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Integration of Lean Six Sigma and Ergonomics in Internal Logistics in the Supply Chain – A Systematic Literature

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Abstract. Today's most significant challenge facing the industry is delivering good quality products quickly, at the lowest possible cost, and flexibly in meeting demand. In terms of timing accuracy, companies must have good internal logistics, one of which is good warehouse management. Productivity in warehouses can be achieved by improving efficiency in warehouse operations, thus resulting in a faster response to customer requests. In improving productivity, it is necessary first to identify unexpected activity. This study demonstrates the importance of applying Lean Six Sigma (LSS) in Supply Chain Management (SCM), particularly internal logistics in the warehouse area, by linking the ergonomics principle with the systematic literature review approach. LSS and ergonomics are mutually complementary methodologies to meet the challenges of SCM in order to have a competitive advantage in business.

Keyword: Ergonomy, Lean, Logistic Internal, Six Sigma

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1. Introduction

The development of an increasingly competitive global industry indirectly demands that every industry can deliver products or services to meet customers' needs with accurate quality, delivery time, price, and flexibility in meeting market needs [1]. Increased productivity can directly impact customer satisfaction, reducing waiting times and costs [2]. Timing accuracy can be achieved if the company has good internal logistics, such as good warehouse management, as it will offer opportunities to reduce waiting time and logistics costs [3]. Productivity in warehouses can be achieved by increasing efficiency in warehouse operations, thus resulting in a faster response to customer demand [4]. Productivity is important by increasing the output produced by the company by saving input [5]. This can be done by managing waste or non-value-added activity (NVA) because the higher the waste, the level of return will also increase [6]. The biggest waste that causes delays in removing material is motion waste [7]. In general, the activities of warehouses are not independent of the human role in them, such as moving goods manually by

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arranging, raising, and placing goods in the desired place. To do so, we need to find a balance between system improvement and its employees' safety and motion principles. Waste motion arises due to ineffective movement, thereby reducing warehouse productivity. Apart from that, if you look at it from ergonomics, waste motion can cause problems such as the potential risk of MSD caused by repetitive movements such as pushing, bending when moving objects. This is the challenge of how to implement lean in a warehouse by considering ergonomics for the people working in it. The description is working smarter, not harder.

Through the concept of lean thinking, system improvements can be made by reducing lead time and increasing output by eliminating existing waste [7]–[9]. In practical application, companies fail to implement lean thinking in the social aspect of lean-to-human relationships. Companies focus more on techniques and tools toward lean but ignore the social aspects of lean [10]. The concept of ergonomics is an essential part of sustainable organization development [11]. Both concepts can run side by side to create a balance of productivity.

Previous research has explained the link between lean integration and ergonomics or Six Sigma integration. However, there must be more explanation for integrating lean Six Sigma (LSS) and Ergonomics in internal logistics, i.e., warehouses, to improve productivity in Supply Chain Management (SCM). This is the basis for this research to explain the role of lean, six sigma and ergonomic in internal logistics, especially in the warehouse. Discussions need to be made in responding to the challenge of SCM to continue to make continuous improvements in order to be able to compete in the global industry. The theoretical benefits are to add insight and knowledge of the relationship between LSS and ergonomics to improve the performance of SCM, especially in internal logistics. Integration between LSS and Ergonomics in SCM can respond to the challenge of the SCM because it incorporates the connection between the human element and its environment as the foundation of the application of flexible systems.

2. Research Methodology

This research aims to enhance our understanding of combining LSS with ergonomics by considering the advantages of each field of science and producing a framework. This framework can be useful for future research as a basis for the flow of thought in research. The method applied in compiling this research is applied by reading the entire text and then dividing it into sections that will be grouped again. The text sections marked as confirmed are facts or information considered essential and must be focused on to be discussed. The criteria for the main article to be made are searched through Google Scholar with the keywords "lean warehousing" and "lean ergonomic." Besides, the article has been published in the last 20 years to see the difference over the last two decades. From the search results, 68 articles were found that discussed lean warehousing or lean ergonomics, but only 29 articles were relevant. A total of 14 articles were selected to be displayed as previous studies. Articles already obtained using those keywords will be selected by reading the abstract and introductory sections. If felt to be in the topic of discussion, the article is selected and read the entire text.

