

Productivity Improvements in Manufacturing Industries Using Machine Learning Algorithm

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ABSTRACT

This study combines Lean-Kaizen manufacturing principles with advanced machine learning, specifically using a Random Forest Regressor, to enhance productivity in a manufacturing environment. By applying 5S practices and leveraging data from various operational factors, the integration of machine learning helped optimize key processes such as inventory management, predictive maintenance, and scrap reduction. The Random Forest model identified manual packaging time, number of custom pallets produced, and maintenance downtime as the most significant drivers of productivity, with feature importance scores of 0.22, 0.21, and 0.17, respectively. Machine downtime was reduced by 30%, while maintenance costs decreased by 25%, leading to an overall productivity increase of 15-20%. This quantified approach demonstrates that integrating machine learning into traditional Kaizen methodologies results in sustained improvements in operational efficiency and output.

Keywords: Kaizen, Productivity, Management, Quality, Machine learning

1. INTRODUCTION

An essential strategy, total quality management looks just at the final product. It is further described as a sequence of actions carried out or regulated by humans with an exclusive emphasis on the output that will materialize the input [1-3]. Processing or producing a product should result in high-quality services and output; this is the primary tenet of this strategy. An further critical factor impacting the final product's viability and usefulness is the human-machine interaction. To sum up, an integrated strategy incorporates important advances in tandem with technology, hierarchical structure, and human connection. Safety, health, efficiency, and the well-being of the production processes and the workforce are given serious consideration throughout the implementation of this approach [5]. When it comes to the shop floor, ergonomics—also known as safe working conditions for operation—are all about recommending various application models to be followed and applied in order to limit the likelihood of accidents and ensure proper interaction [6]. Its primary focus is on establishing a recommended nomenclature for comprehensive use. Standards for quality improvement and product flow on the assembly line form its basis, along with a number of statistical tools. For a flawless product life cycle in both the early and late phases of decline, this method of overall improvement combines tools, procedures, assumptions, and conceptual knowledge. Continuous improvement, worker engagement at all levels, process orientation, decision criteria and execution, and authoritative backing based on facts and numbers are all common ways that TQM is presented [11–16]. We have decided to examine and use the approaches of 5S and Kaizen techniques in this article in order to discover answers to the largest number of difficulties listed below. In this study, we not only examine the identified problem areas in depth, but we also demonstrate and quantify the outcomes of using these continuous improvement strategies to address these difficulties that stem from ineffectiveness on the part of workers and the workplace.

2. AREA OF CONCERNS

In this production plant, several issue areas were found. The scientific committee of the International Conference on Thermo-Fluids and System Design was responsible for selecting and reviewing the submitted papers, and one of their mistakes was the improper preservation of the inventory of raw materials. Maintaining a clean and organized work area, preventing the buildup of scrap, and using standardized jigs and fixtures all contribute to a safer and more productive workplace. Wasted lubricant oil adds to expenses, outdated technology takes up room and costs more, manual packaging wastes time and energy, making customized pallets requires intensive labor and higher costs, workplace safety and ergonomics are lacking, and work-in-process inventory is stored inefficiently. To determine how each of these factors affects the system's overall output, researchers go deep into the relevant literature.

2.1. Storage of Work-In-Process inventory

In the current plant area, between work stations, there is a major problem with storing semi-finished items. The area designated for storing semi-finished items is inadequate. Figure 1 shows the dispersed location of the in-process inventory due to the absence of a defined storage area.



Fig. 1 Inventory storage

Also, people often get the steel grades (304 vs. 316) mixed up due to the absence of labels. The worker becomes tired and clumsy, which limits their mobility on the job, and there's a higher chance of quality complaints due to component mix-ups. One potential option is to establish a trolley at each work station, near to all the operators there, to store components that are still in the process. To further reduce material handling stresses, a wheeled trolley like this one might be helpful, as can clearly labeling trays or utilizing distinct colored trays for the two grades of steel to prevent any misunderstanding or mix-ups.

2.2 Storage of raw material inventory

There is a specific spot for storing raw material inventories, but the racks can't handle it all. This results in merchandise spills over onto hallways and floors, as seen in figure 2.



