GÜSBD 2025; 14(2): 568 - 577 **Gümüşhane Üniversitesi Sağlık Bilimleri Dergisi** **Araştırma Makalesi**
GUJHS 2025; 14(2): 568 - 577 Gümüşhane University Journal of Health Sciences Original Article

Investigation of the Effects of 5S Lean Manufacturing Technique Applications on Occupational Safety in the Woodworking Industry

Ahşap İşleme Endüstrisinde 5S Uygulamasının İş Güvenliği Üzerine Etkisinin Araştırılması

Sirer ALBAYRAK[1], Mustafa ÖZDEMİR[2], Gülbey KARATAŞ[3]

ABSTRACT

This study examined the impact of the 5S lean production methodology on occupational safety in a lumber workshop in Osmaniye. The risk levels were analyzed using the 5x5 Matrix Risk Assessment method before and after the 5S implementation. The implementation process lasted 14 days, and the results revealed significant improvements in occupational safety, with a 53% reduction in risk levels. This finding demonstrates the effectiveness of the 5S methodology in preventing workplace accidents and creating a safe working environment. The 5S methodology not only improved safety but also positively affected workplace productivity by ensuring organization, cleanliness, and standardization. It minimized material waste, reduced time loss, and streamlined work processes. Additionally, employees' safety awareness increased, leading to a safer and more organized work environment. However, as this study was conducted in a single workshop, its findings may need to be more generalizable to other sectors. Further research is needed to evaluate the long-term impacts and sustainability of the method. In conclusion, the 5S methodology effectively enhances occupational safety and prevents accidents in high-risk industries. Regular audits and training programs are essential for sustaining its benefits. Future studies can contribute to the literature by examining the method's effects in different sectors and its long-term advantages.

Keywords: Occupational health, safety, 5S method, 5x5 matrix, Risk analysis.

ÖZ

Bu çalışmada, Osmaniye'deki bir ahşap işleme atölyesinde 5S yalın üretim yönteminin iş güvenliği üzerindeki etkileri incelenmiştir. Araştırma kapsamında, 5S uygulamasından önce ve sonra 5x5 Matris Risk Değerlendirme yöntemi kullanılarak risk seviyeleri analiz edilmiştir. Uygulama süreci 14 gün sürmüş ve sonuçlar, 5S yönteminin iş güvenliği üzerinde önemli bir iyileşme sağladığını ortaya koymuştur. Risk seviyelerinde %53 oranında bir azalma kaydedilmiştir. Bu durum, 5S yönteminin iş kazalarını önleme ve güvenli çalışma ortamı oluşturmadaki etkinliğini göstermektedir. 5S yöntemi, iş yerinde düzen, temizlik ve standardizasyon sağlayarak yalnızca güvenlik değil, iş verimliliği üzerinde de olumlu etkiler yaratmıştır. Malzeme israfını önlemiş, zaman kaybını azaltmış ve iş süreçlerini daha düzenli hale getirmiştir. Ayrıca, çalışanların iş güvenliği bilinci artmış, daha güvenli ve düzenli bir çalışma ortamı oluşturulmuştur. Ancak, bu çalışma yalnızca bir atölyede gerçekleştirilmiş olup sonuçların diğer sektörlere genellenmesi sınırlıdır. Ayrıca, yöntemin uzun vadeli etkilerinin ve sürdürülebilirliğinin daha fazla araştırılması gerekmektedir. Sonuç olarak, 5S yöntemi, yüksek riskli endüstrilerde iş güvenliğini artırmak ve kazaları önlemek için etkili bir araçtır. Bu yöntemin sürdürülebilirliği için düzenli denetim ve eğitim programları gereklidir. Gelecekteki çalışmalar, yöntemin farklı sektörlerdeki etkilerini ve uzun vadeli faydalarını inceleyerek literatüre katkı sağlayabilir.

Anahtar Kelimeler: İş Sağlığı, İş Güvenliği, 5S Metodu, 5x5 matrisi, Risk Analizi.

Çalışma etik izin gerektirmemektedir.

