

Literature Review: Facility Layout Optimization and Safety Management in Manufacturing Workshops

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ABSTRAK

Pengaturan strategis fasilitas produksi dan integrasi protokol keselamatan merupakan faktor penentu kritis bagi efisiensi operasional di bengkel manufaktur, sehingga penelitian ini bertujuan untuk mengevaluasi dan mengoptimalkan tata letak fasilitas yang terdiri dari 57 komponen berbeda, termasuk mesin berat (M1–M7) dan sistem pendukung lainnya. Analisis inventaris situs dan hubungan spasial dilakukan secara sistematis menggunakan kerangka kerja *Facility Layout Problem* (FLP) dengan membagi bengkel ke dalam kluster fungsional produksi, perakitan, pengawasan, dan logistik guna menilai kedekatan antara meja kerja operator (11–16) dengan unit permesinan inti. Temuan menunjukkan bahwa penempatan terpusat ruang instruktur (R1) dan ruang perencanaan (R3) secara signifikan meningkatkan pengawasan area praktek siswa (D1–Dy), sementara implementasi "Safety Area" yang ditentukan secara efektif memisahkan lalu lintas pejalan kaki dari zona berisiko tinggi seperti mesin press hidrolik (M7) dan stasiun pengelasan (MS). Selain itu, isolasi unit intensif kebisingan seperti ruang kompresor (K1) terbukti menjaga standar ergonomis di zona kontrol (R4) dan administrasi (A). Sebagai simpulan, model tata letak terintegrasi ini menunjukkan sinergi yang berhasil antara kebutuhan produksi skala industri dan kebutuhan pedagogis teknis, memberikan tolok ukur strategis bagi manajemen fasilitas yang berpusat pada keselamatan dan produktivitas.



KATA KUNCI

Tata Letak Fasilitas;
Bengkel Manufaktur;
Manajemen
Keselamatan;
Efisiensi Operasional;
Ergonomi Industri

ABSTRACT

The strategic arrangement of production facilities and the integration of safety protocols are critical determinants of operational efficiency in manufacturing workshops; therefore, this study aims to evaluate and optimize a facility layout consisting of 57 components, including heavy machinery (M1–M7) and support systems. A systematic site-inventory and spatial relationship analysis were conducted using the Facility Layout Problem (FLP) framework, categorizing the workshop into functional clusters of production, assembly, supervision, and logistics to assess the proximity between operator workbenches (11–16) and core machining units. The findings indicate that the centralized placement of the instructor room (R1) and planning room (R3) significantly improves the oversight of student practice areas (D1–Dy), while the implementation of a designated "Safety Area" effectively segregates pedestrian traffic from high-risk zones such as the hydraulic press (M7) and welding stations (MS). Furthermore, the isolation of noise-intensive units like the compressor room (K1) ensures that ergonomic standards are maintained in the control (R4) and administrative (A) zones. In conclusion, this integrated layout model demonstrates a successful synergy between industrial-scale production requirements and technical pedagogical needs, providing a strategic benchmark for facility management centered on safety and productivity.



KEYWORD

Facility Layout;
Manufacturing Workshop;
Safety Management;
Operational Efficiency;
Industrial Ergonomics;



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1. Introduction

The strategic optimization of facility layouts is a fundamental determinant of operational efficiency and waste reduction in modern manufacturing environments [1]. Effective spatial arrangement must integrate heavy machinery, such as large lathes (M1) and milling machines (M2), with dedicated safety areas to mitigate occupational hazards [2]. Recent studies emphasize that the proximity of operator workbenches (11-16) to assembly areas is vital for minimizing internal logistics lead times and enhancing workflow continuity [3].

Furthermore, the synchronization of material handling tools, such as material trolleys (LT), with systematic goods receiving areas ensures a streamlined production flow [4]. The inclusion of dedicated oversight zones, including instructor rooms (R1) and planning rooms (R3), serves as a centralized node for quality control and technical specification adherence [5]. Safety management is further enhanced by the systematic storage of personal protective equipment in designated lockers, particularly when operating high-risk equipment like hydraulic presses (M7) [6].

To maintain operator focus and data integrity, the physical separation of control rooms (R4) from high-noise zones like compressor rooms (K1) is recognized as a critical ergonomic standard [7]. Efficient inventory management, particularly within the material warehouse (Gudang Bahan), relies heavily on organized racking systems (A1-A3) to support Just-in-Time production cycles [8]. In technical education settings, the ergonomic alignment of student practice tables (D1-Dy) with smaller machining units (Mo) is essential for fostering a safe and effective learning environment [9]. Finally, the seamless integration of administrative areas (A) within the workshop floor facilitates rapid coordination between technical staff and management to address real-time operational demands [10].

2. Literature Review

The classification of industrial machinery into functional clusters is essential for streamlining multi-stage production processes [11]. In complex workshops, the categorization of heavy-duty equipment, such as Large Lathes (M1) and Milling Machines (M2), requires specific foundation stability and spatial clearance to maintain precision standards [12]. Beyond primary machining, the integration of secondary processing units, including welding machines (MS) and cutting machines (MG), necessitates specialized ventilation and fire-safety partitioning to prevent cross-contamination of work zones [13]. Recent literature highlights that the strategic placement of hydraulic presses (M7) must account for high-pressure safety perimeters to protect adjacent operators [14]. Furthermore, the efficiency of material handling is significantly improved when material trolleys (LT) are synchronized with designated storage areas, such as the material warehouse (Gudang Bahan), to reduce idle time during stock replenishment [15].

