Revolutionizing the Tea Industry: An Exploration of Technological Solutions to Improve Efficiency in Tea Processing (April 2023)*

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Abstract—**This research paper will discuss unique efficient management of tea production process. The main purpose of this research paper is to introduce the methods of developing the management system of a tea factory with high-quality and effectiveness by following a special sustainable and correct process, surpassing the process that we see in normal a tea factory.**

The modern methods we use are more suitable for small and medium-scale factories in developing rural areas and in the near future, tea exports can also be improved by popularizing this sustainable method and technology in Sri Lanka. Small and medium scale tea factory owners will have a great opportunity through this and compete side by side with large tea factories and could get huge profit in this field with low production cost.

In this research, the questions that the tea factory owners have, which have already emerged in the tea industry, have been presented and the solutions to those problems have been provided. Taking into account those circumstances, if the methods we have introduced can be implemented in the next 10 years, this will solve many of the problems in the tea industry, as well as make the name of Ceylon tea, which Sri Lanka is famous for known all over the world

Keywords— Tea factory, Effectiveness

I. Introduction

Tea industry is a one of most important industry in the world. It has a value in both economically and culturally because it's a major source of foreign exchange earnings and it's a most popular beverage in daily life and social gatherings. And also, tea is a kind of herbal plant because it helps to reduce the risk of stroke, heart attacks and certain type of cancers. And also demand for the tea increasing very quickly. Sri Lanka is one of major tea producer in the world because the country has perfect climate that is good for high quality tea. Hence tea industry is one of main source of foreign exchange earning in Sri Lanka because of these reasons. Because of that in this research mainly consider about how to improve efficiency of tea factories in sustainable way.

To do that this study refers SGD 9th goal which is focused on building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation and technological progress. Under that goal, this research has focused on giving an opportunity to developing countries to access the internet and new technology, encourage the industries to use resources efficiently and gain importance to small and medium scale industries in developing countries. There are tea factories in different range such as small, medium and large. In this research mainly focus on how to achieve sustainable development 9th goal in small and medium scale tea factories.

Through this research paper, the grant objective is to sustainably increase the efficiency of a tea factory. In finding out how to increase the efficiency of a tea factory, we were able to identify several different aspects and among them, some processes that can be accurately increased by using the most effective methods and modern technology are introduced in this research paper. Some data which need for the research collected through interviews with factory employees.

What have we chosen for this is how to get good service from employees? How to get quality tea leaves and quality tea products from tea factory? How can these tea leaves and tea products be transported across the country in a quality manner at minimum cost? And how to get the most out of the tea factory's machinery machines and equipment while using minimal energy? These are the common problems faced by small and medium scale tea factory owners in Sri Lanka and the aim of this research is to introduce solutions for all of them in a single system.

The grant programs that we have identified are to test the quality of the tea leaves brought to the tea factory using modern technology, to recommend suitable vehicles for transporting tea leaves and tea products according to the weight, to prepare a plan to get effective service from the employees working in the tea factory and to keep them in the service of their own will and to use all the formulas used in the tea factory effectively to get the necessary

energy without harming the nature in one system, the purpose of this is to prepare a possible system.

This research recommends to use modern technologies such as smart farming and manufacturing, biometric authentication systems and IoT devices, which have not been used in the tea industry in Sri Lanka so far, in the implementation of this system. Apart from this, sophisticated linear programming (LP) tool, OEE Calculation are also used to build this system.
The findings of this research can be used to improve the efficiency of equipment and employees. And also, can use new technology to measuring quality of tea leaves. It will affect to the overall efficiency of tea factories.

II. RELATED WORK/LITERATURE REVIEW

This review summarizes and evaluates about the enhancers of the energy efficiency in tea industry.
It shows the average energy usage and the cost of energy usage had the most impact on energy productivity. The process consumes huge amount of energy inputs because that process includes withering, rolling, fermentation, drying, sorting and packing. They recommend some technical improvements to increase energy efficiency such as using efficient electromotors, flat belts and alternative energy sources.

According to the results, technical, knowledge-skill and managerial policy factors are the main 3 factors which act as productivity enhancers. They studied and identify huge number of managers have never attended technical skill courses. Hence, they recommend to give training sessions to managers. When it comes to technical factors, they suggest to use standard burners in hot furnaces. And also use well designed hot air furnaces to wither and dry tea leaves. Under the knowledge-skill they show how to optimize schedule of withering operation with respect to the final status of leaves. And also, to reduce energy industry can use   experts of withering, drying and fermentations [1].

