Productivity Improvement Analysis of DLL-S Nozzle Assembly

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ABSTRACT : The productivity is a relationship between the output (product/service) and input (resources consumed in providing them) of a business. The ratio of output to the input is called as productivity. Paper mainly focuses on studying assembly process of DLL-S Nozzle at Bosch Ltd. and finding out root cause responsible for low productivity. By finding root causes, analysis is carried out to find solution on low productivity of bottleneck processes of DLL-S Nozzle assembly. Tools used for process are DMAIC cycle, Activity mapping, Fishbone diagram and Time study. With the help of root cause analysis and time study, improvement options are derived. By calculating single resource productivity and productivity index from these options new results are compared with the previous results and appropriate improvement option is suggested. Therefore this study attempts to find out the solution for productivity improvement with the help of analysis.

Keywords: ***DMAIC, Productivity Index, Single Resource Productivity, Time Study*****.**

I. INTRODUCTION

Productivity is a measure of the efficiency of a person, machine, factory, system, etc., in converting inputs into useful outputs. In today's increasingly competitive world, it is important to constantly improve, for a manufacturing or service industry. Quality with quantity is a main characteristic which helps a company stay in the competition. It is essential to study productivity in order to:

- Understand the processes of a business
- Control the business processes
- Continuously improve processes
- Assess performance of a business

Measurement of Productivity

Single Resource Productivity

The first basic measure is Single Resource Productivity (SRP) which measures the productivity ratio of each individual resource broken down into much detail as possible. To obtain single resource productivity the output of process (in either units or value) is divided by each resource input. The result is then expressed as a productivity ratio. [1]

Total Resource Productivity

Total Resource Productivity (TRP) is used to compare the overall productivity of all resource inputs with other results or standards. It is found by converting all the inputs into monetory values, adding them together and dividing them into the output to give the ratio of total output with respect to total input. [1]

Productivity Index

Normal company's reporting systems are mixture of positive and negative figures; some indicates good figures, some bad. For example if cost goes down, that's good but if production goes down, that's bad. Interpreting positive and negative variances is tricky and time consuming. Since measuring productivity would be a waste of time and effort unless results were constantly reviewed and correctly interpreted, productivity results are always as a percentage of standard- results above 100% are positive and results below are clearly negative. This measure is known as Productivity Index(PI) .

It is fundamental principle of productivity improvement that productivity should be measured before any attempt is made to improve it. Equally important it is re measured after every change in process or resource inputs. [1]

II. REVIEW OF LITERATURE

Mr.VengudupathiChinnadurai, Dr. D. Rajenthira Kumar in their research paper "Productivity Improvement Measures in Engineering Services Industry: An analysis using DMAIC tools" mentioned the usage of DMAIC approach of Six Sigma process & its tools to identify various root causes which influences Productivity in Engineering Services Industry. [2]

Harry Rever, MBA, PMP, CSSMBB, CQM, CQC, Director of Lean Six Sigma for International Institute for Learning in their research paper "Applying the DMAIC Steps to Process Improvement Projects 'Define, Measure, Analyze, Improve, Control' is the Roadmap to Improving Processes" mentioned that Project managers, in just about any industry, are faced with the challenge of improving the efficiency and productivity of their businesses. [3]

HemendraNath Roy, SudiptaSaha, Prof. Dr. TarapadaBhowmick and Sufal Chandra Goldar, Khulna University of Engineering & Technology, Bangladesh in their research paper "Productivity Improvement of a Fan Manufacturing Company by using DMAIC Approach: A Six-Sigma Practice" focused on introduction of Six-Sigma philosophy in Bangladesh, especially in Manufacturing Industry. [4]

Md. EnamulKabir, S. M. Mahbubul Islam Boby, MostafaLutfi, Department of Industrial Engineering and Management, Khulna University of Engineering & Technology, Khulna- 9203, Bangladesh in their research paper "Productivity Improvement by using Six-Sigma" mentioned that globalization, advanced technology, and increased sophisticated customer demands change the way of conducting business. [5]

Vilasini P P G N, Gamage J R , Kahangamage U P , and Thibbotuwawa N in their research paper "Low Productivity and Related Causative Factors: A Study Based on Sri Lankan Manufacturing Organisations" mentioned that inability to explore the full potential of available resources is evident in majority of organisations in developing countries. [6]

Jitendra A Panchiwala, Prof. Dr. Darshak A Desai, Mr. Paresh Shah PG Student of Industrial Engineering, Department of Mechanical Engineering, G.H.Patel.College of Engineering and Technology , V.V.Nagar,Anand , Gujarat, India in their research paper "Review on Quality and Productivity Improvement in Small Scale Foundry Industry" mentioned that Today"s competitive environment has, lower manufacturing cost, more productivity in less time, high quality product, defect free operation are required to follow to every foundry man. [7]

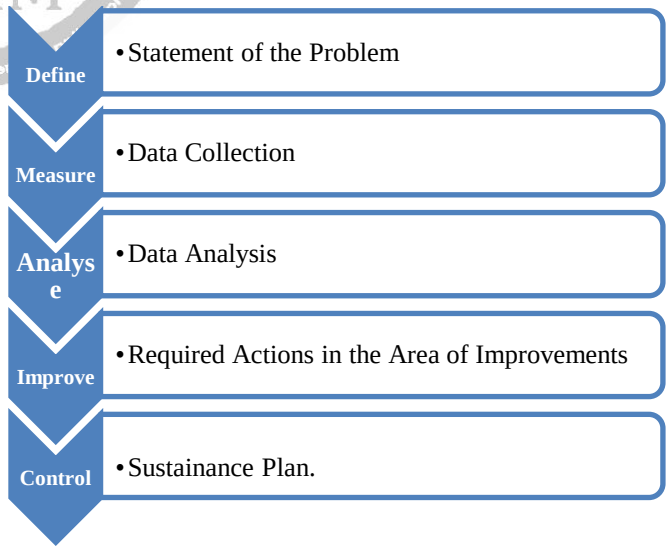
Patange Vidyut Chandra, Assistant Professor, Department of Mechanical Engineering, Sreenidhi Institute of Science and Technology , Ghatkesar, Hyderabad , Andhra Pradesh , India in their research paper "An Effort to Apply Work and Time Study Techniques in a Manufacturing Unit for Enhancing Productivity." focused on the crucial area of productivity improvement with the astute use of work study technique mixed with modern soft skills. [8]

