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APPLICATION OF KARAKURI KAIZEN TO IMPROVE EFFICIENCY AND REDUCE WASTE IN THE PRODUCTION AREA

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Abstract

Competition in the manufacturing industry encourages companies to improve efficiency, productivity, and the smoothness of material flow. This study aims to analyze the implementation of Karakuri Kaizen in reducing waste in the material handling process on the die casting production line of PT AXZ. The material used to develop this article was taken from a thesis document containing the background, theoretical basis, methods, observation results, line balancing, a comparison of touching before and after improvement, and the bibliography. The research method used an applied approach with a quantitative descriptive design through field observation, interviews, documentation, literature study, work-time measurement, and before-after analysis. The results show that layout improvement and the use of the Karakuri Kaizen mechanism were able to reduce transportation and motion waste. The number of touches decreased from 17 times to 7 times, material handling cycle time became approximately 1 minute faster, CT irregular MP lastman improved by about 0.7 seconds, and manpower requirements were reduced from 4 operators to 3 operators. Line efficiency remained in a safe condition at 84.5% because the 60-second cycle time was still below the 71-second takt time. Thus, Karakuri Kaizen effectively supports a leaner, more ergonomic, and more productive production process without increasing electrical energy consumption.

Keywords: Efficiency, Karakuri Kaizen, Lean Manufacturing, Material Handling, Waste.

INTRODUCTION

The development of the global manufacturing industry shows increasingly rapid dynamics along with technological advances, greater product variety, and customer demands for quality and delivery accuracy. In such a competitive environment, companies cannot rely only on machine capacity; they must also build production systems that can move materials quickly, safely, and stably. The automotive industry is one sector that experiences this pressure because any delay in material flow can affect daily output, line target achievement, and production costs. Therefore, process efficiency, waste control, and continuous improvement have become strategic needs for manufacturing companies.

The concepts of Lean Manufacturing and the Toyota Production System place waste reduction as a main principle in production management. Waste does not always appear in the form of defective products; it may also appear as waiting time, excessive motion, unnecessary material movement, inventory accumulation, repeated processes, and unbalanced labor utilization. In the production area, waste is often hidden in activities that are considered routine, such as taking empty boxes, lifting boxes filled with parts, moving trolleys, transferring finished goods to the store, and returning to the line area. If these activities are repeated throughout a shift, the accumulated lost time and operator fatigue become significant.

In modern production systems, material handling is a factor that strongly determines process smoothness. Ineffective material handling increases travel distance, lengthens conveying time, and raises the potential for motion waste. This condition is particularly important on die casting lines because the production process runs with a relatively short cycle time and requires a stable flow of parts from the machine to the next area. When the flow of finished goods from the line to the store is not designed efficiently, operators must perform many touches, lift boxes manually, and rearrange material positions. These activities do not provide direct added value to the product and therefore need to be reduced.

Karakuri Kaizen is one relevant approach for addressing these problems. Karakuri Kaizen is a form of low-cost automation that uses simple mechanisms such as gravity, levers, springs, wheels, and manual mechanical designs to make operators' work easier. Unlike expensive electrical automation or control systems, Karakuri Kaizen emphasizes simple designs that are easy to maintain, safe to use, and energy efficient. This approach is consistent with the Kaizen principle because it starts from real problems in the workplace and emphasizes gradual improvements that can be felt directly by operators.

Based on research material from the die casting line of PT AXZ, the main problem was found in the activity of transferring finished goods from the line to the store. This activity was selected because it has a high frequency of contact, involves lifting and sliding boxes, and requires operators to travel a considerable distance. The identified problems include excessive conveying time, a less-than-optimal work-area layout, transportation and motion waste, material-flow visualization that does not fully support low lead time, and the potential decline of operator productivity due to non-value-added activities.

The problem formulation in this article is directed at three issues: how Karakuri Kaizen is implemented in the production process, how it affects material handling efficiency, and whether its implementation can improve operator productivity. The objectives of the study are to analyze the implementation of Karakuri Kaizen on the die casting line, determine its effect on waste reduction, and assess its impact on the smoothness of the material handling process. Within these boundaries, the discussion focuses on the die casting area, especially the material conveying process from the line to the finished goods store.