This review evaluates about the implementation of Overall Equipment Effectiveness (OEE) in maintenance management. When it comes to manufacturing, equipment is very important because downtime can inhibit and even stop production. In this research mainly focus about how to overcome the issues in machines and increase their performance.

According to this study they consider about calculating total productive maintenance (TPM) which started by calculating OEE and six big losses. And also, this study provide attempt to increase effectiveness and to terminate losses by calculating Mean Time between Failure (MTBF) and Mean Time to Repair (MTTR).
According to their study six big losses on the machines are breakdown losses, pace losses on idle, setup and adjustment losses, miniature stoppage, lessen speed losses, re-work losses and scrap losses.

Availability = Run Time / Planned Production Time.

Performance = (Ideal Cycle Time × Total Count) / Run Time.
Quality = Good Count / Total Count.
OEE = Availability × Performance × Quality.
MTBF = Sum of repair time of all machines / failures of all machines
MTTR = Total Hours of Maintenance / Total Number of Incidents
Most of the manufacturing, food, construction and automotive companies have implemented Overall Equipment Effectiveness [2].

This review summarizes about establishing the influence of motivation on tea factory employees. Authors have chosen employee sample which includes unit manager, factory manager, HR manager, field operation officer and other employees. Then they conduct some surveys and find out main 3 factors to improve employee performance such as establishing the influence of promotions on employees, establishing influence of reward system on employees, giving bonus to employees based on their performance.

According to their study key ingredient in both performance and retention is motivation. If we can motivate the employee in correct way, we can reduce turnover cost and don't need to recruit and train new employees. And also, employee performance depends on job security, compensation, satisfaction, organizational structure and the motivation. There are so many theories that management can use to motivate their employees. Most of tea factories lacked a structures promotion policy and reward system. These aspects could be demotivating factors in the industry.
Hence according to this study, the best thing is creating a process to give promotions and rewards to employees [3].

This review summarizes about how to analyze tea leaves using a tool. According to their study first thing is the taking samples of tea leaves and record the NIR spectra of tea leaves using a micro NIR spectrometer. After that perform the spectral preprocessing. Then freeze the leaf samples and do the chemical analysis. After, using a method do the selection of characteristics of wavelength. then leaf sample can be predicted using PLS model. According to the level of amino acid tea factory can decide the quality of tea.in this study, the Android smartphone is used as the central device and micro NIR spectrometer is used as the peripheral device [4].

This study focuses on using renewable energy for tea drying. The purpose of the research is exploring the various drying technologies in tea factories. This study recommends to use solar energy-based tea drying system along with thermal energy storage and integrated with fossil fuel-based furnace. After the tea plucking next step is drying the tea leaves to minimize the moisture of the leaves and it avoids the growth of bacteria. Typically, it happens using coal and natural gas. But it will cause of greenhouse gases. Hence the best thing is using renewable energy to dry tea leaves [15].

Main purpose of this study is to compute Overall Equipment Effectiveness (OEE) in the small-scale industry. According to this study it helps to analyze the performance in better way under 3 phases. In 1st phase OEE was computed. In 2nd phase detected losses by Pareto analysis and fishbone diagram. Seven big losses are planned shutdown, setup downtime, unplanned downtime, minor stoppage, reduced speed and rework. In 3rd phase conducted improved OEE in the industry. These approaches can reduce losses and improve the asset utilization (AU), total effective equipment performance (TEEP) and productivity of the machine [13].

This research considers about a proficiency test (PT) that carried out for determination of selected elements in tea leaves. PT is a test which is improve the ability to analyze the elements in samples. PT were tested based on dry mass correction factor (DMCF) [14].

