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An Application of Lean Techniques for Process Enhancement in the Food Manufacturing Sector

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Abstract

A smooth production flow results in a high productivity rate; hence, it is important to continually improve processes. Continuous improvement projects are normally derived from organizational goals, policies, and standards, which could be safety, quality, or environmental-related standards in most manufacturing sectors. The safety standard focuses on implementing measures that create a safer work environment, and quality standards focus on quality assurance of the products for defect elimination. The environmental standards focus on examining environmental aspects and their impact. For good compliance in Integrated Management Systems (IMS) kaizen projects should be taken into consideration, which include lean manufacturing activities. Lean manufacturing is the art of using what you have effectively without wasting resources, implementing smaller kaizen impactful tasks daily that could potentially result in drastic improvements. This study aims to provide a packaging solution for the food manufacturing industry using lean-based models. The case study company was experiencing high volumes of human error on the final packaging station due to miscount of the product, as well as inconsistent final packaging resulting from a constant feeding conveyor belt which also creates fatigue for employees. Alean-based model was developed and upgraded by adding Ergonomics to evaluate future kaizen projects for innovation and sustainability

Keywords
DMAIC, Integrated Management Systems, Kaizen, lean-based models, ISO standards.

1. Introduction
Process optimization is the key to an innovative and sustainable organization; therefore the organization needs to adapt to continual improvement projects. The process optimization projects focus on improving product and service quality, eliminating injuries, and creating a safer environment, eliminating delays, reducing cost, and improving employees' morale(Rasheed et al. 2023)]. To improve employees' morale, one should consider the work environment conditions, which include safer and friendlier equipment. To carry out continuous improvement focusing on better working environment and better equipment use, some industries adopt human analysis to evaluate the gap of improvement for effectiveness of equipment(Flores Lara et al. 2025). This study aims to integrate ergonomics study with lean manufacturing by developing models that seek to upgrade problem-solving techniques. The proposed model upgrade will be developed and tested in food manufacturing industry.

2. Related work
Safari et al.(2025) Evaluated that Ergonomics is a scientific tool that assists an analyst to review the level of comfort on the working device for ergonomically friendly work conditions. Lean manufacturing is a tool and a philosophy that is used in organizations to optimize systems for good quality products, safer processes, cost reduction and to increase employees' morale (Azad 2025), The safer work conditions align with one of lean manufacturing benefits which also

includes tool design optimization for user friendly equipment. Ergonomics analysis optimizes the equipment design and work condition for better and more comfortable use hence zero safety injuries. These benefits from ergonomics analysis serve as a common goal with lean manufacturing therefore a need for integration (Brunner et al. 2025). In this review the application of Ergonomics analysis and an application of lean manufacturing in manufacturing industries will be reviewed

The packaging stage is one of the crucial stages in any manufacturing process because the total count of final packed products determines the number of outputs per specific time, it is therefore important to optimize the final stage by simplifying the packaging process, ensuring it is more efficient and less scrap rate hence high productivity (Usul and Olgun 2025). A study was conducted in food packaging industry to reduce waste in the process and eliminate safety injuries, Value Stream Mapping (VSM) and Kanban system as well as single minutes exchange of Die(SMD) was adopted in this research. The analysis resulted in drastic improvements in the packaging area, which resulted in quality issues by 83%, service delivery time was reduced by 7.1% and the internal nonconformances (Quality issues, safety injuries and other nonconformances) were reduced by 55% (Habib et al. 2023). A study was conducted in food packaging industry in a heavy steel manufacturing industry to improve working conditions, an ergonomics analysis to identify areas that affect the human body due to heavy labor as well as the lean manufacturing techniques used to carry out the study. The study resulted to an Overall Effectiveness of the Equipment (OEE) of 136% and further improvements that resulted to removal of nonvalue added activities (Brito et al. 2025).

Hisbani et al. (2025) examined that Ergonomical studies assist in optimizing processes by evaluating improvements for a safer environment, which complements the lean technique tools due to the common goal of process enhancement for business growth. Analysis of the application of both tools for problem-solving has not been the norm in most manufacturing sectors. The study to evaluate the use of integrated Lean Six Sigma and Ergonomics models was carried out by a survey of different research studies. It was found that most of the organizations have not yet adopted the simultaneous use of both ergonomics and Lean manufacturing. However, it was found that a few industries always complement Ergonomics with DMAIC and Value Stream Mapping (Vicente et al. 2024)

Research was conducted in the plastic manufacturing industry to reduce absenteeism rate; it was found that the employees working for this industry were suffering from repetitive motion injuries resulting from the workload which involves more manual work hence regional musculoskeletal disorders. The study was conducted through four phases which was to determine the goals, finding the root cause of the problem, redesigning the processes and an assessment of the proposed solution. An Ergonomic risks assessment model verified using Delmia V5 application as well as RULA, REBA and OCRA methodology was constructed. An application of the proposed model assisted the case study company to decrease Ergonomical risks with 55% in other processes as well as 66.7% in other critical working stations hence this study resulted to 42.929 PEN cost saving due to the reduced absenteeism rate which contributed to the high productivity rate (Quiroz-Flores et al. 2023).

