality is always demanded. The rapid advancement in the technology has reduced the product lead time. This has created a great competition among the manufacturing industries. This justifies the competition among the industries and in turn continuous improvement in their manufacturing system design by taking engineering decision making.

One of the most important tools for improving manufacturing system is line Balancing (LB). It has been developed 1970 and its refinement over the decades has made it one of the most widely used tools in the world leading industries [1]. In this technique the system is designed in such a way that overloading and under utilization can be minimized. Line balancing along with simulation provides a strong tool for analyzing system design. The focus of current research is to analyze existing line balancing techniques in industries involved in the assembly of multi-items. The impediments faced during the assembly of these products are the processing sequence of tasks are subject to precedence constrains. The sub components are not manufactured well in time to meet the fixed target for the final delivery of these components and hence it delays the production of the final component. Some of the manufacturing equipments are over loaded, whereas others are under-utilized. There is a need to investigate bottlenecks in the existing system in systematic manner. Furthermore, there is no exact calculation about the capacity of the existing set up (the set time is assumed here the change over time), which makes it difficult for the management to set exact targets.

This research focuses to overcome these issues. Local industry has been selected which consists of four assembly lines. After preliminary analysis, it was identified that "safety hose" assembly line required attention to improve productivity. The assembly line consisted of manual assembly stations. There was need to pay attention to improve the design, which would aid the management to cope the shop floor activities effectively. The main objective of this paper is: a) line balancing of the manual assembly line with classical line balancing methods in order to stream line the production; b) developing a simulation model of the existing system to identify key performance parameters which would affecting the system; c) to prioritize the input parameters using matrix formation.

II. LITERATURE REVIEW

In flow line production there are many separate and assembly operations to be performed on the product. It is generally the case that the product must be manufactured at some specified production rate in order to satisfy demand for the product. Whether we are concerned with performing these processes and assembly operations on automatic machines or manual flow lines, it is desirable to design the line so as to satisfy all of the foregoing specifications as efficiently as possible. The ongoing literature of assembly line, related issues and mathematical relationships has been comprehensively reviewed in [1]. The line balancing problem is to arrange the individual processing and assembly tasks at the workstations so that the total time required at each workstation is approximately the same. Total Work Content is the collective of all then work elements to be done on the line. Let T_{wc} be the time required for the total work content. Hence, total work contents consist of elements given in (1).

$$T_{wc} = \sum_{j=1}^{n_e} T_{ej} \quad (1)$$

The work performed at the station consists of one or more of the individual work elements and the time require is the sum of the times of the work elements done at the station. It should be clear that the sum of the station process times should equal the sum of the work element times given in (2).

$$\sum_{i=1}^{n} T_{si} = \sum_{j=1}^{n_e} T_{ej} \quad (2)$$

The cycle time is the ideal or theoretical cycle time of the flow line, which is the time interval between parts coming off the line. The design value of T_c would be specified according to the required production rate to be achieved by the flow line in (3).

$$T_c \leq \frac{E}{R_p} \quad (3)$$

The precedence constraints also referred to as "technological sequencing requirements." The order in which the work elements can be accomplished is limited. In addition to the precedence constraints described above, there may be other types of constraints on the line balancing solution. The balance delay sometimes also called balancing loss; this is a measure of the line inefficiency which results from idle time due to imperfect allocation of work among stations. It is symbolized as d as in (4) and can be computed for the flow line.

$$d = \frac{nT_c - T_{wc}}{nT_c} \quad (4)$$

The balance delay is often expressed as a percentage rather than as a decimal fraction in E. The balance delay measures the inefficiency from imperfect line balancing. Several methods have been considered for solving the line balancing problem. These methods are heuristic approaches in the form of algorithms, meaning that they are based on logic and common sense rather than on mathematical proof. The manual methods under study are:1) Largest-candidate rule; 2) Kilbridge and Wester method and 3) Ranked positional weights method. In our case, these heuristics have been used for balancing of assembly system.

Today's customers are becoming more and more aggressive in demanding new products and services within a short period of time [2]. In broader spectrum, [3] provided a strategic picture of the automobile industry in local environment. Taxonomy developed for US small manufacturing industries in which emphasis placed on competition priorities i.e. cost, delivery, flexibility and quality is proposed by [4]. The work of [5] is also significant in which relative importance and competitiveness strength of different Chinese manufacturing companies have been investigated empirically. The authors have found that innovation, after sales service, quality and flexibility are the most important competitive priorities among Chinese enterprises. Elements of mass customization for fast productions systems have been reviewed by [6]. Scale, cost, quality and time in a row is the targets and also paradigms where business is managed. Mass customization is the one of these modern means to achieve these goals. It is customizing product to individual customers and producing those with principles of mass production. The key issue is customer focus. Fast production means delivering products to customer faster than the lead time of the whole manufacturing process in order to satisfy customers. This can be achieved by utilizing standardized methods and modularized product structure. Companies are continuously forced to improve their performance in order to create VA customers and to remove NVA activities and simulation tool is best for modeling of these issues [7]. As companies seek to provide product faster, cheaper and better than the competitors, they have realized that they cannot do it alone. In the new era of production, strategic priorities rather than cost contained focus have proved to be important for competition namely: quality, dependability, flexibility, customer service, after sales service, supply chain management etc. Some supported use of IT related technologies which have proved to be vital for successful competition as it can facilitate the attainment of these strategic targets [8].[9] identified global characteristics of agility which can be applied to all aspects of enterprises: flexibility, responsiveness, speed, culture of change, integration and low complexity, high quality and customized products and mobilization of core competition [9]. The major contribution of [10] is the spelling out of meaning and definition of Advanced Manufacturing (AM). There is still issues of time based competition, quality and innovation for the companies. The use of various performance indictors in a systematic and coherent manner either at tactical or strategic level is required further analysis. Some of the key governing parameters are, time, quality, cost, maintenance, workers, schedules, waiting time, productivity, cycle time, utilization of resources, percentage of good parts i.e. yield. The parameters of interest related to the study are being used for the building of model.