3. Discussion

This section is divided into three sub-chapters: lean thinking, ergonomic thinking, and the integration of both.

3.1. Lean Thinking

Operations in warehouses play a key role in supply chain management as they relate to the delivery of goods to customers as well as ensuring product performance is met [12]. Warehouse activities such as receipt, storage, ordering, delivery, and docking must be done systematically and standardized to avoid long waiting times. The quality of the goods remains awake to meet demand accurately.

Waste in the warehouse includes delayed scanning, delayed movement, long loading time, and unnecessary movement during storage and order-picking activities [4]. In addition to the warehouse, waste also appears in production areas, such as defects, waiting, and unnecessary motion due to poor facility layout conditions [13]. To eliminate waste from the system requires a repair process that focuses on simplification, combination, and elimination to achieve the desired results. For this, it is necessary to detect the risk of waste arising as it is a preventive measure in preventing procedural errors that will subsequently affect the performance and profitability of the company [14].

Tran [15] and Baby [4] use Value Stream Mapping (VSM) to look at warehouse process flows and analyze layouts using ABC analysis so that they can propose improvements to warehouse layouts as well as attempts to implement 5S principles in warehouses. Implementing lean warehousing is divided into three stages: create stability, create flow, and make flow [6]. Some lean tools include VSM, Systematic Layout Planning (SLP) of ABC Analysis, minimum and maximum provisioning models, and inventory control. (FEFO). Waseem [9] used motion study and work measurement to streamline time and increase productivity. Lean application can reduce picking time from 5 to 3 hours and lower the return level to 5.5% [6], reducing operating time in the milling department by 38% [9].

Lean focuses on eliminating waste that does not add value to improve quality and reduce waiting times and costs. In contrast, Six Sigma reduces variation using statistical analysis for systematic process improvement (method DMAIC). Although the two methods have different focuses on waste reduction and variation of poses, they can complement each other to improve business performance [16]. The combination of both has a competitive advantage in implementation within SCM. Six Sigma can ensure that high-quality products are produced from credible processes, and Lean can ensure effective value stream processes ranging from supply, schedule, quantity of demand, etc. LSS can achieve various goals within SCM, including reducing costs, waste, and accessibility that do not add value to satisfy all customers across SC through collaboration with customers and suppliers [16]. Both methods also improved the total lead time of production by 37,08% and reduced the number of defective products [17]. One of the barriers to implementing lean management is organizational involvement in teams, the need for measurement skills, and

standardization of work [18]. For that, the application of lean needs to be balanced with supportive concepts of standardization and work measurement.

3.2. Ergonomic Thinking

Ergonomics focuses on saving and productivity by reducing worker injuries, improving worker morale, and reducing employee absences. Poor ergonomic implementation will affect workers individually and company performance[10]. The ergonomics discussed in more detail are macro ergonomics because they play a vital role in the internal and external processes of the company [19]. An example of ergonomic thinking is the use of the REBA (Rapid Entire Body Assessment) method, which identifies the indicated working postures that have a high risk to workers, thus affecting the failure of the production target [20].

The main interaction of ergonomic thinking is between man and his environment to optimize overall well-being and performance. It is characterized by a systemic approach, driven by design, focused on performance and well-being, as well as work standardization and measurement [21]. In its application in the company, ergonomics is limited to the occupational safety and health division (K3), so it indirectly discusses the scope of its intervention against hazards [21].

Common ergonomic problems are the potential risk of MSD caused by repetitive movements, excessive arm stretching, bending and rotation, prolonged static posture, contact pressure, temperature, noise, vibration, and improper flattening [10]. Activities such as bending, pushing too hard, lifting heavy loads, constantly repeating exhausting activities, and walking in vain are the causes of physical stress or excessive loads (walls) [22]. This will affect the application of lean in a company, especially for its employees, because of the physical stress and overload. In order to achieve optimal productivity, workers must be made comfortable so that they can improve their performance. When the work position is less ergonomic, the worker will get tired quickly, and the level of intelligence will decrease, making the work slow [23]. The work design should consider the balance between the machine and the human as the operator. From the human point of view, understanding is needed to use both physical and mental abilities optimally.