Kanthi M.N. Muthiah and Samuel H. Huang, Intelligent Systems Laboratory, Department of Mechanical, Industrial and Nuclear Engineering, University of Cincinnati, Cincinnati, OH 45221, USA in their research paper "A review of literature on manufacturing systems productivity measurement and improvement" mentioned that globalisation is posing several challenges to the manufacturing sector. Design and operation of manufacturing systems are of great economic importance. [9]

Richard Hedman, Department of Materials and Manufacturing Technology, Chalmers University of Technology Gothenburg, Sweden 2013 in his research paper "Manufacturing Resource Modelling for Productivity Management: Towards a better understanding of the productivity improvement potential at shop floors." mentioned that the role of manufacturing has been vital for the creation of welfare in advanced economies ever since the industrial revolution. [10]

Tushar N. Desai and Dr. R. L. Shrivastava in their research paper "Six Sigma – A New Direction to Quality and Productivity Management." mentioned that the fast changing economic conditions such as global competition, declining profit margin, customer demand for high quality product, product variety and reduced lead–time etc. had a major impact on manufacturing industries. [11]

III. METHODOLOGY



Flowchart 1

DMAIC Methodology: It is a structured five step methodology used in organizations. [12]

IV. DEFINE

Objectives:

1. To study assembly process of DLL-S nozzle.
2. To determine factors causing losses in productivity of DLL-S Nozzle Assembly.
3. To analyze and improve the existing assembly process in terms of quantity.

Scope of the Study:

This study is aimed at giving productivity improvement analysis of DLL-S Nozzle. According to objectives, existing assembly process is studied and improvement options are suggested. This has been carried out with the help of DMAIC cycle.

Limitation of the Study:

Manufacturing of DLL-S nozzle consists of 3 stages:

1. Hard stage process
2. Soft stage process
3. Assembly process

This study is only focusing on the productivity improvement of DLL-S nozzle assembly which is 3rd Stage in the Manufacturing of DLL-S Nozzle.

Because of the time duration of 2 months only, it was possible to work on only 3rd Stage of manufacturing.

This Stage requires more focus as per the guideline from Company Project Guide, hence chosen the third stage.

V. MEASURE

Data collection:

Sample size: One Month Data (May 2016)

Type of data:

1) Secondary data-

Source: Production charts of DLL-S assembly process of the month May 2016. It consists of daily records of output quantity of each of the following assembly processes of DLL-S Nozzle with respect to different machines, operators and shifts. Assembly processes of DLL-S Nozzle:

1. Ball Grinding
2. Pinning and Centrifuge
3. Rota Checking and Spray Direction Checking
4. Needle Lapping
5. GC Assembly
6. Stroke and Length Grind
7. Repetition Test
8. Final Visual
9. Hydraulic Through Flow

2)Primary Data-

Time Study of Guide Clearance and Needle Lapping which is the bottleneck of the entire process. Data was taken for first shift for 3 days.

Sr No.	Process	Fixed Qty	Worked Hours	Fixed Qty/WH
1	Ball Grinding	2800	7.5	373
2	Ball Grinding (CNC11698)	825	7.5	110
3	Pinning &CentriFuge	5870	7.5	783
4	Rota Check & Spray Direction Check	3300	7.5	440
5	Needle Lapping	2100	7.5	280
6	G/C Assembly	1900	7.5	253
7	Stroke &Length Grind	1430	7.5	191
8	Final Visual	2700	7.5	360
9	Repetition Test	2700	7.5	360
10	HTF Test	1900	7.5	253

Table 1: Calculation of fixed quantity per worked hour

Sr No.	Process	TG	Worked Hours (Min)	Target Quantity	Worked Hours	Target Qty/WH
1	Ball Grinding	15	450	3000	7.5	400
2	Ball Grinding (CNC11698	43	450	1047	7.5	140
3	Pinning & Centrifuge	18	450	2500	7.5	333
4	Rota Check &Spray Direction Check	5.2	450	8654	7.5	1154
5	Needle Lapping	17	450	2647	7.5	353
6	G/C Assembly	29	450	1552	7.5	207
7	Stroke & LengthGrind	22	450	2045	7.5	273
8	Final Visual	23	450	1957	7.5	261
9	Repetition Test	17	450	2647	7.5	353
10	HTF Test	13.5	450	3333	7.5	444

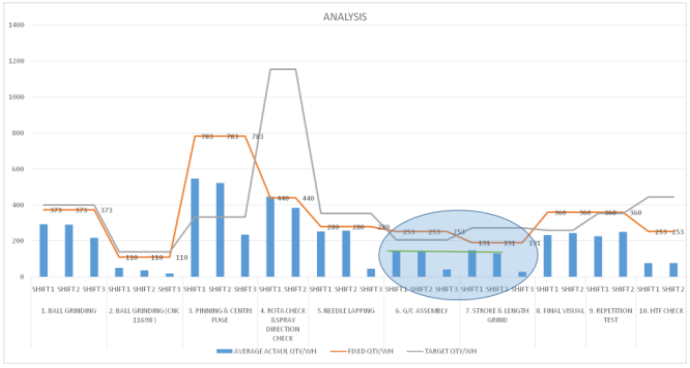
Table 2: Calculation of target quantity per worked hour

Process	Shift	Average Actual Qty/WH	Fixed Qty/WH	Target Qty/WH
1. Ball Grinding	Shift 1	294	373	400
	Shift 2	291	373	400
	Shift 3	219	373	400
2. Ball Grinding (CNC 11698)	Shift 1	52	110	140
	Shift 2	37	110	140
	Shift 3	20	110	140
3. Pinning and Centrifuge	Shift 1	547	783	333
	Shift 2	522	783	333
	Shift 3	237	783	333
4. Rota Checking and Spray Direction Checking	Shift 1	447	440	1154
	Shift 2	386	440	1154
5.Needle Lapping	Shift 1	254	280	353
	Shift 2	259	280	353
	Shift 3	47	280	353
6. G/C Assembly	Shift 1	147	253	207
	Shift 2	143	253	207
	Shift 3	42	253	207
7. Stroke and Length Grind	Shift 1	149	191	273
	Shift 2	132	191	273
	Shift 3	29	191	273
8. Final Visual	Shift 1	233	360	261
	Shift 2	245	360	261
9. Repetition Test	Shift 1	226	360	353
	Shift 2	251	360	353
10. HTF Check	Shift 1	78	253	444
	Shift 2	77	253	444

Table 3: Calculation of average actual quantity per worked hour

VI. ANALYZE

Data Analysis:



Graph 1

Interpretation:

Bottleneck Processes for Low Productivity:

1. Guide Clearance Assembly
2. Stroke and Length Grind

Here Ball grinding (CNC 11698) and HTF Check are not considered as bottleneck processes as these are used for odd types of DLL Nozzle.

