



## Optimization of Logistics Electrical Systems with a Safety Approach

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**Abstract.** *Electrical systems are fundamental infrastructures that support the operational continuity of logistics companies. However, without a structured approach to safety and optimization, these systems can become a source of inefficiency and risk. This study aims to analyze and optimize the use of electrical systems within logistics environments by applying a safety-oriented framework. The research investigates how electricity is distributed, utilized, and safeguarded in logistics companies and warehouses. Using a combination of observational methods and literature-based analysis, the study identifies critical issues related to energy reliability, system efficiency, and workplace safety. The findings are expected to contribute to the development of safer, more resilient, and energy-efficient electrical infrastructures in logistics operations.*

**Keywords:** *Electrical system, logistics optimization, safety, warehouse, infrastructure.*

### 1. INTRODUCTION

Recent developments in logistics optimization research have primarily focused on increasing efficiency, safety, and sustainability within supply chain systems. Smart infrastructures like Intelligent Transport Systems (ITS) and Geographic Information Systems (GIS) have been shown to improve urban transport management and road safety (Sarkisian et al., 2025). The growing adoption of AI and IoT for last-mile delivery using drones and ground robots (Shuaibu et al., 2025), as well as warehouse enhancements through crossdocking and ergonomic design (Soria-Arguello & Villicaña-García, 2025), highlight the sector's evolution. In cold chain logistics, multi-objective optimization through hybrid genetic algorithms combined with large neighborhood search significantly improves energy efficiency, cost, and delivery quality (Lu & Taghipour, 2025). However, these advances often neglect the role of reliable and optimized electrical systems that power and sustain such innovations especially in logistics hubs.

Electrical issues in this study are categorized into two main types: internal and external electrical issues. Internal electrical issues are central to this research and include the types of electricity commonly used in logistics or warehousing companies, installation processes, voltage and power standards, and safety mechanisms within the facilities. These internal aspects are directly responsible for the operational reliability of logistics infrastructure and are the primary focus of this journal. In contrast, external electrical issues refer to external environmental influences, such as community-level power disruptions, regional grid stability, or public safety interactions. Although important, they are considered secondary in this study's scope and serve to provide contextual understanding surrounding internal system vulnerabilities and resilience planning.

The growing complexity of electrical systems in logistics facilities requires non-intrusive, intelligent approaches to monitor and manage load consumption and electrical safety. Techniques such as Non-Intrusive Load Monitoring (NILM) have gained traction, where decision trees (Hassan & Rufai, 2023), bagging classifiers (Kang & Kim, 2020), and random forest algorithms (Guohua et al., 2020) enable detailed load disaggregation. These approaches

are essential for recognizing consumption patterns and detecting abnormalities in real-time. Several studies have also explored load identification using Gaussian Naive Bayes (Adjei et al., 2020), principal component analysis (Machlev et al., 2020), and multiscale residual neural networks (Taha et al., 2022), all of which contribute to smart load management critical for large-scale logistics environments.

Smart device recognition technologies enhance the ability to distinguish between electrical components in operation, allowing for safer infrastructure through automation and contextual awareness (H. Liu et al., 2020). Harmonic-based methods are particularly effective in identifying appliance types (Beck & Machlev, 2019; Machlev et al., 2020), classifying harmonic load types using extreme learning machines (Wong et al., 2018), and supporting energy disaggregation through harmonic signature analysis (Jopri et al., 2020). These approaches not only contribute to energy efficiency but are vital in reducing risks related to harmonic distortion and transformer stress in logistics warehouses (Utomo et al., 2021). Furthermore, advanced NILM architectures using convolutional networks, Fryze-current decomposition, and multivariate LSTM-based detection (Faustine & Pereira, 2020; Garcia et al., 2020; H. Liu et al., 2020) support predictive maintenance and system resilience both of which are key for logistics environments. Therefore, this study proposes a safety-oriented optimization framework for internal logistics electrical systems using smart sensing, harmonics mitigation, and AI-driven monitoring to ensure secure and efficient operations.

