

Road Sweeper Prototype: An Affordable Model Engineered on Motorcycle Functionality

Endang Achdi¹, Widiyanti Kwintarini¹, Farid Rizayana^{1*}, Mohamad Arfansyah¹,
Muhammad Daffa Aliyyandra¹

¹Department of Mechanical Engineering, Faculty of Engineering, Universitas Pasundan, Indonesia

*Corresponding author's email: farid@unpas.ac.id

Article Info

Article history:

Received: 28 September 2025

Revised: 30 October 2025

Accepted: 24 November 2025

Published: 12 December 2025

Keywords:

Cost-efficient,
Environmental sanitation,
Motorcycle,
Prototype,
Road Sweeper.

Abstract

Background: Road sweepers have become essential for urban road maintenance although current versions frequently exhibit inefficiency, especially on small roadways.

Aims: This project aims to design construct an efficient, cost-effective prototype of a street sweeper capable of operating in limited locations, utilizing a motorcycle as the primary driving mechanism.

Methods: The process employed encompasses design utilizing CAD software, prototype construction with carbon steel and standard mechanical components, and subsequent road testing. The results of the experiment indicate that this equipment can clear the road at a velocity of 60 meters per minute when towed by a motorcycle, far faster than the manual method, which requires approximately 5 minutes for the same distance.

Result: This device can gather rubbish at an average rate of 1.6 kg per minute when operated manually and 1 kilogram per minute when trailed by a motorcycle.

Conclusion: Considering the current limitations in waste collection capability, this research offers a more cost-effective and environmentally sustainable approach to urban cleanliness, with opportunities for enhanced waste collection capabilities and the integration of electric motors.

To cite this article: Achdi, E., Kwintarini, W., Rizayana, F., Arfansyah, M., Aliyyandra, M. D. (2025). Road Sweeper Prototype: An Affordable Model Engineered on Motorcycle Functionality. *Open Science and Technology*, 5(2), 90–105.

This article is under a Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) License. [Creative Commons Attribution-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-sa/4.0/) Copyright ©2025 by author/s

1. Introduction

The main function of a road sweeper is to transfer dirt and debris from clean areas to the suction zone, so promoting urban cleanliness efficiently. The street sweeping vehicles' sweeping system comprises multiple components, including a gutter brush designed to remove dirt from the road's edge (Pratama et al., 2023). This tool has experienced advancements in design and technology intended to enhance productivity in sweeping activities (Roni, 2020).

The exorbitant cost of street sweeper units presents a significant challenge, hindering many small cities with constrained resources from procuring them. [Wu et al. \(2025\)](#) indicate that commercial street sweeper vehicles typically retail between USD 150,000 and USD 300,000 per unit, contingent upon their capacity and features. Operational expenses may amount to USD 1,000–2,000 monthly per unit, attributable to elevated fuel consumption and the necessity for regular repair of the hydraulic system, motor, and vacuum. This issue complicates road cleanliness maintenance for numerous communities, particularly those with constrained funds.

The manual sweeping technique, while still prevalent in certain regions, possesses several notable disadvantages. This strategy necessitates considerable time and effort to encompass extensive areas, particularly in locations with elevated traffic density. Research indicates that human cleaning of beaches and public places is often unsuccessful and labor-intensive, highlighting the urgent necessity for automated cleaning solutions ([Deshpande et al., 2023](#)). Voluntary cleaning necessitates substantial human resource engagement, which may diminish operational efficiency ([Manikanta et al., 2025](#)). [Adedeji et al. \(2020\)](#) conducted research that resulted in the development of a portable street sweeper machine suitable for usage in markets and parks, demonstrating enhanced efficiency relative to manual sweeping. [Choudhari et al. \(2025\)](#) conducted research that resulted in the creation of a semi-automatic, battery-powered street sweeper including revolving brushes and a trash container to improve urban cleanliness efficiency. Field testing demonstrated that this instrument could diminish dependence on human labor, accelerate cleaning duration, and offer an energy-efficient and economical alternative to manual methods or traditional motorized street sweepers.

Research conducted by [Hammed et al. \(2024\)](#) produced a powered by solar energy street sweeper that is eco-friendly and energy-efficient, with the objective of diminishing reliance on human labor. This device uses a 40 W solar panel and a 12 V DC motor to run the spinning brush, features a power storage battery, and is engineered to be lightweight and user-friendly in urban environments, producing no harmful emissions. [Kiran et al. \(2019\)](#) developed an eco-friendly electric street sweeper utilizing a 500 W DC motor, with a chain transmission system and an automatic dust collection mechanism. This device effectively cleans streets without producing emissions or noise, while minimizing human labor and operational expenses relative to manual techniques.

One proposed solution is to develop a more cost-effective and efficient street sweeper that can be towed by a motorcycle. This equipment provides adaptability in navigating tight streets that are challenging for giant street sweepers to access. [Yang et al. \(2018\)](#) conduct experimental study on the efficacy of a compact street sweeper utilizing a three-factor orthogonal test approach to identify the optimal parameter combination. The research findings indicate that a driving speed of 5.27 km/h, a disk brush speed of 106.85 rpm, and a roller brush speed of 159.86 rpm produce a cleaning efficiency of 92.81%, consistent with the experimental verification results.

