A Framework for Improving Productivity of SMEs Economically

By

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Outline

- Introduction
- Problems in SME
- Literature review
- Framework
- Case study

Introduction

- SMEs Play major role in countries GDP and employment
- 37.2% of India's manufacturing output with 40% of India's workforce
- Contributes 7.28% of countries GDP*
- Empirical study on several industries near Kanpur reveals that, most of the SMEs are plagued with:
  - Unorganized process flow
  - Improper layout
  - Inadequate planning
  - Overtime production

*Annual report 2013-14, Ministry of micro, small, and medium industries.

Problems in SME

- Nenzhelele (2009), SMEs in South Africa
  - Less educated workers
  - Limited technological know-how
  - Improper productivity improvement implementation strategies or plan
- Ates, A., Garengo, P., Cocca, P., Bititci, U., (2013) (The development of SME managerial practice for effective performance management)
  1. Short term priorities
  2. Internal operational focus and lack of external orientation
  3. Tacit knowledge
  4. Looking for flexibility
  5. Poor managerial skills
  6. Entrepreneurial orientation
  7. Command and control culture
  8. Limited resources

- Empirical study in the similar industry reveals a few more…
  - Shared utilization of man and machine
  - Enormous use of makeshift approach
  - Limitation in space
  - Unwillingness to adopt change

Literature Review

- Case based
- Framework development

Case based

Researchers	Year	Industry	Approach
Gunasekaran, and Cecille	1998	wiper systems for the automotive industry	1) JIT 2)Kanban 3)Kaisen
Edis, Kahraman, Araz, Özfırat	2011	Marbel factory	Simulation based investigation on facility layout change
Norani, Suhadak, Johari, Kassim	2012	Food manufacturing company	Simulation based investigation on facility layout change
Alkaya, Demirer	2014	surface coating	Lean manufacturing, green manufacturing

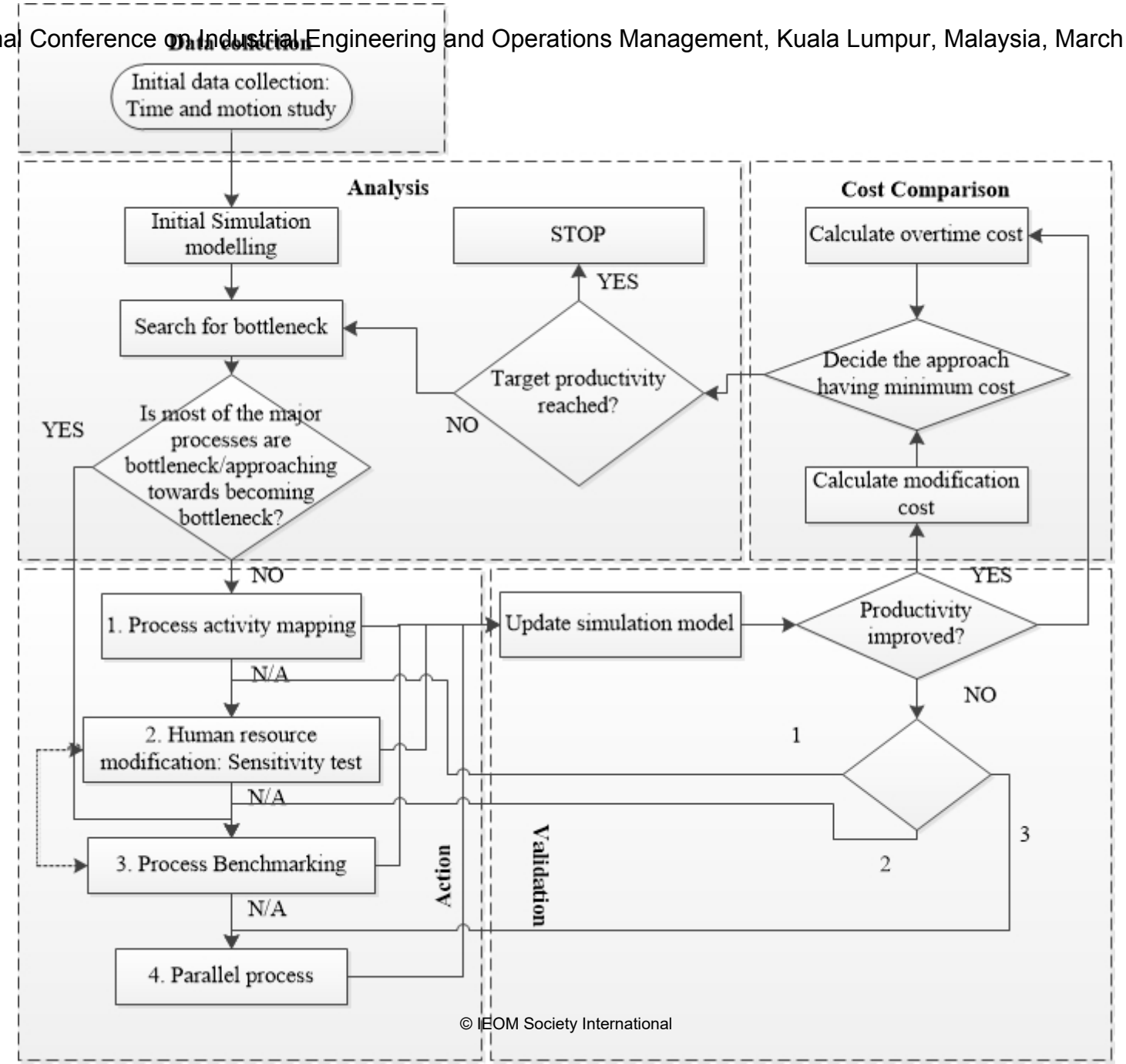
Framework development

Researcher	Year	Aproach
Khan, Bali, Wickramasinghe	2007	Mainly applicability of Kaizen in SME
Dassisti	2009	business process re-engineering, continiuos performance improvement, continious quality improvement
Bautista, Ortega, Zubieta, Macías	2010	Business process re-engineering, continuous improvement
Pecas, Jorge, Morgado, Hemiques, Cernadas	2012	Continious Improvement, Lean Manufacturing, Benchmarking
Ham and Park	2014	Continious Improvement,time and motion study, Line balancing

Discussion and research gap

- Single approach is not holistic enough to deal with the incumbent challenges
- Most of the approaches utilizes continuous improvement, which is a long term approach and requires highly educated and competent team within the industry itself
- No provision for economic based analysis (considering they are already manufacturing the required quantity by overtime)

Framework



Data Collection

Initial data collection: Time and motion study

- Identification of major parts manufactured in house
- Processes involved in manufacturing those parts
- Time and motion study to measure flow of processes and time

Analysis

Initial Simulation Modelling

- The data collected and processes selected important for study in the first step will be used for making the initial simulation model for the manufacturing system.
- The model should depict the plant properly. The simulation run should also validate the plants productivity properly.
- The simulation modelling can be done by using any standard simulation software e.g. ARENA, SLAM, AweSim, Technometrics etc.