## 2. RESEARCH METHOD

This study employs a qualitative research method through direct observation at a major logistics company in Indonesia with Japanese PMA investment, characterized by a highly organized and tightly controlled operational environment. Field visits were conducted to examine the electrical systems and related facilities, focusing on the integration of safety measures within operational workflows. The research draws upon empirical insights gained from on-site inspections, supported by the company's use of advanced software applications mandated by both Japanese and Indonesian management. In the context of rapid technological development, the implementation of modern electrical infrastructure not only enhances operational efficiency but also ensures compliance with stringent safety standards. This dual emphasis on efficiency and safety serves as a strategic foundation for optimizing logistics electrical systems in alignment with industry best practices.



**Figure 1. Integrated Logistics Safety System**

Figure 1 presents an integrated logistics system encompassing transportation, warehouse management, and distribution, supported by monitoring tools and performance analytics to ensure operational efficiency. This study employs a structured research method to optimize logistics electrical systems through a safety-oriented approach, focusing on independent variables transportation, distribution center location, and product availability and the dependent variable of business performance.

Recent studies emphasize the role of integrated logistics safety systems in diverse sectors. In urban contexts, Intelligent Transport Systems and Geographic Information Systems enhance traffic flow, reduce congestion, and improve road safety (Sarkisian et al., 2025), while in renewable energy logistics, edge-cloud intelligence with machine vision strengthens wind turbine blade transport safety, lowering downtime and costs (Wang, Wang, et al., 2025). In remote areas, self-healing databases support emergency response by repairing data anomalies (McGarvey et al., 2025), and IoT improves automotive safety through better data acquisition and quality in transport and production (Kodym et al., 2025), collectively enabling efficient, safe, and sustainable logistics..

The digitalization of logistics is reshaping supply chain management through AI, IoT, blockchain, big data analytics, cloud platforms, and robotics, optimizing processes, reducing costs, and enhancing service (Olifirenko & Sydorenko, 2024). These technologies enable real-time tracking, demand forecasting, route optimization, and inventory management (Korman et al., 2025), while also improving transparency, speed, and accuracy despite challenges such as high investment costs, cybersecurity risks, and integration complexities (Olifirenko & Sydorenko, 2024; Ujah, 2023), (Korman et al., 2025). In agriculture, IoT and AI integration improve cross-border trade efficiency (Cortez-Clavo et al., 2025), though many organizations face implementation barriers, underscoring the need for systematic frameworks (Lu & Taghipour, 2025).

### Smart Logistics

Recent smart logistics research underscores the role of advanced technologies in boosting efficiency and sustainability, with IoT-enabled predictive analytics, digital twins, and Industry 4.0 tools like AI and blockchain improving freight mobility, resource use, and predictive maintenance (Alkhodair & Alkudhayr, 2025; Fatorachian et al., 2025). AI-mediated HR practices, AI-driven fleet optimization, mixed reality, and large language model assistants further enhance logistics agility, warehouse operations, and decision-making (Ieva et al., 2025; Jahangir et al., 2025).



**Figure 2. Integrated Global Smart Logistics Network**

Figure 2 illustrates the concept of smart logistics, integrating air, sea, and land transportation within a connected global network to enhance efficiency and coordination. This approach leverages advanced technology to optimize delivery processes while ensuring safety and reliability.

### Green Logistics

Green logistics seeks to reduce environmental impact while enhancing efficiency, supported by technologies such as electric vehicles, drones, AI, IoT, and sustainable packaging (Irenita, 2025; Jefimovait\,e & Vienažindien\,e, 2025). AI-driven predictive analytics and IoT

optimize transport networks and reduce fuel use (Kale, 2025). though adoption faces cost and regulatory challenges, and integrating green skills into vocational education remains essential for a global green transition (Pujun, 2025).