This research seeks to design and develop a prototype street sweeper that is more efficient, cost-effective, and environmentally sustainable by utilizing a motorcycle as its propulsion system. The utilization of motorbikes is significant due to their low investment and operational costs, fuel

efficiency, ease of maintenance, and accessibility of replacement parts. This design aims to provide an effective solution for small towns and budget-constrained places, while improving mobility and cleaning capabilities in confined spaces inaccessible to larger vehicles. The utilization of motorbikes enhances cleaning time efficiency, operational flexibility, and diminishes emissions and operator workload, rendering it a sustainable solution for urban cleaning systems.

2. Methods

The research methodology consists of five main phases. The initial phase consists of a literature review aimed at collecting information regarding street sweepers, drive mechanisms, standard components, and the current developments in technology.

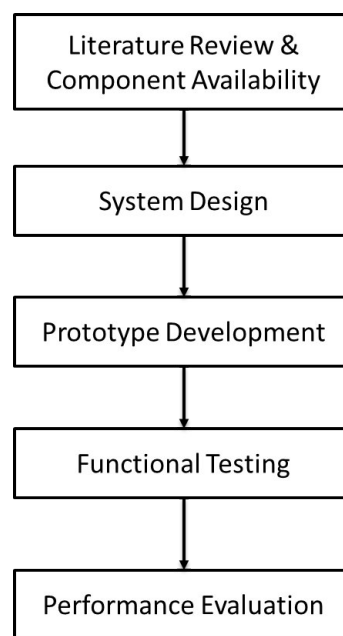


Figure 1. Research Flowchart

Based on Figure 1 could be utilized in the design of a road sweeper. The second stage concerns the design of the implement, encompassing an overview that covers dimensions, drive mechanisms, and the configuration of other components. This design prioritizes user-friendliness, efficiency in cleaning duration, and minimal operational expenses. Upon completion of the design, the subsequent phase is prototyping, which entails fabricating a framework from low-carbon steel that is cut and welded utilizing a welding apparatus. Subsequently, mechanical elements including motors, gearboxes, sprockets, chains, and pulleys are installed to create a transmission system that will operate the primary brush and waste collector.

During the fourth step, functional testing of the prototype is performed to evaluate the tool's efficacy in road cleaning. This assessment is conducted by utilizing the tool on a designated roadway, with the objective of evaluating the efficacy of the drive system and the tool's capacity to gather minor debris, including leaves, lightweight plastic, and dust. The observed parameters

are: (1) rotating velocity, (2) swept area, (3) cleaning duration, (4) fuel usage, and (5) vehicle velocity. The fifth stage is data analysis, conducted to evaluate the prototype's performance based on test results. The measured parameters include brushing time efficiency, the tool's waste collection capability, and its operational costs. This study included calculation to assess the tool's performance efficiency. One of the main calculations is determining the torque required for running the mechanical system of the road sweeper. The torque estimations are conducted using the following formula:

$$T = \frac{P \times 9550}{N} \quad (\text{Shigley et al., 1985})$$

Description:

T = Torque (Nm)

P = Power (kW)

N = Rotation Per Minutes (RPM)

The torque ratio obtained through this calculation is a key reference for selecting power transmission components, including pulley diameter, chain size, and the suitable type of driving motor. For the Evaluation of fuel consumption and operational expenses of the equipment was performed, with a comparison with manual sweeping methods and traditional street sweeping vehicles. Regular maintenance of the equipment is conducted by brush cleaning, chain lubrication, and frequent inspections of the drive motor's condition to prevent early damage and maintain low running costs.

Table 1. Likert Scale

Evaluation categories	Code	Score
Very Good	VG	5
Good	B	4
Fairly Good	FG	3
Poor	P	2
Very Poor	VP	1

3. Results and Discussion

3.1 Design and Development

The cleaning equipment includes gutters brooms, a drive motor, and a sweeper arms. The engine that powers the drive is charged with rotating the brooms in both clockwise (CW) and counterclockwise (CCW) directions. The operational idea of the sweeper system involves channeling trash towards the center, where it is collected by the primary brush. The procedure commences by aligning the arms in accordance with the designated area to be cleaned, ensuring the brooms make contact with the road surface. Two brooms are positioned to rotate in opposite

directions, one clockwise and the other counterclockwise, to channel debris toward the center of the sweeper (Pratama *et al.*, 2023).

The gutter sweeps perform as an important equipment for gathering many forms of debris from road surfaces or designated locations. A study by Kuncoro *et al.* (2024) elucidates the incorporation of a hydraulic system in an electric road sweeper. The motor is an essential component that supplies power to operate the sweeper arms and gutter brooms. Putro *et al.* (2022) combined an autonomous control system with the DC fan motor to improve the performance of the cleaning equipment. The installation of a drive with accurate speed regulation improves cleaning efficacy, as evidenced by Amirudin *et al.* (2022), which indicated that cleaning duration can fluctuate according to the tool's speed.

The prototype of the constructed tool contains several main components: the frame, driving system, main brush, and waste collector. This tool's design is predicated on utilizing a motorcycle as the primary propulsion mechanism. The prototype frame is constructed from low carbon steel, namely ASTM A500, in a hollow configuration with dimensions of 30 mm x 30 mm x 1.2 mm. This frame is engineered to be robust enough to bear the weight of additional components while maintaining a lightweight design to enhance mobility.

The propulsion system employs a 2-stroke engine with a displacement of 63cc, which powers the sprocket and chain to revolve the primary brush and debris collector. The primary brush serves to direct the debris towards the collector, which is utilized to contain the gathered waste. This prototype's transmission system includes a gearbox to modulate the engine's rotational speed according to the tool's operational requirements.