[1] Dr. Öğr. Üyesi Sirer ALBAYRAK, İş Sağlığı ve Güvenliği, Ağrı İbrahim Çeçen Üniversitesi, Meslek Yüksekokulu salbayrak@agri.edu.tr, ORCID: 0000-0002-3201-1789
[2] Dr. Öğr. Üyesi Mustafa ÖZDEMİR, İş Sağlığı ve Güvenliği, Bayburt Üniversitesi, Uygulamalı Bilimler Fakültesi mozdemir@bayburt.edu.tr, ORCID: 0000-0002-6067-2007
[3] Öğr. Gör. Gülbey KARATAŞ, İş Sağlığı ve Güvenliği, Ağrı İbrahim Çeçen Üniversitesi, Meslek Yüksekokulu , gulbeykaratas1@gmail.com, ORCID: 0000-0003-1858-2013

İletişim / Corresponding Author: Sirer ALBAYRAK
e-posta/e-mail: salbayrak@agri.edu.tr

Geliş Tarihi / Received: 01.10.2024
Kabul Tarihi/Accepted: 30.12.2024

INTRODUCTION

A healthy, motivated, and focused workforce is recognized as a fundamental element for enhancing businesses' social and economic welfare. Ensuring employee health and maintaining a safe working environment are critical factors that influence individual well-being and significantly impact productivity and the sustainable success of enterprises. Globally, approximately 2.78 million people lose their lives each year due to work-related accidents and occupational diseases. Of these fatalities, 2.4 million result from occupational diseases, while workplace accidents cause the remainder. Additionally, 374 million occupational accidents are reported annually, leading to severe injuries or prolonged disabilities.[1]. These striking figures underscore the urgent need for innovative, systematic, and sustainable occupational health and safety approaches.

Research indicates that approximately 80% of industrial accidents are attributed to human factors, highlighting the necessity of implementing human-centered safety measures.[2] These data emphasize the importance of developing effective strategies to ensure worker safety, enhance workplace productivity, and optimize organizational processes. This need is particularly critical in the timber industry, characterized by physically demanding and hazardous work environments.

The timber sector is inherently a high-risk industry due to the nature of its production processes. Workers often operate heavy equipment, work near moving machinery, and use sharp saws and cutting tools, distinguishing this sector from other manufacturing industries. Moreover, timber processing generates wood dust, chemical substances, and other environmental hazards that pose significant risks for occupational diseases and long-term health issues.[3] Workers also face high probabilities of physical injuries, such as falling, tripping, or being struck by collapsing timber piles. Since most processes rely heavily on manual labor, the likelihood of accidents caused by human error is exceptionally high.[4]

Despite these challenges, implementing occupational safety standards in the timber sector needs to be revised or more effectively. Therefore, investigating how lean production techniques, such as the 5S methodology, can be integrated into this sector to mitigate risks provides valuable insights into preventing workplace accidents. The 5S method is an effective tool rooted in lean production principles, designed to create orderly, safe, and clean work environments.[5] It encompasses the steps of Seiri (sorting), Seiton (set in order), Seiso (shining/cleaning), Seiketsu (standardizing), and Shitsuke (sustaining). This approach aims to improve efficiency and safety through systematic organization, cleanliness, and standardization of workplace practices.[6-9]

The literature demonstrates that 5S reduces workplace accidents and errors, enhances employees' safety awareness and systematizes production processes.[10] Studies conducted in the timber sector highlight the impact of the 5S methodology in improving workplace safety and organizational efficiency. For instance, implementing 5S in a timber workshop resulted in a 30% reduction in workplace accidents and a 20% increase in overall productivity.[11]

In the study conducted by Divanoğlu et al. (2021), the applicability of the 5S methodology in improving quality and enhancing productivity in the automotive industry was investigated. The research results demonstrated that the 5S method enables more efficient and balanced processes.[12]

In the research by Ünal et al. (2024), the Single Minute Exchange of Die (SMED) technique and the 5S methodology were implemented in a packaging company to observe improvements in workflow efficiency. The study concluded that the 5S technique made the working environment more organized and ergonomic, ultimately increasing overall productivity.[13]