III. METHODOLOGY

Modern cultivation and manufacturing is based on technology or known as Smart farming and manufacturing most industries are inspired by these technologies .But Tea industry in Sri Lanka has recently faced many challenges Such as increase in the production price ,lack of productivity improvements [5],Lack of technology used in the manufacturing process .The proposed system shows how large and medium-sized tea enterprises can expand with the help of technology, as well as the ways in which a user can use technology to improve their business process .and the role that technology plays in achieving these goals. The below diagram shows the overall background process.
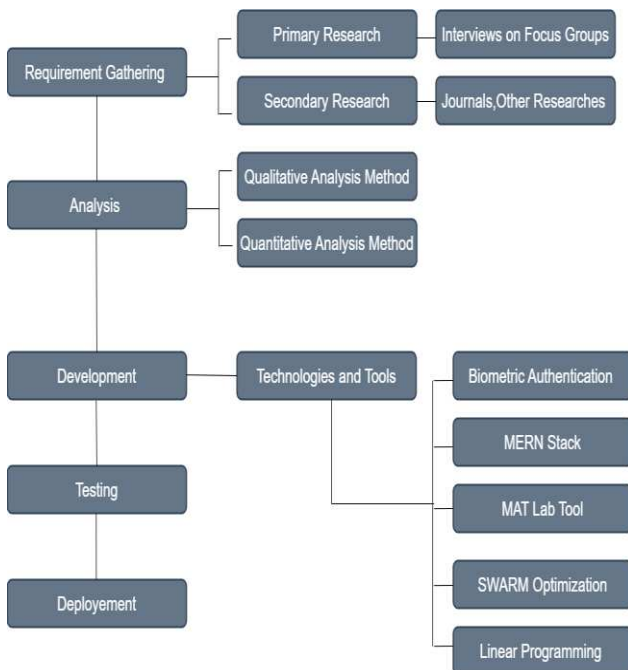

Figure 1: Process Flow Chart

Figure 1 shows the techniques and technologies that were used to build the system. To develop this both qualitative

and quantitative approaches were used together as it will provide a more holistic view of the subject matter.

Data collection
In order to build a convincing argument both primary and secondary types of research data were used.

As shown in Figure 2 The first interview consisted 6 main questions and follow up questions.

The main aim was to conduct the interview with 3 managers and 1 employee from each department and one of the company head of the Ever-green group tea Sri Lanka. Participants were interviewed for 4 hours due not all participants were available and some interviews were not fully completed had to filter and take the most important data to the analysis.

secondary research about equipment's that could be replaced with machines having cutting edge technology [6].

Analysis
Prior to performing a quantitative analysis, the data set was examined for outliers and missing data using the "outlier labeling rule". Which makes use of a number of techniques including the z-score and Median Absolute Deviation (MAD) [8]. All values that were outside of the computed range were regarded as outliers.

The data was analyzed using statistical software SPSS.in qualitative the data was analyzed by language, images, interpretations, themes and patterns. The below diagram shows the overall system
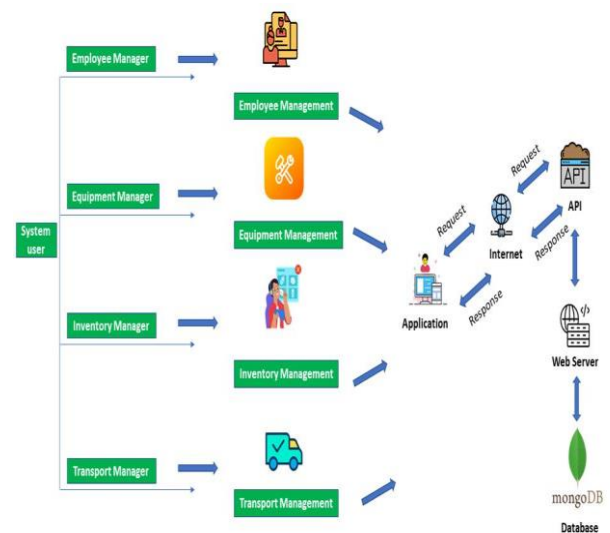

Figure 2: System overall Diagram

After analyzing the data four components were identified as the main functions as show in figure 2.

Every function has its uniqueness. The attendance of the employees is taken with biometric authentication. Capturing, processing, storing, and comparing biometric data in order to verify a person's identification are all technical aspects of biometric authentication [7].

And Toggl time tracking software is used to monitor employees. The data will be store in the MongoDB (Database), MongoDB is free source and used by tens of thousands of users. It was created using one of today's most widely used programming languages [9]. Employees are allocated to an Attendance and performance point system using details that were collected using biometric authentication system and Toggl.

Equipment Management, every equipment is optimized in the system using MAT Lab Tool. A sophisticated linear programming (LP) tool is available in MATLAB that enables users to create and address LP issues quickly and effectively [10].