Calculations:

Productivity = Output/Input

= Number of units/Man hours

Calculation of Single Resource Productivity (SRP) on weekly basis:

Number of units: 147

Manhours : 7.5 hours per shift

Hence 7.5*3= 22.5 hours per day

22.5*7=157.5 hours per week

Single Resource Productivity:147/157.5=0.93

Productivity Index: (Actual output/Standard output)*100

Actual output: 147

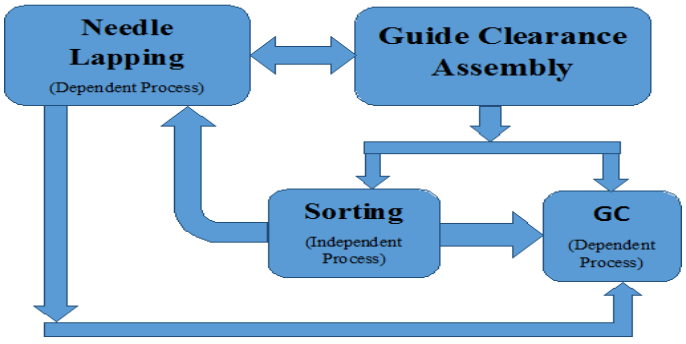
Standard output: 253

Productivity Index: (147/253)*100

=58.10%

Observations:

G/C Assembly and needle lapping are parallel processes as shown below:



Operation Flow of Needle Lapping and GC Assembly

Flowchart 3

- As per the analysis G/C Assembly and Stroke and Length Grind are bottleneck processes.

- Output of G/C Assembly is input to Stroke and Length Grind process. Hence G/C Assembly process is focused for finding out reasons for low productivity.
- If productivity of G/C Assembly is improved, it will automatically help to improve productivity of Stroke and Length Grind process, as both are sequential processes.
- Cycle time for guide bore sorting of first batch of150 nozzle bodies : 86 minutes
- Cycle time for guide bore sorting of second batch of150 nozzle bodies : 96 minutes
- Cycle time for guide bore sorting of third batch of 150 nozzle bodies : 106 minutes
- It is found that after every 9-10 minutes next batch of 150 nozzle bodies is sorted out.
- Cycle time for needle lapping of 150 needles : 18-22 minutes
- Cycle time for guide clearance of 150 needles : 30 minutes

Activity Mapping:

Activity chart of G/C Assembly and Lapping
Shift: 1 (6 am-2 pm)

Time	Sorting	Guide Clearance	Lapping
06:00 am-07:30 am	☑	✖	☑
07:30 am-08:30 am	☑	✖	☑
08:30 am-08:45 am	Breakfast break		
08:45 am-09:10 am	☑	✖	✖
09:10 am-09:30 am	☑	✖	☑
09:30 am-10:15 am	Break (Parts unavailable)		
10:15 am-10:45 am	☑	✖	✖
10:45 am-11:30 am	Lunch break		
11:30 am-12:30 pm	✖	☑	☑
12:30 pm-01:00 pm	✖	☑	☑
01:00 pm-1:45 pm	✖	☑	☑

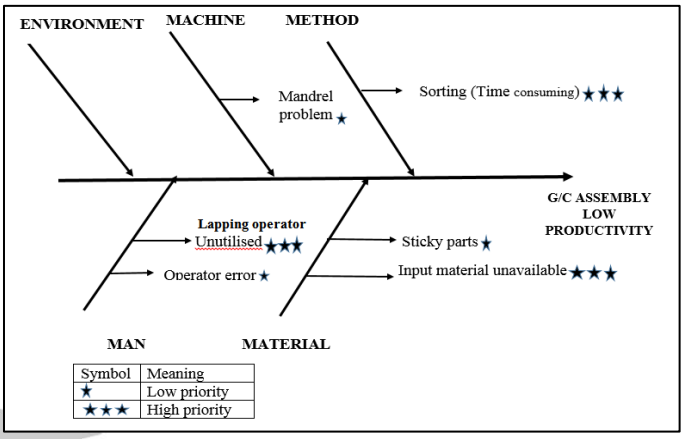
Table 4

Reasons for low productivity according to

1. Machine
2. Method
3. Man
4. Material
5. Environment

Root Cause Analysis:

Fishbone Diagram for Low Productivity of G/C Assembly:



4Ms& 1E	Impact	Remark
Machine	No	No issues observed
Method	Yes	Sorting time is concerned
Man	Yes	For lapping : Operator is not utilized properly due to time consuming sorting process
Material	Yes	Input for lapping is concerned
Environment (Mother nature)	No	No issues observed

Table 5

Time study:

1. **Sorting :**

- Cycle time for guide bore sorting of first batch of150 nozzle bodies : 86 minutes
- Cycle time for guide bore sorting of second batch of150 nozzle bodies : 96 minutes
- Cycle time for guide bore sorting of third batch of 150 nozzle bodies : 106 minutes
- It is found that after every 9-10 minutes next batch of 150 nozzle bodies is sorted out.
- Hence total worked hours : 8=8*60=480 minutes
- 480-30=450 minutes (lunch break of 30 minutes)
- Now 450-86=364 minutes (cycle time for guide bore sorting of first batch is 86 minutes)
- Hence 5460 nozzle bodies can be sorted out in 364 minutes and 5610 nozzle bodies (5460+150) can be sorted out in 350 minutes (364+86)

2. **Needle lapping :**

- Cycle time for lapping of 150 needles : 20 minutes.

Minutes	No of lapping cycles
20	1
450	?