This article is important because it offers an example of improvement that does not depend on high-technology investment. Many companies assume that efficiency improvements must be achieved through full automation, whereas a number of wastes can be reduced through layout changes, standard work, and simple supporting tools. Karakuri Kaizen provides a more economical alternative because it does not increase electricity consumption, does not require a complicated control system, and can be adjusted to operators' needs. Practically, the results of this study can serve as input for companies in improving material flow. Academically, this article strengthens the study of Lean Manufacturing in material handling activities in the automotive industry.

LITERATURE REVIEW

Lean Manufacturing and the Toyota Production System

Lean Manufacturing is a production management approach that aims to create added value for customers by using the minimum possible resources. The main focus of lean is to identify value-added activities and reduce non-value-added activities. Womack, Jones, and Roos (1990) emphasize that the transformation of the modern automotive industry is influenced not only by technology but also by how companies manage workflow, quality, time, and human involvement. In this context, lean is not merely a collection of tools, but a thinking system for making processes flow more smoothly.

Lean principles include value, value stream, flow, pull system, and continuous improvement. Value relates to what customers truly need. Value stream is used to map the entire process from raw materials until the product reaches the customer. Flow emphasizes process smoothness without obstacles or material accumulation. A pull system directs production based on demand so that overproduction can be reduced. Meanwhile, continuous improvement, or Kaizen, ensures that improvement does not stop at one project but becomes a daily work culture.

The Toyota Production System (TPS) is an important foundation for the development of lean. Ohno (1988) explains that TPS rests on two main pillars, namely Just In Time and Jidoka. Just In Time directs companies to make the required product, at the required time, and in the required quantity. Jidoka emphasizes automation with a human touch, namely the ability of a system to stop the process when an abnormality occurs so that quality can be controlled at its source. Liker (2004) also emphasizes that the success of TPS lies not only in production tools, but also in long-term philosophy, human development, and organizational learning.

In material handling practice, TPS principles are relevant because every process must flow according to takt time. Takt time is the available time reference for meeting customer demand. If cycle time is smaller than takt time, the line can still meet demand. However, if manual handling and material movement activities are too long, the line may experience imbalance, operators may wait, or the next process may lack material. Therefore, measuring cycle time, machine time, manual process time, and operator workload is an important part of efficiency evaluation.

Waste, Kaizen, and Karakuri Kaizen

Waste refers to all activities that use time, energy, cost, space, or other resources but do not add value to the product. In lean, the seven main wastes include overproduction, waiting, transportation, overprocessing, inventory, motion, and defects. In this study, the most dominant wastes are transportation waste and motion waste. Transportation waste occurs when material must move too far or through an inefficient route. Motion waste occurs when operators must move, lift, bend, slide, or search for tools excessively. These two wastes may not appear large in a single cycle, but they have a significant impact when repeated.

Kaizen is continuous improvement carried out gradually by involving all elements of the organization. Imai (1986) positions Kaizen as a key to competitiveness because improvement does not have to wait for a large project, but can begin with small changes in the work area. In its implementation, Kaizen requires the ability to observe the actual process, listen to operator experience, measure conditions before improvement, design solutions, and evaluate results. Kaizen also emphasizes that the best solutions are often found at the gemba, or the actual workplace.

Karakuri Kaizen is the application of Kaizen based on simple mechanisms or low-cost automation. Yamazaki (2020) explains that Karakuri Kaizen uses natural energy or manual mechanisms, such as gravity, levers, springs, weights, inclined rails, wheels, and simple locks. Its purpose is not to replace humans completely, but to help operators avoid heavy and repetitive movements. With the right supporting tool, the material transfer process can become safer, faster, and more ergonomic.

The advantage of Karakuri Kaizen lies in its simplicity. This system is relatively inexpensive, easy to make, modifiable, does not require additional electrical consumption, and encourages worker creativity. In production areas with product variety and limited space, Karakuri Kaizen can be a more flexible option than full automation. However, Karakuri design must still consider safety, material stability, ease of maintenance, and compatibility with the production layout. Without good design, a supporting tool may instead create new obstacles.