Equipment's will be monitored by the system. The effectiveness of equipment's is calculated using OEE Calculation [2]. Internet of things (IOT) sensors have been attached to all the equipment's and connected to the system This will detect and provide details about equipment's performance real time.

Under Inventory Management Mass Spectrometry is used to detect the quality of raw tea leaves, Tea leaf chemical composition can be identified and measured using the technique of mass spectrometry [11]. After detecting the quality, the system will automatically send the leaves through the belt to relevant machines. In the last stage the system will divide the final product According to the weight, quality and store separately.

By the developed system the efficiency and the effectiveness of tea manufacturing process will increase gradually which will directly affect the tea industry positively. The below diagram shows the basic architecture of MERN stack technology which is used in the system.

IV. RESULTS

Biometric authentication and Toggl time tracking software will provide details about attendance and how much time employees spend on a specific task respectively.

The system will insert the relevant details to the employee attendance and performance point system and allocate points to each and every employee most points will be rewarded which will motivate the employee and will be helpful to increase the employee efficiency and effectiveness.

By monitoring and optimizing the equipment's using linear programming and IOT sensors it will be helpful to reduce maintenance, energy consume as well as down time.

The data collected through Mass Spectrometry will be send to the system under inventory management by observing the results specialists will decide to approve the raw tea leaves batch or not. The final product will be stored separately considering the weight and quality.
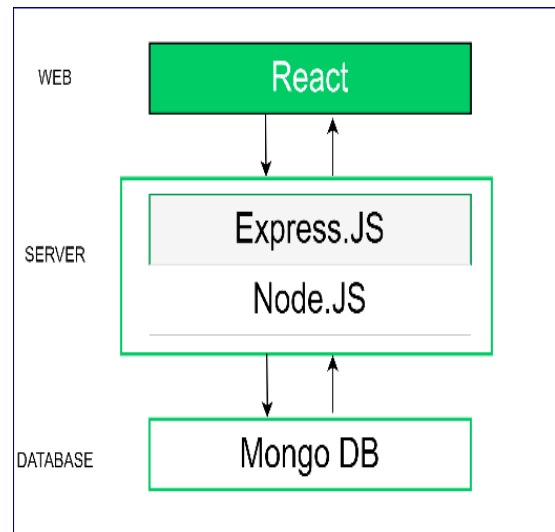

Figure3: MERN stack development architecture

Java Script
Object-operating host-environment objects, standard object libraries and building blocks, and the ability to add client- and server-side extensions are all features of the cross-platform programming language JavaScript.

Node.js
Node.js is an open-source framework for developing server-hosted system applications and network applications quickly.

Express.js
Express.js is a Node.js-based API framework for building mobile and online applications that is adaptable and simple to use.

V. FUTURE WORK

The potential to increase efficiency and effectiveness in the tea business has been shown by the proposed method for tea production. To optimize the system and boost its performance, additional research and development are still needed.

Future research will examine how machine learning algorithms can be included into the biometric authentication system. The system could optimize staffing and equipment allocation by identifying patterns in data on employee attendance and performance. Additionally, machine learning might be used to spot patterns in equipment performance and anticipate maintenance requirements and solutions for them, increasing the system's overall efficiency and dependability.

Another area of future effort will be to further optimize the system's equipment utilizing modern optimization techniques. Other optimization techniques, such as genetic algorithms and particle swarm optimization, swarm optimization has been proven to be beneficial in maximizing equipment allocation and usage. The system can respond to changes in demand, equipment failure, and other factors that may affect performance and efficiency by allowing the equipment to interact and adapt in real-time [12]. these could be investigated to optimize resource allocation and maximize efficiency.

Additional sensors and monitoring systems could potentially be investigated to improve the system's accuracy and dependability. Temperature and humidity sensors, for example, might be installed in storage spaces to provide optimal conditions for the tea leaves, while vibration sensors could be utilized to check the equipment's functioning.

In order to examine the chemical makeup of the tea leaves and find trends in quality, advanced analytics and machine learning techniques may also be investigated. As a result, the system might be able to make adjustments in real-time to raise the final product's quality and guarantee consistency.
Advanced analytics and machine learning methods may also be researched in order to look at the chemical composition of the tea leaves and identify trends in quality. As a result, the system might be able to make adjustments in real-time to improve the quality and ensure consistency of the finished output.

