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Process Improvement Study In A Ceramic Industry - A Heuristic Approach

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Abstract - This study focuses on the process involved in making industrial oriented small ceramic tile. This study concentrates on process improvement, in a ceramic industry with DMAIC methodology as foundation. In the *Define* phase problem statement is presented with 5Ws approach. A pilot experiment was conducted during *Measure* phase in order to measure various defects which are possible to occur during production. Process flow chart, Cause and effect diagram, Pareto analysis are the tools used in the *Analysis* phase. ImageDiff, a pixel by pixel image comparison tool to ease the process of inspection is presented in the *Improve* phase. A new modified process flow is introduced. A comparative cost / benefit analysis is also discussed. This study meets the management commitment in a perfect way.

Key words: DMAIC, pareto analysis, cause and effect analysis, 5Ws, industrial ceramic tiles

I. INTRODUCTION TO CERAMIC INDUSTRY

Industrial tiles and particularly small tiles (less than 100mm in size) are used in various areas such as grinding media, ball mill liners, wear resistance liners, electronics industry, textile machinery, defense, automobile industry, avionics, high power/high temperature applications. In this study, data is gathered from a manufacturer dedicated to the manufacturing of various ceramic products for industrial applications. The industry is well known for its quality and innovation in its sector. It is located in south India and continuously improving to be the best in the market with more than 3000 employees. The company is trying hard to reduce defects particularly in the stage of green tiles rather than baked tiles to reduce cost of recycling. One of the way to improve a process, is to identify and remove the causes of defects and minimizing variability in manufacturing and business processes. Process improvement is a systematic approach using DMAIC methodology for organization managers to achieve objectives. It requires an intelligent use of data and emphasis the use of statistical analysis and designed experiments.

II. DMAIC

The DMAIC process is used for making improvements to an existing process. DMAIC is an acronym for the 5 key phases in a process improvement project (MirkoSoković et al., 2010); Define, Measure, Analyze, Improve, and Control as illustrated in Figure 1. In the *Define* phase, the project team clarifies the purpose and scope of the project. During *Measure*, the focus is on gathering data to describe the current situation. In this phase appropriate data is collected and process measures are identified, so that once improvements are made, the impact can be verified. The main aim of the *Analyze* step is to determine the root causes of the process problems and inefficiencies. A variety of methods are used to identify potential root causes. The relationship between the suspected causes and the performance of the process is confirmed, using statistical analysis. The next step, *Improve*, involves establishing a means of countering the root causes. Data analysis and charting techniques are used to confirm that performance has in fact improved sufficiently to meet the project's goal. Finally in the *Control* phase, steps are taken to ensure that the gains obtained during improve phase are maintained, by (i) setting up ongoing data tracking and (ii) a plan to identify the deviation of the process performance and to take appropriate action.

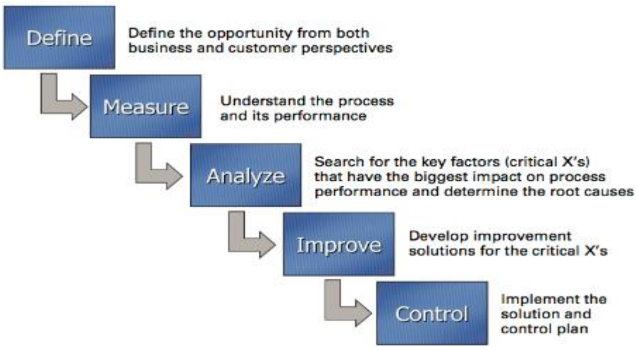

Figure 1 schematic diagram for DMAIC phases.

MirkoSoković et al., (2009); Lokkerbol and Mast (2012) presented the systematic use of seven basic quality tools (7QC tools) in phases of DMAIC. This paper aims to meet out the management commitment of process improvement and minimizing the cost by DMAIC approach and the scheme of investigation is shown in Figure 2.