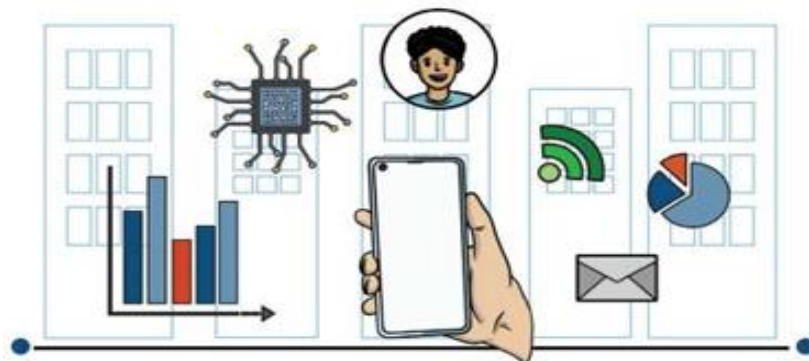


**Figure 3. Integrated Global Green Logistics System**

Figure 3 illustrates a green logistics system integrating air, sea, rail, and road transport with eco-friendly practices to minimize environmental impact. This approach supports sustainable supply chain operations while maintaining efficiency and safety.

### **Big Data**

Big Data Analytics (BDA) is reshaping supply chain management and logistics by enhancing operational efficiency, decision-making, and predictive accuracy across industries, including healthcare, retail, manufacturing, and logistics (Machavarapu et al., 2025; Umoren et al., 2025). The integration of IoT with BDA supports data-driven strategies and innovative business models, while cloud-based adaptive models covering the Business Intelligence lifecycle enable sustainable supply chain management and greater resilience in global networks (Stefanovic et al., 2025).



**Figure 4. Big Data-Driven Logistics Analytics**

Figure 4 illustrates the role of big data in logistics, integrating data collection, analysis, and visualization to enhance decision-making and operational efficiency. This approach enables predictive insights, resource optimization, and improved safety compliance.

### **Artificial Intelligence (AI)**

Recent studies underscore AI's expanding influence in logistics and supply chain management, with applications in green logistics reducing emissions through predictive analytics, IoT integration, and warehouse automation (Kale, 2025). AI also mediates sustainable HR practices to enhance logistics agility (Jahangir et al., 2025), optimizes last-mile delivery fleets with mixed reality and language model assistants (Ieva et al., 2025), and strengthens supply chain risk management via machine learning, deep learning, and optimization algorithms, despite challenges like data privacy and implementation barriers (Grover, 2025).



**Figure 5. Artificial Intelligence Applications in Logistics**

Figure 5 illustrates the use of artificial intelligence in logistics, enabling automation, predictive analytics, and real-time decision-making. AI integration enhances operational efficiency, safety compliance, and adaptability to dynamic supply chain conditions

### **Internet of Things (IoT)**

The integration of IoT in logistics is revolutionizing supply chain management by enhancing efficiency, sustainability, and real-time monitoring of goods and environmental conditions through convergence with AI and blockchain (Alkhodair & Alkhudhayr, 2025; Raziq et al., 2025). This transformation improves resource utilization, ethical sourcing, and reduces downtime in SMEs, while in agriculture, digitalisation and automation in cross-border logistics optimize costs and time (Cortez-Clavo et al., 2025), though adoption barriers for SMEs highlight the need for policy and targeted support (Alkhodair & Alkhudhayr, 2025; C. Li, 2025).