In the study conducted by Yağlı et al. (2024) within a machining company, the 5S model was applied to reduce production-based errors, and manufacturing activities were performed accordingly. A comparison with the previous production process revealed improvements, including a 66% reduction in costs, a 78% decrease in defective product rates, and an increased production efficiency.[14]

Furthermore, this system has been reported to boost employee satisfaction and contribute to organizational development.[15]

This study investigates the application of the 5S methodology in the timber industry, making it one of the few studies to comprehensively evaluate the effects of this approach on safety and productivity in high-risk industrial settings. Additionally, it integrates the 5x5 Matrix Risk Assessment method with 5S applications, highlighting the effectiveness of combining these two methods. Thus, this study contributes to the literature by addressing industry-specific issues and offering practical solutions.[16]

The timber workshop where this study was conducted utilizes various equipment, including log loaders, feed carriages, band saws, circular saws, and different cutting and shaping tools. These machines are crucial in cutting, shaping, and transporting timber. While heavy machinery like log loaders and feed carriages enhance efficiency, they also pose significant safety risks. Band and circular saws, often used for precision cutting, present potential hazards due to their high-speed rotating components. Ensuring this equipment's efficient and safe use directly impacts both process efficiency and worker safety. The workshop incorporates manual and mechanized processes, underscoring the need for meticulous organization and safety standards.[17]

While this study evaluates the applicability and impact of the 5S methodology on occupational safety in the timber industry, certain limitations exist. The research was conducted in a single timber workshop, which may limit the generalizability of the findings to other processes or sectors. Additionally, more extended observation periods are necessary to assess the sustainability and long-term effects of 5S applications. The study does not thoroughly examine the transformation of workers' attitudes and habits during the implementation process, highlighting the need for further analysis of the human factors associated with 5S. Future studies can address these limitations by exploring 5S applications in different industries and conducting longer-term evaluations.

MATERIALS AND METHODS

Materials

This study was conducted in a timber production and processing workshop located in Osmaniye, Türkiye. The workshop spans approximately 1,000 square meters of open and closed space and employs 17 workers. The study's primary objective is to evaluate the effects of the 5S methodology on this facility and analyze the results of the 5x5 Matrix Risk Assessment method applied to improve occupational safety conditions. The study site was systematically examined to identify, analyze, and mitigate occupational safety risks.

5S Methodology

The 5S methodology is a management system used to increase efficiency, reduce waste, and ensure workplace occupational safety. Developed in Japan, the 5S system derives its name from the initial letters of five Japanese words: "Seiri, Seiton, Seiso, Seiketsu, Shitsuke." It involves steps such as organization, cleaning, and standardization and includes the following processes:

Seiri (Sorting): This step consists of sorting out unnecessary items and identifying only what is necessary. The goal is to reduce workplace waste and increase efficiency.

Seiton (Set in order): This step ensures that necessary items are arranged in an orderly manner and are easily accessible. It is crucial for maintaining order in the workplace and improving workflow.

Seiso (Shine): This step focuses on keeping the workplace clean and conducting regular cleaning. A clean work environment helps prevent accidents and errors.

Seiketsu (Standardize): This step involves establishing and consistently applying standards. It is essential for standardizing processes and ensuring consistency in the workplace.

Shitsuke (Sustain): This step involves continuously applying and maintaining the 5S principles and ensuring that employees adhere to the 5S principles, as well as focusing on continuous improvement.[18,19]

The 5S methodology enhances workplace efficiency by ensuring organization, cleanliness, and standardization while also helping to reduce accidents and waste. This management system aims to achieve a competitive advantage by providing continuous improvement and cost savings in businesses.[20-22]

5x5 Matrix Risk Assessment Method

The 5x5 Matrix Risk Assessment Method was used in this study. In the 5x5 Matrix Risk Assessment Method, the risk is calculated as shown in Equation 1, where P stands for probability, S for severity, and R for the risk score:

$$R = P * S \quad (1)$$

Probability

Probability is the frequency with which a hazard is likely to occur. The identified risks are categorized into "Very Unlikely, unlikely, moderate, likely, and very likely," with scores of 1 for very unlikely, 2 for unlikely, 3 for moderate, 4 for likely, and 5 for very likely.[23]