Search for Bottleneck

- Bottleneck can be defined as the processes that limits the performance of a production system.
- Identification of bottlenecks are utmost important for further proceeding in this framework.
- There are several methods for detecting the bottleneck.
- An easy and effective method to find out the bottleneck is by searching for highest utilization factor (Law and Kelton, 2000).

Stopping criteria

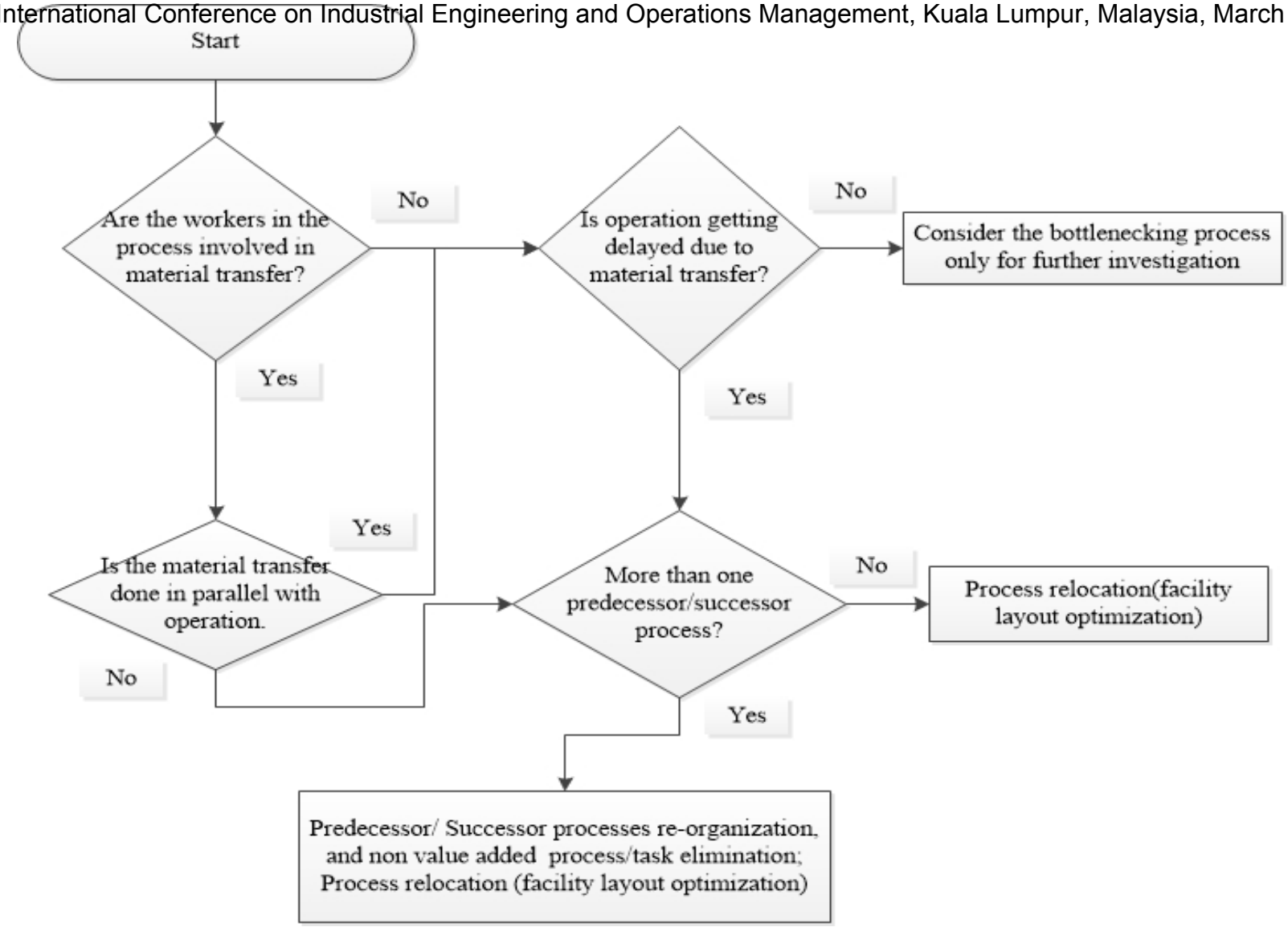
- If the productivity of the system reaches to the targeted productivity with the proposed strategy in the comparison step, the iteration of the framework stops. Else, the iteration repeats from bottleneck identification.

Action

Process Activity Mapping

- Process activity mapping is one of the seven lean management tools as described by Hines and Rich (1997).
- This tool aims in identifying the possibility of improvement of a process within itself without any additional resource.
- The tool consists of four major work:
  - Analyse processes.
  - Identify and eliminate non value added tasks/works/processes.
  - Study for rearranging of activities or processes.
  - Relocation of activities or processes.

- This tool should first be applied to the bottlenecking process itself in order to identify any possibility of performing the operations in better way within the process.
- Once it is applied within the process and the productivity do not reach to the required productivity, or no improvement is possible within the process, then this tool should also be applied within the entire manufacturing system in a way described in the next figure.



Flowchart for process activity mapping steps under various material transfer strategies

Human Resource Modification: Sensitivity Test

- Sensitivity analysis means investigation of changes in the output by modification in the resources.
- If productivity improvement of a bottlenecking process is not possible with the previous method, then the process can further be analysed if there has a possibility of modification of human resource for the process.
- In some process, increment of human resource may reduce the operation time. This step identify these possibilities within a bottlenecking process.
- However, before adding those resources in simulation model, the possibility of the addition must also be justified with the real situation to avoid any unrealistic solution.