- Hence 22 lapping cycles can be carried out in 450 minutes.
- 1 lapping cycle constitutes lapping of 150 needles.
- Hence 3300 needles (22*150) can be lapped in 450 minutes.

3. Guide clearance assembly :

- Cycle time for guide clearance of 1 nozzle body : 12 seconds

No of nozzle bodies	Seconds
1	12
150	?

- Cycle time for guide clearance of 150 nozzle bodies:1800 seconds=1800/60=30 minutes

Minutes	No of nozzle bodies
30	150
450	?

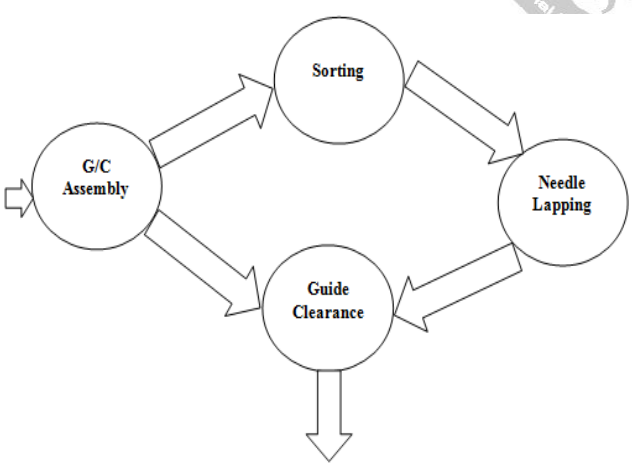
- Hence guide clearance of 2250 nozzle bodies can be carried out in 450 minutes.

Summary:

Operation	No of bodies	Minutes
Guide bore sorting	5610	450
Needle lapping	3300	450
Guide clearance	2250	450

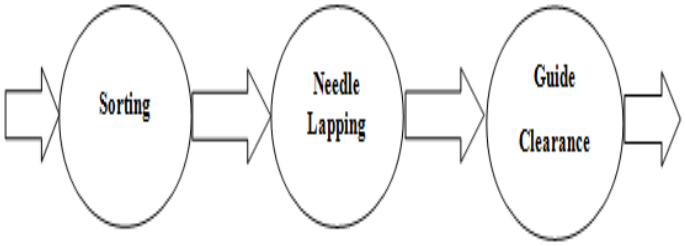
VII. IMPROVE AND CONTROL

Existing Process:



Flowchart 4

Proposed Process:



Flowchart 5

Improvement Options as per Analysis:

Improvement Option 1:

- As G/C Assembly is one man 2 operation method:
  - I. Guide bore sorting according to diameter
  - II. Guide clearance
- If we shift the entire guide bore operation to shift 3 (night shift), it will make readily available input of sorted nozzle bodies for shift 1 and shift 2.
- According to time study,
- Guide bore sorting of 5610 nozzle bodies can be performed in 450 minutes i.e. in 1 shift.
- Due to this lapping operators of shift 1 and shift 2 will get fully utilized as they will get continuous input which will help to get continuous input for guide clearance operation.

Operation	No of bodies	Minutes
Guide bore sorting	5610	450
Needle lapping	3300	450
Guide clearance	2250	450

Shift 3:

- Guide bore sorting of 5610 nozzle bodies in 450 minutes.

Shift 1:

- 3300 needles can be lapped in 22 cycles with cycle time 450 minutes.
- Total quantity of guide clearance: 2250 in shift 1.
- Hence 3300-2250=1050 needles will remain in the

Minutes	No of nozzle bodies
10	150
364	?

inventory for next shift.

- 5610-2250=3360 nozzle bodies will remain in the inventory for next shift.

Shift 2:

- Quantity available of sorted nozzle bodies in shift 2: 5610-2250=3360
- But available lapped needles from first shift:1050
- As per the requirement of guide clearance: 2250-1050=1200 needles to be lapped.

Needles	Needle Lapping Cycles
150	1
1200	?

- Hence 1200 needles can be lapped in 8 cycles.

Needle Lapping Cycles	Minutes
1	20
8	?

- Hence 1200 needles can be lapped in 20 cycles with cycle time 160 minutes.
- This indicates that lapping operator will remain free for (450-160)=290 minutes.
- Utilization of free 290 minutes by lapping operator:
- For Needle Lapping:

Needle Lapping Cycles	Minutes
1	20
6	?

Hence 6*150=900 needles can be lapped in 120 minutes.

290-120=170 minutes can be utilized for guide clearance.

For guide clearance:

Minutes	No of nozzle bodies
30	150
170	?

- Hence guide clearance of 850 nozzle bodies can be carried out in 170 minutes.
- Total quantity of guide clearance of nozzles: 2250+850=3100 in shift 2.
- Total quantity of needle lapping of needles: 1050+1200+900=3100 in shift 2.
- Hence 3150-3100=50 needles will remain in the inventory for next shift.
- 3360-3100=260 nozzle bodies will remain in the inventory for next shift.

Findings of Improvement Option 1:

For G/C Assembly:

Actual proposed quantity per worked hour for shift 1:

Minutes	No of nozzle bodies
450	2250
60	?

Hence for G/C Assembly actual proposed quantity per worked hour is 300.

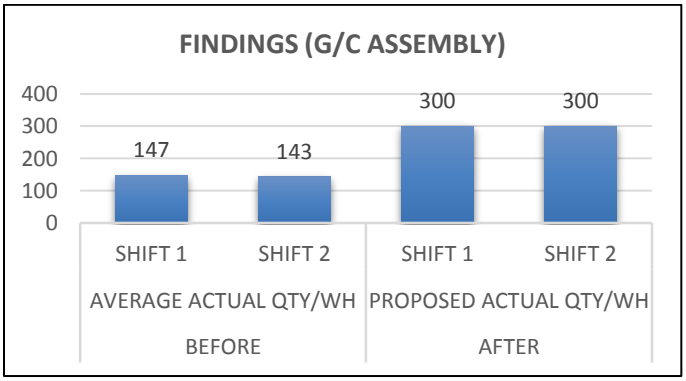
Actual proposed quantity per worked hour for shift 2:

Minutes	No of nozzle bodies
450+170=620	3100
60	?