The framework suggested in Figure 2 represents the vitality process diagram produced by the machine, subsequently conveyed to the gearbox. Energy is conveyed to rotate the primary brush, with the shaft adjacent to the brush fitted with a pulley connected to the waste collector's pulley via a cross belt system. This structure enables the garbage collector to rotate in the opposite direction, facilitating waste collection, while the main brush sweeps and directs the waste into the waste box.

The exploded visualization of the sweeper unit (Figure 3) illustrates the power transfer mechanism from the drive motor to the main brush and two collectors. The motor's position (M) is initially directed across a gearbox to decrease speed and augment torque, subsequently transferred to the 11T gear, which rotates the 54T gear on the main brush shaft. The brush's spinning is linked to two pulleys that operate the collection system through a belt. The belt arrangement is crosswise on one side, causing the two collectors to rotate in opposite directions, with one turning clockwise and the other counterclockwise. This approach enables the primary brush to propel dirt into the center, while both collectors revolve to accumulate and channel the debris into the collecting container, so assuring an effective and balanced cleaning operation.

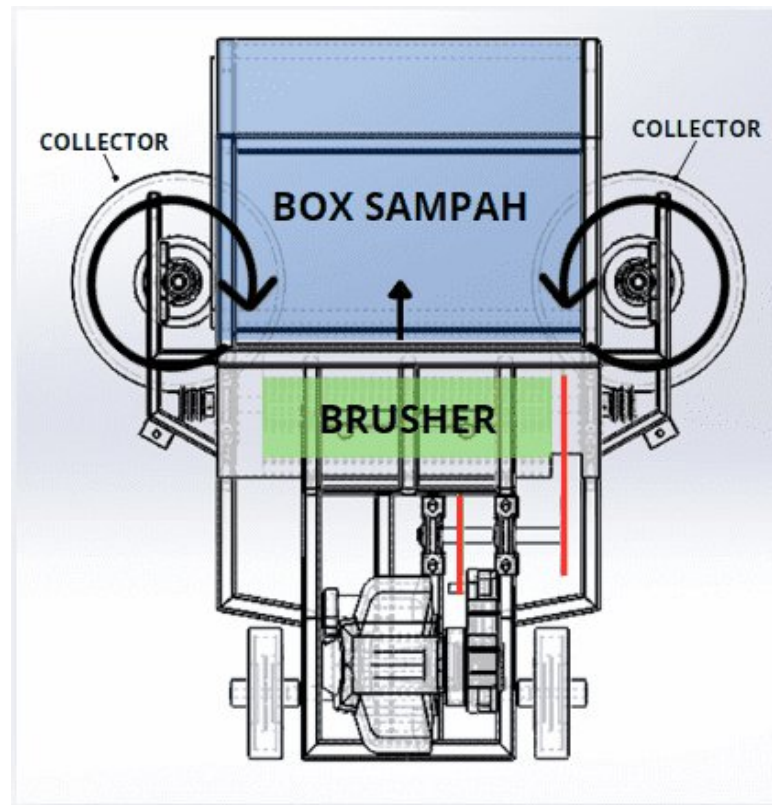


Figure 2. Design of the constructed brushing mechanism

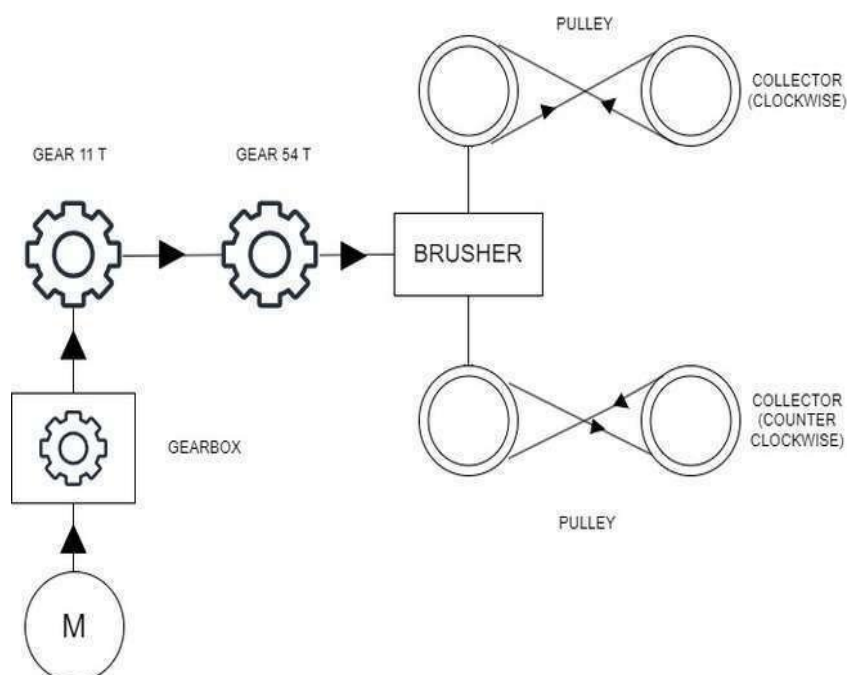


Figure 3. A model of the constructed sweeper

The conceptual results of the motorcycle-driven road sweeper demonstrate the final appearance of the sweeper design, together with the configuration of its primary components (Figure 4). This design incorporates a compact frame constructed from 30×30×1.2 mm hollow steel, engineered to

endure substantial loads while maintaining a lightweight profile, facilitating towing by a motorcycle. At the top of the structure, there's a mount for a 2-stroke drive motor with a displacement of 63 cc, linked to a transmission system comprising a sprocket, chain, and pulley to operate the primary brush. The sweeping brush is positioned in the bottom central section of the frame, with the rotation direction calibrated to direct garbage toward the center, while the collection container is set up at the rear of the instrument. This design emphasizes a balance of power efficiency, structural integrity, and maintenance effectiveness, making it the tool to function correctly in urban environments defined by small roads and minimal operational costs.