Process Benchmarking

- Process benchmarking means comparing one industries process with the industries best practice from other company.
- the steps involved in benchmarking are:
  - Identify other industries that have similar processes
  - Identify organizations that are leaders in these areas
  - Survey companies for measures and practices
  - Visit the "best practice" companies to identify leading edge practices
  - Estimate the time changes and update the simulation model

Parallel processing

- If all the above methodologies cannot be applied or do not make considerable improvement in productivity, a parallel process can be added to improve the productivity of the process.
- However, the possibility of addition of a parallel process depends on the availability of required space in the layout.

Validation

Validation

- If any methodology would found suitable for the modification of a process, then the modified process measurements should be estimated properly and simulation model should be updated accordingly.
- The simulation model should again be run by keeping all the other process characteristics similar.
- If significant improvement in system productivity is not possible with the proposed changes in the processes, then the next available methodology, as shown in the framework, should be explored for improvement.
- If the productivity of the system improved with the modified process, then cost comparison should be performed as discussed in the next section.

Cost comparison

Cost comparison

- This part of the framework mainly identifies whether the process modification is beneficial or the overtime production for the same quantity is beneficial.
- The overtime cost for the same process is estimated for the modified quantity after implementation of a process.
- The process modification cost is also estimated.
- These two costs are compared to determine the process have the lower cost of production.

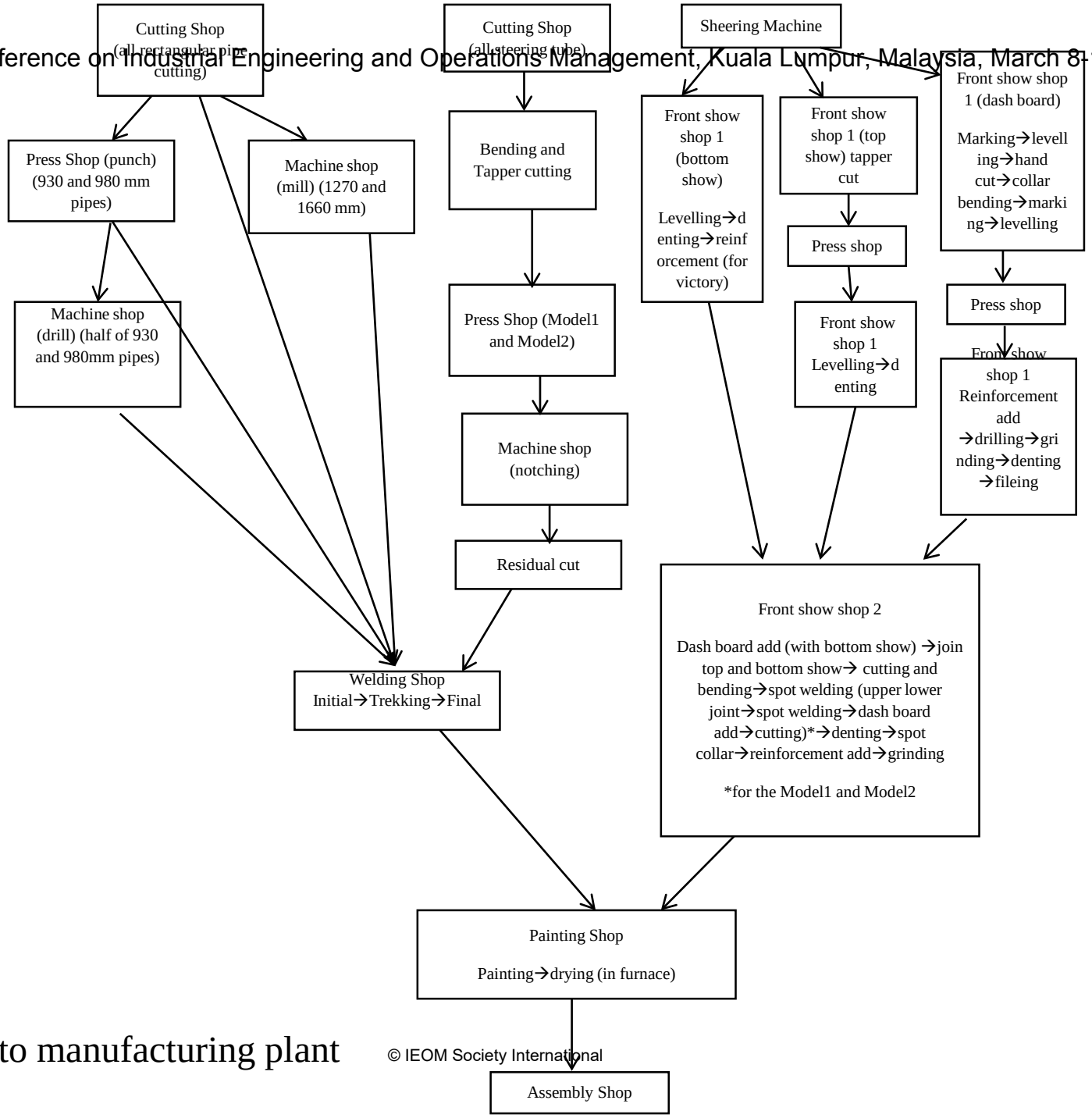
Case study

Case

- In order to demonstrate the real world implementation of the framework, a local three wheeler manufacturing SME in India is considered. The plant works under make-to-stock environment. The plant faces a problem of daily overtime expenses. Their productivity per day within the normal eight hour working shift is 16-20 autos depending upon the mixture of models they produce. On a random requirement check, it is found that, the company is scheduled to produce 710 different types of auto within 30 days. This implies, they require 23.667 auto productivity per day to match the demand. The organization fulfils the demand by using overtime production strategy.