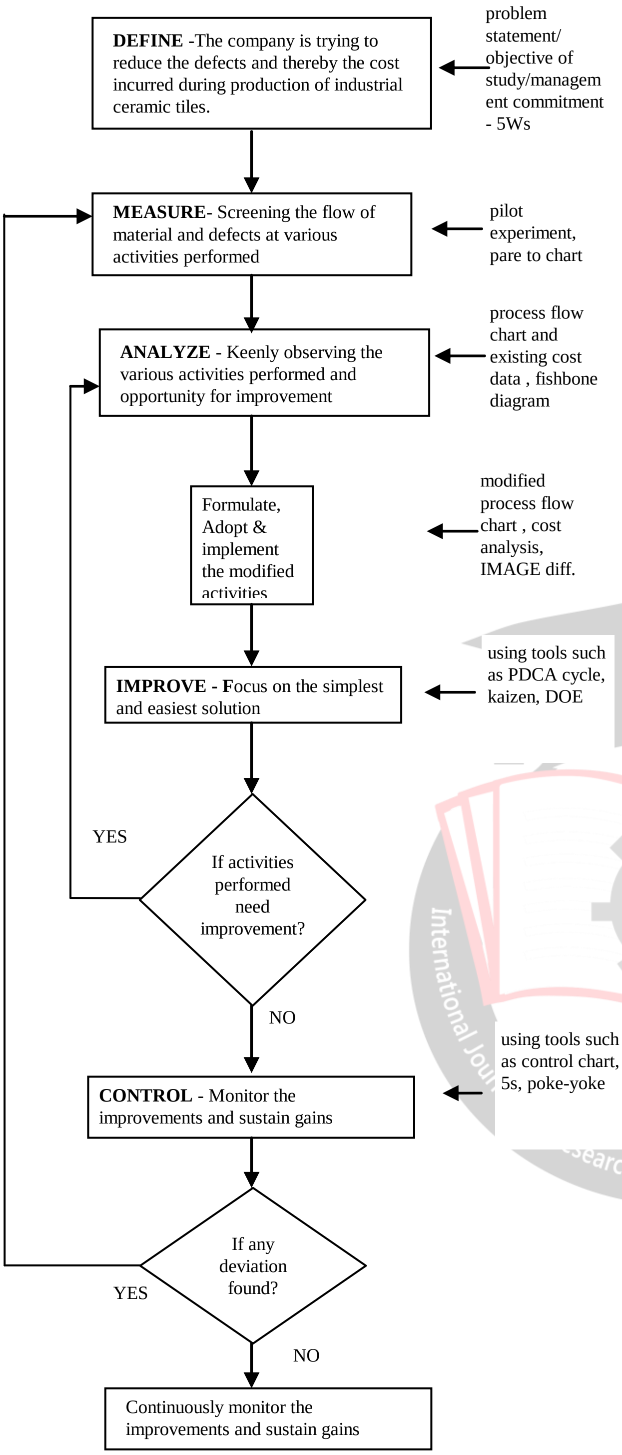

Figure 2. scheme of investigation(DMAIC)

III. DEFINE – PHASE

For better understanding the problem statement is presented in Table 1 using 5Ws approach. Even though the company is manufacturing nearly 18,000 varieties, a small tile of 20×20×5 size with small projection is taken for study (Figure 3). Its area of application are grinding media, ball mill liners, power distribution equipments, wear resistance liners and lined equipments to steel industry, power generation industries. The major factors influence in selection of this tile includes

a. Volume of production – moderately high.
b. Rejection rate – high.
c. Acute care needed during production- only trained operator.
d. Profit – high.
e. Production throughout the year (not Seasonal).
f. Dust & dirt should be eliminated.
g. Only manual inspection is carried out

Table 1 5Ws approach for problem statement

WHAT (problem statement)	WHERE	WHEN	WHY	Production system variables (3Ms) - WHO (In the case of ceramic Industry)
To reduce defects	High sped moulding press area , stacking andre-stacking area	During stacking and re- stacking (handling)20×20× 5 mm small projection tile - green tiles, industrial tiles	To improve the process flow and to reduce cost	Men and material

Figure 3 20×20×5 mm small projection tile.

IV. OBJECTIVE OF THIS STUDY

1. To reduce the defects occurring during the handling of 20×20×5 mm small projection industrial tiles.(green tiles).
2. To analyse the feasibility of stacking of the moulded green tiles directly in Sic bats in the moulding press area .
3. To conduct a comparative cost analysis by eliminating the existing process of stacking the green tiles in the wooden bats
4. To improve the process flow.