- Hence for G/C Assembly actual proposed quantity per worked hour is 300

Before	**Average Actual Qty/WH**	**Shift 1**	147
		Shift 2	143
After	**Proposed Actual Qty/WH**	**Shift 1**	300
		Shift 2	300

Table 6

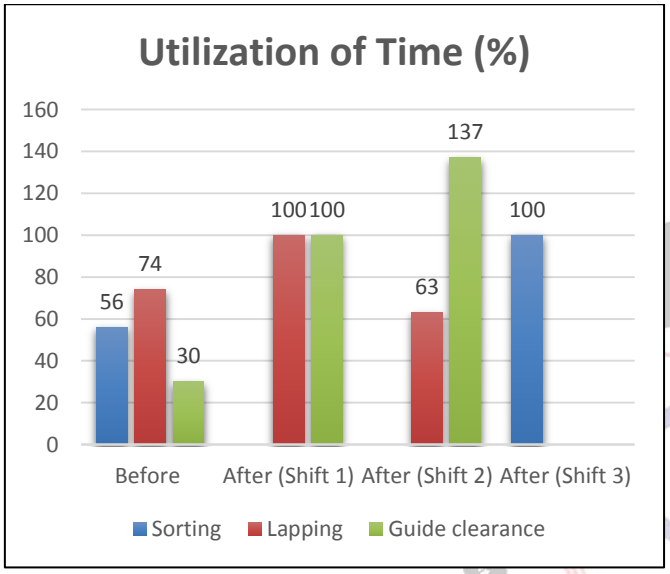


Graph 2

Utilization of Time(%) for Improvement Option1:

Operation	Before	Operation	After		
			Shift 1	Shift 2	Shift 3
Sorting	56%	Sorting(Separate operation)	-	-	100%
Lapping	74%	Lapping	100%	63%	-
Guide clearance	30%	Guide clearance(Combined opearion:G/C operator+Lapping operator)	100%	137%	-

Table 7



Graph 3

Improvement Option2:

Shift 3:

- Guide bore sorting of 5610 nozzle bodies in 450 minutes.

Shift 1:

- Calculations of time study shows that guide clearance of 2250 nozzle bodies can be done in one shift.
- Hence out of 5610 sorted nozzle bodies 5610-2250=3360 nozzle bodies can be sorted out in shift 2
- According to time study,
  Needle lapping of 3300 needles can be performed in 450 minutes.

  If lapping operator is fully utilized for needle lapping during a shift, needle lapping of 3300 needles can be performed.
- But guide clearance of only 2250 can be done in 450 minutes. Hence 3300-2250=1050 needles will remain in inventory for next shift.

Shift 2:

- Quantity available of sorted nozzle bodies in shift 2: 5610-2250=3360
- Hence needle lapping of 3360 needles is required.
- Available needles in the inventory are 1050
- Hence 3360-1050=2310 needles to be lapped for guide clearance.

Needles	Needle Lapping Cycles
150	1
2310	?

- Hence 2310 needles can be lapped in 15 cycles.

Needle Lapping Cycles	Minutes
1	20
15	?

- Hence 2310 needles can be lapped in 15 cycles with cycle time 300 minutes.
- This indicates that lapping operator will remain free for (450-300) =150 minutes. So for the remaining 150 minutes lapping operator can be utilized for G/C Assembly.
- For G/C Assembly:

Minutes	No of nozzle bodies
30	150
150	?

- Hence in 150 minutes lapping operator can perform guide clearance of 750 nozzle bodies.
- Total quantity of guide clearance: 2250+750=3000 in shift 2
- But quantity available of sorted nozzle bodies in shift 2: 5610-2250=3360

- Hence 3360-3000=360 nozzle bodies will remain in the inventory for guide clearance.
- Also (2310+1050) =3360-3000=360 needles will remain in the inventory.

Findings of Improvement Option 2:

- For G/C Assembly:Actual proposed quantity per worked hour for shift 1:

Minutes	No of nozzle bodies
450	2250
60	?

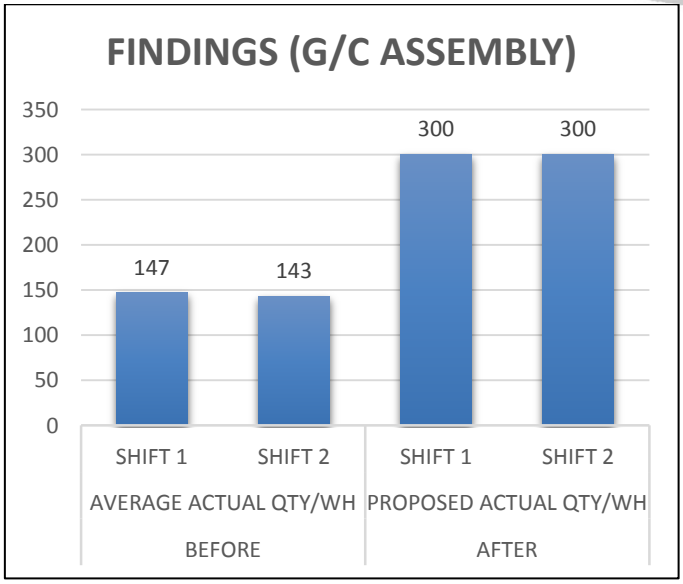
- Hence for G/C Assembly actual proposed quantity per worked hour is 300.
- Actual proposed quantity per worked hour for shift 2:

Minutes	No of nozzle bodies
450+150=600	3000
60	?

- Hence for G/C Assembly actualproposed quantity per worked hour is 300.