Severity

Severity is defined as the magnitude of damage after an event. The severity of an event is categorized as "very mild, mild, moderate, serious, and very serious," with scores of 1 for very mild, 2 for mild, 3 for moderate, 4 for serious, and 5 for very serious.[23] The risk levels and values are obtained by multiplying the probability and severity scores such as 1-5 (Very Low (controls should be implemented to eliminate risks)), 5-10 (Low (additional control measures should be taken to eliminate risks)), 10-15 (Moderate (activities should be initiated to reduce identified risks)), 15-20 (High (work should not be started until the identified risk is reduced)), 20-25 (Very High (work should be stopped until the identified risk is reduced)), respectively.[23]

Probability and severity values are obtained from the respective tables based on the identified risk, and the risk score is determined by multiplying these two parameters. The obtained risk scores are classified according to risk score values as given in.[23]

RESULTS AND DISCUSSION

In this study, the 5x5 Matrix Risk Assessment and 5S methodology were applied in a timber processing workshop to enhance occupational safety, and the results were comprehensively evaluated. In the initial phase, potential risks in the working environment were identified, and each risk was assessed based on its likelihood and severity, with priority levels determined accordingly. Subsequently, the 5S methodology was implemented in the workspace, and the data obtained from a follow-up risk assessment were compared to the initial evaluation. The results demonstrate that the 5S methodology significantly improved occupational safety in the workshop.

5x5 Risk Assessment Implementation

A comprehensive risk assessment was conducted in a wood and lumber processing workshop to observe the daily working habits of the workers and verify their interactions with the surrounding environment through

direct observation. After identifying the risks, the 5S methodology was implemented in the workshop, and a subsequent 5x5 risk assessment revealed significant reductions in the identified risk levels [Table 1].

Based on the risk assessment results, the most critical hazards identified in the workshop include collisions between the log loader and workers, tripping over feed trolley cables, electric shock from the feed trolley, and hand entrapment in band and circular saws. The log loader, in particular, was classified as a high-level hazard due to its potential to collide with workers and nearby materials. Additionally, scattered materials in the workshop increased workers' risks of falling, tripping, and injuries. The improper stacking of lumber was also identified as a significant issue, posing a high risk of toppling.

Table 1. Risk Assessment Table

Hazard	Before 5S				After 5S				
	Probability	Severity	Score	Risk Level	Probability	Severity	Score	Risk Level	Change in Risk Level
Collision of log loader with workers	3	5	15	High	1	5	5	Very Low	67% Reduced
Tripping over feed trolley cables	4	3	12	Moderate	2	3	6	Low	50% Reduced
Electric shock from feed trolley	3	5	15	High	2	5	10	Moderate	33% Reduced
Hand entrapment in band and circular saws	3	3	9	Low	2	3	6	Low	33% Reduced
Stepping on a circular saw blade and falling	3	4	12	Moderate	1	4	4	Very Low	67% Reduced
Tripping over parts and falling	4	4	16	High	1	4	4	Very Low	75% Reduced
Falling or toppling of lumber	5	3	15	High	2	3	6	Low	80% Reduced

Risk Prioritization Matrix

The identification and evaluation of risks were conducted using the 5x5 Matrix Risk Assessment method, which classifies risks based on their likelihood and severity. A prioritization matrix was developed to enhance the effectiveness of intervention planning, ranking all identified risks by their level of urgency [Table 2].

The prioritization of risks was based on risk scores calculated as R= Probability × Severity, with the following priority levels established:

High-Priority Risks (R≥15): Critical risks requiring immediate intervention. Measures to mitigate these risks should be implemented urgently.

Moderate-Priority Risks (10≤R<15): Risks requiring planned interventions in the short term.

Low-Priority Risks (R<10): Risks that should be monitored and addressed with routine controls.