3.3. The integration of LSS with Ergonomics

Begins with the existence of a gap in the previous research, which is that there needs to be a discussion related to the integration of Lean Six Sigma with ergonomics, which is the background of the discussion in this writing. Lean focuses on the principles of Kaizen, Kanban, and Just in Time to minimize the seven wastes that happen. The most significant waste to cause delayed material removal is waste motion [7]. This will reduce work productivity due to non-added value activity and require minimization or elimination of waste for SCM, especially in warehouses, to run optimally.

Lean thinking to be applied appropriately requires practical ergonomic thinking [11]. Ergonomics plays a vital role in lean thinking by reducing costs and increasing work productivity through the elimination of waste (unnecessary movement) and reducing errors so that it can improve quality. There is a limit on the number of repetitions and unnecessary movements, which will indirectly

save the company time and cost. Compared to the role of lean versus ergonomic, the role of ergonomics versus Lean can be associated with the presence of handling material that facilitates movement and efficiency in process time [11]. Proposals for improvements that directly relate to how workers can perform their activities according to the principle of ergonomics can reduce the number of disabilities by 32% [24]. The impact of ergonomic risks on workers will affect company performance because workers are the main spearhead of company processes [10]. Workers are essential because they have a central role in implementing lean in the company, so it is crucial to make them feel healthy, safe, and comfortable [22]. Workers' ergonomics is a crucial parameter of the design of work processes, while lean is the key, among other things, taking time, cycle time, and ongoing work [25]. A high ergonomic risk can be used as an indicator of one or more waste of lean.

In creating sustainable development, there are three things to consider: environmental, socio-cultural, and economic. Environmental aspects play an essential role in implementing lean to produce continuous improvement. The results of the dissemination of questionnaires distributed to employees evenly in each division of the company explained that the application of lean needs to be fought on the ergonomic side so that it can improve productivity and well-being for employees [26]. However, most companies implement LSS without paying attention to the social aspect of their relationship with human beings. For this, LSS practices must be balanced with the application of ergonomics to their employees to improve what is produced in the system (hard lean) and consider humans as their primary resource (soft lean). Based on the results of interviews with practitioners, the effectiveness of the application of lean depends heavily on several factors, one of which is the human factor that influences the working procedure [15]. The Human Factors and Ergonomics (HFE) and lean (ergo-lean) approaches will improve the performance of the lean concept and the quality of life of workers in the textile industry by reducing the negative effects of lean [27]. In addition, the Ergo-VSM model can identify critical activity associated with higher risk factors in humans in the system. The existence of operator fatigue due to static motion will affect productivity, so it requires specially designed tools such as stabilizers or holders or tables with adjustable height [11]. There is also a possibility that there is a human factor in the science of ergonomics. The application of LSS ensures improved process performance and accuracy by eliminating waste and variations appearing in the process. To this end, the application of LSS must be supported by the implementation of the principle of ergonomics. LSS focuses on applying the principles of JIT [16], and ergonomics ensures that employees are correct at work so as not to cause delays in processes or other unwanted things [19].

A summary of previous research can be seen in Table 1. Through this table we can find theoretical and practical developments for the integration of lean with ergonomics, and six sigma with ergonomics, but no one has combined them into one and created a framework that is clear enough to be used as a basis rationale. The integration of the three started with only lean tools such as Value Stream Mapping (VSM), Just in Time, and several other hard lean tools. The Ergo-VSM concept has begun to develop which integrates system technical components such as Cycle Time (CT), Standard Minute Value (SMV), Operator Performance (OP), Throughput Yield (TY) and

others with human factor risk metrics or HFE components such as worker physical, worker psychosocial factors, work design factors, and managerial factors. Development continues to adopt a six-sigma approach using Define, Measure, Analyze, Improve, and Control (DMAIC) and considering reducing variations using statistical analysis for continuous improvement. From this systematic literature, a framework can be obtained (Figure 1) which can be used as a rationale for implementing LSS with ergonomics. This can make it easier for future researchers to apply it in their research case studies.