Before	**Average Actual Qty/WH**	**Shift 1**	147
		Shift 2	143
After	**Proposed Actual Qty/WH**	**Shift 1**	300
		Shift 2	300

Table 8

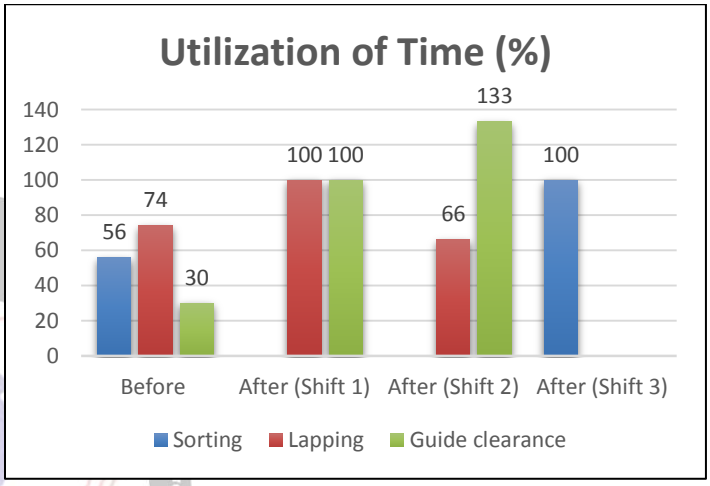


Graph 4

Utilization of Time(%) for Improvement Option2:

Operation	Before	Operation	After		
			Shift 1	Shift 2	Shift 3
Sorting	56%	Sorting (Separate operation)	-	-	100 %
Lapping	74%	Lapping	100 %	66%	-
Guide clearance	30%	Guideclearance(Combined opearion:G/C operator+Lapping operator)	100 %	133 %	-

Table 9



Graph 5

Improvement Option3:

Shift 3:

- Guide bore sorting of 5610 nozzle bodies in 450 minutes.

Shift 1:

- If lapping operator is fully utilized for needle lapping during a shift, needle lapping of 3300 needles can be performed.
- If guide clearance operator is fully utilized during a shift, guide clearance of 2250 nozzle bodies can be performed.
- Hence 3300-2250=1050 needles will remain in the inventory as out of 3300 needles only 2250 needles will be inserted in nozzle bodies by G/C operator.

Shift 2:

- Similarally for second shift:
- Number of available sorted nozzle bodies in shift 2:5610-2250=3360
- If lapping operator is fully utilized for needle lapping during a shift, needle lapping of 3300 needles can be performed.
- If guide clearance operator is fully utilized during a shift, guide clearance of 2250 nozzle bodies can be performed.
- Hence 3360-2250=1110 sorted nozzle bodies will remain in the inventory.
- Also 3300-2250=1050 needles will remain in the inventory as out of 3300 needles only 2250 needles will be inserted in nozzle bodies by G/C operator.
- Inventory avaialble:

Inventory	Shift 1	Shift 2
Sorted nozzle bodies without G/C	3360	1110
Lapped needles	1050	1050

- Inventory avaialble at end of the day :

Inventory	Shift 1	Shift 2	Total
Sorted nozzle bodies without G/C	-	1110	1110
Lapped needles	1050	1050	2100

- Hence inventory available after 3 days or 6 shifts:

	Inventory
Sorted nozzle bodies without G/C	1110*3=3330
Lapped needles	2100*3=6300

- Now because availability of inventory of 6300 lapped needles we can hold the needle lapping operation for one complete day i.e. two shifts
- Also because of availability of 3300 sorted nozzle bodies, only 6300-3300=3000 nozzle bodies will be sorted during night shift i.e. shift 3
- Now this available inventory will be utilised by operator of G/C assembly.

	Inventory
Sorted nozzle bodies without G/C	3300+3000=6300
Lapped needles	2100*3=6300

- In two shifts guide clearance of 2250*2=4500 nozzle bodies can be performed by operator of G/C assembly.
- 6300-4500=1800 sorted nozzle bodies and needles can be utilised by lapping operator for the guide clearance in one shift.
- In this way available inventory will be fully utilised and also we can utilise lapping operator on other workstation according to the requirement for one shift.
- We can continue the same cycle after evey 3 days or 6 shifts without disurbing regular operations of sorting, needle lapping and guide clearance.

Findings of Improvement Option 3:

- For G/C Assembly:
- Actual proposed quantity per worked hour for shift 1:

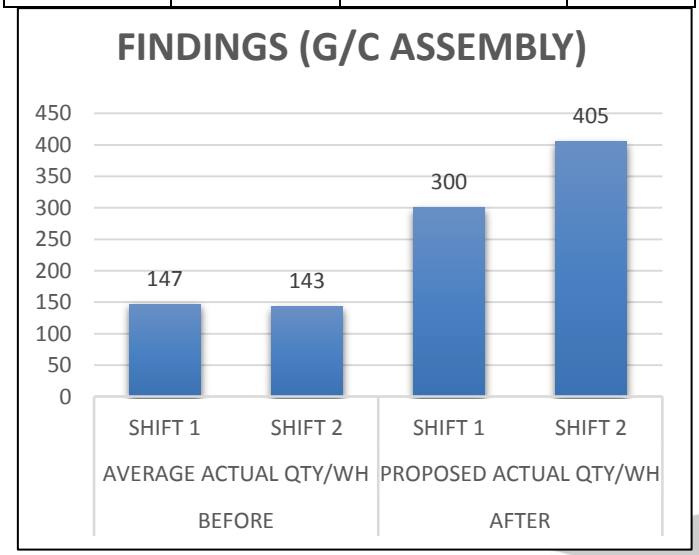
Minutes	No of nozzle bodies
450	2250
60	?

- Hence for G/C Assembly actual proposed quantity per worked hour is 300.
- Actual proposed quantity per worked hour for shift

Minutes	No of nozzle bodies
450+150=600	2250+1800=4050
60	?

- Hence for G/C Assembly actual proposed quantity per worked hour is 405.

Before	Average Actual Qty/WH	Shift 1	147
		Shift 2	143
After	Proposed Actual Qty/WH	Shift 1	300
		Shift 2	405

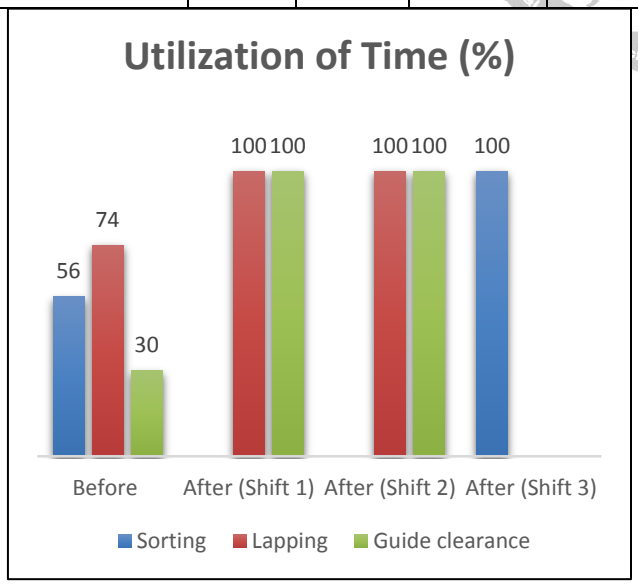


Graph 6

Utilization of Time(%) for Improvement Option 3

Table 11

Utilization of time (%)				
Operation	Before	After (Shift 1)	After (Shift 2)	After (Shift 3)
Sorting	56	-	-	100
Lapping	74	100	100	-
Guide clearance	30	100	100	-