Table 2. Risk Prioritization Matrix

Risk Type	Probability	Severity	Score	Priority Level
Tripping over parts and falling	4	4	16	High
Collision of log loader with workers	3	5	15	High
Electric shock from feed trolley	3	5	15	High
Falling or toppling of lumber	5	3	15	High
Tripping over feed trolley cables	4	3	12	Moderate
Stepping on a circular saw blade and falling	3	4	12	Moderate
Hand entrapment in band and circular saws	3	3	9	Low

This matrix provides a clear prioritization of risks and facilitates the identification of the

hazards requiring urgent attention. For instance, high-priority risks such as "Collision of log loader with workers" and "Falling or toppling of lumber" demand immediate implementation of mitigation plans. Conversely, lower-priority risks, such as "Hand entrapment in band and circular saws," can be managed through regular monitoring and minor adjustments.

Implementation of the 5S Methodology

To evaluate the impact of the 5S methodology on workplace safety, the 5S system was implemented in a high-risk area of the production site where items such as log loaders, feed trolleys, band and circular saws, raw materials, products, and waste materials were disorganized, cluttered, or randomly placed, thereby posing significant accident risks. Using motorized industrial equipment in many sectors can increase productivity and efficiency while presenting significant occupational health and safety threats.[24]

Initially, a 5x5 matrix risk assessment was conducted to quantify the safety in the workspace. Risk Assessment Values were obtained by multiplying the scores for Probability and Severity. After completing this step, the 5S methodology was implemented, and a comparative risk assessment was conducted post-5S implementation to evaluate the effect of 5S on initial risk levels [Table 1].

The 5S implementation took approximately 14 days, and to compare the conditions before and after the 5S application, photographs of the initial workshop state and the post-5S implementation state were taken.

Risk Mitigation and the Impact of 5S

Following the implementation of the 5S methodology, significant reductions in the levels of all identified risks were recorded, as detailed below:

Collision with Log Loader: Before the 5S implementation, this hazard was classified as a "high-risk" scenario with a score of 15. Post-implementation, it was downgraded to a "very low risk" level (score: 5). This improvement was achieved by reorganizing the movement area of the log loader and establishing secure passageways, resulting in a 67% reduction in risk level.

Tripping Over Feed Trolley Cables: The risk associated with this hazard was reduced by 50%, lowering it from a "moderate risk" to a "low risk" level. This was accomplished by organizing and securing loose electrical cables, eliminating clutter and potential trip hazards.

Electric Shock from Feed Trolley: Electrical system adjustments to the feed trolley reduced this risk from a "high-risk" level to a "moderate risk" level, with an overall improvement of 33%.

Hand Entrapment in Band and Circular Saws: Removing unnecessary materials around the saws, creating defined safety zones, and adding safety markings decreased this risk by 33%, maintaining it at a "low-risk" level.

Stepping on Circular Saw Blade and Falling: Addressing clutter and implementing anti-slip measures around the saws reduced the risk level by 67%, downgrading it from a "moderate risk" to a "very low risk."

Tripping Over Parts and Falling: Systematic organization of all workshop areas, maintaining clear passageways, and proper disposal of waste materials led to a 75% reduction in this hazard, bringing it down to a "very low risk."

Falling or Toppling Lumber: Proper stacking of lumber and standardizing stacking procedures reduced this risk by 80%, lowering it from a "high-risk" level to a "low-risk" level.

Overall Risk Reduction

The risk assessment results indicate that the workshop's total risk was reduced by 53% following the 5S implementation. This significant reduction highlights the effectiveness of the 5S methodology in achieving substantial improvements in occupational safety when applied correctly [Figure 1]. These findings emphasize the importance of structured and systematic

approaches to mitigating risks in high-hazard industrial environments.

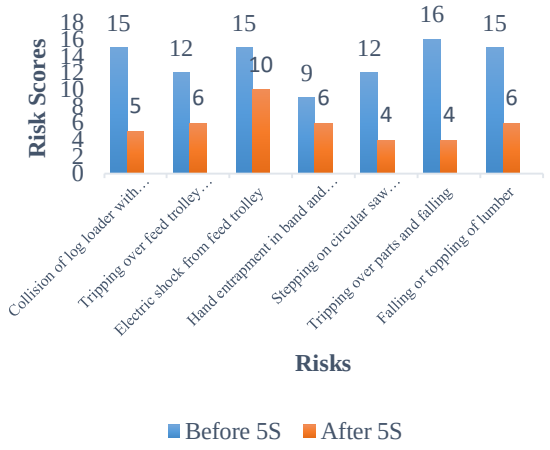

Figure 1. Risk Assessment Before and After 5S Implementation.