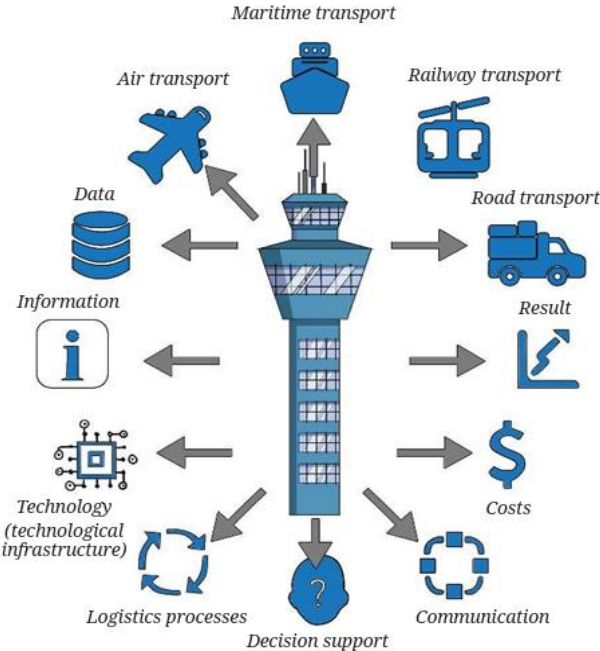
**Figure 6. Internet of Things Integration in Logistics**

Figure 6 illustrates the integration of the Internet of Things (IoT) in logistics, enabling real-time monitoring, automated control, and interconnected operations. IoT enhances efficiency, safety, and transparency across the entire supply chain.

### **Control Tower**

Recent studies on logistics control towers highlight the critical integration of digital technologies, sustainability practices, and ethical leadership to enhance efficiency and reduce environmental impact. Frameworks addressing Middle Eastern construction logistics stress the role of lean methodologies and advanced technologies in improving sustainability (Abdullahi et al., 2025), while digitalization is shown to strengthen outsourcing decisions through a new process development model (Tamás, 2025). Data-intelligence-driven digital twin approaches reduce carbon emissions in supply chains (Alrawashdeh et al., 2024), and green logistics

frameworks position supply chain ethical leadership as central to developing green core competencies (Tetteh et al., 2025).

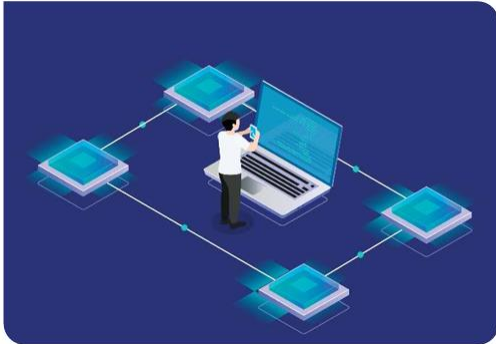


**Figure 7. Logistics Control Tower Framework**

Figure 7 illustrates the logistics control tower concept, integrating multimodal transport, technological infrastructure, data, and communication to enable real-time decision-making. This framework enhances visibility, efficiency, and safety across the supply chain.

**Blockchain**

Recent research emphasizes blockchain’s transformative role in logistics and supply chain management, with blockchain-enabled strategic planning improving transparency, efficiency, and trust (Khawaldeh et al., 2025). Integration with IoT and AI in SMEs enhances resource utilization, ethical sourcing, and predictive maintenance despite financial and technical barriers (Alkhodair & Alkudhayr, 2025), while in global supply chains, blockchain–IoT synergy supports carbon tracking, real-time monitoring, and carbon credit transactions (Ojadi et al., 2025). In the seafood sector, blockchain boosts data efficiency, sustainability, and supply chain integration, stressing accurate data management, stakeholder engagement, and regulatory compliance (Bharathi S et al., 2025).



**Figure 8. Blockchain Integration in Logistics**

Figure 8 illustrates the use of blockchain technology in logistics to ensure secure, transparent, and tamper-proof data exchange across the supply chain. This approach enhances trust, traceability, and operational efficiency.

### Distribution Order Management (DOM)

Distribution Order Management (DOM) systems are vital for optimizing processes and boosting competitiveness in distribution companies through the planning, organization, and control of material, goods, and service flows (Завербний & Шаровський, 2025). In e-commerce, Domain-Driven Design (DDD) enhances flexibility and development speed in order management and inventory synchronization by aligning business goals with technical solutions. The term DOM also applies in other fields, such as dissolved organic matter management in estuarine-coastal systems to assess carbon budgets (P. Liu et al., 2025) and deep learning models like DOMSCNet for improving stomach cancer classification and prediction (Borah et al., 2025).