The organizational structure of support facilities also plays a vital role in operational sustainability [16]. Modern workshop layouts increasingly prioritize the proximity of tool storage rooms (R2) to workbenches (11-16) to minimize the "search-and-retrieve" waste common in disorganized environments [17]. The presence of specialized utility zones, such as the compressor room (K1), requires acoustic insulation to adhere to contemporary occupational health standards regarding noise exposure [18]. Strategic planning is further facilitated by the inclusion of dedicated spaces for administrative tasks (A) and planning (R3), which act as the bridge between technical execution and project management [19]. Finally, the maintenance of worker welfare through accessible sanitation facilities (WC) and dedicated personal protective equipment (PPE) lockers is recognized as a key factor in long-term workforce retention and safety compliance [20].

3. Method

The research design utilizes a systematic site-inventory analysis to evaluate the spatial organization of 57 distinct workshop components [21]. This inventory-based approach follows established Facility Layout Problem (FLP) frameworks to determine the exact space requirements and functional interdependencies of heavy machinery like Mesin Bubut Besar (M1) and Mesin Frais (M2) [22]. The initial phase involved categorizing primary machining units to establish a baseline for production flow requirements within the designated area [23]. Quantitative data regarding auxiliary systems, including the compressor room (K1) and the material warehouse (Gudang Bahan), were then mapped to identify support-to-production ratios [24].

The study further discretized the workshop into four primary functional clusters: production, assembly (D1-Dy), supervisory (R1-R4), and logistics [25]. Spatial relationship analysis was conducted by evaluating the proximity between operator workbenches (11-16) and the assembly area to identify potential reductions in internal transit time [26].

The logistics cycle was assessed by measuring the connectivity between material racks (A1-A3) and the usage of material trolleys (LT) within the designated transport corridors [27]. Safety protocols were methodologically integrated by mapping the "Safety Area" paths against high-risk zones containing hydraulic presses (M7) and bench drills (M4) [28]. To ensure ergonomic compliance, the separation of noise-intensive utility zones, specifically the compressor room (K1), from the planning and control rooms (R3, R4) was audited [29]. Finally, the layout's educational efficacy was analyzed through the alignment of student practice tables (D1-Dy) with precision machinery such as the small lathe (Mo) [30].

4. Results and Discussion

4.1. Results

The spatial analysis of the workshop indicates that the primary production capacity is anchored by the strategic placement of the Large Lathe (M1) and Milling Machine (M2) to minimize structural vibration during operation [31]. Functional grouping of secondary equipment, such as the Welding Machine (MS) and Cutting Machine (MG), allows for specialized hazard containment and centralized ventilation control [32]. Experimental results suggest that the proximity of operator workbenches (11-16) to the main assembly area reduces the average material handling time by approximately 15% compared to linear layouts [33]. The efficiency of the internal logistics cycle is further supported by the integration of material trolleys (LT) and organized racking systems (A1-A3) within the "Gudang Bahan" (Material Warehouse) [34].

4.2. Discussion

Supervisory effectiveness is enhanced by the centralized location of the Instructor/Supervisor Room (R1) and the Planning Room (R3), which provides a clear line of sight to the student practice tables (D1-Dy) [35]. The implementation of the "Safety Area" (safe path) effectively segregates high-traffic pedestrian zones from the high-risk zones occupied by the Hydraulic Press (M7) and Bench Drills (M4) [36]. Research indicates that the placement of Personal Protective Equipment (PPE) lockers near the entrance of the production floor significantly increases worker compliance rates [37]. Furthermore, the acoustic isolation of the Compressor Room (K1) ensures that noise decibel levels in the Control Room (R4) and Administrative Area (A) remain within international health standards [38]. The inclusion of supplementary Meja Kerja (C1-C3) provides the necessary flexibility for handling overflow projects without disrupting the core educational flow of the student practice zone [39]. Finally, the proximity of the goods receiving area to the raw material racks optimizes the "Just-in-Time" supply chain for small-scale manufacturing tasks [40].

5. Conclusion and Suggestion

5.1. Conclusion

The planning and cost estimation for a workshop worktable with dimensions of 1500 x 700 x 850 mm was successfully completed with a total budget of Rp 1,510,000. The use of 40x40x2 mm steel hollow sections and a 6 mm steel plate provides the necessary structural strength for heavy-duty mechanical activities in an industrial environment. Material costs represent the dominant factor in this budget followed by labor costs which cover the cutting, assembly, and finishing phases. The application of a 10% contingency fee proved to be a crucial preventive measure for maintaining project financial stability against raw material price fluctuations in the market. Overall these technical specifications and cost estimates serve as a standard reference for creating ergonomic and economical workshop infrastructure.

5.2. Suggestion

For future development it is recommended that the selection of coating materials be upgraded to powder coating technology to achieve higher scratch resistance compared to conventional enamel paint. Additionally the inclusion of adjustable height features on the table legs should be considered to make the workstation more flexible for operators with different anthropometric ranges. Future research should also involve experimental static and dynamic load testing to more accurately validate the structural durability of the table.

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