Initial Data Collection: Time and Motion Study

- The firm mainly manufactures five models of three wheelers (auto)
- Similar sequence of manufacturing steps are involved in making all these models
- The model variation is mainly based on the size of the auto and engine (diesel based or compressed natural gas (CNG) based)
- Several subparts are manufactured altogether before they reach to the main assembly area where all the subparts are joined to make the auto
- Among them, two major parts having significant process flow and manufactured daily are
  - Chassis, and
  - Front Show
- All the other parts are very small and does not have very much significant process flow lines and also manufactured per month or per week basis
- The firm has total eight main departments/shops in their manufacturing plant viz. – 1)cutting shop, 2)machining Shop, 3)press shop, 4) sheering shop, 5) front show shop, 6) welding shop, 7) painting shop, 8) assembly shop
- The plant manufactures total 5 verities of model viz: model1-model5
- Each model again have sub classification of diesel and CNG (based on the fuel used in the engine)
- The manufacturing process flow is more or less similar in all the cases with very minor difference



Process flow chart of the auto manufacturing plant

Time study

- Based on the time taken in each process and similarity in their manufacturing, the auto models are now onward classified into 5 categories:
  - Auto1: model5
  - Auto2: model3 (diesel)
  - Auto3: model4 (both diesel and CNG)
  - Auto4: model3(CNG)
  - Auto5: model1 and model2 (both diesel and CNG)
- The manufacturing percentage combinations of the five types of autos in a financial year is approximately 4.2%, 6.34%, 23.98%, 9.15%, and 56.33% respectively.
- The processing time of various processes are shown in the next table

Process	Min time	Max time	No. of resources	Name of the resource
Cutting (rectangular tube)	45 sec	50 sec	1	Cutting Machine
Press (rectangular tube)	2.5 hr/40	3 hr/40	1	Press_rectangular pipe
Drill (rectangular tube)	20 sec/hole	30 sec/hole	1	Drill
Mill (1270)	2 min	2.25 min	1	Mill
Mill (1660)	3.1 min	3.25 min		
Initial welding	10 min	12 min	1	Welder
Cutting (steering tube 70)	2 min	2.3 min	1	Hexacutter
Cutting (steering tube 76)	2.25 min	2.6 min		
Tapper cut(steering tube 70)	2.85 min	3 min	1	Taper cutter
Residual cut (steering tube 70)	2 min	2.3 min		
Tapper cut(steering tube 76)	2.85 min	3 min		
Residual cut (steering tube 76)	2.25 min	2.6 min		
Bending(steering tube 70)	8 min/10 tubes	10 min/10 pipes	1	Bending mc
Bending(steering tube 76)	8 min/10 pipes	10 min/10 pipes		
Pressing(steering tube 70)	2 hr /10 tubes	2.5 hr/10 tubes	1	tube_press
Notching(drill) (steering tube 70)	15 min	`18 min	1	notch_drill
Notching (lathe) (steering tube 76)	18 min	20 min	1	Leathe
Trekking (chassis1)	35 min	40 min	1	trekking_welder
Trekking (chassis2)	24 min	28 min		
Trekking (chassis 3)	25 min	30 min		
Trekking (chassis 4)	24 min	28 min		
Trekking (chassis 5)	22 min	26 min		
Final (chassis 1)	25 min	30 min	1	final_welder
Final (chassis 2)	18 min	20 min		
Final (chassis 3)	20 min	24 min		
Final (chassis 4)	20 min	24 min		
Final (chassis 5)	18 min	20 min		
Chipping and grinding	10 min	12 min	1	Chipper

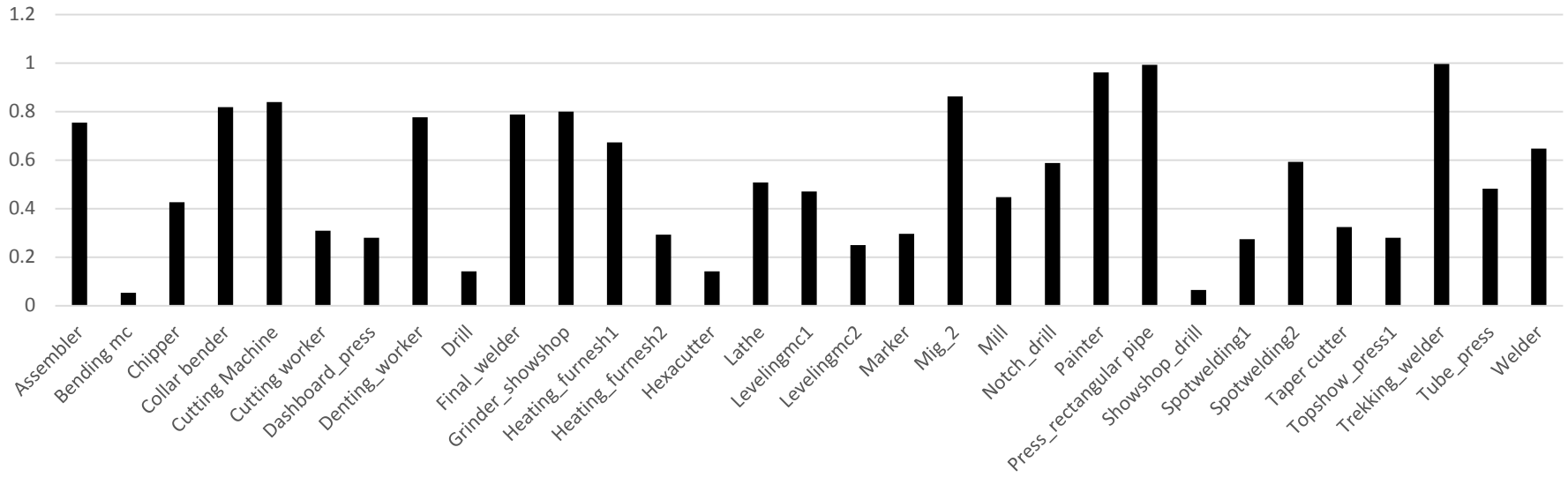
Process	Min time	Max time	No. of resources	Name of the resource
Top show levelling (taper cut)	1 min	1.5 min	2	levelingmc1, levelingmc2
Top show levelling	3 min	3.2 min		
Bottom show levelling	7 min	8 min		
Dashboard levelling	20 min/25pieces	25 min /25pieces		
Dashboard levelling 2	25 min/25pieces	30 min/25pieces		
Top show (press)	2 hr /25 pieces	2.5 hr/25 pieces	1	topshow_press1
Top show denting	5 min	7 min	2	denting_worker
Dashboard denting-filing	4 min	5 min		
Front show denting	8 min	10 min		
Re enforcement of auto5	2 min	2.5 min	1	spotwelding1
Dashboard reinforcement	2 min	3min		
Dashboard marking	3 min/25pieces	4min/25pieces	1	Marker
Dashboard hand cut	20 min/25pieces	25 min/25pieces		
Dashboard collar bending	20 min/25pieces	25 min/25pieces		
Dashboard marking2	3 min/25 pieces	5 min/25 pieces		
Dashboard press	2 hr/25pieces	2.5 hr/25pieces	1	dashboard_press
Dashboard drilling	1 min	1.5 min	1	showshop_drill
Auto5 top-bottom show join	4 min	5 min	1	spotwelding2
Other auto bottom-dashboard join	2 min	2.5 min		
Auto5 Dashboard join	4 min	5 min		
Other auto top-bottom join	8min	10 min		