V. MEASURE – PHASE

In order to screen the defects occuring during the production of 20×20×5 mm small projection tile, a pilot experiments was conducted. The weight of the green small tile ranges from 0.48 grams to 0.50 grams. Two thousand kilograms of virgin powder with folic acid as additive is utilized to produce 1,00,000 small projection tiles. Care is

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taken, not to affect regular production and so only hundred kilogram of powder is used in each shift and the experiment is done for about 17 days. High speed mechanical moulding press is used to make the green compact. These green tiles are stacked initially at the moulding area by the operator in the wooden bats and stored separately in the racks provided. Then green tiles are inspected manually. Nearly 30 daily wages employees are engaged in the process of inspection and re-stacking. The defective tiles are discarded and good tiles are re-stacked in silicon bats. Dry alumina powder is sprayed over each layer of the green tile to avoid sticking of tiles with each other during sintering. These green tiles are then loaded in furnace and sintered for 36 hours. Finally the fired tiles are then cleaned and inspected. The defects found after inspection of the fired tiles were tabulated in Table 2 and a pareto analysis for defects is attained (Figure 4).

Table 2 Details of defects accounted during pilot study

Defects	Count	Cumulative Count	Cumulative %
Mo.Green Chip (moulding)	14200	14200	26.56%
H.Green chip (handling)	12050	26250	49.11%
Fired ware Chip	11100	37350	69.87%
Join	9900	47250	88.39%
Body stick	4375	51625	96.58%
Black Spot	925	52550	98.31%
Before Fired Chip	500	53050	99.24%
Sic stic	375	53425	99.94%
Alumina	30	53455	100.00%

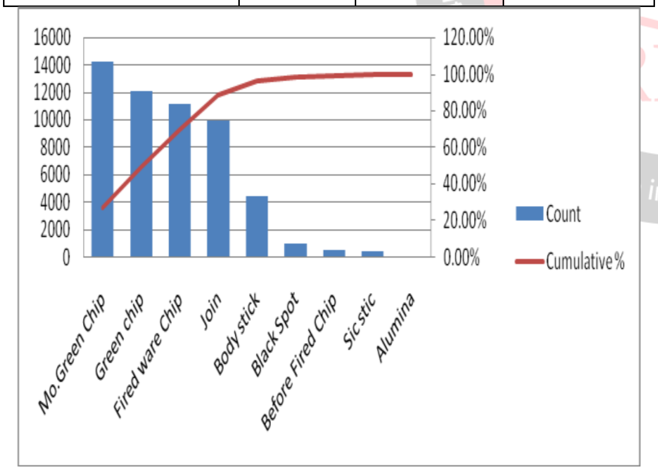

Figure 4. Pareto analysis on defects.

VI. ANALYZE – PHASE

Initially the management wants to take up measures to reduce defects due to handling (From the pareto analysis it is found that nearly 25% of the defects were due to Mo.green chip). The cause and effect diagram is drawn for the defects (Figure 5). Based on industrial expert's opinion and with a brain storming session the causes for the defects in the small projection tile is majorly due to men- causes such as improper handling, improper stacking and lack of periodic inspection.

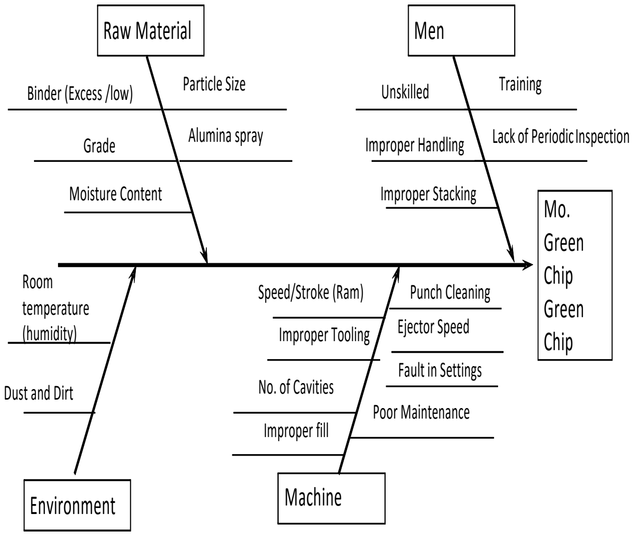

Figure 5.cause and effect diagram for defects

Even though a variety of operations performed in the industry, moulding of the small tiles limits with high speed moulding mechanical press, followed by other operations in the manner of stacking, re-stacking, baking in furnace and finally inspection and packing. Various stages existing in the production of small projection tiles were described and the process is analyzed by a process flow chart as shown in Figure 6.