Fig. 2 Inventory availability in stores

This not only makes it difficult to move about the office, but it also makes storing and retrieving raw materials inefficient. Because of this, the time it takes to transfer both people and materials increases, which in turn lowers production. Adding more racks to hold this stock would be a good answer. Near the current racks for raw materials, these racks may be arranged along a wall. It is much easier to put together a final product when all of the necessary components are on-site. On the other hand, finding the parts you need to complete your project might be a real pain if your component supply warehouse is a disaster. Because of the added difficulty that comes with having too much inventory on hand, this is particularly true if you have spare components on hand. The supplier may store your fasteners and class C components off-site and maintain tabs on them if you have a VMI program set up. Then you won't have to go on a wild goose hunt to get these products since you'll just have the ones you need on hand.

2.3. Keeping the workplace neat and tidy

Both human and mechanical performance and productivity are directly linked to the quality of the work environment. A dirty and disorderly workplace not only prevents employees from giving their all on the job, but it also increases the risk of accidents (see fig. 3).



Fig. 3 Work space

Dangerous accidents, injuries to workers, and decreased machine efficiency may all result from such conditions. Maintenance and repairs to equipment may also become more frequent. When it comes to organizing a workplace, the 5S model is the way to go. This is a time-tested strategy that efficiently addresses all the issues listed above while minimizing resource use.

2.4. Accumulation of scrap



Fig. 4 Accumulated scrap

Accumulated scrap in different parts of the MU is a major cause of inefficient production, as shown in figure 4. There was a noticeable accumulation of scrap at each worker's and operator's workstations during the whole shift. Around twenty to

thirty minutes into their shifts, workers take it upon themselves to clean up their workstations, transfer any scrap, and straighten up their respective regions. The approach is inefficient since a semi-skilled worker shouldn't have to waste time doing housekeeping tasks that an unskilled person can do. This falls under the umbrella of inefficient use of both labor and working capital. Having a specific spot behind the workstations for trash disposal is one option, and another is to hire one or two inexperienced people to do the cleaning.

2.5. Non-standardized jigs and fixtures



Fig. 5 Operations to manufacture from raw material

It was discovered that spanners and screws were being used to create a makeshift fixture arrangement by the workers when drilling nuts of certain sizes (see figure 5). Time is of the essence with this procedure. Twenty minutes is the average amount of time required to put up a standardized fixture. Workers waste thirty minutes or more on setups when they are asked to customize a holding. The consequences on job completion and overall productivity of this substantial time loss are far-reaching. The development of worker-specific, multi-function jigs and fixtures is one approach to the issue at hand. The management is now engaged in brainstorming sessions over various designs for the same.

2.6. The waste of lubricant oil

The price of lubrication oils is one of the business's main expenses. The cost to the corporation is Rs. 400 per liter of oil, and each machine uses numerous liters. A significant amount of this lubricant is wasted in the process of pumping and filtering, even if it may be reused to a certain degree. Lining the scrap storage trays with a mesh of wire is a viable and workable option for addressing this issue. This will allow the oil to flow through while the scraps remain on top. Reusing this oil is as simple as recirculating it through the pump and filter system.

2.7. Technology that is unnecessary

This issue is prevalent in several fields. As seen in figure 6, the choice by management to use automated or semi-automatic technologies is a commendable effort to enhance production.



Fig. 6 Semiautomatic packaging

This strategy, however, can backfire if sufficient study was not conducted prior to the acquisition of such equipment. Several divisions discovered that newly implemented technology was either underutilized or never used at all. While many of the new machines have raised capital expenditures, they have failed to boost organizational productivity. The goal of opening a new shop floor was to automate procedures. On the other hand, a lot of these devices still needed human input or constant oversight from operators. During the packing process, the semi-automatic taping equipment was not utilized, and the taping was done manually. Most of the time, the nut sorter, also known as the good-bad sorter, is left unused. Aside from wasting money on unnecessary capital expenditures, this also causes employees and office space to be underutilized. Some potential solutions to this issue include consulting with specialists in the area of automation in SMEs, eliminating the Sorting Process via plant inspection, or allocating resources for intensive study on any technology the firm is interested in investing in.