III. PROCESS DESCRIPTION AND MODELING

The product under study is safety hose pipe which is used in different machines for the fluid transmission. The pressure of the fluid is normally greater than the one atmospheric. That is why the quality as well as reliability issues are required. The main elements of the product consists of steel pipe, rubber pipe and copper connectors. The steel pipe used as core and the rubber pipe is for insulation while the connectors are used for the assembly with the other parts of the machine. The manual assembly line of consists of the following processing steps:

1) The steel pipe of high grade and flexible is received at pipe assembly station.
2) The rubber pipe of high quality is also received at pipe assembly station.
3) The steel pipe is inserted inside the rubber pipe through air pressure.
4) The length of rubber pipe is kept larger than the steel pipe before insertion after completing the process the extra length is cut down.
5) Both ends of the assembled pipe are marked for the connecter fitting.
6) Connectors come from the inventory
7) Visual inspection of connector is done.
8) The connectors are assembled with pipes.
9) The assembled pipe is passed through metrology and hydro testing.
10) Identification number is marked on each pipe and then packed it in the delivery boxes.

The process sequence of the production line is given below in which positions and precedence links are described.

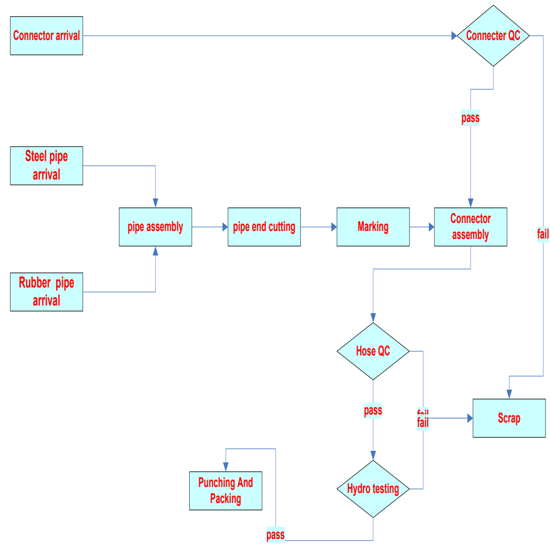


Fig. 1. Process flow diagram

Traditional line balancing methods and simulation has been used. Three techniques explored has been modeled using Largest Candidate rule, Kilbridge & Wester method and ranked positional weight methods).These techniques are based on the algorithms (the complete algorithms are beyond scope of work and only results have been described) and the line balanced before simulation study. The reason is to optimize the assembly line prior so that to focus on other performance measures. After balanced line, simulation as a tool for the study has been implemented. The collected data from the local industry is used for developing of the model. After developing the model it has been verified with the existing practices in the local industry. It has been observed that the base model is ideal and different experiments of effecting parameters are required to overcome the associated impediments. The validation of the modified model is done with "what if" effects with the base model of the assembly line. After the discussion on the results we are able to get some useful results which may improve the overall performance of the assembly line.First the assembly line has been balanced using algorithms: a) Largest Candidate Rule, b) Kilbridge and Wester Method and c) Ranked positional Weights [11]. After the line balancing with classical methods, simulation platform Arena has been used for experimentation. Interestingly, balance efficiency is same and it is required for company to stream line the single model assembly line to maximum balance i.e. 82.9%as given in Table I.

TABLE I
LINE BALANCING METHOD RESULTS

	Largest Candidate Rule	Kilbridge and Wester Method	Ranked Positional Weights Method
Line Efficiency	82.9%	82.9%	82.9%
Balance delay	16.75%	16.75%	16.75%

In order to analyze system completely i.e. queue length at each station, production information etc and its effects on the assembly system, a comprehensive treatment is required. A simulation using what-if scenario, various scenarios have been established and results communicated to the case company. The next section describes the generic mathematical model developed for the process time, quality level and setup time; which have been identified sensitive to the assembly system.

IV. MATHEMATICAL MODELING AND ANALYSIS

The mathematical model of the existing case study is given below. The model is with 'K' independent variable .The mathematical expression of the model is;

$$Y_i=\beta_0+\beta_1 X_{1i}+\beta_2 X_{2i}+ \beta_3 X_{3i+} \ . . . + \beta_K X_{Ki} +E_i \qquad (5)$$

Where

Yi=Response of the model.
β_0=Y- Intercept.
$\beta_{1=}$Slope of Y with variable X_1, holding variables X_2, X3,……….,X_K constant
$\beta_{2=}$ Slope of Y with variable X_2, holding variables X_1, X3,……….,X_K constant
$\beta_{3=}$ Slope of Y with variable X_3, holding variables X_1, X2,……….,X_K constant
$\beta_{K=}$ Slope of Y with variable X_K, holding variables X_1,X_2,……….,X_{K-1} constant
$E_{i=}$Random Error

During manual assembly operations, each operator work at each work station. The process time is obtained by time study. The working time in the factory is 720min per day and the process time for each work station is determined for process time and modeled for appropriate distribution given in Table II.