Sarbat et al. (2022) evaluated that Ergonomical friendly processes results to motivated employees hence high productivity rate. Ergonomics study to improve comfort of body features on human body posture and motion on interaction with robot in semi-automated operation was conducted using an anthropometric table as well as Ergonomical risks assessment was applied hence the robotic system was optimized to reduce heavy workload on manual operations. The simulation was performed to verify the success of the study, the proposed method added more knowledge in the smart manufacturing field as well as the advanced technology for employee's wellness (Chintada 2022).

A study was conducted in the construction sector to reduce safety incidents and to increase productivity rate by increasing employee's moral. A model integrating physical Ergonomics methodology and the Discreet Event Simulation was constructed and applied to evaluate processes that are not Ergonomical friendly in the construction sector. The proposed model results were successful in a manner that the employees moral increased due to Ergonomical friendly processes resulting to high productivity rate. Furthermore, the proposed model was flexible to analysis of bigger production scales hence it is applicable in most manufacturing industries (Chen and Zhang 2025).

The simplicity of the workstation processes results to a highly motivated employee hence less safety incidents and high productivity rate (Yunusa-Kaltungo et al. 2024).The aim for physical Ergonomics study is operational excellence by ensuring employees well-being during operations. Physical Ergonomics study assists in simplifying the machine and process design in a way that best suits the operator. Hence, high productivity rate, zero safety incidents and good

Quality products (Sarbat and Tasan 2022)A study was carried out in an auto ancillary Industry to eliminate nonvalue adding activities within the process by combining Occupational Health and Safety standards with Ergonomics as well as lean techniques. It was evaluated that the study resulted to drastic improvements, the stress and fatigue of repetitive movements were removed within the processes hence improvement on employee's wellness (Chintada 2022)

Research was conducted in the automotive industry to improve productivity rate by focusing on employee's safety, to improve employee's safety who are operating the process Lean techniques was integrated with physical Ergonomics study focusing on Employees motion during operations. The Value Stream Mapping tool was used for a systematic review of the process. The Single Minutes Exchange of Dies were combined with physical Ergonomics analysis to produce a solid model that would reduce safety incidents and increase productivity rate. The proposed model was applied in a metallurgical production plant. The preparation workstation of a molding machine was examined using the proposed model, where Rapid Upper Limb analysis, Rapid Entire Body analysis, Job Strain Index, Key Indicator Methods as well as Shoaf's procedures were applied. The study resulted into a cycle time reduction by 55% and it was found that a lot of elements within the process are contributing to repetitive strain injuries hence kaizen project to improve operating equipment's were recommended (Afonso et al. 2022).

3. Gap Analysis and findings from literature

The reviewed literature clearly demonstrates that ergonomics and lean manufacturing are effective tools for improving productivity, safety, quality, and employee well-being across various manufacturing sectors. Numerous studies confirm that ergonomics analysis reduces musculoskeletal disorders, fatigue, and absenteeism, while lean tools such as Value Stream Mapping, Kanban, SMED, and Kaizen reduce waste, cycle time, and non-value-added activities. Several researchers also highlight that ergonomics and lean manufacturing share common objectives, particularly in creating safer, more efficient, and user-friendly processes, which supports the argument for their integration.

However, despite the proven benefits, the literature reveals a significant gap in the simultaneous and structured integration of ergonomics with lean manufacturing tools, particularly in packaging operations. Most studies focus on either ergonomics or lean manufacturing independently, or apply integration in limited contexts such as heavy manufacturing, automotive, construction, or plastic industries. There is limited research that specifically targets manual secondary packaging processes in the confectionery or food packaging industry, where repetitive tasks, long working hours, miscounting, and high scrap rates are prevalent. Furthermore, while improvements in productivity and safety are reported, fewer studies explicitly link these improvements to counting accuracy, packaging consistency, and final product appearance, which are critical performance indicators in packaging systems.