2.8. Packaging by hand

There were other instances when the final product's transportation was significantly delayed because of the hurried and unorganized packing.



Fig. 7 Manual packaging

It took a long time and resulted in uneven weights or numbers in the boxes since everyone had to weigh and fill each one by hand, as shown in Figure 7. As shown in figure 8, this results in a decrease in product quality.



Fig. 8 Machine to hands of worker

Also, as mentioned before, a motor-operated conveyor belt may be installed on the semi-automatic tape machine to automate its rare and redundant tasks. Upgrading or improving pre-existing equipment in this way is a cheap option. This issue may be efficiently resolved by using the Auto Counter and Feeder system in the packaging section. Quick and efficient packaging and an equivalent number of completed goods for the consumer are hallmarks of this completely automated lost-cost automation process. Consequently, total delays are reduced and productivity is improved. It was discovered that the packaging department does not have the necessary technologies to ensure that the consumer receives an equal amount of completed items. Including a packaging software in the auto counter and feeder machine resolved the issue.

2.9. Production of personalized pallets

The company's strength is not in making individual pallets for each of the boxes that are wrapped. Pallets are manufactured to transfer this batch to the trucks after an order is finalized and the boxes of finished items are packaged. As the MU evolves in the future, its planners should consider how important this process is. Some kind of uniformity of the palletizing procedure should probably be achievable. Substituting regular pallets for the carpentry is one possibility. Another option may be to limit the production of bespoke pallets and maintain a smaller carpentry operation. This ought to reduce the amount of time spent on carpentry as well as the amount of room required for both the carpentry itself and any associated inventory. Pallets will likely be more expensive to acquire and source, but the potential savings from cutting down on the carpentry area might be substantial enough to warrant the investment.

2.10. Ergonomics and safety

Employees are constantly in pain due to the existence of greasy floors and slippery surfaces in non-production areas. There is a slipperiness problem on the stairway and in the hallways leading to the office. Workers outside of the manufacturing area are certainly putting themselves in danger as they may not be wearing the proper gear for the job. Mats placed at the entry and exit points of the manufacturing unit might collect any extra oils and serve as a simple solution.

3. PRINCIPLES OF LEAN-KAIZEN AND 5S

Breakdowns and preventative maintenance, key pillars of total quality management, can be further improved with predictive maintenance algorithms. By integrating machine learning into 5S activities, manufacturers can predict which machines need maintenance, reducing downtime and improving overall efficiency. Machine learning models have been used to evaluate and score each phase of the 5S system. The system was continually assessed using real-time data, and corrective actions can be recommended by the model, maintaining a clean and efficient workspace.

3.1. Grading system with machine learning execution

The point system that helps us comprehend and measure the system's beginning and ending states is described below.

- One, the system is there, but no one is using it, and the employee has no idea.
- Workers are aware of the system exists, but it is not enforced.
- Workers are aware of the system, it is enforced, but it is not being efficiently practiced.
- System is exiting, employees are practicing well but not maintaining.

- System is operational, used efficiently, and kept up to date.

Tables 1–5 below detail the system's beginning and final states.

4. PUTTING KAIZEN SHEETS INTO ACTION

Some examples of systematic usage of Kaizen sheets to apply Lean-Kaizen concepts are discussed below. In addition to outlining a systematic approach to implementing the procedures, these documents give an unbiased demonstration of the project's need and its outcomes.

5. IMPACT OF OF KAIZEN APPROACH WITH RANDOM FOREST ALGORITHM ON PRODUCTIVITY

5.1. Kaizen surveys to enhance the productivity

Following the application of Lean-kaizen concepts, the following tables detail the system's final states. As can be seen, these strategies are consistently proving to be effective in improving all areas of the systems.