Observation Results

The impact of the 5S implementation is demonstrated through photographs that capture the initial state of the workshop [Figures 2 and 3] and its condition following the implementation [Figure 4]. Before 5S, the workshop exhibited disorganized material placement, exposed electrical cables, and cluttered work areas. After the implementation of 5S, all materials were systematically organized, the workspace became cleaner and more orderly, and safety signs were installed. It was observed that employees paid greater attention to safety procedures following these improvements.

During the study, the workshop's state before and after the 5S implementation was carefully evaluated using visual documentation. The photographs vividly illustrate the effects of the 5S methodology, highlighting the significant impact of these organizational improvements on workplace safety and productivity.

Pre-5S Conditions

Feed Trolley and Cables: Photographs taken before the 5S implementation revealed disorganized electrical cables around the feed trolley and a generally cluttered workspace. This created significant trip hazards and increased workers' risk of electric shocks.

Log Loader: The log loader was parked haphazardly within the workspace, restricting workers' movement and posing a high risk of collisions.

Band and Circular Saws: Unnecessary materials were accumulated around the saws, increasing the risk of workers coming into contact with the blades or tripping and falling.

Overall Workshop Condition: The workshop was generally cluttered, with materials and waste scattered throughout space. This disorganization impeded workflow efficiency and elevated the risk of accidents, creating a hazardous work environment.

These observations underline the critical need for systematic organization and safety measures in high-risk environments such as timber workshops. The subsequent improvements achieved through the 5S methodology directly addressed these challenges, demonstrating the tangible benefits of structured interventions in workplace organization and safety.

Figure 2. Feed Trolley (a) and Log Loader (b).

Post-5S Conditions

Feed Trolley and Cables: The cables were organized and secured, ensuring that passageways remained clear. Properly coiled and neatly arranged cables significantly reduced the risk of tripping and electric shocks.

Log Loader: The movement paths for the log loader were reorganized and designated safe parking areas were established. These changes eliminated the risk of collisions between the loader and workers.

Figure 3. Band Saw (a), Circular Saw (b) and the General Condition of the Workshop Before 5S Implementation (c-d).

Band and Circular Saws: Unnecessary materials around the saws were removed, and safety barriers were installed to prevent unauthorized personnel from entering the saw operation zones. Visual safety warnings were also placed around the saws to enhance awareness.

Overall Workshop Condition: All materials were systematically stored, and passageways were kept unobstructed.

Comprehensive cleaning initiatives were introduced, and daily cleaning routines were established. Clutter and unnecessary material piles were removed, creating a larger, more organized workspace. These improvements also contributed to increased productivity and heightened safety awareness among workers. A cleaner, more orderly environment facilitated employee movement and expedited workflows, while visual cues and safety barriers enhanced compliance with safety protocols.

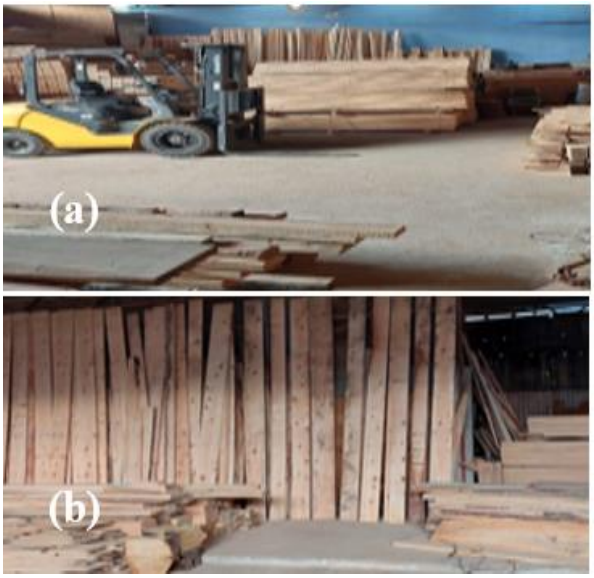

Figure 4. Photographs Showing the General Condition of the Workshop After 5S Implementation.