Additionally, many existing studies rely on ergonomic risk assessment tools and lean techniques to improve manual or semi-automated processes, but there is a lack of research that translates these findings into the design justification for automated packaging solutions. The transition from identifying ergonomic and lean-related problems to proposing automation as a long-term, sustainable solution is not sufficiently addressed. This indicates a research gap in using integrated ergonomics and lean analysis as a systematic framework to justify and guide the design of automated secondary packaging systems. Therefore, this project addresses the identified gap by integrating ergonomics analysis and lean manufacturing principles to evaluate manual secondary packaging challenges and to support the design of an automated toffee packing solution. By focusing on employee well-being, waste reduction, counting accuracy, and packaging quality within a confectionery packaging context, the study contributes to existing knowledge while providing a practical, industry-relevant application that is currently underrepresented in the literature.

4. Current and existing models

Currently the model combining the basics of Integrated Management Systems is composed of Lean techniques, Occupational Health and Safety systems, Quality Assurance, and Engineering Maintenance as well as risks analysis. The outcome from existing Integrated Management is kaizen projects which assist an organization to remain innovative and profitable. Below on Figure 1 is an illustration of an existing Integrated Management Systems troubleshooting model which is composed of three phases. The 1st phase includes the different codes which are the Quality Assurance, Occupational Health and Safety Systems as well as Engineering Maintenance Systems. The 2nd phase is composed of Lean techniques for analysis purposes. The third phase is risks assessment and kaizen projects which are the part of the outcome from an existing model.

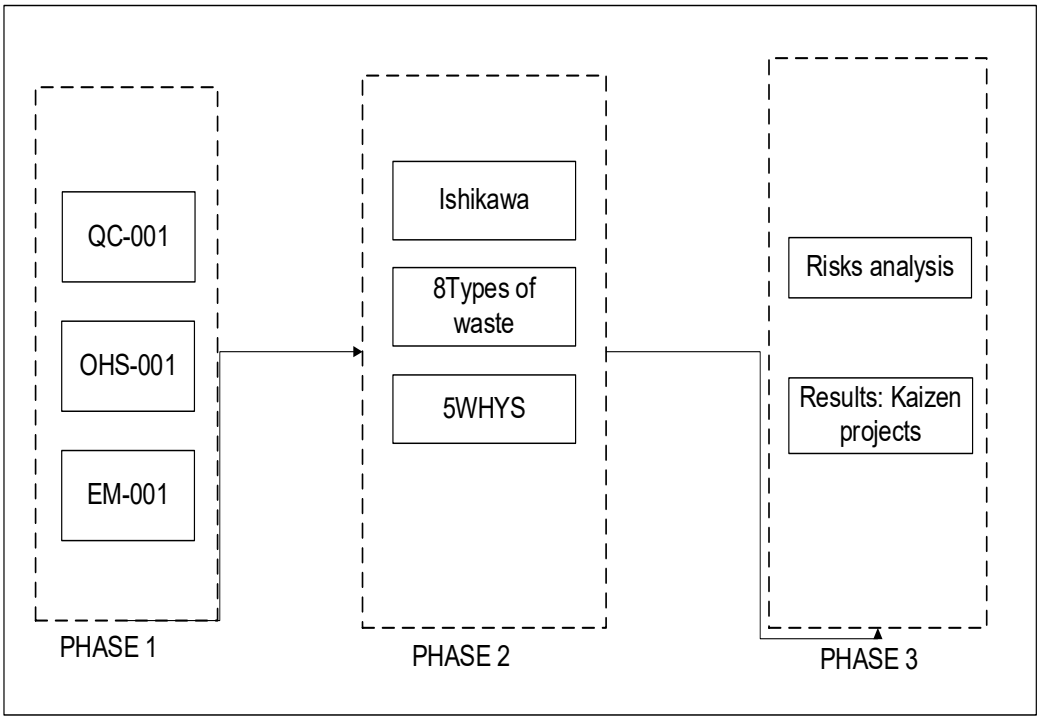


Figure 1. An illustration of the current existing IMS troubleshooting model
Source: [Author]

5. Findings from current existing models

The Occupational Health and Safety standards encompass both safer work conditions and a high productivity rate. In this review it has been evaluated that Occupational Health and Safety standards with Ergonomics share the same goals. The lean techniques act as a catalyst of optimizing both Occupational Health and Safety standards as well as Ergonomics. An opportunity of combining Ergonomics with problem solving techniques to eliminate safety incidents, improve quality of products, reduce cost and increase employee morale has been identified in this review since the current Ergonomics and safety models are modelled separately from troubleshooting systems which include Integrated Management System.