Process	Min time	Max time	No. of resources	Name of the resource
Other auto MIG welding dashboard	10min	12 min	1	mig_2
Reinforcement add	10 min	12 min		
Cutting (all type front show)	5 min	7 min	1	Cutting worker
Other auto bending	4 min	5 min	1	Collar bender
Collar bending	12 min	14 min		
spot collar	1 min	2 min		
Dashboard grinding	2min	3 min	1	grinder_showshop
Grinding	12min	14 min		
Painting (chassis)	17min	20 min	1	Painter
Painting front show	4.5 min	5 min		
heating	1 hr /4 chassis or 8 front show		2	heating_furnesh1, heating_furnesh2
Assembly	3hr/10 auto	3.5 hr./10 auto	2	Assembler

Initial Simulation Model Generation

- The simulation model that captures all such aspects is developed using ARENA simulation software (Kelton et.al, 2004). The entity creation criteria at each create node that are associated with different processes is as follows:
  - Rectangular tube: 60/day
  - Steering tube: 5/day
  - Top show: 25/day
  - Bottom show: 25/day
  - Dash board: 25/day
- The simulation model is then run for a year considering 300 working days with 8 working hours per day. Types of auto manufactured after simulation run are:
  - Auto1: 225
  - Auto2: 330
  - Auto3: 1343
  - Auto4: 458
  - Auto5: 3204
- The obtained average productivity of the plant per day is 18.533. The plants actual productivity per day varies between 16 and 20 depending upon the auto mix they produce. This can be concluded with the result that the obtained average productivity is within limits of actual productivity per day.

Present utilization of various processes



From the figure it is quite evident that the highest utilized resource is the Trekking welder (0.9961), followed by rectangular pipe press (0.9925) and Painter (0.9617). All the other resources exhibit utilizations below 90%, suggesting that the above three processes are the bottlenecks.

Present cost to the company for the additional production

The company requires to manufacture 23.667 autos on average per day to meet the required productivity. The simulation result shows, they can produce 18.533 autos per day with the present set up and also it is known that presently the company fulfils the requirement by overtime production only. Hence,

- Overtime production every year: 5.134 x 300 = 1540.2
- Number of skilled labour require to work for the overtime (press, paint, and welding): 6
- Number of helper required for overtime: 4
- Total hour required to produce this number of auto: 1540.2/2.3166 = 664.76
- Total effective man hour requirement (considering each hour in over time is equivalent to 1.5 hour of work in normal shift): 664.76 x 1.5 = 997.14
- Cost of skilled labour (@INR250 per 8 hour shift): INR 186963.75
- Cost of unskilled labour or helper (@INR 170 per 8 hour shift): INR 84756.9
- Total overtime expenditure in a year for the organization with present working condition: INR 271720.65

Process activity mapping

The bottlenecking processes will be considered sequentially in this step. We will start discussing with the bottlenecking process having highest utilization factor i.e. the trekking welding process.

- The processing time here can be divided in two part viz. 1) the operation (welding) time, and 2) the material transfer time from the other departments. The operation trekking is basically joining of all the rectangular pipes to form a chassis. Not much significant possibility of rearranging, relocating, or eliminating of activity is found in this operation after detailed study of the process activities.
- The process uses “pull” strategy for material transfer and is fed by five predecessor processes (pipe cutting, drilling, milling, press, steering tube residual cut). Hence, all the predecessor processes are to be considered for re-organization and non-value added task elimination possibilities and all the processes are to be considered for facility layout optimization.
- Following table summarizes pertinent observations and decisions on various predecessor processes of the process trekking.

Observation	Decision
The transfer of material times for the process is about 10-12 minutes for each auto type.	By reducing this movement; loading-unloading times of the process can be reduced.
The workers visit four workstations, viz., (i) cutting shop to collect 155/100/205mm pipes, (ii) machine shop to collect 1600/1660mm milled pipes and 988/930mm drilled pipes, (iii) press shop to collect 988/930 mm press holed pipes, and (iv) tube cutting shop to collect steering tube.	
The diameters of holes are same for the drill and the press.	Drilling machine can easily make all holes; but, the press cannot make all holes.
Upon discussion with the plant manager, it was found that previously only drilling machine was used to make the holes, which was shared by many small processes. This resulted in heavy work load on the drill and its worker. To reduce some work load, making of two holes were assigned to the press shop. However, press machine cannot make all the holes due to criticality of the part. Hence, the edge holes are made by the press, after which the raw material is brought back to the drill for drilling other holes.	
There has another drill with same capacity, which is used for other operations for the small parts along with notching operation in the 70 mm steering tube	As both the drilling machine are of same capacity, the drilling and notching can easily be transferred to one drill and other drill can easily be dedicated for machining other small parts.
The cutting machines (in the cutting shop), the milling machine, the lathe used in notching the 76mm dia. steering tube, the hexa-cutter at the auxiliary cutting shop, and the bending machine, all are special purpose machines dedicated to a specific process.	All these machines can be combined into a small work cell.