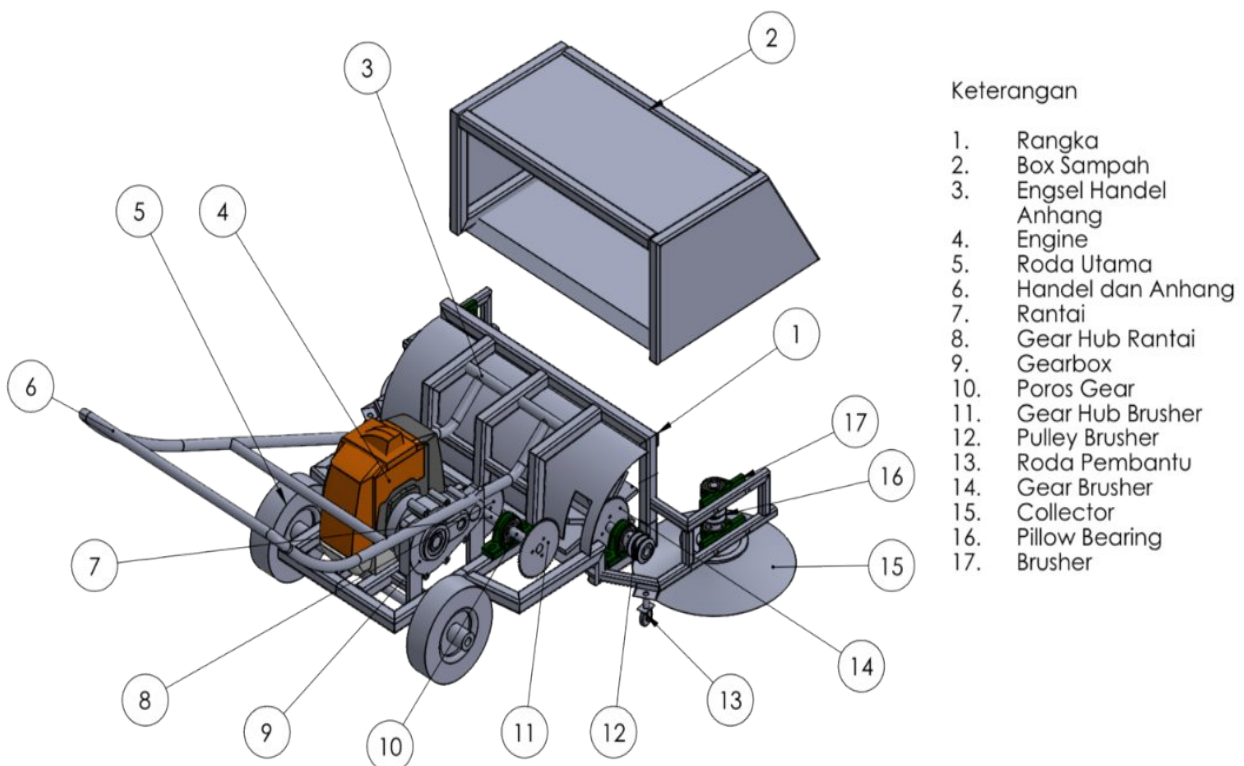


Figure 4. Illustration of the assembled sweeper component

Figure 5 shows the loading diagram developed for evaluating the stability of the primary structure. The diagram shows the stress distribution on the frame caused by the weight of the main components, specifically the drive engine, main brush, and waste collector, along with the reactions at both frame supports. The driving motor is situated at the front of the frame, producing a concentrated load at position $x=0.4$ m, while the primary brush is centrally located at $x=0.8$ m, and the waste dump is positioned at the bottom of the frame at $x=1.0$ m.