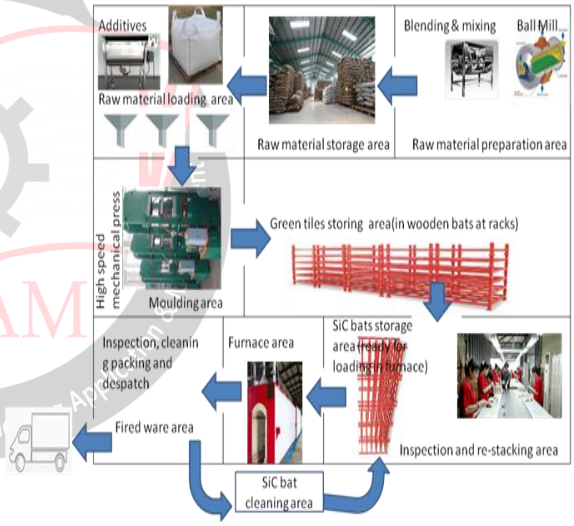

Figure 6.process flow chart existing method

VII. STAGES IN PRODUCTION OF SMALL PROJECTION TILES (EXISTING METHOD)

1. *Raw material preparation*

In industrial ceramics tiles three distinct material categories are used:

- Oxides: alumina, beryllia, ceria, zirconia
- Nonoxides: carbide, boride, nitride, silicide
- Composite materials: particulate reinforced, fiber reinforced, combinations of oxides and nonoxides.

Each one of these classes can develop unique material properties, because ceramics tend to be crystalline. The small tile taken for study utilize aluminum oxide, more commonly known as alumina as its raw material (Framinan.et.al., 2014). Operations such as milling,

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batching, blending- mixing of alumina, refractories and binders are carried out to get uniform fine particle powder. As this small tile is designed with small projection, folic acid is used as an additive (binder) in order to ease the moulding process.

2. Moulding (compacting)

The blended mix is introduced into a mould cavity or a die and pressed to produce a green tile (compact). This moulding operation is done in a high speed mechanical press as shown in Figure 7.

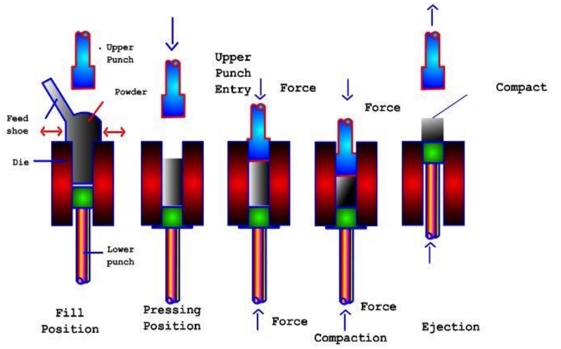

Figure 7.Operations of High Speed Mechanical Press

3. Stacking & re stacking.

The green tiles produced are initially stacked in the wooden bats in the moulding press area by the machine operator and stored separately in racks provided. These green tiles are then inspected manually. Nearly 30 daily wages employees are involved in the process of inspection. The defective green tiles are discarded and tiles those meets the specification are re-stacked in silicon bats. Dry alumina powder is sprayed over each layer to avoid sticking of tiles with other and then sintered in the tunnel furnace. The small green tile moulded will be rather very fragile, and handling should be done with acute care to avoid breakage.

4. Sintering

Figure 8.tunnel furnace for sintering

The re-stacked green tiles in the Sic bats with dry alumina powder spray is then loaded in the cars of the tunnel furnace for sintering (Figure 8). The principal goal of sintering is the reduction of porosity in the green tile and to strengthen it (Agrawal, 2006). The initial spaces between compacted grains in small tiles are called "voids". Sintering process is concerned with closing of voids present in the green small tiles. Finally the sintered small tiles are inspected, packed and dispatched.