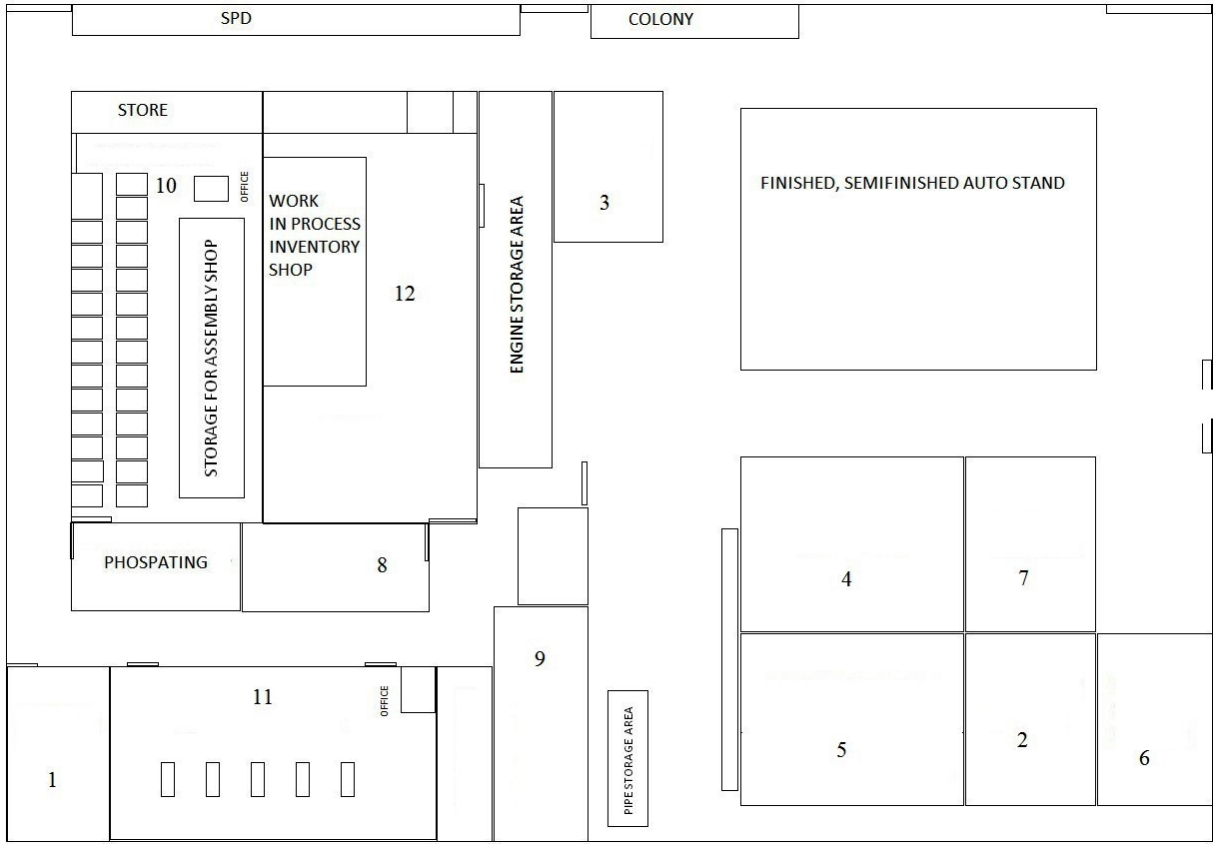
Observations and decisions regarding the process concerning Trekking

Based on the observations and decisions discussed in Table 1, the following changes are suggested:

- A manufacturing cell can be developed by combining one cutting machine, two hexa-cutting machines, one mill, and one drill from the two available drills for drilling holes and notching 70 mm dia. steering tube, one lathe, and the bending machine.
- This separation of drill is possible because the utilization factor of one drill which is used for notching operation is 0.58 whereas the utilization for the drilling operation in other drill is 0.14. Although the utilization factor for drilling operation is 0.14, the operator is basically ideal for some time because once one batch of drilling is made, he has to wait till the next batch of work piece come. Which eventually decreases the overall efficiency. With the cell like formation, this problem of pulling of work piece will be eliminated as well.
- The process of making hole by press is eliminated.
- The process flow will remain largely the same with minimal modifications like eliminating the press operation, and reducing the trekking worker movement to five workstations to one workstation.
- No change in the work force is required. Only work station and worker re-adjustment is required.

Facility Layout optimization of the plant

- In the current layout, workers travel 5770 meters per day for an eight hour shift. After applying process re-organization; cutting area, and steering tube cutting/bending shop are eliminated. The machine shop cannot be eliminated as it performs other operations. Under this scenario, the facility layout problem was solved to minimize the interdepartmental material movement.
- Quadratic Assignment Problem (QAP) (Koopmans and Beckman, 1957) approach was used to optimize the facility layout of the plant with the modified process flow.
- Artificial Bee Colony algorithm (ABC) is used to solve the problem
- The results show subsequent reduction in the interdepartmental material movement. The optimal material movement was only 3080 meters per day (as found by ABC algorithm) to maintain same throughput. This amounted to a reduction of approximately 46.6% in material movement.



Facility layout of the plant

Location no	Present department	Proposed department
1	Painting shop	Painting shop
2	Sheering section	Front show shop1
3	Cutting shop	
4	Machine shop	Shaping shop
5	Steering tube cutting and bending	Front show shop2
6	Front show shop1	Generator room
7	Front show shop2	Sheering section
8	Shaping shop	Rectangular pipe and steering tube making cell
9	Generator room	Machine shop
10	Assembly shop	Assembly shop
11	Welding Shop	Welding Shop
12	Press Shop	Press Shop

present and proposed location of various work stations

- The second highest bottlenecking process i.e. press operation in the rectangular pipe is eliminated and the discussion remains open for the painting.
- In this process two helpers bring the chassis to the painting area from final welding; painting is done by the painter, and the painted chassis is put into the heating chamber for drying.
- Although the material transfer and operation are not in parallel, due to fixed position of the painting and final welding, the possibility of relocating these processes are eliminated.
- No significant un-necessary activity found in the painting process, neither any activity can be re-arranged. Hence as per the framework described, the next possible method is tried to improve the productivity of the process.

Human Resource Modification: Sensitivity Test

As discussed in the earlier section, the painting process seems to be critical but cannot be improved with the previous step hence the possibility of adding one human resource for the process is checked. It is found that mainly spray painting is used for painting all the parts under consideration.