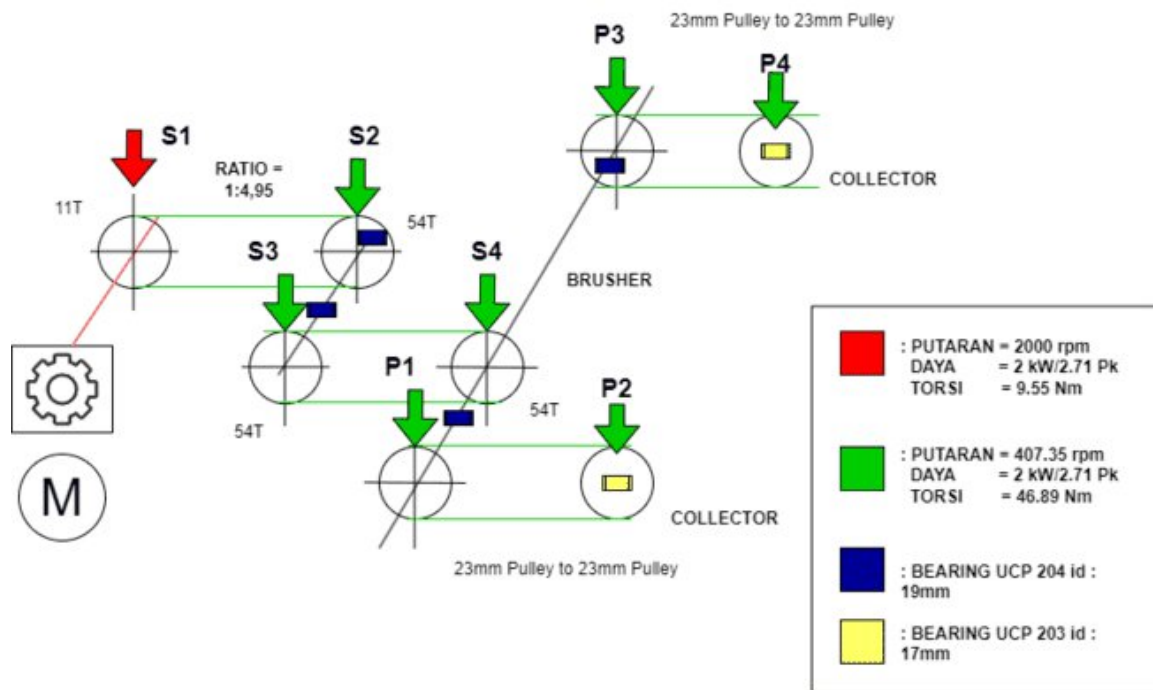


Figure 5. Load diagram for the sweeper

The torque analysis findings indicate the distribution of internal forces placed on the frame by the biggest forces, specifically the drive motor, main brush, and waste collector (Figure 6). The response force at the left support is 100.67 N, while at the right support it is 147.83 N, with a notable alteration in the axis of the shear force occurring at the location of the main brush. The moment of tensile diagram shows that the peak moment is located roughly 0.8 meters from the left support, with a magnitude of 49.13 N·m (Figure 7). The stress during tensile analysis indicates a peak value of 38.5 MPa in the hollow frame profile measuring 30×30×1.2 mm, significantly lower than the yield strength of carbon steel, around 250 MPa. This condition signifies that the frame structure possesses adequate strength to endure the static operational stress of the tool. It is important to acknowledge that these results do not currently consider dynamic impacts, such as vibrations and shock loads, which may elevate the risk of material fatigue, particularly at junctions.