VIII. IMPROVE –PHASE

From the pilot experiments, and the outcome of brainstorming session it is proposed to eliminate the process of stacking the green tiles in wooden bats. The basic ideas behind the proposal of eliminating the stacking of green tiles in wooden bats includes:

1. The time taken for re-stacking.
2. To avoid defects during handling.
3. To reduce the cost of contract labours.
4. To increase the productivity.
5. An attempt to reduce the cycle time.
6. To reduce waiting time (tiles produced in two shifts are stored in racks and then inspected)

From the high speed moulding press, the green tiles moulded in the mould cavities are ejected and passes in a small belt conveyor. In the existing method, the operator stack the green tiles in wooden bats. In the process of inspection, with a special arrangement as shown in Figure 9. High resolution camera were involved to monitor the defects using the software ImageDiff.

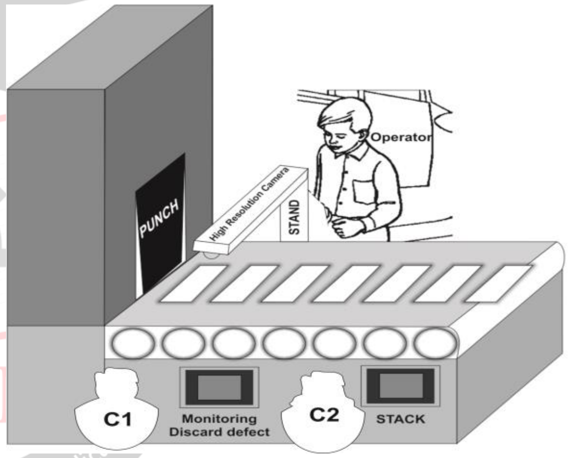

Figure 9 Process of Inspection, with a special arrangement

ImageDiff is a pixel by pixel image comparison tool. ImageDiff allows researchers to compare two images side by side, and see a difference mask showing the exact pixels that have changed. With ImageDiff researchers can compare two images in different formats, different sizes automatically down to the pixel.

The main interface is divided into 4 sections as shown in Figure 10. The upper left is where reduced size versions of the two files to be compared are displayed. These are set by clicking the Left or Right buttons at the top of the control area on the right side of the interface. The Compare button starts a diff with the currently selected options and displays the result below the left and right images. The Threshold slider allows you to adjust how different two pixels must be before they are displayed. Moving the slider up or down sets the percentage of difference between pixels that will be allowed before they are considered different. This is very useful to reduce the amount of compression noise that is displayed in the difference view. With the Overlay box checked, the pixels that didn't change at all (or less than the

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threshold) are shown as they are in the originals but with reduced intensity. The various diff filters highlight the differences between images in different ways:

Predator displays how much something changed on a scale. Black is no change (in overlay mode, there will be no black), then purple, blue, green, yellow, orange, red and pink are increasing amounts of difference. **Thermal** is very similar, but with fewer steps in its scale. It uses black, purple, red, orange and yellow to show the degree of difference, from least to most. **X-ray** uses a greyscale to show degrees of difference. The more different a pixel is, the closer it is to white. **Monochrome** uses white for any pixel that has changed less than the threshold and black for unchanged pixels. The "Show Left Large / Show Right Large / Show Diff Large" buttons allow to cycle through the three images and display them in turn as the larger image.

Figure10. The interfaces of ImageDiff. Tool

In this study, Monochrome style is used with a threshold zero to visualize the differences. Monochrome shows white for any change and black for unchanged.Non defective tile image is set in the left of the control area and the one to be tested is placed in the right control area and compared. As shown in Figure 9, One among the contract labour (C1) is utilized to monitor the screen and to remove the defective tiles from the conveyor, if he founds white space in the result area. The other one (C2) is utilized to stack the green tiles in SiC bats with dry alumina powder spray over each layer. Then these green tiles are loaded in cars and baked in tunnel furnace. The sintered tiles are finally inspected, packed and despatched. The modified process flow chart is shown in Figure11.