Material Handling, Productivity, and Efficiency

Material handling relates to the movement, storage, control, and protection of materials during the production process. Tompkins et al. (2010) emphasize that good facility planning must consider travel distance, movement frequency, material weight, operator safety, and relationships between workstations. An improper layout causes operators to travel longer distances and repeat the same activities. In the die casting context, an effective layout should bring the empty-box pickup point, buffer area, finished goods transfer route, and store closer together so that material flow becomes shorter.

Productivity shows the ratio between the output produced and the input used. Sinungan (2018) and Hasibuan (2016) explain that productivity is influenced not only by labor but also by work methods, facilities, discipline, and management systems. Efficiency shows the ability of a process to produce optimal output with minimum resource use. In this study, productivity improvement is viewed from the reduction of manual handling activities, the decrease in touches, the acceleration of material handling cycle time, and the reduction of manpower requirements without reducing the line's ability to meet production targets.

Previous studies on Lean Manufacturing and the Toyota Production System show that improving process flow can reduce waste and increase efficiency. Maulidin (2025) emphasizes the importance of waste reduction to improve production efficiency, while Rahman and Hidayat (2021) show that TPS helps manufacturing companies control production flow. Based on this literature, this study strengthens the evidence that lean principles can be translated into simple improvements through Karakuri Kaizen, especially in the activity of transferring finished goods from the line to the store.

Principles of Karakuri Design in the Production Area

Karakuri design in the production area must begin with an understanding of the actual problem, not by immediately making a tool. In material handling cases, the problems that need to be examined include material position, flow direction, operator working height, empty-box pickup frequency, material load, and the possibility of material becoming stuck during transfer. This principle is important because a good supporting tool must eliminate unnecessary work, not merely move the burden from one point to another. In other words, Karakuri design must be part of process improvement, not merely an additional facility in the work area. Within the Toyota Production System framework, Karakuri design must support one-way flow, reduce waiting time, and help operators maintain a work rhythm according to takt time. If a supporting tool makes operators wait longer or adds new steps, then the tool cannot yet be called an improvement. Therefore, before making a tool, the team needs to compare the before condition and the target condition. The before condition shows the actual activities that create waste, whereas the target condition describes the desired material flow after non-value-added activities are reduced. Safety is also a primary consideration in Karakuri Kaizen. Mechanisms that use gravity, rails, wheels, or springs must ensure that materials do not slide too quickly, do not fall easily, and do not create pinch points for operators. In addition, the tool must be easy to stop and easy to inspect. Simple maintenance is an important requirement because the goal of Karakuri is not to create a complicated system, but to create a supporting tool that can be used consistently by production operators without high dependence on technicians.

Good Karakuri must also consider ergonomic principles. In the finished goods transfer process, lifting and sliding boxes are sources of fatigue that need to be reduced. The supporting tool design should maintain a comfortable working height, reduce the need to bend, reduce body twisting, and minimize excessive pushing. Thus, efficiency does not only mean time reduction, but also the reduction of operators' physical workload. Efficiency that ignores ergonomics risks being unsustainable because operators will continue to experience fatigue.

In addition to the tool, material-flow visualization needs to be clarified. Trolley routes, empty-box locations, finished goods positions, and buffer areas must be marked clearly and easy to understand. Visual management helps operators maintain standard work after improvement has been implemented. If visualization is unclear, operators may return to old routes or place materials in inappropriate positions, causing waste to reappear. Therefore, the success of Karakuri Kaizen requires a combination of mechanical design, layout, visual management, and standard work. Karakuri design also needs to consider flexibility. Die casting production lines may handle part variations and changes in demand. Supporting tools that are too specific may be difficult to use when there are changes in model or box size. Therefore, the design must allow simple adjustments, such as stopper settings, track width, or support position. This flexibility keeps Karakuri useful in the long term and prevents it from quickly becoming unused equipment.