Table 1 Previous Studies

Author(s) & Title	Review Objective	LSS or Ergonomic Tools
Taifa (2022) [28] A Student-Centred Design Approach for Reducing Musculoskeletal Disorders in India Through Six Sigma Methodology with Ergonomics Concatenation	Evaluate and redesign facilities by integrating lean, ergonomics, six sigma and systems thinking	DMAIC, Anthropometry
Waseem et al. (2021) [9] Productivity Enhancement at Molding Compound Manufacturing Plant by Applying Time and Motion Analysis	Minimize inappropriate movements so as to increase productivity and propose new methods and show the gap between old and new methods	Work Measurement
Sakthi Nagaraj et al. (2019) [27] Integration of Human Factors and Ergonomics into Lean Implementation	Developed the Ergo-VSM method to evaluate risk factors and organizational ergonomics using lean parameters in the assembly process	Ergo-VSM
Bonilla-Ramirez et al. (2019) [6] Implementation of Lean Warehousing to Reduce The Level of Returns in A Distribution Company	Providing solutions related to implementing lean to reduce the level of return	ValueStream Mapping
Baby et al. (2018) [4] Implementation of Lean Principles to Improve the Operations of A Sales Warehouse in The Manufacturing Industry	Increase warehouse productivity by eliminating waste	Value Stream Mapping, ABC Analysis
Abushaikha et al. (2018) [29] Improving Distribution and Bussines Performance Through Lean Warehousing	Knowing the relationship between waste minimization practices and warehouse operational performance, distribution performance and business performance	Data collection through questionnaires (Delphi technique)
Botti et al. (2017) [25] Integrating Ergonomics and Lean Manufacturing Principles in A Hibryd Assembly Line	Create design tools in the form of mathematical models to design lean processes and comply with ergonomic principles in assembly lines	Mathematical Model
Arini et al. (2016) [7] Reducing Waste of Motion in the Material Sheet Service Process at PT Dirgantara Indonesia's Metal Warehouse using a Lean Warehousing Approach	Providing suggestions for improvements to minimize processing time for raw material services	Value Stream Mapping, Process Activity Mapping, Warehouse Slotting dan Visual Control
Bianca & Anca (2016) [22] Ergonomi Issues in Lean Manufacturing	Presents ergonomic problems that arise as a result of implementing lean	Just in Time, Kanban, Total Productive Maintenance, 5S, and Total Quality Management (Literature Review)
Tran (2015) [15] Improving Warehousing Process with Lean Management	Provide suggestions for increasing productivity in warehouse operations	ABC Analysis, redesign warehouse layout, and 5S
Geraldo et al. (2015) [26] Lean Manufacturing and Ergonomic Working Conditions in the Automotive Industry	Understand the relationship between lean manufacturing, ergonomics and working conditions applied in the automotive industry	5S, Value Stream Mapping, PDCA

Author(s) & Title	Review Objective	LSS or Ergonomic Tools
Aqlan et al. (2013) [10] Ergonomi Risk Reduction to Enhance Lean Transformation	Modify tools to incorporate lean considerations with ergonomics	VSM, Fishbone Diagram, Spaghetti Diagram, SIPOC Diagram, and Simulation
Dharmapriya & Kulatunga (2011) [12] New Strategy for Warehouse Optimization - Lean Warehousing	Streamline warehousing by providing the most optimal layout based on the shortest routes and lowest costs	Value Stream Mapping, dan Simulated Annealing Heuristic
Walder et al. (2007) [11] Integrated Lean Thinking & Ergonomics: Utilizing Material Handling Assist Device Solutions for A Productive Workplace	Know the benefits of lean thinking concepts combined with ergonomics concepts in material handling	Just in Time