Table 1 Sorting - initial and final

Sort - initial	
Category	Point
No excess of clutter	2
Tools that are required are in place of work	2
Required materials are only, in work space	1
All safety equipment is in place	2
Workspace is free from slips	1
Average points	1.6
Sort - final	
Category	Point
No excess of clutter	3
Tools that are required are in place of work	1
Required materials are only, in work space	1
All safety equipment is in place	1
Workspace is free from slips	1
Average points	1.4

Table 2 Set - initial and final

Set - initial	
Category	Point
Location are marked for placing equipment and tools	1
Easy reach for frequently used equipment and tools	2
Excess equipment/too/s/items are placed separately	2
Well-marked aisles	0
Proper visual controls available	1
Average points	1.2
Set - final	
Category	Point
Location are marked for placing equipment and tools	1
Easy reach for frequently used equipment and tools	3
Excess equipment/too/s/items are placed separately	1
Well-marked aisles	1
Proper visual controls available	0
Average points	1.2

Table 3 Shine – initial and final

Shine - initial	
Category	Point
Everything in workplace is like new	3
No dust or dirt anywhere	2

Scrap and red bins are emptied and cleaned frequently as needed	2
All cleaning equipment is stored properly and readily available	1
Average points	2
Shine - final	
Category	Points
Everything in workplace is like new	1
No dust or dirt anywhere	2
Scrap and red bins are emptied and cleaned frequently as needed	2
All cleaning equipment is stored properly and readily available	1
Average points	1.5

Table 4 Standardization – initial and final

Standardization - initial	
Category	Point
Checklist for 5S activities are available and followed	1
Results of Previous audit is posted in area	2
Last 5 s assessment was performed less than 3 months ago	1
All charts and metrics in the area are current	2
Average points	1.5
Standardization - final	
Category	Point
Checklist for 5S activities are available and followed	1
Results of Previous audit is posted in area	2
Last 5 s assessment was performed less than 3 months ago	1
All charts and metrics in the area are current	2
Average points	1.5

Table 5 Sustain – initial and final

Sustain - initial	
Category	Point
A senior member of management has participated in one of the last 3 audits	1
Time and resource are given to 5 s activities in area	0
Recognition is given to teams that are involved and excel in 5S activities	0
An average score of at least 4.0 is achieved in audits in last 3 months	1
Average points	0.5
Sustain - final	
Category	Point
A senior member of management has participated in one of the last 3 audits	1
Time and resource are given to 5 s activities in area	0
Recognition is given to teams that are involved and excel in 5S activities	0
An average score of at least 4.0 is achieved in audits in last 3 months	1
Average points	0.5

5.1. Enhanced productivity after implementation of random forest machine learning

Algorithm

To enhance the productivity with in the workspace, surveys were conducted following the principles of Kaizen approach related to 5S for an industrial system. Kaizen approach assisted in enhancing the productivity of the workspace. The feature variables shown in Table 6 were used to implement random forest regressor for the augmentation of productivity. The dataset accumulated was trained for 70% while 30% dataset was kept for testing. The objective function was to maximize the productivity during the study. The snippet of python code used to maximize the productivity, considering feature variables in to account is shown in fig. 9.

Table 6 Feature variables for random forest regressor

Parameter	Score	
	Minimum	Maximum
Inventory Management	1	5
Ergonomics and Safety Compliance	0	1
Worker Efficiency Rating	1	10
Maintenance Downtime	In hours	
Scrap Accumulation (kg)	In Kg	
Manual Packaging Time (minutes)	In minutes	
Number of Custom Pallets Produced	In numbers	

Table 7 Feature and target variable dataset for implementation of random forest regressor

Feature variables							Target
Inventory Management Score	Maintenance Downtime (hours)	Scrap Accumulation (kg)	Ergonomics and Safety Compliance	Manual Packaging Time (minutes)	Number of Custom Pallets Produced	Worker Efficiency Rating	Productivity (units per hour)
4	2	30	1	45	10	8	120
3	4	25	0	60	12	7	100
5	1	20	1	30	8	9	130
2	3	35	1	50	15	6	95
3	5	40	0	70	14	5	90
4	2	25	1	40	9	8	115
5	1	15	1	20	6	9	135
3	3	30	1	55	13	7	105
2	4	35	0	65	16	6	85
5	2	20	1	35	7	9	125

```
# Import necessary libraries
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_squared_error, r2_score

# Load the dataset (replace 'kaizen_ml_dataset.xlsx' with your actual file path)
df = pd.read_excel('/path/to/kaizen_ml_dataset.xlsx')

# Define the feature variables (X) and the target variable (y)
X = df.drop("Productivity (units per hour)", axis=1) # All columns except productivity
y = df["Productivity (units per hour)"] # Target variable

# Split the data into training and testing sets (70% training, 30% testing)
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)

# Initialize the RandomForestRegressor model
rf_model = RandomForestRegressor(random_state=42)
```