The 5S methodology has proven to be an effective tool for systematically improving occupational safety. This study's findings highlight that physical reorganization and a robust safety culture are critical to preventing workplace accidents. Post-implementation, workers demonstrated increased adherence to safety measures, and an improvement in job satisfaction was observed. However, to ensure the sustainability of 5S, regular training and monitoring are necessary. These results indicate that 5S is an organizational tool and a robust safety strategy in high-risk environments like the timber industry.

Contributions and Limitations of the 5S Methodology

The 5S methodology used in this study significantly contributed to improving safety,

productivity, and organizational order in the timber workshop. Applied systematically, 5S proved to be an effective tool for identifying and mitigating workplace hazards. In particular, proper stacking of materials, expanding workers' movement areas, and keeping passageways unobstructed played a key role in reducing accidents. Additionally, removing unnecessary items from the workspace and introducing regular cleaning routines enabled faster and more efficient execution of work processes. Increased safety awareness among employees and notable improvements in job satisfaction were also observed as positive cultural impacts of 5S.

However, certain limitations in the application of 5S were identified. First, sustaining the benefits of 5S requires stronger monitoring and follow-up mechanisms. Challenges encountered during the adaptation process, particularly in the sustainability phase (Shitsuke), emphasize the need for continuous training and awareness-raising initiatives. To integrate 5S principles into daily work routines, more intensive guidance and regular feedback processes must be provided. Lastly, the need for complementary tools, such as ergonomic analyses or workload assessments for analyzing complex processes in greater detail, emerged as a technical limitation. Addressing these gaps could further enhance the effectiveness of 5S, amplifying its positive impact on safety and productivity.

CONCLUSION AND RECOMMENDATIONS

This study evaluated the impact of implementing the 5S methodology on occupational safety and production efficiency in a timber production and processing workshop in Osmaniye, Türkiye. Throughout the study, all principles of the 5S method (Sorting, Setting in Order, Shining, Standardizing, and Sustaining) were systematically integrated into the workshop environment. This process resulted in significant improvements in occupational safety and operational processes, which were objectively measured using the 5x5 Matrix Risk Assessment method.

The findings reveal that the 5S methodology effectively reduces workplace risks, decreasing total risk levels by approximately 53%. These reductions were particularly notable in managing critical hazards, such as collisions with the log loader, tripping over electrical cables, and hand entrapment in band and circular saws. Through the organization and standardization phases, passageways were cleared, materials were systematically stored, and workplace clutter was eliminated. Consequently, a safer working environment was created for employees, and disruptions in work processes were minimized.

In addition to its impact on occupational safety, the 5S methodology also yielded significant benefits in terms of production efficiency. A clean and orderly work environment enhanced workers' mobility and enabled daily tasks to be performed more swiftly and effectively. Furthermore, increased awareness of workplace safety among employees contributed to reduced workplace accidents and downtime, indirectly boosting overall productivity.

This study also highlights that the 5S methodology is not merely a short-term solution but is crucial in fostering a sustainable occupational safety culture. However, maintaining the effectiveness of 5S requires regular audits and monitoring mechanisms. In particular, during the sustainability (Shitsuke) phase, continuous training and awareness-raising activities are essential to ensure that employees integrate 5S principles into their daily routines and maintain adherence to them.

While this research demonstrates the positive impact of the 5S methodology on occupational safety and production efficiency in the timber sector, further studies are needed to evaluate its sustainability and broader implications. Future research could evaluate the generalizability of these results by conducting similar applications in facilities of varying sizes and other high-risk industries. Moreover, the long-term effects of 5S on

employee behavior and safety culture transformations should also be explored.

Future studies could assess the synergistic effects of combining 5S with other lean production tools (e.g., Kaizen or Kanban) on safety and efficiency.

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