Table 1. Summary of Previous Studies

Researcher/Source	Study Focus	Contribution to the Study
Womack, Jones, & Roos (1990)	Lean Manufacturing and transformation of the automotive industry	Provides the basis that process efficiency and waste reduction are key to manufacturing competitiveness.
Ohno (1988) and Liker (2004)	Toyota Production System, JIT, Jidoka, and process flow	Provides a framework for assessing cycle time, takt time, bottlenecks, and production process balance.
Imai (1986)	Kaizen as continuous improvement	Provides the basis for gradual improvement involving operators and starting from actual conditions in the work area.
Yamazaki (2020)	Karakuri Kaizen and low-cost automation	Provides the basis for designing simple mechanical supporting tools without electrical energy.
Maulidin (2025); Rahman & Hidayat (2021)	Waste reduction and TPS implementation in manufacturing	Confirms that waste reduction can improve production process efficiency and productivity.

METHOD

This study uses applied research with a quantitative descriptive approach. Applied research was selected because its main objective is to solve real problems in the production area, especially the conveying process on the die casting line. The quantitative descriptive approach was used because the analysis describes the actual condition of the production process using numerical data, such as processing time, number of touches, cycle time, takt time, operator workload, and manpower requirements. With this approach, the impact of Karakuri Kaizen can be measured through a comparison of conditions before and after improvement. The research was conducted at PT AXZ, located in the KIIC Karawang area. The company manufactures automotive components and applies Lean Manufacturing and Toyota Production System principles in its operations. The research period ran from August to September 2025 and included field observation, data collection, work-time measurement, process analysis, improvement design, and report preparation. The research object was the material conveying process on the die casting line toward the finished goods store, especially the finished goods transfer flow from the line to the store.

Data collection techniques included field observation, interviews, documentation, and literature study. Observation was carried out by directly observing operator activities, material movement routes, trolley use, box lifting, and the finished goods transfer process. Interviews were conducted with operators, technicians, and supervisors to obtain information about work constraints and process habits. Documentation was used to collect production-area layouts, cycle-time records, efficiency data, and material-flow visuals. Literature study was conducted to strengthen the theoretical basis concerning lean, TPS, waste, Karakuri Kaizen, material handling, productivity, and efficiency.

Data analysis was conducted through several stages. First, initial-condition data were collected and mapped to identify material flow and non-value-added activities. Second, types of waste were identified with a focus on transportation waste and motion waste. Third, data on touching, cycle time, and operator workload were compared with process targets. Fourth, the Karakuri Kaizen design and layout changes were prepared to reduce lifting, sliding, and operator movement activities. Fifth, the improvement results were evaluated through before-after comparisons of touching, cycle time, manpower, and line efficiency indicators.

Table 2. Research Stages

Stage	**Activity**	**Output**
1	Problem identification in the material handling process of the die casting line	The main types of waste are identified, especially transportation and motion.
2	Mapping of material flow, layout, and operator activities	Movement routes, touch points, and non-value-added activities are identified.
3	Work-time measurement and line-balancing analysis	Data on cycle time, manual process, machine time, takt time, and operator workload are obtained.
4	Design of Karakuri Kaizen and layout changes	A simple mechanical supporting-tool design and work-area rearrangement are produced.
5	Before-after evaluation	The impact of improvement on touching, cycle time, manpower, and line efficiency is assessed.

Table 3. Data Analysis Indicators

Indicator	**Operational Definition**	**Data Source**
Touching	The number of touches or material transfer activities performed by operators in one process cycle.	Process observation and before-after records.
Cycle time	The process cycle time required by the line or material handling activity to complete the work.	Work-time measurement and DC005 line data.
Takt time	The time available to produce products according to customer demand.	Company production target data.
Manpower	The number of operators required to carry out material handling and supporting processes.	Line-balancing observation and workload evaluation.
Line efficiency	The comparison of cycle time with takt time to assess the line's ability to meet demand.	Results of efficiency calculation analysis.