Following assumptions are made during the simulation:

- Assembly line never starved;
- Set up time is not considered
- Twenty minute time without any brake;
- Not any maintenance time included in the simulation model;
- All operation are not includes any insignificant breakdowns.

TABLE II
TIME DISTRIBUTIONS FOR PROCESS

Station #	Process time	Distribution
01	Steel Pipe arrival	NORM(42,1)
02	Rubber Pipe Arrival	NORM(38,1)
03	Pipe Assembly	TRIA(24,25,26)
04	Pipe End Cutting	EXPO(27)
05	Marking	NORM(36,1)
06	Connector Arrival	UNIF(35,36)
07	Connector QC	EXPO(16)
08	Connector Assembly	NORM(35,1)
09	Hose QC	NORM(46,1)
10	Hydro Test	TRIA(28,30,32)

The transportation of material is also done by the workers their selves. Now the base model was run according to the provided input parameters. The following abbreviations has been used

TABLE III
SOME PERFORMANCE INDICATORS ASSEMBLY LINE
(INITIAL ANALYSIS)

Station #	Performance Measures	Abbreviations	Values
01	Total Production	TP	21 parts
02	Average Delay in Queue	ADQ	110.95 sec
03	Max Delay in Queue	MDQ	225.64 sec
04	Max. number of parts in queue	MPQ	53 parts
05	Max Utilization	MU	98.7%
06	Min Utilization	Min U	57.75%
07	Number of parts rejected	--------	4 parts
08	Cycle time	TC	56.67 sec
09	Balance efficiency	Eb	82.5%

The following observations are obtained during the line balancing simulations Table III, which cannot be obtained using the classical line balancing methods. Utilization of each station is also being able to be determined. The cycle time is marginally less than the obtained in the classical methods. This difference is due to insignificant break downs and setup times. It is clear from the model that the maximum queue is formed at the Hose QC station. It means this is the main Bottleneck station in this production line. It is shown that what- if effect of changing the process time of Hose QC..The following parameters have been changed in the base model of the Safety Hoses, I) Process Time (PT); II) Quality Level (QL) and III) Set up Time (SuT).

A. Model for PT

The mathematical model for the all KPI can be generalized as; the response of all the KPI can be determined by the generic equations which are elaborated (rest of models is similar and details not provided):

$$Y_i=\beta_0+\beta_1 X_1+\beta_2 X_2+ \beta_3 X_3 +E_i \quad (6)$$

Where, $X1=X_{PT}$, $X2=X_{QL}$, $X3=X_{SuT}$.

Here X_2 and X_3 are kept constant while the response for all KPI can be expressed as Ei=it is the random error,

For TP

$$Y_{TP}= \beta_0+\beta_{PT}X_{PT}+E \quad (7)$$

$\beta_{PT=}$ Slope of Y_{TP} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For ADQ

$$Y_{ADQ}= \beta_0+\beta_{ADQ}X_{PT}+E \quad (8)$$

$\beta_{ADQ=}$ Slope of Y_{ADQ} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For MDQ

$$Y_{MDQ}= \beta_0+\beta_{MDQ}X_{PT}+E \quad (9)$$

$\beta_{MDQ=}$ Slope of Y_{MDQ} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For PR

$$Y_{PR}= \beta_0+\beta_{PR}X_{PT}+E \quad (10)$$

$\beta_{PR=}$ Slope of Y_{PR} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For MPQ

$$Y_{MPQ}= \beta_0+\beta_{MPQ}X_{PT}+E \quad (11)$$

$\beta_{MPQ=}$ Slope of Y_{MPQ} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For MU

$$Y_{Mu}= \beta_0+\beta_{MU}X_{PT}+E \quad (12)$$

$\beta_{MU=}$ Slope of Y_{MU} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For MinU

$$Y_{Min\ U}= \beta_0+\beta_{MinU}X_{PT}+E \quad (13)$$

$\beta_{MinU=}$ Slope of $Y_{MinU}$with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For TC

$$Y_{TC}= \beta_0+\beta_{TC}X_{PT}+E \quad (14)$$

$\beta_{TC=}$ Slope of Y_{TC} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

B. Effect of Changing PT

The utilization of Hose QC is 98.7% and the next Hydro Testing station is 57.27%. The process time of Hose QC is NORM 46,1.Making the assumption is that what effect on the overall performance measures with 20% reduction in the performance time of the Hose QC. The following responses are obtained:

1) Effect of PT on TP: It is clear from the graph Fig. 2 that with reducing the 20% value in the PT of Hose QC the 25% boost up is observed and it goes if we reducing the values up to 60% then the trend become smooth and corresponding slope is also recorded.