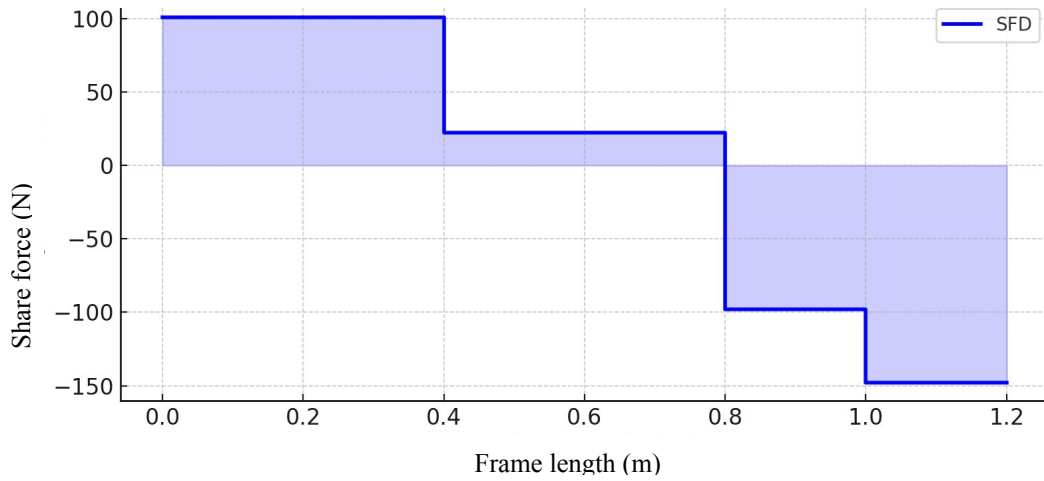


Figure 6. Force of shear Diagram

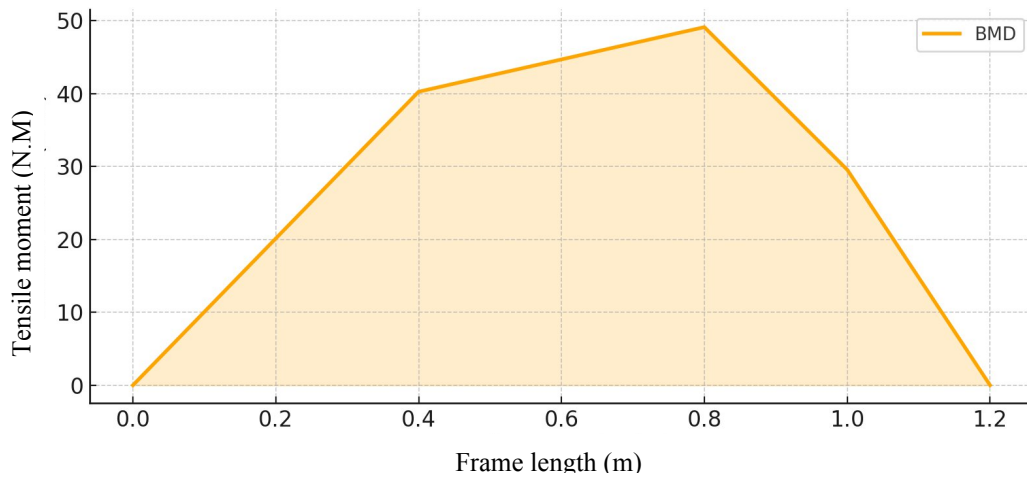


Figure 7. Tensile diagram of moments

3.2 Model Development

The sets up with accurate design using CAD (Computer-Aided Design) software. The initial layout concentrated on the primary elements of the tool, comprising the frame, driving mechanism, principal brush, and waste collection system. Following the approval of the design, the subsequent phase involved the production of these components.

The prototype frame is constructed from low-carbon steel ASTM A500, with a hollow configuration with dimensions of 30 mm x 30 mm x 1.2 mm. This frame is fabricated and assembled with a welding machine to guarantee the tool's strength and stability. In the subsequent phase, a 63cc 2-stroke propulsion motor is affixed to the prototype chassis. This engine drives a transmission system with a sprocket, chain, and pulley, utilized for the movement of the primary brush and waste collector. The manufacturing process encompasses the assembly of mechanical components, including the gearbox, bearings, and shaft. The sprocket and chain facilitate the transmission of rotational motion from the driving motor to the primary brush and waste collection. Following completion of the assembly of all components, the tool undergoes testing to verify compatibility among components and operating performance.



Figure 8. Prototype without a waste container

The main components of this prototype include a drive motor, gearbox, sprocket, chain, bearing, pulley, and main brush. The driving motor is a 2-stroke engine with a displacement of 63cc, a power output of 2 kW, and a torque of 9.55 Nm. The employed gearbox features a ratio of 4.91 to reduce the motor's rotary speed and align it with the tool's operating requirements. Sprockets and chains enable the transfer of torque from the motor to the primary brush and the waste collector. The primary brush employs plastic bristles to gather debris, whereas the waste collector is constructed from low-carbon steel in a hollow configuration with a capacity of 0.0727 m³. This prototype features 8-inch wheels to increase its portability on roads.

3.3 The Testing

The key components of this prototype include a drive motor, gearbox, sprocket, chain, bearing, pulley, and main brush. The utilized drive motor is a 2-stroke engine with a displacement of 63cc, a power output of 2 kW, and a torque of 9.55 Nm. The gearbox employed has a ratio of 4.91 to diminish the motor's rotational velocity and tailor it to the tool's operational requirements. Sprockets and chains facilitate the transmission of power from the motor to the primary brush and the waste collector. The primary brush employs plastic bristles for trash collection, whereas the waste receptacle is constructed from low-carbon steel in a hollow configuration with a capacity of 0.0727 m³. This prototype features 8-inch wheels that facilitate mobility on the road.

Table 1. Primary Sweeper and Collector Cleaning Rotation Test

Rotation Speed (RPM)	Test Remarks	Information
200	30 %	Trash gets tossed beside the sweeper due to insufficient spinning to elevate and drive particles.
300	70 %	It works well in depositing waste into the container, although it continues to keep a little volume of refuse.
400	100 %	The garbage was properly disposed of with no remains.
500	80 %	Some of the dirt came out due to the brush's overly rapid turning rpm.

A following test was performed to assess the waste disposal capacity. The prototype collected an average of 1.6 kg of rubbish every minute when operated manually and 1 kilogram in the same duration when operated by motorcycle. The results demonstrate that the device can efficiently manage modest junk volumes, however its collection capacity remains constrained in comparing with larger road sweepers.

Table 2. Outcomes of Refuse Collection

Parameters	Human-driven Testing Parameters (Average)	Motorcycle-pulled Testing (average)
Time (m)	1	1
Weight of Waste Transported (kg)	1.6	1
Mileage Gained (m ²)	30	60

Mobility testing of a road sweeper was performed to look at the transition of the equipment between operational and inactive states, facilitated by the installation of a stopper on the handler arm. This stopper facilitates the effortless elevation of the sweeping component, enabling the equipment to be relocated or readied for operation.



Figure 9. Mobilization operation when the equipment is passive

A design study was conducted to evaluate the concept's feasibility for functionality, reliability of construction, comfort, efficiency in operation, and potential for further development. This evaluation aimed to establish the design's effectiveness against field needs and to offer recommendations for future design improvement. The machine's construction emphasized improving sweeping efficiency in small areas while ensuring minimal operation costs. The device's operating system features two lateral brushes that revolve in opposing directions to channel trash into the center, together with a primary brush that propels the debris into the collection container. Test results indicated that the device can enhance sweeping efficiency by as much as 50% relative to manual techniques, with an optimal sweeping speed of 400 rpm. This illustrates that the transmission and drive system efficiently convey power from the motorcycle to the sweeping mechanism, resulting in optimal cleaning outcomes for light material, including leaves, dust, and small plastics.

The main frame utilizes ASTM A500 low-carbon steel in a hollow profile of $30 \times 30 \times 1.2$ mm, providing adequate strength for supporting component tension without adding a lot of weight. This material is appropriate for the prototype phase because of its malleability, lightweight nature, and cost-efficiency. Galvanized aluminum or steel is suggested for manufacturing to enhance corrosion resistance from environmental exposure. The mechanism for transmission employs a mix of sprockets, chains, and pulleys, which is effective and efficient in power transfer, although generates considerable noise and necessitates frequent lubrication. Consequently, it is advisable to transition to a closed belt drive system or a direct electric motor to enhance reliability and minimize routine maintenance.