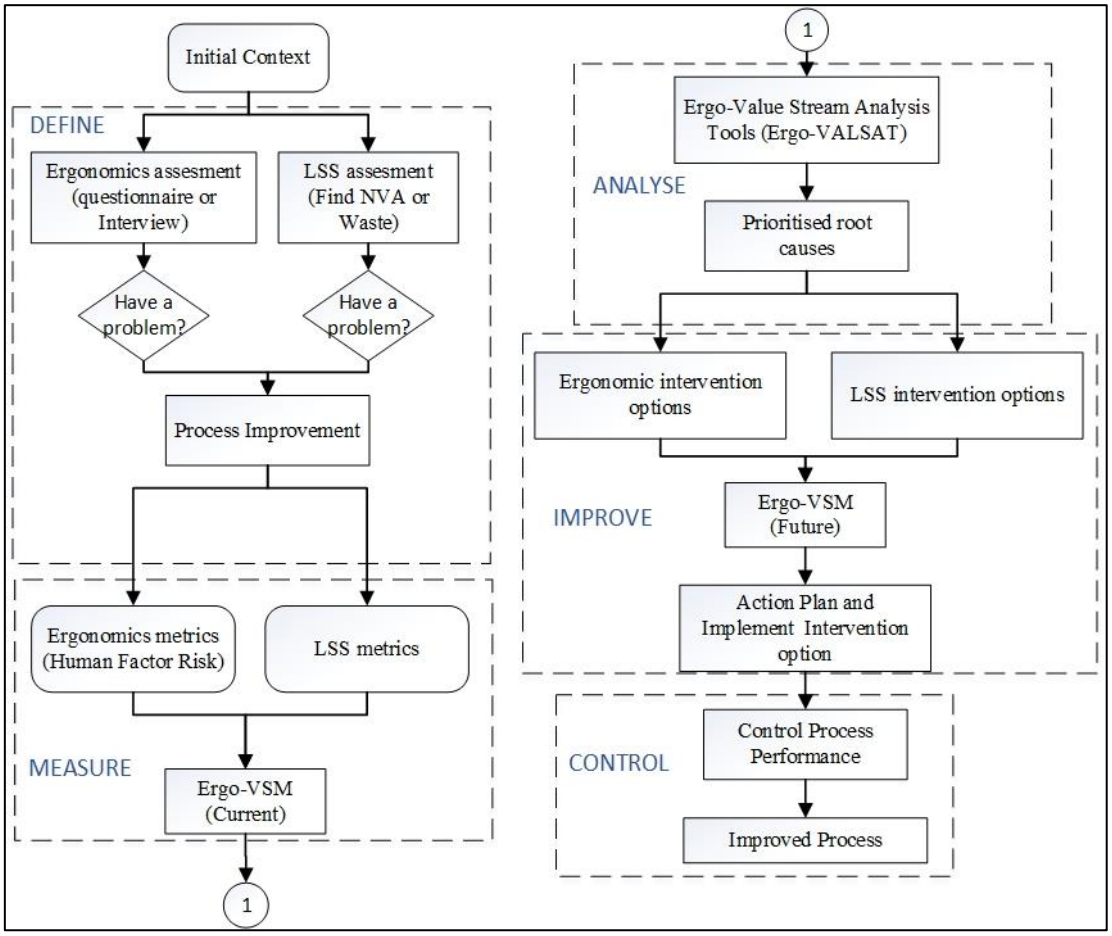

Figure 1 Framework of Integration LSS with Ergonomics

4. Conclusion

Lean focuses on waste reduction, whereas Six Sigma focuses on process variability reduction. Both are complementary methodologies to meet the challenges of SCM and competitive advantage in business. That needs to be balanced by considering the ergonomics principle that focuses on man and his environment. Human beings have a vital role in SCM. They must be guaranteed safety, health, and comfort in order to have a positive impact on the overall performance of the company in distribution performance. The principle of ergonomics can support the implementation of LSS to improve customer satisfaction and work productivity. The study also displays some examples of lean and ergonomic implementation in warehouses as part

of the company's internal logistics. Development for this research can be continued with in-depth tools that can combine these two principles of science to respond to the challenges of SCM.

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