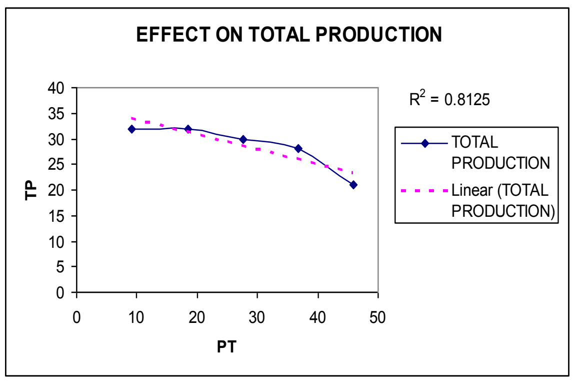


Fig . 2. PT Vs TP

2) Effect of PT on ADQ and MDQ: The trend shows that with the change of PT up to 20% reduction in ADQ is 14% and this goes reducing with the TP up to 60%. This is the reason that utilization of next station has been increased. The same change in MDQ has been observed that is 14 % reduction with the reduction of 20% in TP as in the case of ADQ. The change becomes almost smooth around 60% reduction in TP and is shown in Fig. 3.

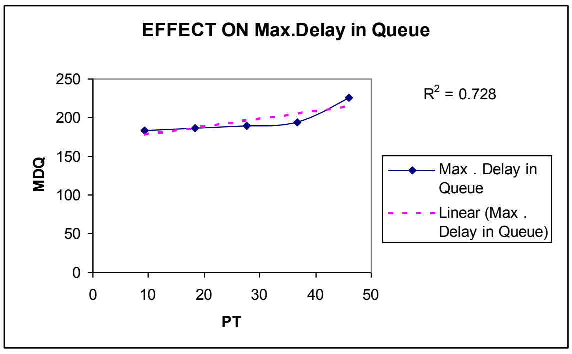
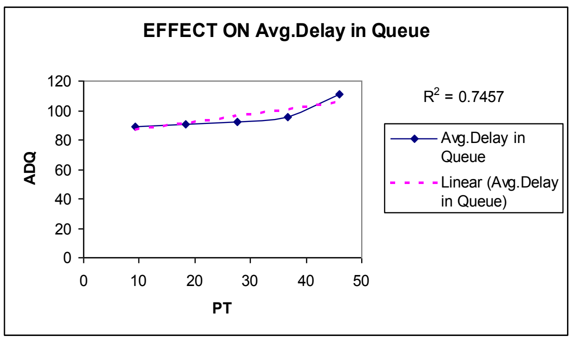
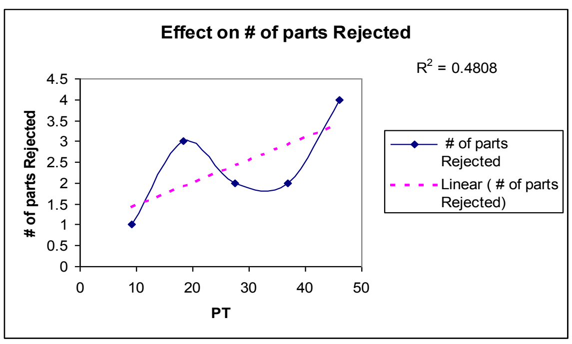


Fig. 3. PT Vs ADQ and MDQ

3) Effect of PT on Number of Parts Rejected and MTQ: The numbers of rejected parts are also reduced with change in the TP as shown in Fig. 4. This trend is not smooth because of the probabilistic and it becomes almost 50% at 60% reduction in TP. The total production is based on the reduction of queue length which is because of maximum number of parts in queue. It is very clear that at 60% reduction in TP, the reduction in MPQ is about 50% and it is a significant change.





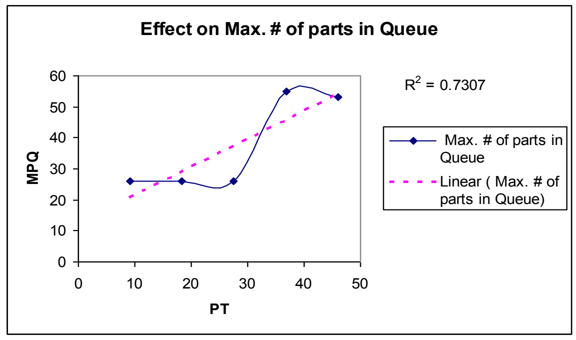
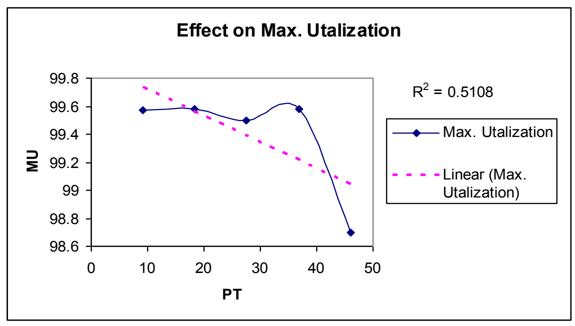
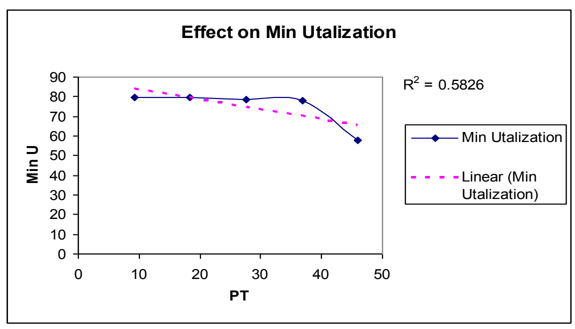