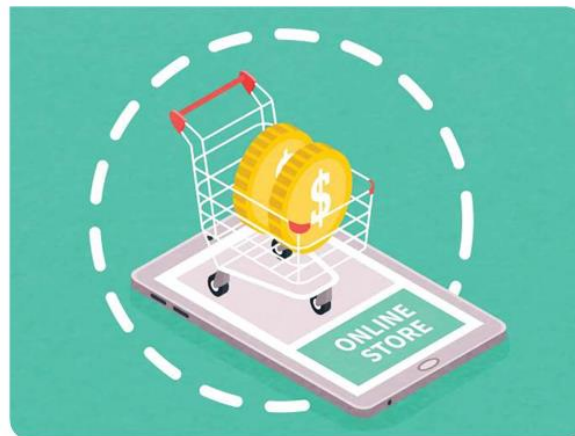


**Figure 9. Distribution Order Management Workflow**

Figure 9 illustrates the workflow of distribution order management (DOM), encompassing order processing, inventory coordination, and customer communication. This system ensures accurate, efficient, and timely order fulfillment.

### E-Commerce

E-commerce platforms are transforming logistics and supply chain management, with channel selection strategies such as platform franchising maximizing supply chain value and consumer satisfaction (Lee et al., 2025). In fresh e-commerce, logistics service quality particularly quality assurance and convenience has a strong influence on customer satisfaction, varying by region and season (Yang, 2025). Wholesale platforms like E-Mart streamline B2B transactions through bulk order management and logistics integration (Hossain, 2017), while U.S. e-commerce supply chains adopt digital transformation frameworks integrating AI, blockchain, IoT, and big data analytics to boost efficiency, resilience, and competitiveness (Famoti et al., 2025). Many e-commerce platforms already exist in Indonesia, such as Lazada, Shopee, Bukalapak, Blibli, and others.



**Figure 10. E-Commerce Platform in Logistics**

Figure 10 illustrates the role of e-commerce platforms in facilitating online transactions, connecting sellers and buyers seamlessly through digital marketplaces. This integration supports efficient order processing, payment, and delivery coordination.

**Some of the advanced technologies already implemented in many companies are as follows:**

#### **Drones for transporting goods**

Recent advances in drone technology are transforming logistics and last-mile delivery, with Unmanned Aircraft Systems (UAS) enabling versatile, cost-effective, and accessible cargo transport in urban areas, giving rise to Urban Air Mobility (UAM) (Ariante & Del Core, 2025). Hybrid delivery networks integrating drones, ground vehicles, and robots improve efficiency and reduce environmental impact (Shuaibu et al., 2025), while AI-driven algorithms, IoT-based real-time monitoring, and deep learning object detection on embedded platforms like NVIDIA Jetson enhance tracking and decision-making (Aggarwal et al., 2025; Ariante & Del Core, 2025)(Shuo Wei et al., 2025; Dilmi et al., 2025). Despite restrictions such as no-fly zones and time-dependent routes, these innovations promise optimized operations while addressing regulatory and infrastructure challenges



**Figure 11. Drone Technology for Goods Transportation**

Figure 11 shows the use of drone technology for transporting goods, enabling rapid and efficient delivery in various terrains and conditions. This innovation enhances logistics flexibility, reduces delivery time, and supports emergency supply distribution

#### **AGV (Automated Guided Vehicle) Robots**

Recent research on Automated Guided Vehicle (AGV) robots in logistics emphasizes advancements in navigation, collaboration, and system integration. Parameter tuning using Pure Pursuit and Vector Field Histogram algorithms in ROS/Gazebo simulations has been shown to improve navigation performance (Tang et al., 2025), while collaborative transport strategies for dual AGVs in smart ports enhance motion safety and docking precision (Song et al., 2025). Reference architectures for integrating autonomous vans and robots into last-mile logistics demonstrate practical viability through pilot implementations (Spagnuolo et al., 2025), and hybrid path planning methods combining artificial potential field and ant colony algorithms improve efficiency in grid-based environments (Tang et al., 2025) (Y. Li & Liu, 2025). Collectively, these advancements address critical AGV challenges, from obstacle avoidance to platform integration, driving the development of autonomous logistics solutions



**Figure 12. Automated Guided Vehicle (AGV) Robot in Logistics Operations**

Figure 12 depicts an Automated Guided Vehicle (AGV) robot used in logistics operations to transport goods autonomously within warehouses. This technology improves efficiency, reduces labor dependency, and enhances operational safety.