RESULTS AND DISCUSSION

Initial Condition of the Material Handling Process

The observation results show that PT AXZ has implemented the concepts of Lean Manufacturing and the Toyota Production System, but there are still opportunities for improvement in operators' daily activities. The main problem is not product defects, but material flow and repetitive manual handling activities. On the die casting line, the process of transferring finished goods from the line to the store requires several steps, starting from taking the cart, bringing empty boxes to the chute in line, picking up finished goods, bringing them to the store, transferring finished goods, taking empty boxes, returning to the line, and parking the cart. This sequence causes operators to perform many touches in one cycle. The initial analysis also shows that there are three main transportation activities in the DC-DS area, namely transferring ingots to the melting furnace, supplying molten metal to the DCM, and transferring finished goods from the line to the store. Of these three activities, finished goods transfer from the line to the store was selected as the improvement focus because it has a high touch frequency, requires box-lifting movements, and involves operator travel over a considerable distance. This focus is consistent with the lean principle of improving areas that directly influence lead time and operator workload.

In the initial condition, operators still moved parts from the conveyor to trimming, filled parts into boxes, supplied empty boxes to the chute in line, picked up finished goods, and transferred finished goods to the store. The total touching before improvement reached 17 times. This number shows that materials experienced many contacts and movements before arriving at the store. The more touches there are, the greater the potential for lost time, irregular flow, operator fatigue, and errors in material placement. From the line-balancing perspective, the initial data show that workload among operators was not yet fully even. Operator MH1 had a workload of about 5.95 seconds/minute, MH2 about 5.91 seconds/minute, MH3 about 5.09 seconds/minute, and MH4 about 4.39 seconds/minute, while the target line was around 7 seconds/minute. Although all workloads were still below the target, this distribution shows that MH1 and MH2 were higher than MH4. This imbalance became an opportunity to rearrange activities so that manpower requirements could become more efficient.

On line DC005, the line cycle time was 60 seconds, manual process time was 58 seconds, machine time was 60 seconds, and takt time was 71 seconds. The efficiency calculation showed a value of about 84.5%. This value indicates that the line was still in a safe condition because cycle time was lower than takt time, so the line could meet customer demand without overtime. However, analysis of manual process time and machine time showed that the machine was the bottleneck because the 60-second machine time was greater than the 58-second manual process time. Operators had idle time of about 2 seconds per cycle while waiting for the machine.

Table 4. Initial Condition Data of the Die Casting Line

Analysis Component	**Value/Condition**	**Meaning**
Cycle time of line DC005	60 seconds	The actual line cycle time is still lower than takt time.
Manual process (MP)	58 seconds	Operator manual work time in one process cycle.
Machine time (MC)	60 seconds	The machine determines line speed because it is greater than MP.
Takt time	71 seconds	The available time limit for meeting customer demand.
Line efficiency	84.5%	The line condition is safe, but there is still an opportunity to reduce waste.
Operator idle time	2 seconds/cycle	Operators wait for the machine because MC is greater than MP.

Karakuri Kaizen Design and Layout Changes

Improvement was carried out through Karakuri Kaizen design and rearrangement of the production-area layout. The Karakuri design was directed at eliminating or reducing manual box-lifting activities, shortening movement routes, and stabilizing material flow from the line to the store. The main principle used was the utilization of simple mechanisms without electrical energy so that the supporting tool could be operated easily by operators. The design also considered safety, ease of maintenance, and suitability with the available workspace.

The target Material and Information Flow Chart for part OPN D72F was used to map the desired material-flow condition. The target condition emphasized the reduction of non-value-added activities, especially the manual box-lifting process. Through this mapping, areas that became sources of waste could be seen more clearly. Improvement did not focus only on the supporting tool, but also on the relationship among the empty-box pickup point, the chute-in-line position, the finished goods store area, the operator route, and the buffer. If these points are arranged more closely and logically, operators do not need to travel long distances.

Layout changes were made by rearranging the positions of trolleys, buffers, inspection areas, and operator movement routes. In the before layout, material flow was not yet fully short, so operators still performed lifting and sliding movements at several points. In the after layout, the transfer route was made more compact so that operators could perform pickup, arrangement, and transfer activities with fewer actions. This layout rearrangement is important because Karakuri Kaizen will only be effective if it is supported by a clear process flow with minimal obstacles.

The Karakuri design was also directed at reducing irregular motion by the lastman. In practice, operators are influenced not only by the main cycle time, but also by additional activities such as tidying box positions, sliding materials during transfer, and adjusting trolleys. These additional activities are often not recorded as core work, but they affect fatigue and process time. With a simple mechanical supporting tool, the box-lifting process can be eliminated and box-sliding movement during finished goods transfer to the store can be reduced.