Fig. 4. PT Vs Number of parts rejected and MPQ

4) Effect of PT on MU, Min U and TC: The maximum utilization is not changing with the change of TP, because the utilization is very high in Fig. 5. MU increased up to 2% at 60% reduction in TP. The main target is the Min U of Hydro Test station which is being increased up to 22% with the reduction 60% reduction in TP. Then it is almost same with the change in TP. The TC also reduces about 50% at the changing of PT up to 60% reduction. Then it becomes almost same. The over-all effect of changing the process time seems to be very significant for the production line.





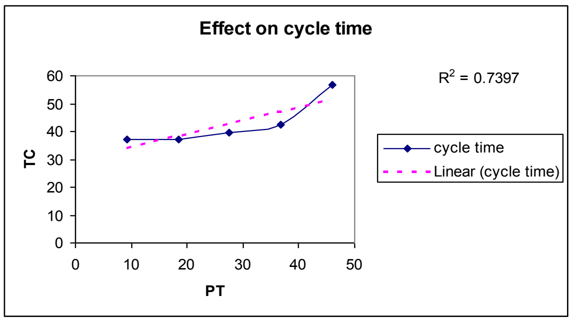
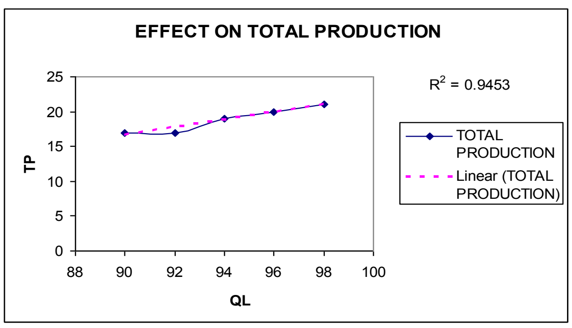


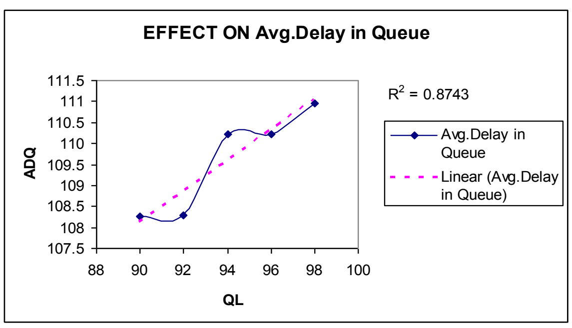
Fig. 5. PT Vs MU and Min U and TC

C. Effect of Changing QL

In the process diagram we have three inspection stations which have 2% (98% Quality Level) parts rejection. Now we see what effect the Quality level of the said stations effects if we increase the rejection rate as 4% (96% Quality Level); 6% (94% Quality Level); 8% (92% Quality Level) and 10% (90% Quality Level). After changing the Quality Levels the following effects on the performance measures have been observed:

1) Effect of QL on TP, ADQ and MDQ: If the quality level reduces only 2% the 5% reduction in TP is observed and it becomes smooth at 8% reduction in QL. It is seen in Fig. 6 that the change in the TP is directly proportional to the QL for specific case. The change in ADQ is showing random behavior with the change in QL and not affected. The change effected minor on the ADQ. The MDQ is at minimum at 98% QL and then it become smooth at the level of 96% to 92% and onward.





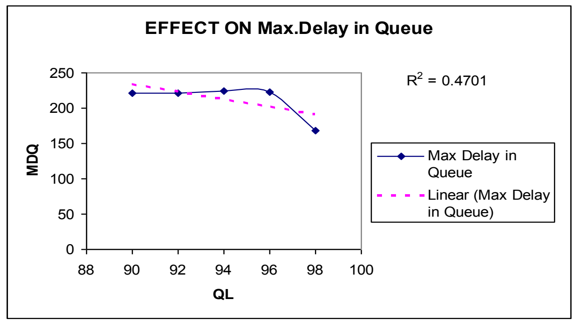
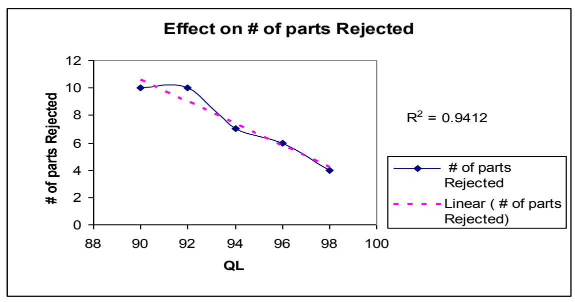


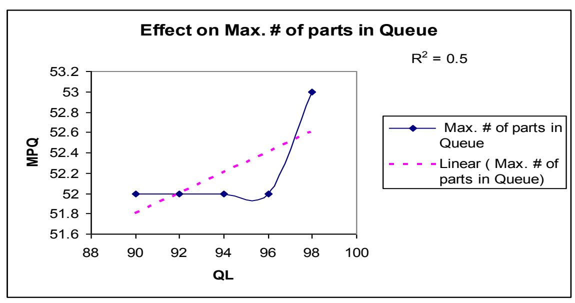
Fig. 6. QL Vs TP, ADQ and MDQ

The trend also shows that the minimum delay is at higher quality level and it goes down if we changed downward.