Graph 7

Deployement of Improvement Options:

Deployement of Improvement Option 1:

Sorting									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	✖	✖	✖	✖	✖	✖	✖		
2	✖	✖	✖	✖	✖	✖	✖		
3	☑	☑	☑	☑	☑	☑	☑		
Output Qty	5610	5610	5610	5610	5610	5610	5610	39270	
Whours	7.5	7.5	7.5	7.5	7.5	7.5	7.5	52.5	748

Needle Lapping									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	☑ (450 min)	☑ (450 min)	☑ (450 min)	☑ (450 min)	☑ (450 min)	☑ (450 min)	☑ (450 min)		
2	☑ (280 min)	☑ (280 min)	☑ (280 min)	☑(280 min)	☑(280 min)	☑(280 min)	☑(280 min)		
3	✖	✖	✖	✖	✖	✖	✖		
Output Qty	5400	5400	5400	5400	5400	5400	5400	37800	
Whours	12.16667	12.16667	12.16667	12.16667	12.16667	12.16667	12.16667	85.16667	443.8356

Guide Clearance									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	☑	☑	☑	☑	☑	☑	☑		
2	☑(540 min)	☑(540 min)	☑(540 min)	☑(540 min)	☑(540 min)	☑(540 min)	☑(540 min)		
3	✖	✖	✖	✖	✖	✖	✖		
Output Qty	5350	5350	5350	5350	5350	5350	5350	37450	
Whours	16.5	16.5	16.5	16.5	16.5	16.5	16.5	115.5	324

Table 12

Deployement of Improvement Option 2:

Sorting									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	✖	✖	✖	✖	✖	✖	✖		
2	✖	✖	✖	✖	✖	✖	✖		
3	☑	☑	☑	☑	☑	☑	☑		
Output Qty	5610	5610	5610	5610	5610	5610	5610	39270	
Whours	7.5	7.5	7.5	7.5	7.5	7.5	7.5	52.5	748

Needle Lapping									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	☑	☑	☑	☑	☑	☑	☑		
2	☑ (300 min)	☑ (300 min)	☑ (300 min)	☑ (300 min)	☑ (300 min)	☑ (300 min)	☑ (300 min)		
3	✖	✖	✖	✖	✖	✖	✖		
Output Qty	5610	5610	5610	5610	5610	5610	5610	39270	
Whours	12.5	12.5	12.5	12.5	12.5	12.5	12.5	87.5	448.8

Guide Clearance									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	☑	☑	☑	☑	☑	☑	☑		
2	☑ (600 min)	☑ (600 min)	☑ (600 min)	☑ (600 min)	☑ (600 min)	☑ (600 min)	☑ (600 min)		
3	✖	✖	✖	✖	✖	✖	✖		
Output Qty	5250	5250	5250	5250	5250	5250	5250	36750	
Whours	17.5	17.5	17.5	17.5	17.5	17.5	17.5	122.5	300

Table 13

Deployement of Improvement Option 3:

Sorting									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	⊠	⊠	⊠	⊠	⊠	⊠	⊠		
2	⊠	⊠	⊠	⊠	⊠	⊠	⊠		
3	☑	☑	☑	☑(240 min)	☑	☑	☑		
Output Qty	5610	5610	5610	3000	5610	5610	5610	36660	
Whours	7.5	7.5	7.5	4	7.5	7.5	7.5	49	748.1633

Needle Lapping									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	☑	☑	☑	⊠	☑	☑	☑		
2	☑	☑	☑	⊠	☑	☑	☑		
3	⊠	⊠	⊠	⊠	⊠	⊠	⊠		
Output Qty	6600	6600	6600	0	6600	6600	6600	39600	
Whours	15	15	15	0	15	15	15	90	440

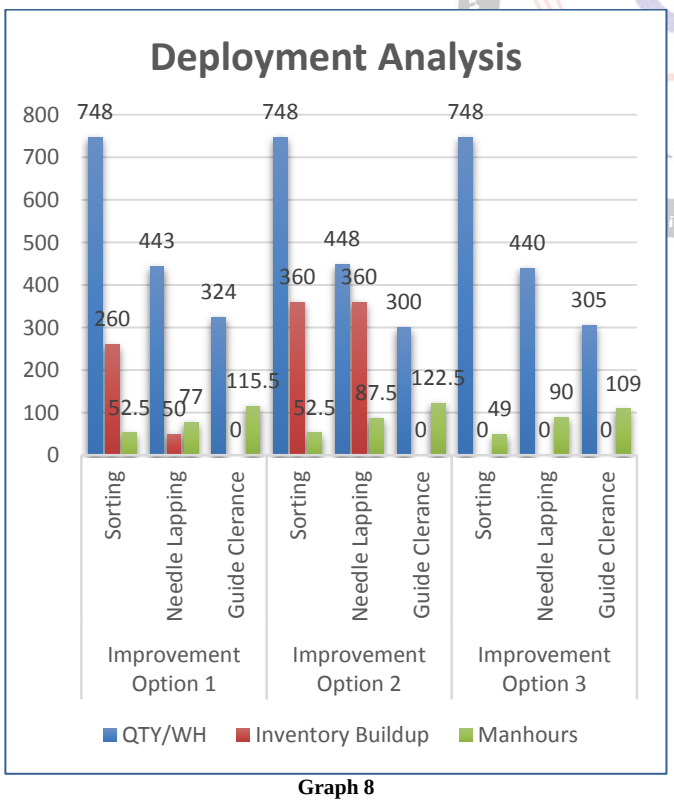
Guide Clearance									
Shift	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Qty/WH
1	☑	☑	☑	☑(695 min)	☑	☑	☑		
2	☑	☑	☑	☑	☑	☑	☑		
3	⊠	⊠	⊠	⊠	⊠	⊠	⊠		
Output Qty	4500	4500	4500	6300	4500	4500	4500	33300	
Whours	15	15	15	19	15	15	15	109.0833	305.2712