### **Electricity in Logistics Companies**

The adoption of electric vehicles (EVs) in logistics offers both sustainability and efficiency gains, with optimal fleet management particularly using self-produced electricity and time-varying energy prices reducing costs and improving performance (Coppo et al., 2025). EVs are highly effective in last-mile logistics, lowering emissions and operating costs when supported by smart technologies and robust legislative frameworks (Aswani et al., 2025), while in multi-depot networks, collaboration and resource sharing facilitated by hybrid algorithms enhance operational efficiency (Wang, Chen, et al., 2025). Beyond technology, organizational learning, knowledge management, and training are essential for achieving high logistics performance, though these areas are not always strategically managed, leaving room for improvement (Budihardjo & Supriyadi, 2025).

### **Regulatory Basis**

- 1) Law No. 1 of 1970 concerning Occupational Safety, Article 3 states that every workplace must have experts to ensure the safety of workers and installations.
- 2) Minister of Manpower Regulation No. 12 of 2015 concerning Electrical Occupational Safety and Health in the Workplace
  - a) Article 2: Employers are required to implement an Electrical Occupational Safety and Health management system.
  - b) Article 4: Electrical activities must be supervised by personnel with Electrical Occupational Safety and Health competencies.
- 3) SKKNI No. 131 of 2018 Establishes national work competency standards for Electrical Occupational Safety and Health Experts. This standard is used as a reference for training and certification by the National Agency for Standardization (BNSP).
- 4) SKKNI No. 343 of 2013: Serves as a competency benchmark for Electrical System Installation and Maintenance Technicians, especially for technical implementers in the field.

### **Risks Without Competent Electrical Personnel**

The electric power industry presents serious occupational hazards such as electrocution, burns, and falls (Lee et al., 2025), with major risk factors including non-compliance with safety regulations, inadequate work organization, improper use of personal protective equipment, and human errors (Пестре́в & Пыхов, 2025). Effective risk management requires thorough hazard identification, comprehensive risk assessment (Pamungkas et al., 2025), and, in high-risk environments like offshore oil and gas platforms, robust emergency planning under extreme

conditions (Пестре́в & Пухов, 2025). Mitigation strategies include strict adherence to safety protocols, regular training, and the deployment of advanced technologies, such as AI-based autonomous safety platforms for data-driven risk management (Lee et al., 2025). Additional measures encompass continuous technical system monitoring, modern fire suppression systems, and regular emergency response drills (Juliyanto et al., 2024; Пестре́в & Пухов, 2025).

The absence of competent Electrical OHS Experts and Technicians in logistics operations with extensive electrical infrastructure creates serious risks, including fires, electrocution, equipment damage, and potential legal sanctions, making their employment a legal requirement under Ministerial Regulation No. 12 of 2015 for systems above 200 kVA. These professionals are responsible for planning, installation, modifications, and maintenance to ensure compliance with safety standards, thus safeguarding workers, protecting assets, and ensuring operational continuity. Electrical OHS involves preventive measures such as equipment maintenance, PPE usage, and emergency systems, with high-risk sectors like energy, manufacturing, construction, telecommunications, and mining requiring rigorous procedures supported by hazard identification, risk analysis, and tailored programs. Implementation demands technical controls, procedural safeguards, and continuous training, including inspections, preventive maintenance, and hazard response readiness. Integrating safety into operations reduces downtime, prevents costly disruptions, and ensures regulatory compliance, thereby enhancing resilience. Employing Electrical OHS Experts provides substantial benefits, from increased safety and productivity to reduced losses and legal compliance, while enabling continuous safety improvements through investigations, standard updates, and innovative solutions. In the context of rapid technological growth and automation, optimizing logistics electrical systems with a safety approach secures efficiency without compromising worker well-being or environmental integrity, creating sustainable and competitive logistics operations.