On this review it has been evaluated that most of the Ergonomical studies are conducted using lean manufacturing or by combining the Occupational Health and Safety standards. An integrated Management Systems basics are composed of Environmental, Quality and Safety standards which requires one to identify an opportunity to the problem that has occurred (Moso and Olanrewaju 2024), hence this study seeks to improve the accuracy of troubleshooting techniques by integrating Ergonomics with a non-conformance troubleshooting model. It has been evaluated that even though there are troubleshooting models that have been developed to enhance problem solving techniques when the processes are nonconforming either quality or safety wise, there is still a gap in the accuracy of resolving safety incidents. Therefore, the gap of an integrated troubleshooting model including safety injuries investigation incorporated with Ergonomics study, quality defects investigation as well as Process engineering breakdowns to predict future kaizen projects have been identified. It has also been proven on this review that Ergonomics complements Occupational Health and Safety goals, this research seeks to integrate an existing nonconformance troubleshooting model with Ergonomics analysis.

6. Comparison and discussion

The proposed model is composed of Quality Assurance systems, Occupational Health and Safety systems, Engineering Maintenance systems as well as Ergonomics analysis for the accuracy of kaizen future projects which results in more opportunities of growth within the organization. The ergonomics analysis decision is verified from the second phase which is the Ishikawa analysis within the three elements which is the Man, Method and Machine. Man represent huma error which might result from fatigue and stress, Method refers to the process methodology, Machine refers to the

equipment analysis. All these three elements if they could be potential reasons from the root cause, according to the proposed model ergonomics analysis is performed. Figure 2 is a diagram illustrating the proposed model where the additional analysis is circled. The figure illustrates a four-phase structured problem-solving and continuous improvement framework used to identify, analyse, and address operational challenges in a production or packaging environment. Phase 1 focuses on problem identification and compliance review through quality control, occupational health and safety, and environmental management systems. This phase highlights issues such as incorrect product counts, poor package appearance, high scrap rates, employee fatigue, back pain, and material waste, ensuring that the problem is clearly defined and aligned with quality, safety, and environmental requirements.

Phase 2 applies root cause analysis using the Ishikawa (fishbone) diagram, categorizing potential causes under the 6M framework: man, method, machine, measurement, material, and environment. This approach captures human factors such as fatigue and reduced concentration, procedural inconsistencies, lack of automation, inaccurate counting methods, material sensitivity, and unsuitable workplace conditions. Phase 3 then builds on these findings by incorporating ergonomics, the eight types of waste, and the 5 Whys technique to identify inefficiencies and deeper causes related to process flow, human limitations, and unnecessary waste, strengthening the case for automation.

Phase 4 focuses on risk analysis and continuous improvement through Kaizen initiatives. The risks of continuing manual packing such as increased injuries, quality defects, and financial losses, are evaluated, leading to practical improvement actions including automated counting and packing, ergonomic workstation design, standardized methods, and temperature-controlled handling. Overall, the framework demonstrates a logical progression from problem identification to root cause analysis and sustainable improvement, supporting the transition from manual to automated secondary packaging while improving efficiency, accuracy, worker well-being, and product quality.

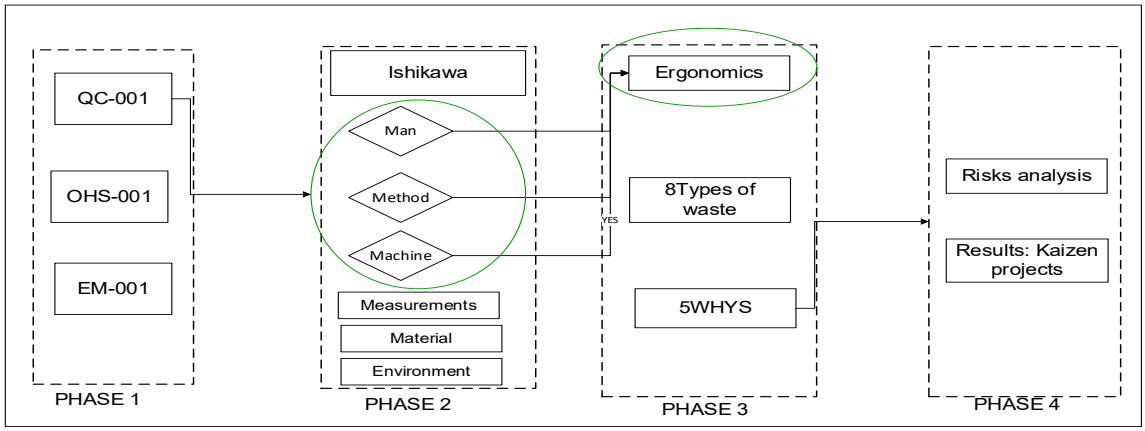


Figure 2. An Illustration of the Proposed Model

The difference between the current and proposed model is the additional Ergonomics analysis. The current model is only focused on lean technique analysis for kaizen projects prediction; the proposed model seeks to improve the accuracy of problem solving as well as the improvement of the project's prediction related to the process enhancement. The proposed Ergonomics analysis is performed on the second phase of the proposed model which depends on the nature of the problem. Figure 3 is an illustration of the comparison between the current and the proposed model.