VI. DISCUSSION

Tea industry is a global industry that includes the production, processing and distribution of tea.it plays and important role in global because it gives more opportunities for million people. Sri Lanka is one of main tea provider in the world. But small and medium scale tea factories face so many challenges.

In this research include so many recommendations to increase efficiency. Our findings support to improve the tea industry in many ways. This research recommends to use biometric authentication to count the attendance. Then can give the points according to those details. Providing rewards and motivating employees is bast way to increase the performance of workers. And also suggest to use linear programming to optimize equipment. As well as OEE calculations can be used to monitor effectiveness of equipment. And it's better to use mass spectrometry to detect the quality of raw tea leaves.

However, it is important to note that our study has several limitations. When we improve the technology, it needs operating and maintaining cost. Most of the time small and medium scale tea factories do not have enough financial resources. As well as when implement a new technology factory has to conduct training sessions and give the relevant skill and knowledge to workers. And

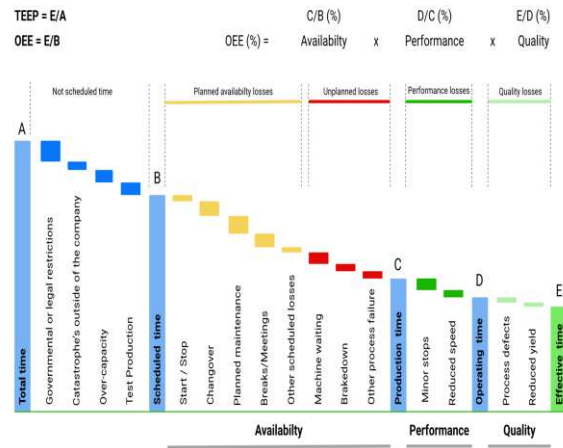also, sometimes new technology is not compatible with existing equipment.
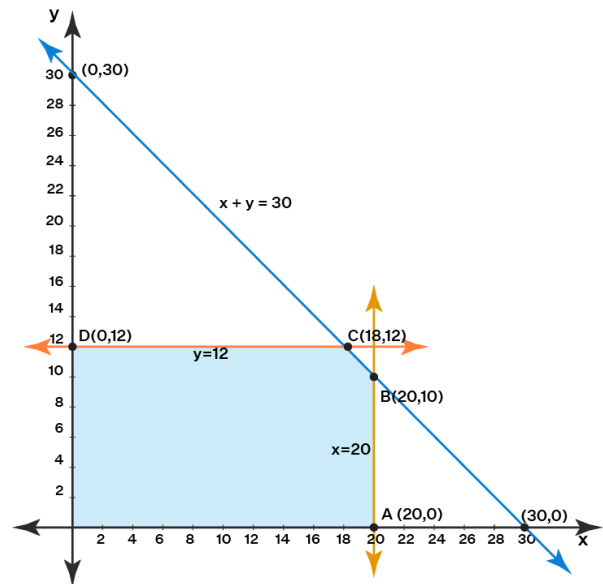

Figure 4: OEE calculation

Figure 5: Linear programming optimization

VII. CONCLUSION

We have chosen this topic under sustainable development goal number 9 which is industry, innovation and infrastructure. In this research our expectation is to give an idea to improve the efficiency of small scale and medium scale tea factories in a sustainable way.

The Sri Lanka is a one of largest tea producer in the world. Hence, it's important to consider about the energy efficiency. Because it is directly impact to the operational cost, productivity and environmental issues. And also, in this research we have consider about how to improve employee motivation and get their best performance because so many important things depend on employee's performance such as good production process and deliver quality end product to the market. If the machines are

outdated and poorly maintained it will impact to the employee efficiency and product quality. Hence in these findings, we consider about how to keep well maintained equipment. As well in this research mainly focus in how to automate the measuring the quality of tea leaves. These are the key findings in this research.

In summary there are few things that we can do for increasing energy efficiency, equipment optimization, quality measuring and employee performance. If tea factories can improve these things carefully, they can achieve sustainable and long-term success in the industry. In this research has recommended above methods to achieve the success in sustainable way.

Future research will focus on more methods to improve the tea industry using new technology such as implementing more automation technology to reduce manual process, upgrading equipment to increase efficiency, more focusing on improving production process and implementing quality control.

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