Simulation model modification and results

In order to numerically evaluate the effect of manufacturing process re-engineering; the initial Arena simulation model was modified as follows:

- The press operation was eliminated for making holes.
- The drilling times were changed as follows:
  - For the pipes that were holed by the press initially, a replacement drilling operation of U (40, 60) seconds to drill two holes.
  - The replacement drilling time was added to the original drilling times as all the holes are now made on the drilling machine.
- Material movement from one shop to another was done in pre-defined batches. However, with the proposed manufacturing cell layout; such batching is eliminated as all machines are in the same cell.
- The drilling machine will be also used for notching of the 70mm dia. Steering tube.
- With the proposed layout, distance travelled by the trekking worker got reduced to approximately 10 meters from the earlier 110 meters. We estimated that this saves around 4 minutes of time, in reduced travel, loading-unloading, collection, and chatting times. The present time requirements and estimated time requirements are given in the next table

Present scenario		Proposed Scenario	
Loading Unloading steps	Time (seconds) (minimum required)	Loading Unloading steps	Estimated Time (seconds)
Moving chassis from trekking jig	90	Moving chassis from trekking jig	90
Worker movement from welding shop to cutting shop (position 3 to position 11 in Figure 5)	30	Worker movement from welding shop to new rectangular pipe and steering tube making cell (8 to 11 in Figure 5)	10
Loading material at cutting shop	40	Loading material at the cell	60
Returning back to welding shop from cutting shop	50	Returning back to welding shop from the cell	30
Worker movement from welding shop to machine shop (4 to 11 in Figure 5)	20	Fixing all parts into the trekking jig	140
Loading material at machine shop	40	Flexibility	30
Returning back to welding shop from machine shop	40		
Worker movement from welding shop to Steering tube cutting/ bending shop (11 to 5 in Figure 5)	20		
Loading material at to Steering tube cutting/ bending shop	30		
Returning back to welding shop from Steering tube cutting/ bending shop	40		
Worker movement from welding shop to press shop (11 to 12 in Figure 5)	10		
Loading material at press shop	30		
Returning back to welding shop from press shop	20		
Fixing all the parts into the trekking jig	140		
Total	600	Total	360

Present and proposed loading-unloading steps and corresponding times for trekking

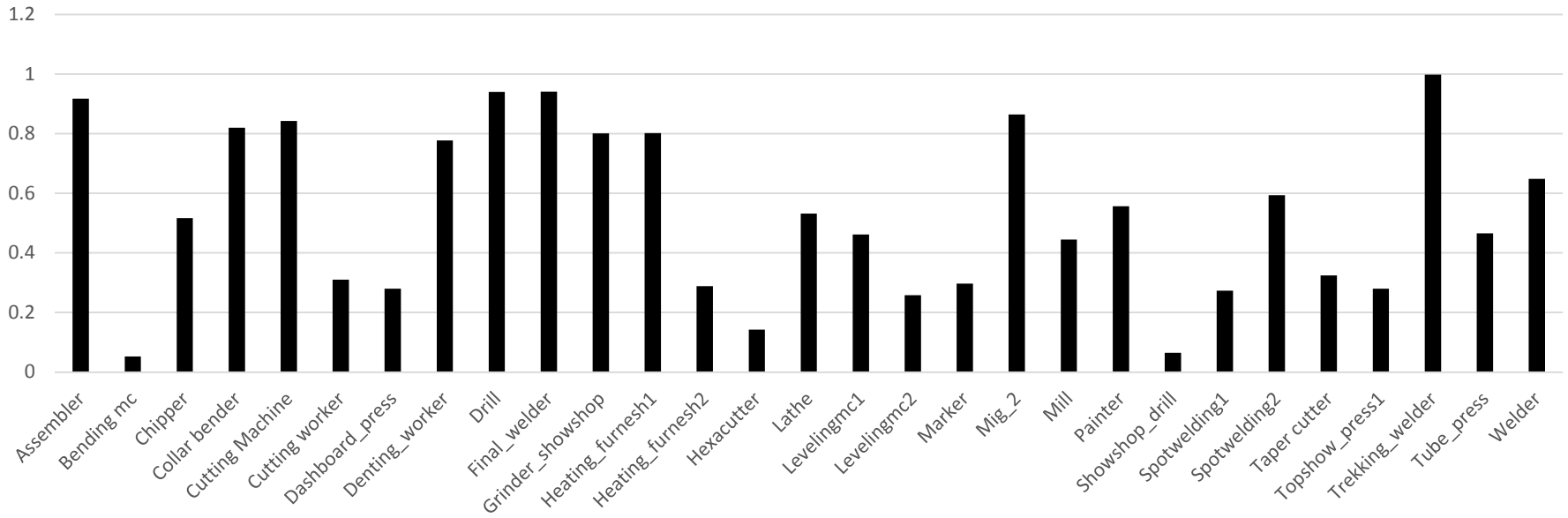
- The simulation run time and other inputs were kept the same as the initial model. The major results are:
  - Total autos manufactured: 6720
  - Type wise output :
  - Auto1: 276
  - Auto2: 423
  - Auto3: 1593
  - Auto4: 607
  - Auto5: 3821
- Average output per day: 22.4

Modification cost, overtime cost, comparison

- Per day avg. improvement in productivity = 3.86
- Increase in total output in a year: 6720-5560 = 1160
- Percentage improvement: 20.86%
- Number of additional human resource required for this improvement: 1
- Total extra cost to the company for this employment: 1 X 250 X 300 = INR 75000
- Other handling expenditure (Approximate): INR 50000
- Total cost of modification: INR125000
- Overtime cost of producing 1160 auto: INR 204539.88

The required productivity of the plant is 23.667 autos per day. The modification described above can reach the productivity up to 22.4 autos per day. Hence the iteration will not stop here and again begin with the “search for bottleneck” section.