2) Effect of QL on Number of Parts Rejected and MPQ And Mu: It is very obvious that if the quality level in any production line reduces it effects upon the number of rejection, the same thing is observed as given in Fig. 7 but the glaring thing is that the rejection is increases 50% with changes of 2% reduction in the QL and it goes on increases with more reduction in QL. The effect on the MPQ by the changing QL is also not very smooth. As the maximum utilization is already very high then it is not affected by the changing the QL.

3) Effect of QL on Min U and TC: The QL as shown in Fig. 8 influence on the minimum utilization as it reduces the minimum utilization also reduces. Just 6% reduction in the QL the reduction in Min U is about 15%. The TC is also impacted by the QL very much; it is also an indicator of low production.





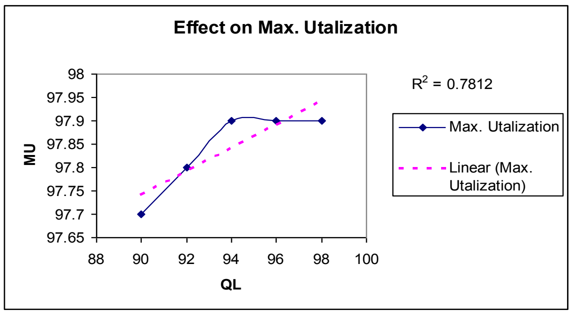
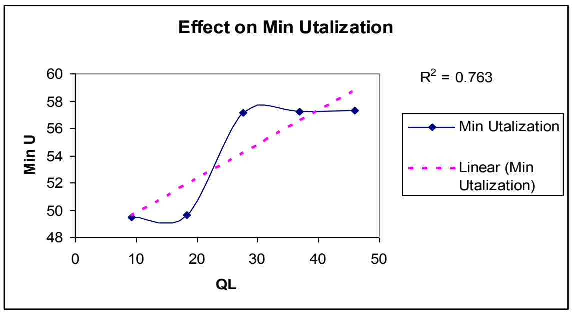


Fig. 7. QL Vs Number of parts Rejected, MPQ and MU



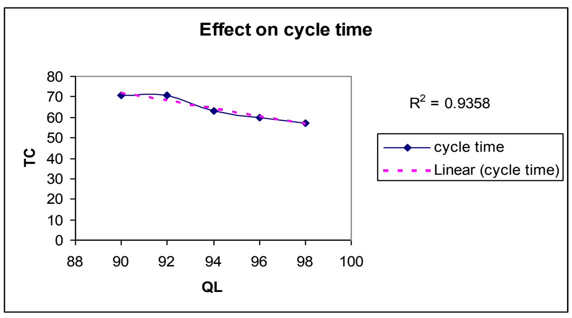
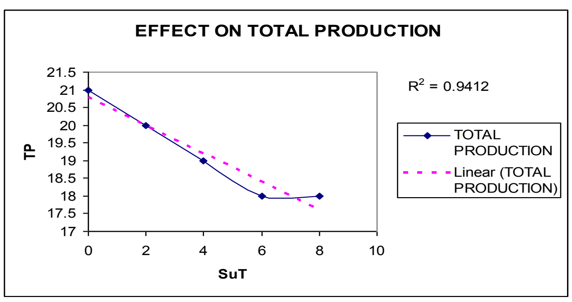
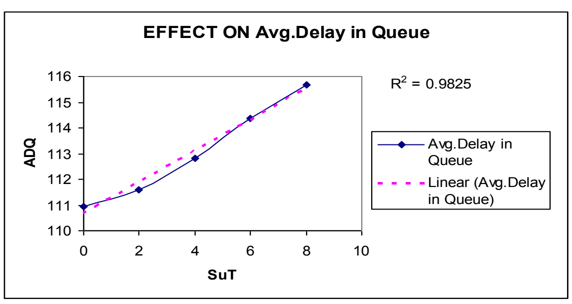


Fig. 8. QL Vs Min U and TC





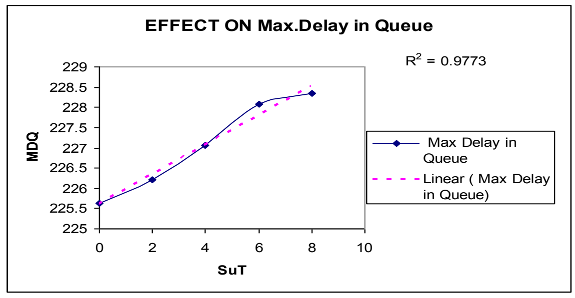
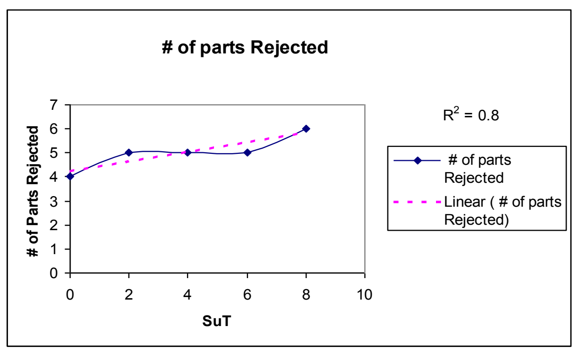


Fig. 9. SuT Vs TP and ADQ and MDQ

D. Effect of Changing SuT:

Initially the consideration was that the set up (Change over) time considered is zero second. But the set up time effects the line balancing. So, we made another assumption of changing setup time from 0 sec to 2 sec. 4 sec. 6 sec and 8 sec to analyze the effects on the performance measures. After changing the above parameters in the base model; following effects were observed.