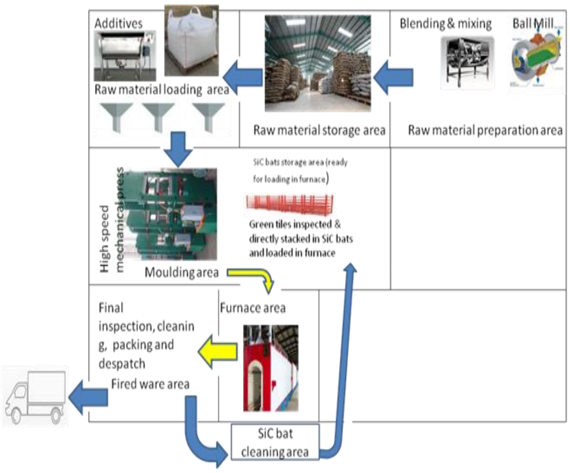

Figure11. The modified process flow chart

Table 3 Comparative recurring cost analysis.

Description	Recurring cost incurred per day in Rs..	
	Existing process	Modified process
cost of raw material 300 kgs per day @Rs.600 per kg.	180000.00	180000.00
operator cost 3 shifts per day, 3 operators per day, Rs.15000/- per operator per month	1500.00	1500.00
cost of contract labour utilized for restacking with alumina spray Rs. 400 per day/labour	2800.00 (7nos)	800.00 (2nos)
cost of Mo.Green chip Rs.7 per chip × 835 nos.	5845.00	5845.00
cost of H.Green chip Rs.7 per chip	4900.00 (700nos.)	700.00 (100nos.)
cost of reclaim nation 75kgs @ Rs.300 per kg.	22500.00 (75kgs)	13800.00 (46kgs)
Total cost	217545.00	202645.00
Savings/day/machine		14900.00

Table 4 Comparative fixed cost analysis

Description	Fixed investment in Rs	
	Existing process	Modified process
cost of wooden bat @ Rs.100	150000.00 (1500 nos)	nil
Cost of SiC bat @ Rs.150	225000.00(1500 nos)	450000.00 (3000 nos)
cost of camera and accessories	nil	70000.00
cost of Image Diff . software tool	nil	nil
cost of computer and accessories	nil	60000.00
cost of labour for arrangements	nil	20000.00
Total cost	375000.00	600000.00
Additional investment/ machine		225000.00

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IX. Control – Phase

The first step of the control phase is to document and standardize the improvements The monitoring plan clarifies how the process performance will be continuously monitored, who will be notified if there is a problem and how that will happen and what response is required. The process map of the new process that was created should be reviewed and updated as necessary to reflect any modifications that may have occurred during roll out. Control charts and poke-yoke are most common and widely used tool.

X. Result and Conclusion

With the application of DMAIC methodology, along with pilot experiments, opinion of the experts, outcome of the brain storming session, the management commitment is highlighted in the define phase with 5Ws approach. The cause and effect diagram explains the possible areas of defects occurring during the manufacturing small projection tile. Green chip (during the process of moulding and while handling) contributes nearly 70% of the defects (improper handling, improper stacking and lack of periodic inspection). This found with the help of Pareto analysis. In the existing method, the green tiles produced is initially stacked in wooden bats, inspected and then restacked in Sic bats for sintering is modified. The proposed method eliminates the process of restacking the green tiles from wooden bats to SiC bats, the moulded green tiles are inspected and directly stacked in SiC bats for sintering.

In the view of productivity all the tiles produced and stored in the three shifts, in the existing method are inspected and re-stacked in two shifts. In the proposed method, as the green tiles are directly stacked, they are ready to be loaded in the furnace in the same shift itself. The re-stacking time (unnecessary movement of material) is saved facilitating higher productivity.

The recurring cost incurred for the modified process is cheaper approximately by Rs.15000 per day. Presently, in the existing method, the company is having four machines of same kind and nearly 30 contract workers on daily wages are involved, Whereas in the proposed method eight workers are enough to carry out the task. The wages paid to contract workers are minimized to a greater extent from Rs.360000 (30×30×400) to Rs.96000 (30×2×4×400) for a month. The remaining workers may be deployed to other areas.

The fixed cost comparison is also made. For uninterrupted flow, additional SiC bats are essentially required and an approximate additional investment of 2.5 lakhs per machine is affordable, on considering the profit, productivity and other benefits.

On the basis of the results obtained, opinion of the experts, the presented approach meets the management commitment in a perfect way. This approach can be applied in all type of industries with suitable modifications.

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