The tool includes a carrying handle and stopper that helps in elevating the cleaning mechanism for transportation, and additionally 8-inch wheels for mobility on level surfaces. This design emphasizes convenience and storage, yet lacks to fully adhere to the principles of operator ergonomic. It is advisable to incorporate a variable elevation function that adapts to the user's posture and to install a dust shield to safeguard the operator from particles in the air during operations. The examination results suggest the tool has a cleaning ability of up to 60 m² per minute while maintaining minimal fuel usage. This number signifies a commendable degree of energy efficiency and productivity. However, the long lifespan of transmission components, including chains, sprockets, and bearings, requires additional testing to ascertain reliability over extended periods of usage. The equipment's design needs to include easily maintainable features, including rapid inspections accessibility and automated lubricating paths, that encourage effective maintenance processes in the field.

The result of the test findings showed that the sweeping mechanism worked properly, with two side brushes (gutter brooms) channeling material into the center, where it is collected by the main brush into a receptacle. Nevertheless, the cleaning performance remains suboptimal, particularly concerning small and lightweight waste such as fine dust, thin plastic, and dried leaves.

The experiments were conducted on various road surface conditions with various brush rotation speeds. The results indicated that:

- During brush speeds under 200 rpm, centrifugal force was inadequate to transport waste to the collector, leaving numerous particles at the periphery of the sweeping region.
- During speeds that ranged from 350 to 450 rpm, the sweeping operation was highly efficient; the majority of garbage was transferred to the collection container in a little duration.
- During speeds exceeding 500 rpm, the brush produced excessive thrust, resulting in debris being ejected from the sweeping zone.
- This signifies that the tool's efficacy is considerably influenced by the brush rotation speed and the state of the road surface. Irregular surfaces hinder certain portions of the brush from achieving optimal contact with the ground, hence diminishing the cleaning efficiency.

Multiple factors that result in substandard cleaning outcomes include:

- The contact pressure between the brush and the road surface is distributed unevenly. The side brushes keep coming across changes in pressure resulting from an imbalance between the drive shaft and the surface.
- The rotational direction and arrangement of the brushes are suboptimal. The proximity of the side brushes to the main brush is excessive, resulting in incomplete redirection of waste to the center.
- The characteristics and length of the brush bristles influence the propulsion and capacity to collect minute material. Brushes constructed from rigid plastic are less efficient for removing dust and sand, whilst those composed of too pliable materials tend to deform under substantial weight.

- The dimensions and configuration of the collecting container remain constrained, resulting in the inadvertent release of collected material when the tool vibrates or alters its position.
- Variations in field conditions, including wet, sandy, or uneven surfaces, result in fluctuations in the tool's performance.

To improve the tool's performance, various improvements can be implemented, including:

- adjusting the brush rotation velocity using a variable speed controller, enabling the operator to tailor the sweeping force to the surface characteristics and waste volume.
- Modifying the angle of the side brushes (5° – 15°) in relation to the road surface to enhance the lateral force directing waste towards the main brush.
- Utilizing a combination of bristle materials (rigid nylon outside and pliable fiber within) to enable the tool to manage both coarse and fine debris concurrently.
- Redesigning the collection container with inclined walls and a straightforward locking mechanism to avert waste ejection caused by vibrations.
- Additional experiments on diverse road surface conditions to establish a correlation curve between brush speed and cleanliness level (% of waste eliminated).

Based on field tests, average cleaning efficiency reaches 80–85% for medium-sized debris (leaves and small plastic), while for fine particles like dust and sand, efficiency drops to 65–70%. Although these results are suboptimal, the gadget has exhibited commendable functional capabilities and can perform continuously for 30 to 40 minutes without mechanical disruption.

The key difference between this study and prior research resides in the design methodology and propulsion system employed. Our study involved the creation of a road sweeper prototypes including a mechanical system that facilitates both manual and motorbike operation. This design aimed to minimize labor and time for cleaning, with operational testing indicating that the device efficiently cleans greater areas, achieving up to 60 m² per minute, while maintaining low fuel consumption and an optimal sweeping speed of 400 rpm. Nonetheless, the encountered issues persisted, specifically the device's inadequacy of handling rough terrain, necessitating additional enhancements in the wheel configuration and propulsion system.

However, the study conducted by Iqbal Raihan et al. ([Raihan et al., 2024](#)) focused primarily on the mechanical design of the drive system, employing a gear and chain transmission to run the primary broom and waste collector, powered by a motorized vehicle. This strategy prioritized mechanical strength and material durability for consistent operation on flat surfaces; nevertheless, this study did not comprehensively examine the device's operational performance and efficiency. Consequently, although both studies examined motorcycle-powered street sweepers, our research emphasized operational efficiency and cost-effectiveness, while Raihan's study concentrated on the mechanical robustness and reliability of the driving mechanism.

4. Conclusion

The study substantially developed and constructed a prototype motorcycle-driven road sweeper that improved the efficiency of cleaning narrow roadways at minimal operational costs. Test results showed that the sweeping system, featuring two side brushes and one main brush, achieved a cleaning effectiveness of 80–85% for medium-sized debris and 65–70% for tiny particles.