Table 14

Deployment Analysis of Improvement Options:

	Improvement Option 1			Improvement Option 2			Improvement Option 3		
	Sorting	Needle Lapping	Guide Clearance	Sorting	Needle Lapping	Guide Clearance	Sorting	Needle Lapping	Guide Clearance
Qty/WH	748	443	324	748	448	300	748	440	305
Inventory Buildup	260	50	0	360	360	0	0	0	0
Worked Hours	52.5	77	115.5	52.5	87.5	122.5	49	90	109
Total Worked hours	245			262.5			248		

Table 15



Graph 8

Calculations:

Improvement Option 1:

SRP= Number of units/Manhours

=324/245

=1.3

PI=Actual Output/Standard Output

=(324/253)*100

=128.06%

Improvement Option 2:

SRP= Number of units/Manhours

=300/262.5

=1.14

PI=Actual Output/Standard Output

=(300/253)*100

=118.57%

Improvement Option 3:

SRP= Number of units/Manhours

=305/248

=1.22

PI=Actual Output/Standard Output

=(305/253)*100

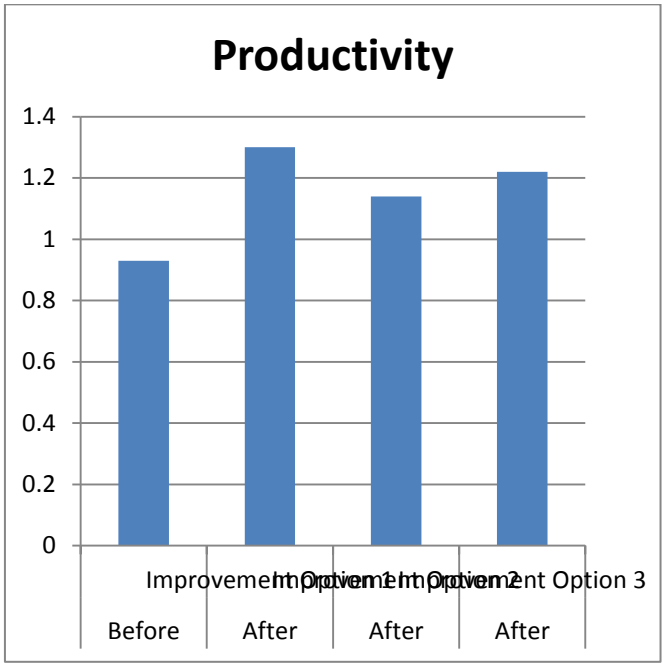
=120.55%

Interpretation:

	Improvement Option		
	1	2	3
Qty/WH	More	Less	Moderate
Inventory Buildup	Less	More	Nil
Man hours	Moderate	More	Less
Productivity	1.3	1.14	1.22
PI (%)	128.06	118.57	120.55
Remark	Reject	Reject	Accept

Productivity				
	Before	After Improvement Option 1	After Improvement Option 2	After Improvement Option 3
Productivity	0.93	1.3	1.14	1.22

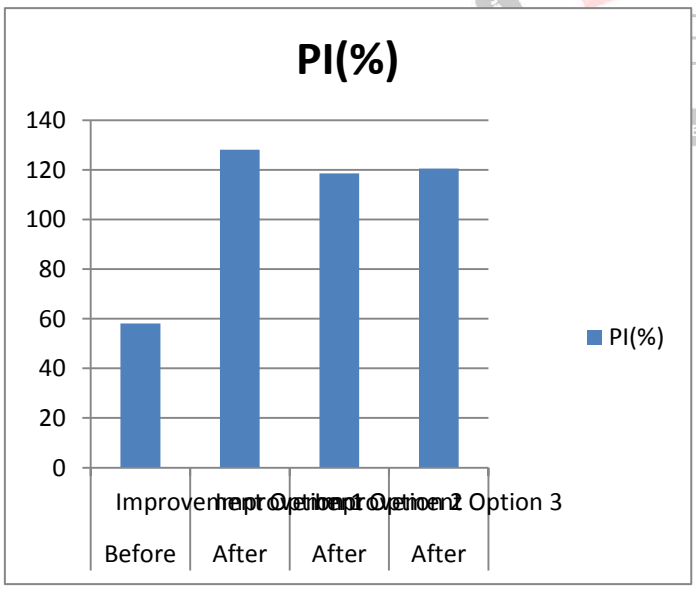
Table 16



Graph 9

Productivity Index(%)				
	Before	After	After	After
		Improvement Option 1	Improvement Option 2	Improvement Option 3
PI(%)	58.1	128.06	118.57	120.55

Table 17



Graph 10

Improvement option 3 should be selected according to deployment analysis and calculations. Improvement option 2 and 3 should not be selected because inventory build up and working man hours are more than improvement option 3.

Control:

Front Line Manager should deploy the improvement option 3.

VIII. CONCLUSION

Assembly process of DLL-S Nozzle involves 10 stages in which guide clearance assembly and stroke and length grind are found out as bottleneck processes.

Root causes for low productivity of guide clearance assembly are mainly time consuming sorting method, unutilized operator and unavailability of input material. These root causes are found out with the help of activity mapping and represented with the help of fishbone diagram.

Analysis with the help of time study based on primary data of guide clearance and needle lapping processes taken from shop floor is carried out which gives 3 improvement options.

Out of 3 improvement options, improvement option 3 should be selected which gives Single Resource Productivity and Productivity Index 1.22 and 120.5% respectively which is more than existing Single Resource Productivity and Productivity Index which is 0.93 and 58.10% respectively. Productivity improvement of guide clearance assembly will help to improve productivity of further operations as quantity per worked hour is increased.

Advantages of deployment of improvement option 3 which will lead to productivity improvement of DLL-S Nozzle Assembly:

1. Increased actual quantity per worked hour for the operation of G/C Assembly of DLL-S Nozzle.
2. Practically easy to implement.
3. Convenient shop floor management.
4. Less inventory.

Hence study gives productivity improvement analysis of DLL-S Nozzle assembly process with the help of DMAIC methodology.

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