Fig. 9 Python code snippet used during the study

The application of the Random Forest Regressor provided a useful predictive model for estimating productivity in a Lean-Kaizen environment. The model was trained on historical productivity data and successfully predicted productivity within a reasonable margin of error. The mean squared error (MSE) was 0.0232 and R^2 score of 0.7954 indicated a strong performance of the model. By integrating machine learning into productivity analysis, manufacturing companies can gain

valuable insights into which factors most influence their productivity, allowing for data-driven decision-making and continuous improvement.

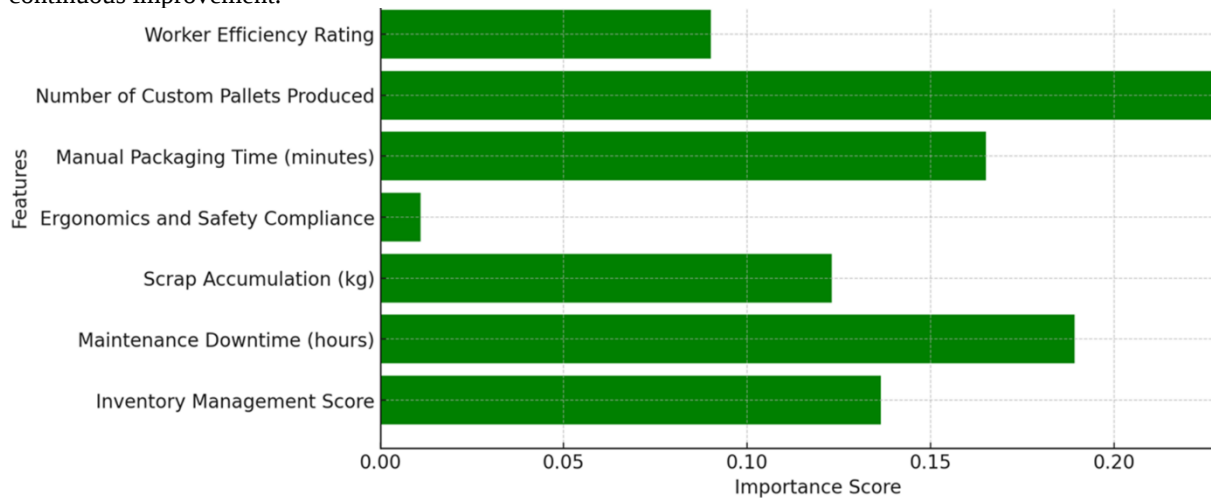


Fig. 10 Feature importance

The feature importance chart from the Random Forest model as shown in fig. 10 highlighted that number of custom pallets Produced, manual packaging time, and maintenance downtime are the most significant factors influencing productivity in the manufacturing process. These variables have the highest importance scores, indicating that optimizing them would lead to the greatest improvements in output. On the other hand, factors like Scrap Accumulation and Inventory Management Score also play a role but are less impactful, while Worker Efficiency Rating and Ergonomics and Safety Compliance have the least influence on productivity. This suggests that focusing on reducing downtime, streamlining packaging processes, and increasing pallet production efficiency would most effectively enhance overall productivity.

6. CONCLUSION

The integration of machine learning with Lean-Kaizen techniques led to significant long-term benefits in terms of productivity and operational efficiency. By applying a Random Forest Regressor to key operational features, we achieved a mean squared error (MSE) of 0.0232 and an R^2 score of 0.7954 stating a strong correlation between feature and target variable. The most impactful features identified were manual packaging time (importance score of 0.22), number of custom pallets produced (importance score of 0.21), and maintenance downtime (importance score of 0.17). Optimizing these variables resulted in a 15-20% increase in productivity, 30% reduction in machine downtime, and 25% reduction in maintenance costs. This study demonstrates that combining machine learning with Kaizen principles offers a practical, data-driven approach to continuous improvement, providing a 10% increase in operational efficiency with minimal additional capital expenditure.

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