The ideal sweeping speed was attained at 400 rpm, where the force distribution and brush rotation direction yielded the most efficient cleaning outcomes without allowing debris to escape the designated region. The frame design, constructed from ASTM A500 low-carbon steel, had sufficient strength and lightweight characteristics to sustain all mechanical components, while the sprocket and chain transmission system displayed dependable performance, albeit necessitating routine maintenance. The tool demonstrated stability at low motorcycle speeds and facilitated transport due to its 8-inch diameter wheels and a stopper mechanism on the driving arm.

The developed prototype successfully achieved the design objectives of creating a portable street sweeper that is efficient, cost-effective, and operable by a single individual. Nonetheless, many factors like brush composition, the design of the collection receptacle, and the transmission mechanism necessitate enhancement to augment cleaning efficacy and the tool's durability over prolonged use across diverse road surface conditions. Nonetheless, some challenges require enhancement, particularly with the waste collector's restricted capacity and the tool's capability to manage larger or heavier waste. The durability of mechanical components, including sprockets and chains, must be evaluated to guarantee the tool's long-term resilience and lifespan.

5. Acknowledgement

This project received support from the Faculty of Engineering at Pasundan University through the Internal project initiative for the years 2024-2026. We wish to convey our profound appreciation to the Dean of the Faculty of Engineering at Pasundan University for assisting us in completing this research.

6. References

- Adedeji, K. A., Adebessin, E., & Adekunle, A. (2020). Design and construction of a street sweeping machine. *International Journal of Engineering Applied Sciences and Technology*, 5(2), 626–630.
- Amirudin, F., Hakim, L., & Zulfika, D. N. (2022). Rancang bangun alat penyapu debu. Seminar Nasional Fakultas Teknik, 1(1), 191–194. <https://doi.org/10.36815/semastek.v1i1.34>
- Choudhari, R. M., Zope, S. P., Kolhe, B. S., Bhople, A. V., Ambekar, M. D., & Nile, S. V. (2025). Design and fabrication of a semi-automatic road cleaning machine for sustainable urban maintenance.
- Deshpande, P., Milkhe, O., & Kamble, A. (2023). Beach cleaning robots: A comprehensive survey of technologies, challenges, and future directions. *International Research Journal of Modernization in Engineering Technology and Science*. <https://doi.org/10.56726/irjmets37666>

- Hammed, T. A., Isah, A., Ojochoko, E. S., Teslim, A. O., & Hamzat, M. B. (2024). Design and fabrication of motorized solar street sweeping machine. *Caliphate Journal of Science and Technology*, 6(2), 184–188.
- Kiran, C. H., Teja, B. R., & Chandrasekhar, M. (2019). Fabrication of electric street sweeping machine. *International Journal of Research in Engineering, IT and Social Sciences*, 9(2), 33–45.
- Kuncoro, R. T. K., Sugiyanto, S., Kurniawan, S. D., & Ikhsan, R. (2024). Integrasi sistem hidrolik vessel double cylinder dan lengan penyapu pada electric road sweeper. *Jurnal Teknologi dan Rekayasa Alat Berat*, 1(1), 1–5. <https://doi.org/10.22146/jtrab.v1i1.8604>
- Manikanta, M. R., Srinivas, C. V., Kurthkoti, K., Rao, J., Kumar, P., & Akhil, B. (2025). Smart cleaning of road pavements. *International Journal of Scientific Research in Engineering and Management*, 9(3), 1–9. <https://doi.org/10.55041/ijssrem42826>
- Pratama, A. B., Sugiyanto, S., Krisnaputra, R., Prayoga, B. T., Prayitno, Y. A. K., & Djati, I. (2023). Kinerja sistem penyapu tipe gutter brooms pada prototipe kendaraan penyapu jalan. *Jurnal Rekayasa Mesin*, 14(2), 499–512. <https://doi.org/10.21776/jrm.v14i2.1288>
- Putro, A. M. S., Sutisna, S. P., & Siregar, T. H. (2022). Rancang bangun dan uji kinerja sistem vacuum cleaner pada robot pembersih lantai. *Almikanika*, 3(4), 32–38. <https://doi.org/10.32832/almikanika.v3i4.6898>
- Raihan, I., Lubis, M., Siregar, A. M., & Siregar, C. A. (2024). Design and manufacture of mechanical drive systems for road sweepers on flat surfaces. *JTTM: Jurnal Terapan Teknik Mesin*, 5(1), 144–148.
- Roni, H. (2020). Perancangan sarana penyapu jalan raya untuk kawasan perkotaan. *Jurnal Kreatif Desain Produk Industri dan Arsitektur*, 1(2), 16. <https://doi.org/10.46964/jkdpia.v1i2.107>
- Shigley, J. E., Mitchell, L. D., & Saunders, H. (1985). Mechanical engineering design.
- Wu, E., Su, R., Tang, T., Zhu, G., & Geng, D. (2025). Ambient versus household PM2.5 exposure and socioeconomic disparities in intracerebral hemorrhage burden: A 32-year global analysis (1990–2021) with projections to 2050. *Frontiers in Public Health*, 13. <https://doi.org/10.3389/fpubh.2025.1615934>
- Yang, Q., Zhou, Y., Ying, K., Li, R., & Wang, X. (2018). Study on cleaning performance of small road sweeper vehicle. <https://doi.org/10.2991/eame-18.2018.41>