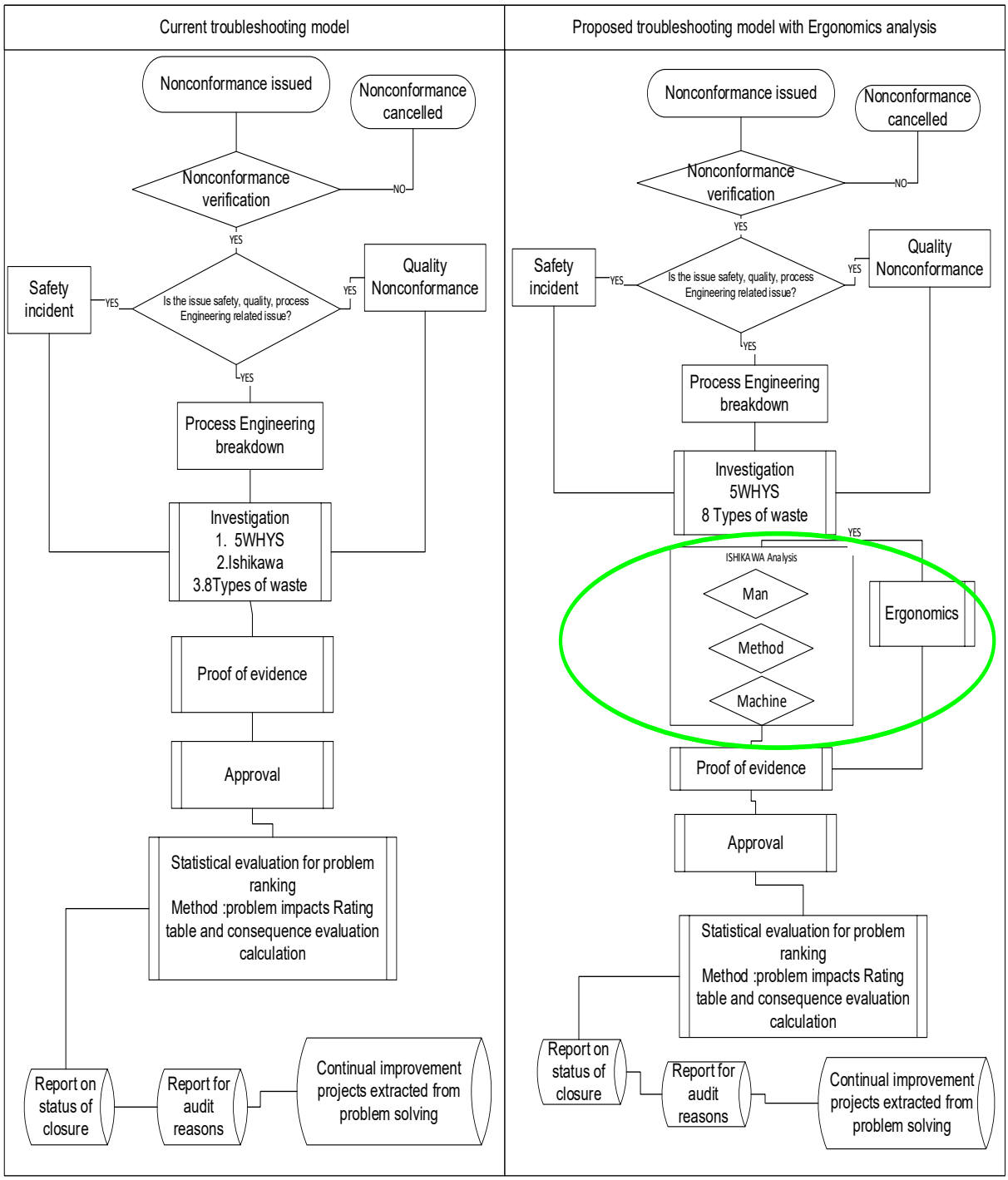


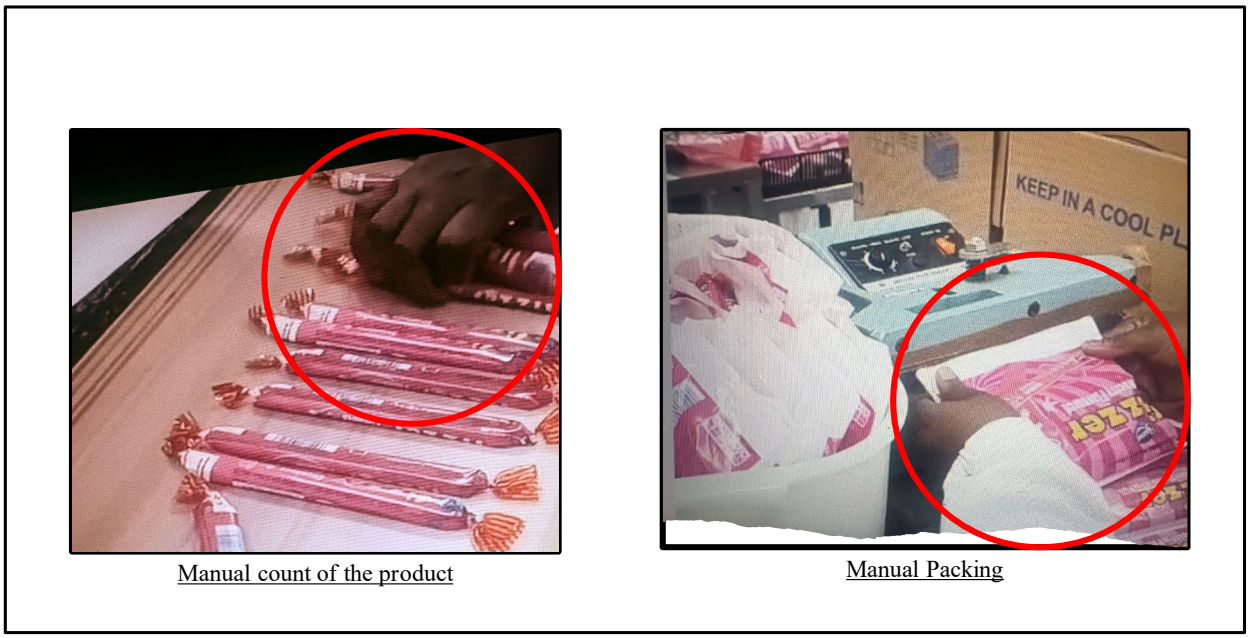
Figure 3. An illustration of the difference between the current and the proposed model

Application of the proposed model

Background of the case study company and problem statement

With the increasing demand for confectionery products, efficient and reliable packaging solutions are critical for maintaining productivity, product quality, and market competitiveness. Currently, individually wrapped toffee products are manually packed into bags and sealed at the candy factory. This manual process has resulted in several operational challenges, including frequent miscounting of products, inconsistent packing methods, and a high scrap rate caused by poorly shaped or unattractive final packages.

Employees involved in the manual packing operation are required to work long shifts, leading to complaints of back pain, physical fatigue, and reduced concentration. These ergonomic and cognitive challenges contribute directly to incorrect product counts, improperly packed toffee, and increased material waste. Additionally, variations in individual packing techniques result in inconsistent bag shapes and appearances, which negatively affect product presentation and overall brand image. Below on Figure 4 is an illustration of the product manual packaging, where the operators count the product manually, pack and seal it manually.



Manual count of the product

Manual Packing

Figure 4. An illustration of the manual packaging of the product
Source: [Case study company]