Table 5. Comparison of Touching Before and After Improvement

Activity	Before Improvement	After/Plan	Impact
Moving parts from conveyor to trimming	1 time	1 time	The activity remains, but the next flow becomes more compact.
Filling parts into boxes	1 time per box	Parts are arranged directly in boxes/pallets	Arrangement becomes more directed and reduces further movement.
Supplying empty boxes to the chute in line	6 times	3 times	Supply frequency decreases because the flow arrangement is better.
Picking up finished goods	6 times	1 time	Finished goods pickup becomes simpler.
Transferring finished goods to the store	3 times	1 time	Transfer becomes shorter and reduces box-sliding motion.
Total touching	17 times	7 times	Reduced by 10 touches, or approximately 58.8%.

Impact on Efficiency, Waste, and Productivity

The implementation of Karakuri Kaizen showed a positive impact on waste reduction. The number of touches decreased from 17 times to 7 times, or by 10 touches. This decrease is important because touching is directly related to motion waste and transportation waste. Each additional touch means that operators must perform activities that do not add direct value to the product. With reduced touching, material flow becomes simpler, the risk of operator fatigue decreases, and transfer time becomes more controlled. Improvement also affected material handling cycle time. Based on the evaluation results, CT irregular MP lastman became about 0.7 seconds faster, while material handling cycle time became about 1 minute faster than before. This acceleration shows that simple changes to supporting tools and layout can have a real impact. Although the initial line efficiency was already in a safe condition, reducing material handling time still has value because it helps stabilize the process, reduce the potential for delays, and increase operator flexibility.

From the manpower perspective, the improvement enabled workload to be rebalanced so that the number of required operators decreased from 4 to 3 without disrupting production targets. In this context, manpower reduction does not merely mean reducing the number of workers, but allocating human resources more effectively. Operators who were previously tied to repetitive manual handling activities can be assigned to more value-added activities or to support other areas that need assistance. This shows that Karakuri Kaizen can support productivity through process simplification. Line efficiency remained in a safe condition because the 60-second cycle time was still lower than the 71-second takt time. This means that after improvement, the line could still meet customer demand. This condition shows that the improvement did not disrupt the production rhythm. On the contrary, layout changes and supporting tools supported process stability because activities that previously had the potential to create time variation were reduced. Stability is important in lean because a stable process is easier to control and easier to improve. The ergonomic impact is also an important finding. Manual box-lifting and box-sliding activities have the potential to cause fatigue, especially if they are repeated throughout a shift. Karakuri Kaizen helps eliminate box lifting for material handling and reduces box-sliding movements during finished goods transfer to the store. Thus, improvement is oriented not only toward efficiency figures, but also toward operator comfort and safety. Such ergonomic improvement can reduce the risk of work-related complaints and increase the consistency of operator performance.

From the lean perspective, the success of this improvement shows that waste can be reduced through a combination of field observation, flow mapping, time measurement, and the design of simple supporting tools. Karakuri Kaizen is not a stand-alone solution but part of an improvement system. If a tool is made without layout changes, operators may still need to travel long routes. If the layout is changed without supporting tools, some lifting and sliding activities may still occur. Therefore, the integration of Karakuri, the after layout, and standard work becomes a key factor. This improvement also shows the importance of involving operators in the improvement process. Operators understand details of movement, small obstacles, and work habits that are not always visible to management. In Kaizen, operator knowledge is an important input for designing solutions that can truly be used. Supporting tools that are too complicated or do not fit work habits are at risk of not being used consistently. Conversely, simple Karakuri that suits operators' needs is easier to accept because it directly reduces their workload.

The limitation of this study lies in the analysis focus, which remains dominant on time, touching, and manpower aspects. Investment cost analysis, payback analysis, and quantitative ergonomic measurement have not been discussed in depth. These aspects are important for strengthening managerial arguments. Future research can add cost-benefit analysis, posture assessment, physical workload measurement, and sustainability evaluation several months after Karakuri is used. In this way, the benefits of Karakuri Kaizen can be assessed more comprehensively.