1) Effect of SuT on TP and ADQ: Set up time is also impacting upon the TP of the production line. It is clear from the Fig. 9 that the change of 2sec the change in TP is 5% reduction and at 4sec it is 10% at 6sec the change is 15% in TP. After 6 sec the change in the graph stopped and it continued until it reached 18 sec. It is obvious that the change in ADQ will be increased as the SuT time added up in the ADQ .The trend in the graph shows that the change is directly related to SuT and over all change is about 5%.The similar effect as observed in ADQ by the change of SuT. As, it is added up in MDQ, the overall change is about 3%.



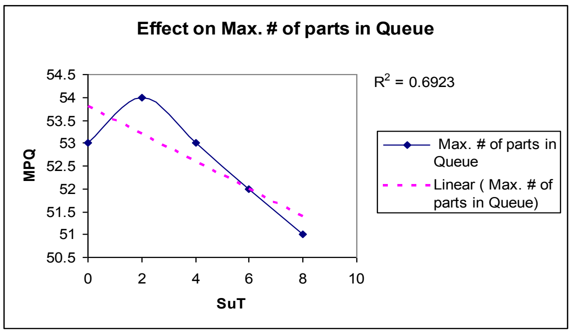
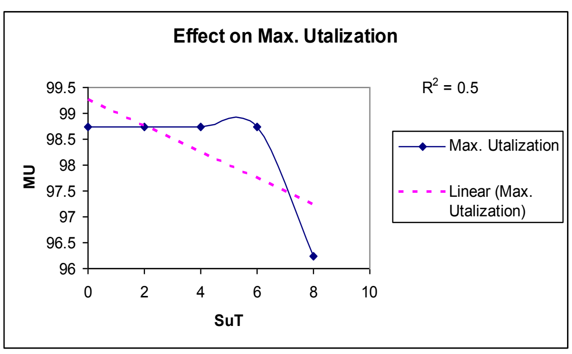


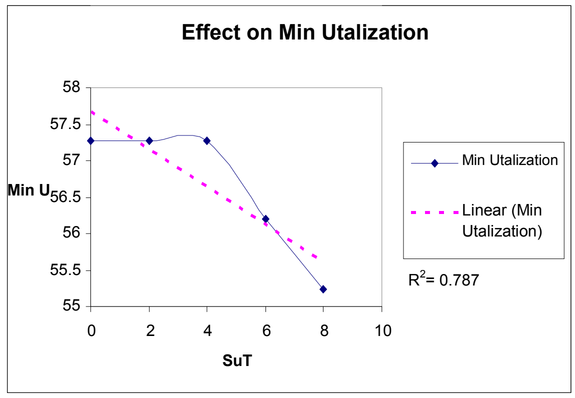
Fig. 10. SuT Vs Number of parts Rejected and MPQ

2) Effect of SuT on Number of Parts Rejected and MPQ: The SuT is increasing the number of parts rejected. The change is 10% increase with increase of 2 Sec in SuT. It becomes smooth up to the 6sec as shown in Fig. 10 and then number of parts rejected goes on increasing. The performance parameter cannot directly be related with SuT, because the number of parts rejected is probability based parameter. The trend in this graph shows that with the increase of 2 sec in SuT, the MPQ increases 2% then this go down with the increase of SuT. At 8 sec of SuT the change in MPQ is 6% down.

3) Effect of SuT on Mu, Min U and CT: The trend in Fig. 11 shows that the impact of SuT on the maximum utilization starts at 8sec and it goes increasing. This may be due with addition of time to all the station. The SuT decreases the Min U, as in the above case. It may be due to the increasing the process time of each station.

4) Effect of cycle time: The cycle time increases 5% with the increase of just 2 sec in SuT. It is going to increased till the increase in 6sec of SuT and then become smooth. The increase of cycle time means that the overall production goes increase. The effect of Set Up (Change over) time was initially ignored in the model, but actually it impacts the production. In the manual assembly line of Safety Hoses, the management did not analyzed the effect that is why the over production does not meet the actual target.





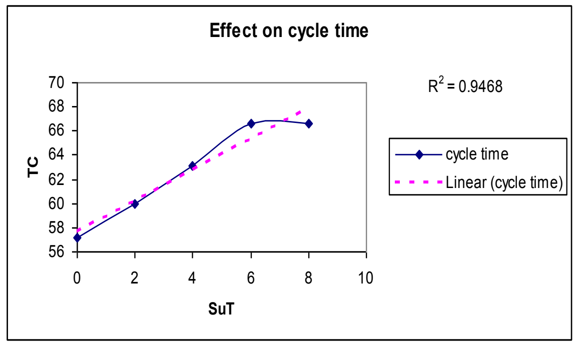


Fig. 11. SuT Vs MU, Min U and CT

Through the Simulation technique we are able to predict the effect of change over time throughout the production.