The proposed model was applied to evaluate the cause of defects, the miscount and different shape packaging of the product as well as employee fatigue. The fault as logged and found to be a quality related issue due to customer complaint of inconsistent packaging, some product were find extra some lesser. The Ishikawa analysis was performed and it was found that the problem was Man,Method and Machine. The Man problem results from the fatigue due to inger hours and fully manual process,The Method problem related to the lack of adequate procedure due to the absence of proper tools and the Machine problem resulted from the lack of portable tools to work. The next step was Ergonomics analysis which resulted to arm joint high movement frequency which causes pain and cramps as well as the back pain. The 8types of waste identify motion and defect as the main waste on the process, Finally, the kaizen projects that were proposed was the re-designing of the conveyor feeding the product with sensors for quality assurance as well as scale for proper count of the product and automated sealer.

To address these challenges, the candy factory requires the design and development of an automated secondary packaging solution for toffee. The proposed system aims to replace manual packing by accurately counting, grouping, and packing individually wrapped toffee products consistently and efficiently. The machine must gently handle the toffee to prevent deformation, incorporate temperature control to avoid melting during operation, and integrate seamlessly with the existing primary packaging process. The scope of this project includes a comprehensive process design supported by a literature review, mechanical drawings, and detailed safety and cost analyses. Figures 5 and 6 illustrate applications of the proposed model.