Table 6. Summary of Karakuri Kaizen Improvement Results

Indicator	Before	After	Impact
Material handling touching	17 times	7 times	Reduced by 10 touches and lowered motion waste.
Material handling cycle time	Longer	Approximately 1 minute faster	Material flow becomes smoother and transfer time is more controlled.
CT irregular MP lastman	Slower	Approximately 0.7 seconds faster	Irregular activities are lower.
Manpower	4 operators	3 operators	Workload can be balanced and resources become more efficient.
Line efficiency	84.5%	Remains safe	Cycle time remains below takt time, so the production target is still met.
Box lifting/sliding activities	Still dominant	Reduced	Operators' work becomes more ergonomic and the risk of fatigue decreases.

Integrative Discussion of the Lean Concept

The research results can be explained through the value stream concept. In the initial condition, the flow of finished goods from the line to the store contained several activities that did not add value for customers. Customers do not pay for lifting boxes, moving trolleys, or repeating material transfers; customers only need quality products delivered on time. Therefore, every activity that does not support quality and delivery needs to be questioned. The reduction of touching from 17 to 7 shows that the value stream became leaner.

From the flow perspective, Karakuri Kaizen helps create a smoother material flow. Flow does not only mean that products move, but that they move without obstacles and without unnecessary transfer. In the before process, operators had to perform a series of movements such as picking up, carrying, sliding, and rearranging materials. After improvement, several of these activities were simplified so that the finished goods flow became shorter. A shorter flow makes the process easier to predict and easier to control.

From the pull-system perspective, the material handling process must follow the needs of the line and store. If empty boxes are not available on time or finished goods are transferred late, the next process may be disrupted. Karakuri helps maintain material availability by simplifying the flow of boxes and finished goods. Although this study does not specifically discuss kanban, the logic of pull remains visible because material transfer is directed according to process needs, rather than based on unplanned repeated movement.

From the Kaizen perspective, the success of this study shows that small improvements can produce meaningful operational impacts. The changes made did not replace the entire production system, but improved work points that caused waste. This is consistent with the Kaizen principle that gradual, inexpensive, and actual-problem-based changes are often easier to implement than large programs that require a long time. The successful reduction of touching proves that detailed observation of operator work is very important.

From the Jidoka perspective, Karakuri Kaizen not only helps transfer materials, but can also make the process more controlled. Supporting tools designed with stoppers, fixed tracks, and clear material positions can reduce variation in operator movement. When movement variation decreases, the potential for material-placement errors also decreases. Although Jidoka is usually associated with the ability to detect problems, the principle of process control from the source remains relevant in material handling design.

This improvement also shows the relationship between line balancing and material handling. Line balancing is often understood as equalizing operator workload in the main process, whereas supporting activities such as box and finished goods transfer also influence work balance. When some operators perform many additional activities, workload becomes uneven. With Karakuri, additional activities can be reduced so that manpower requirements become more efficient. This explains why material handling improvement can affect operator requirements.

Viewed from the sustainability aspect, Karakuri Kaizen has an advantage because it does not increase electrical energy consumption. Amid industrial needs to improve efficiency while controlling energy costs, simple mechanical supporting tools can be a more cost-friendly solution. The use of gravity and manual mechanisms allows companies to gain efficiency benefits without adding energy burdens. Therefore, Karakuri can be viewed as an improvement that supports both economic efficiency and resource efficiency.

However, long-term success still requires control. Companies need to conduct periodic audits of tool condition, operator compliance with standard work, and changes in production patterns. If production volume increases or part types change, the Karakuri design needs to be re-evaluated. Through periodic evaluation, companies can ensure that the improvement remains relevant and does not create new waste. This is important because lean is a continuous learning process, not a one-time project.

Table 7. Checklist for Sustainable Karakuri Kaizen Implementation

Aspect	**Evaluation Question**	**Follow-up Action**
Safety	Does the tool have a stopper, a safe route, and no pinch points?	Conduct routine inspections and repair worn components.
Ergonomics	Do operators still need to lift, bend, or slide boxes repeatedly?	Adjust working height, material position, and movement standards.
Material flow	Is the transfer route the shortest and does it avoid crossing other routes?	Improve the layout and route visualization if obstacles occur.
Standard work	Do all operators use the tool in the same way?	Prepare work instructions, training, and compliance audits.
Performance	Do touching, cycle time, and manpower remain on target?	Compare before-after data periodically.