### **3. RESULTS AND DISCUSSION**

Electricity plays a pivotal role in modern logistics, encompassing applications in warehouse lighting, transportation systems, automation, and security infrastructure. The concept of “logistics electricity” refers to the use, management, and safeguarding of electrical energy across supply chain operations, ensuring efficiency, reliability, and safety. Its scope ranges from powering electric vehicles and automated conveyor systems to sustaining climate control for perishable goods and supporting data-driven inventory management platforms. Secure and reliable electricity supply is essential, as disruptions can result in significant operational and financial losses. Therefore, integrating optimized electrical systems with a strong safety approach is not only an operational necessity but also a strategic imperative for sustainable logistics performance.

In practice, optimizing logistics electrical systems involves targeted interventions that align technological upgrades with energy efficiency goals. The case study illustrates four main strategies: upgrading lighting to motion-activated LED systems, implementing smart HVAC automation, scheduling off-peak electric forklift charging, and shifting to variable electricity tariffs. These measures yielded measurable benefits, including reduced standby lighting hours, enhanced climate control, and cost savings from strategic energy procurement. Such initiatives not only lower energy consumption but also improve system reliability and resilience, supporting both operational continuity and long-term cost efficiency in logistics operations.

The adoption of smart automation technologies further enhances the efficiency of logistics electrical systems by aligning energy use with real-time operational demands. The ISTABAI HVAC control system, for instance, demonstrated a 12% reduction in annual electricity use and a 60% reduction in gas heating demand through adaptive scheduling and occupancy-based adjustments. These improvements also contributed to better air quality,

thermal stability, and occupant satisfaction, showing that the benefits of energy optimization extend beyond monetary savings. By combining technical solutions with effective operational management, logistics companies can create environments that are both energy-efficient and worker-friendly.

Moreover, behavioral factors and staff training are critical to sustaining the benefits of electrical system optimization in logistics. Technical interventions can be undermined by inconsistent usage patterns, such as manual overrides or improper equipment operation. Therefore, successful implementation requires a comprehensive approach that integrates technological upgrades, safety compliance, and human factor management. In a rapidly evolving logistics landscape, this synergy between energy efficiency, operational safety, and behavioral discipline ensures that electrical systems not only meet performance standards but also contribute to sustainable and competitive business operations.

#### **4. CONCLUSION AND SUGGESTIONS**

Electricity is a critical enabler in modern logistics, supporting operational efficiency, sustainability, and productivity enhancement across warehousing, transportation, and automated systems. The protection of all electrical installations within logistics companies must be systematically planned to prevent potential hazards, including short circuits, fires, and equipment failures. The appointment of qualified Electrical Occupational Safety and Health (K3) experts is essential to continuously monitor, assess, and safeguard electrical infrastructure, ensuring compliance with safety standards. These experts serve as independent and competent evaluators, identifying critical points susceptible to electrical faults and implementing preventive measures. A robust electrical safety framework not only minimizes operational disruptions but also safeguards company assets and workforce well-being.

Given the high operational dependency on electrical systems, logistics companies must integrate continuous safety training, installation of protective devices, and clear safety signage to cultivate a safety-oriented culture. Employees' awareness of electrical risks plays a pivotal role in preventing accidents, making education and awareness campaigns an indispensable component of electrical safety management. Furthermore, the placement of safety-related pamphlets and banners in strategic areas reinforces safe working behavior and readiness for emergency situations. By combining infrastructure protection with ongoing training and awareness programs, companies can maintain productivity, ensure operational continuity, and create a secure and comfortable work environment for all personnel.

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