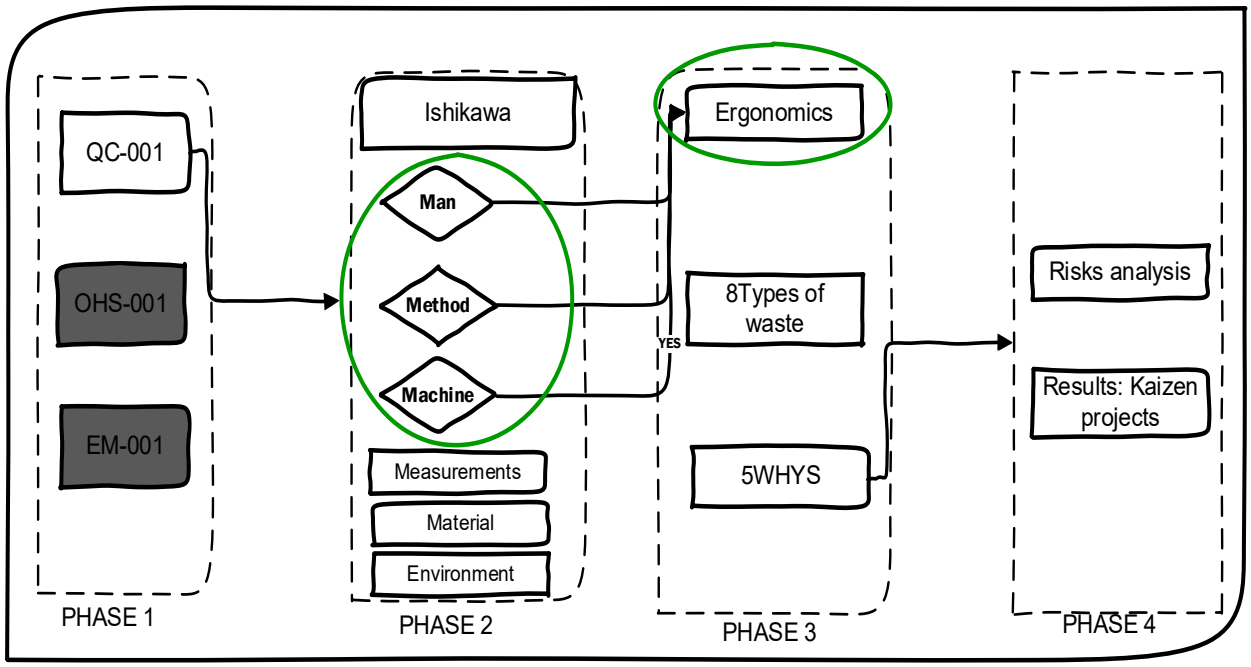


Figure 5. An illustration an overview of an application of the proposed model (application 1)
Source: [Author]