Practical Implications

The practical implication of this study is that companies can use Karakuri Kaizen as a cost-efficient and quickly implementable improvement strategy. Companies do not always have to wait for automatic machine investment to improve material flow. As long as the problem can be clearly identified, simple mechanisms can be used to eliminate non-value-added activities. In the PT AXZ case, the reduction of touching from 17 to 7 shows that focusing on the details of daily activities can produce real results.

Companies also need to ensure that improvement results are maintained through work standardization. After the layout and supporting tools are implemented, operators need clear work instructions regarding how to use Karakuri, box positions, trolley flow, capacity limits, and safety procedures. Periodic evaluation is also required to ensure that the tool continues to function, does not create new obstacles, and remains suitable for product variation. Without standardization, the improvements already achieved may return to the old work pattern.

In addition, this approach can be replicated in other production areas with similar characteristics, such as material supply activities, empty-box pickup, component movement from one process to another, or finished goods transfer to the store. Replication should be carried out through gemba analysis, not by simply copying the tool design. Each area has different layouts, distances, material loads, and transfer frequencies. Therefore, the Karakuri principle may be the same, but the technical design needs to be adjusted to the actual conditions.

Technical Recommendations for Further Development

Further development needs to be directed toward more detailed measurement of costs and benefits. The company can calculate the cost of making Karakuri, maintenance costs, work-time savings, reduction in manpower requirements, and potential output increases. These data are important to show that simple improvements can provide clear economic value. With cost analysis, management can determine priorities for Karakuri replication in other areas more objectively. The company is also advised to add ergonomic measurements, for example using the Rapid Entire Body Assessment or Rapid Upper Limb Assessment methods. These measurements can show changes in posture risk before and after the tool is implemented. In this study, the ergonomic impact is explained through the reduction of box-lifting and box-sliding activities. With more formal ergonomic measurements, the benefits of Karakuri for operator occupational health can be demonstrated more strongly.

From the operational side, a simple control board should be created to display touching indicators, material handling cycle time, the number of tool disturbances, and abnormality records. This control board helps supervisors monitor whether the process continues to run according to standards. If transfer time increases or operators return to unnecessary manual movements, the cause can be analyzed immediately. This kind of visual control is consistent with lean culture because problems are made visible so they can be fixed quickly. From the human-resource side, operators need to be involved in evaluation activities after implementation. Operator input can be used to improve tool details, such as handle position, track inclination, stopper strength, or trolley parking location. Operator involvement makes improvement more accepted and encourages a Kaizen culture. When operators feel that the tool helps their work, compliance with standard work will be easier to maintain.

CONCLUSION

The implementation of Karakuri Kaizen on the die casting line of PT AXZ has proven able to improve production process efficiency and reduce waste in material handling activities. Improvement was carried out through layout changes, reduction of touching activities, and the use of simple mechanisms that support the material transfer process without electrical energy. The implementation results show a decrease in transportation and motion waste that previously appeared in the finished goods transfer process from the line to the store.

The number of touches was successfully reduced from 17 times to 7 times, making operators' manual handling activities fewer and more ergonomic. In addition, material handling cycle time became approximately 1 minute faster, CT irregular MP lastman improved by about 0.7 seconds, and manpower requirements were reduced from 4 operators to 3 operators. Line efficiency remained in a safe condition at 84.5% because the 60-second cycle time was still lower than the 71-second takt time. Thus, Karakuri Kaizen effectively supports a leaner, more ergonomic, productive, and energy-efficient production process.

The recommendation for the company is to conduct periodic evaluations of Karakuri Kaizen implementation, develop standard work for tool use, and consider applying similar concepts to other production areas that have high transportation and motion waste. Future research is recommended to add cost, ergonomic, occupational safety, and long-term productivity analyses so that the benefits of Karakuri Kaizen can be demonstrated more comprehensively.

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