V. Sensitivity Scores and Results

After analyzing the effects, we get the trend of improving the line balancing through various set of experiments. For this purposes we have assumed the slope ranges of each effect having the different scores; if slope range (%) = 0~30, sensitivity score is 1, slope range (%) = 31~60, Sensitivity score is 2, slope range (%) = 61~80, Sensitivity score is 3 and if slope range (%) = 81~100, Sensitivity score is 4. Now the slope values from the effect graphs have been placed against each slope with corresponding sensitivity scores and are given in the following Table IV.

TABLE IV

SLOPES OF PERFORMANCE INDICATORS AND SCORES

Sr.#	Effect of	Slope	Score
01	Changing PT on TP	81.25	4
02	Changing PT on ADQ	74.57	3
03	Changing PT on MDQ	72.8	3
04	Changing PT on Number of parts rejected	48.08	2
05	Changing PT on MPQ	73.07	3
06	Changing PT on MU	51.08	2
07	Changing PT on Min U	58.26	2
08	Changing PT on CT	73.97	3
09	Changing QL on TP	94.53	4
10	Changing QL on ADQ	87.43	4
11	Changing QL on MDQ	47.01	2
12	Changing QL on # of parts rejected	94.12	4
13	Changing QL on MPQ	50	2
14	Changing QL on MU	78.12	3
15	Changing QL on Min U	76.3	3
16	Changing QL on CT	93.58	4
17	Changing SuT on TP	94.12	4
18	Changing SuT on ADQ	98.25	4
19	Changing SuT on MDQ	97.73	4
20	Changing SuT on # of parts rejected	80	3
21	Changing SuT on MPQ	69.23	3
22	Changing SuT on MU	50	2
23	Changing SuT on Min U	78.7	3
24	Changing SuT on CT	94.68	4

The above sensitive parameters have been combined in matrix form useful for the company to analyze the impact of each parameter on the output given in Table V. The scores have been added as row sum and assigned as global sum because they are very critical influencing the performance. The three performance indicators of process time, quality level and setup time gave an insight of the system. According to the case problem, setup time comes out to be most sensitive parameter followed by quality level and process time. Here it is required to balance the line first because it has major role for productivity.

TABLE V

FINAL SENSITIVITY MATRIX RESULTS

	TP	ADQ	MDQ	#PR	MPQ	MU	Min U	CT	G. sum
PT	4	3	3	2	3	2	2	3	22
QL	4	4	2	4	2	3	3	4	26
SuT	4	4	4	3	3	2	3	4	27
L. Sum	12	11	9	9	8	7	8	11	

At local level company need to focus on total production and best way to achieve is concentration on cycle time and minimizing delays in the queues and processes.

VI. CONCLUSIONS AND RECOMMENDATIONS

It has been observed that by using line balancing, the assembly line has been balanced with an efficiency of 82.9% with balance delay equals 16.75%. Performance parameters have been obtained from literature and discussion with the case company and significant ones have been evaluated i.e. process time, quality level and setup time (change over time). The existing scenario has been modeled and recorded given in Table III. It is found that hydro testing is underutilized giving 57% of utilization and is precedent by hose QC which is overloaded. Target for the process time of hose QC has been set. Quality level for existing model is 98% and it has been designed with different experiments to get realistic picture inside that what should be the minimum quality level for operating the system from the results we see that up to the 94% reduction in quality level, the system operates at the optimal level and the production shows worst impact if we reduced more quality level. Similarly the setup time impacts upon the key performance indicators and the optimal level for this case study comes out six seconds. It is evident that with the decrease of process time, the total production increases impart positive impact in reducing ADQ, MDQ and MPQ. This is also very important to note that maximum refined output parameters are obtained at 60% of Eb. Quality level reduction up to 94% shows minor effect on the total production and over 94% of quality level it start giving low total production. The SuT also important input parameter which cannot consider in classical methods but exists in real system, and after deliberations with the case company, it is suggested to incorporate different set up times and it is evident that total production reduces with increase SuT. It is also established that change occurs up to 6 seconds in SuT and similar behavior of SuT upon ADQ, MDQ, and MPQ has been observed too. Cycle time have the same behavior, ultimately we can describe the whole situation as that the 6 sec is the optimal point for SuT in the current case. The effects of changes are analyzed that what level of sensitivity occurs upon key performance indicators with the changes of input parameters and also what is the level of sensitivity for the input parameters as the slops of each effect. It is recommended that company producing high tech parts focus on:

- SuTis found the most sensitive parameter with maximum time is six seconds. It is recommended to use some temporary storage buffers and cycle time to be set according to the work content time and fixed launching sequence be used for optimal utilization.

- Quality level to be maintained at 94% and if it goes down, reworking or even scrap rate increases. It is recommended that for mass production, six sigma quality initiatives to be initiated.
- Balanced assembly line and assigning workers to the workstation is the third important parameter. Using some standard techniques like largest candidate rule, Kilbridge and Wester method, properly balance assembly line.

The future work includes incorporating of the cost factor like material, energy and operating cost, variable schedules in two shifts, breakdown modeling and stoppage of the assembly line, line pacing issues.

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