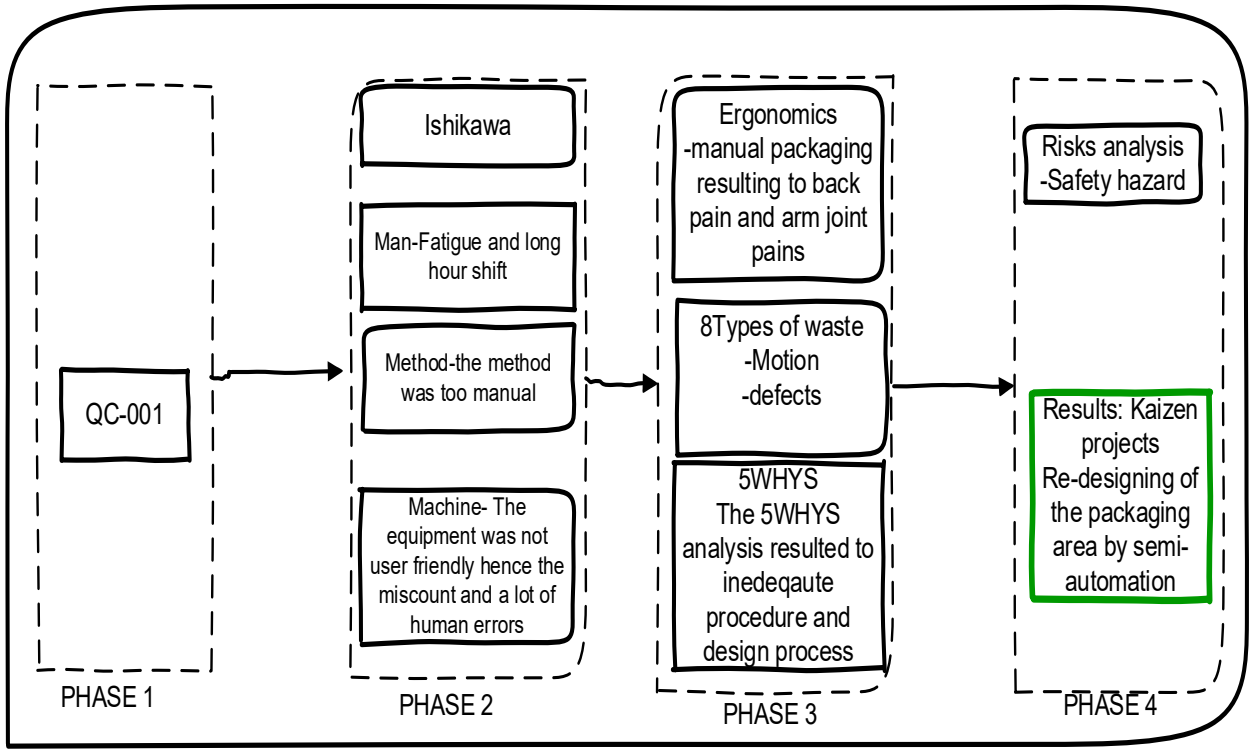


Figure 6. An illustration an overview of an application of the proposed model (application 2)
Source: [Author]

7. Recommendations and conclusion

The existing model did not include Ergonomics study which also enhances Occupational Health and Safety systems problem solving and the additional Ergonomics analysis on the proposed model will also assist in avoiding the implementation and design of the machinery that could potentially increase safety injuries hence the accuracy of selecting the optimal machinery design and process layout. For future upgrade of the existing troubleshooting models, one would recommend the environment analysis underneath Ishikawa analysis to enlarge Ergonomics scope, not to focus only on physical Ergonomics which enhances machinery, processes as well as work instruction but to also evaluate environmental suitability which is the noise level as well as the temperature or any other environmental aspect.

Lean manufacturing focuses on optimizing systems by eliminating non-value adding elements which result in good quality products, cost reduction, safer work conditions and employees moral increase hence a profitable organization (Hadi et al 2023). Ergonomics study focuses on improving work conditions by studying the human body and other factors that affects the well-being of an employee which results to safer work conditions , therefore one can conclude that Ergonomics study and lean manufacturing both focuses on improving work conditions. Below is the review on the integration of lean manufacturing with Ergonomics study for process improvements.

The aim for physical Ergonomics study is operational excellence by ensuring employees well-being during operations. Physical Ergonomics study assists in simplifying the machine and process design in a way that best suits the operator, hence high productivity rate, zero safety incidents and good Quality products (Andriyani et al. 2024).This research focuses on improving an existing troubleshooting model by integrating Lean Manufacturing with Ergonomics analysis which once can conclude that, an application of the proposed model could potentially results to drastic improvements on Occupational Health and Safety. The proposed model also enhances Quality assurance systems as well as Engineering Maintenance Systems.

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Biography

Dr. Matshidiso Moso is a lecturer and researcher in the Department of Industrial Engineering at the Durban University of Technology (DUT), Faculty of Engineering and the Built Environment. She holds a Doctor of Engineering (PhD) in Industrial Engineering, a master's degree, a BTech, and a National Diploma in Industrial Engineering. She is a registered member of the Engineering Council of South Africa (ECSA) and the Southern African Institute for Industrial Engineering (SAIIE).cShe is committed to advancing engineering education and developing sustainable, high-performing industrial systems in South Africa and beyond. Dr. Moso has extensive industry experience in the automotive, food manufacturing, electronics, and chemical sectors, where she has applied advanced industrial engineering tools in real operational environments.cHer research focuses on improving operational performance through lean manufacturing, Total Productive Maintenance (TPM), and kaizen-based continuous improvement. She integrates these approaches with sustainability and circular-economy frameworks to develop models aligned with the United Nations Sustainable Development Goals (SDGs). Her work supports organizations in improving efficiency while strengthening environmental responsibility.cA key focus of her research is addressing climate change through the application of lean principles, TPM strategies, and kaizen methodologies to optimize industrial systems. Using tools such as value stream mapping, Ishikawa, 5S, and A3 problem-solving, she works to eliminate waste, improve resource utilization, and enhance operational resilience, contributing to cleaner production and reduced greenhouse gas emissions.cBeyond research and teaching, Dr. Moso is dedicated to mentoring future engineers, particularly young women, and promoting international collaboration to advance sustainable, lean-based industrial innovation.