Search for Bottleneck



Utilization of various factors after first modification

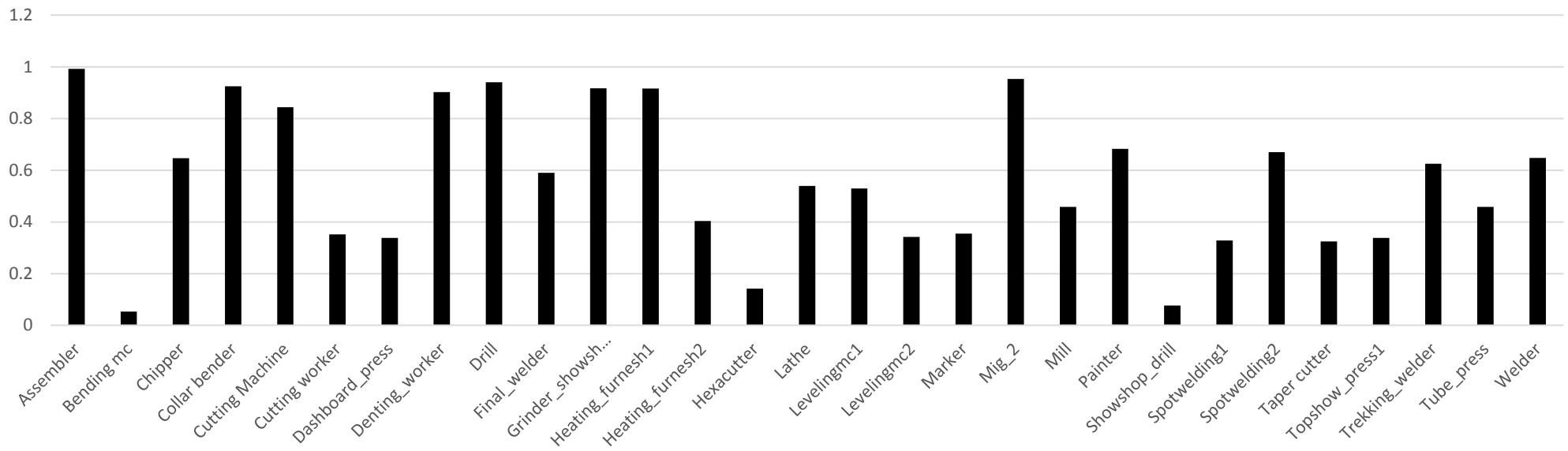
From figure, it is clear that the trekking process remains bottleneck again with utilization factor of 0.99. The final welding process has a utilization factor of 0.94. Although the assembly process is at the utilization factor 0.91, understanding that with the previous modification, the plant requires only to improve its daily productivity by 1.267, this process is exempted from considering a potential upcoming bottleneck under present requirement

Parallel Process

- As the material transfer time of the process trekking is already considered and not possible to improve further with the present system, now we will consider the feasibility of increment of human resource to the process to improve the productivity.
- For the process trekking, two welders and two helpers work simultaneously along the four sides of a special jig.
- Addition of one more welder is not possible because of the place restrictions.
- Addition of helper for working is not feasible because the two helpers are sufficient to help the process.
- Considering the fact that after trekking process, these two workers only moves to bring the parts for the next process, addition of one more worker who will bring the parts in the intermediate time is also thought of.
- But the idea is not applicable because of unavailability of place for storing the parts for next operation circle. Hence addition of human resource is not possible for this case.
- The welding process solely cannot be changed because there does not have any replacement for such welding. Hence only addition a parallel process remains only option for the present scenario.

Simulation model modification and results

- After adding one more resource to the trekking and final welding process, the simulation model is run with the same input parameters. The following analysis can be made with the results:
- Total no. of output: 7350 with various types of auto as:
  - Auto1: 291
  - Auto 2: 427
  - Auto 3: 1712
  - Auto 4: 613
  - Auto 5: 4307
- Productivity: 24.5 autos per day
- The bottleneck is now shifted to assembly process with an utilization factor of 0.99, followed by mig welding 2 (where the enforcement of front show is joined) with utilization factor of 0.95; Drilling process is at 0.94; heating furnace 1 (where painted chassis is dried) and show shop grinder is at 0.91; colour bending process (front show) is at 0.92; denting process is at 0.9 utilization factor. The utilization of various processes are shown in the next figure.
- With the latest increment of resource, the plant can be able to produce its present requirement productivity of 23.667 per day.



Utilization of various processes after second modification

Modification cost, overtime cost, comparison

- The total cost to reach the required productivity with adding additional parallel process for the trekking and final:
  - Number of worker requirement: 7 (4 skilled and 3 unskilled)
  - Total labour cost: 3x300x170+4x300x250=INR 453000
  - Other expenditures (Approximate): 10000
  - Total cost : INR 463000 (1)
- The total cost to the organization to reach the required productivity with overtime and after first modification:
  - Average overtime production requirement per day: (23.667-22.4) = 1.267
  - Total overtime production requirement in a year: 380.1
  - Total overtime expenditure in a year: INR 40215.9375 (2)
- Comparing (1) and (2), it can be concluded that, inclusion of another trekking and final welding parallel process is not beneficial for the present required productivity. The plant should be rearranged according to the way discussed in the previous sessions and then the remaining 1.267 autos on an average per day should be manufactured with overtime production.
- The total cost of production with the advised process modification and overtime production (2 and 4) = INR 161907.03125. Which reduces the present production cost by INR 106504.7125. Which approximately 39.2% less comparing to the strategy of doing all the required additional amount of production in overtime.

Conclusions

- This paper presents a framework which consists of five interactive levels (data collection, analysis, action, validation, cost comparison) for the iteration based improvement of productivity of a SME. At each iteration, the bottlenecks are to be found out and modified according to the methodologies provided in the framework.
- The application sequence of methodologies are also arranged logically in the ascending order of their modification cost.
- The modification done by any methodology is then validated with the simulation run to identify improvement quantity.
- The cost of modification is calculated and compared with overtime production cost or with other methodology cost as shown in the framework.
- The minimum cost strategy is suggested.
- A case of Indian three wheeler manufacturer is considered to illustrate the applicability of the framework. The result shows the additional production cost can easily be reduced by 39.2% from their present cost by improving the productivity of the plant by 20.86% with the suggested changes.
- In conclusion, it can be said that the framework not only improves the productivity but also compares the cost of improvement with the overtime production cost.
- This ensures the managers of the firm to select the most economic strategy for the additional production.
- However, the applicability of this framework may be limited to the flow shop kind of environment. Development of similar framework for job shop or other environment remains the future scope of this work.

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