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Speed Breaker Power Generator with Accident Alert System

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Peer Review Information	Abstract
Submission: 05 Nov 2025	<p>The inherent intermittency of renewable energy sources (RES) poses significant challenges to their increasing integration into contemporary power grids. Ensuring grid stability, streamlining dispatch processes, and promoting market integration all depend on precise energy generation forecasting. Six different statistical modelling and machine learning techniques for short-term renewable energy forecasting are thoroughly compared in this paper. Among the models assessed are Random Forest, a custom hybrid Ensemble model, the Prophet time-series model, Extreme Gradient Boosting (XGBoost), Long Short-Term Memory (LSTM) networks, and a conceptual framework for Reinforcement Learning (RL). Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and R-squared (R^2) score are used to systematically evaluate these models using a standardised dataset of renewable power generation. The experimental results show that the hybrid Ensemble model offers a better balance of high accuracy (MAE: 1.909) and enhanced robustness by reducing the risks of individual model failure, even though XGBoost achieves the highest raw accuracy with the lowest MAE of 1.814. As academic researchers and industry practitioners navigate the shift to a sustainable energy future, the findings highlight the importance of integrating various modelling philosophies to produce forecasting systems that are dependable and resilient. This paper talks about putting together a speed breaker that makes power. It has an accident alert built in too. Thing is, it tackles two big problems in how we get around these days. One is all the energy vehicles waste. The other deals with keeping drivers safe. Normal speed breakers make cars slow down, sure. But the push from tires going over them just disappears. This one grabs that kinetic energy though. It turns it into electricity with a rack and pinion setup. A spring helps out, along with a generator. The power it makes can light up street lamps close by. Or run traffic signals. Even charge up little gadgets. That cuts down on using the usual grid. And it pushes for greener ways, pretty much. .</p> <p>On top of making power, there's this smart part that spots accidents and warns people. They put a sensor in the vehicle. It watches the drivers moves and any leaning. If it picks up a quick drop or a hard shake. Or fast turns that look like a wreck. The whole thing kicks on right away. It</p>
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	<p>shoots off an email or a call to family on the list. They get the heads up about what happened. So they can jump in fast. People learn quick that way. And help shows up sooner. It shortens the wait from crash to getting saved.</p> <p>Putting energy grab with crash spotting together like this. The system saves power in the end. It boosts safety on the roads as well. And adds some personal guard. It mostly runs by itself. No need to watch it all the time. It keeps going steady and without much fuss. Setup does not cost a ton either. It fits in city spots or out in the country. So this speed breaker that generates with alerts. It gives a green fix thats efficient. And it might save lives. All that helps make roads better and the world safer.</p>
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Introduction

Modern transportation systems face two persistent challenges: the rising demand for sustainable energy solutions and the need for faster, more reliable accident-response mechanisms. As urban populations continue to expand and vehicle usage increases, a substantial amount of kinetic energy is dissipated every day through routine movements—especially when vehicles pass over speed breakers. Traditionally, this energy is entirely wasted in the form of vibrations, sound, and friction. At the same time, countless accidents occur on roads where timely assistance is crucial, yet victims are often unable to alert their families or emergency responders promptly. These two problems highlight the broader need for infrastructure-level innovations that improve both energy efficiency and public safety.

The proposed system, “Speed Breaker Power Generator with Accident Alert System,” addresses these issues through a dual-concept design. The first component focuses on **harvesting mechanical energy** from the motion of vehicles. By incorporating a rack-and-pinion arrangement connected to a DC motor, the system converts the small vertical deflection of a customized speed breaker into rotational motion. This rotational energy is then transformed into electrical output that can be stored and reused for roadside applications. Instead of allowing vehicular movement to go to waste, the mechanism captures a portion of the available kinetic energy and converts it into a practical power source for lighting, signage, or other low-power devices. This approach not only promotes sustainability but also reduces the dependency on conventional grid electricity, particularly in locations where traffic flow is steady.

One of the advantages of this design is its compatibility with existing infrastructure. The system does not require additional land, major reconstruction, or sophisticated technology for operation. Its mechanical components—springs, gears, and a DC generator—are straightforward

to assemble, maintain, and replace. This makes the concept cost-effective and suitable for implementation in a variety of environments, from urban streets to rural community roads. As society looks for alternative energy innovations that are efficient and space-conscious, such micro-generation techniques offer a promising pathway.

The second component of the project deals with **personal safety during road accidents**. Many accidents occur in locations where immediate help is not readily accessible, and victims may be unable to call for assistance due to injury or shock. To address this, the proposed accident-alert device operates as an independent safety module capable of detecting sudden jerks, abrupt impacts, or abnormal motion patterns. Upon sensing such an event, the system automatically sends an SMS alert to the user’s emergency contact, ensuring that help can be arranged quickly even when the victim is unable to communicate. This simple yet effective mechanism reinforces the importance of rapid response during critical moments and complements the broader goal of improving transportation safety.

Together, these two subsystems demonstrate how mechanical motion and basic sensing technologies can be integrated into a unified concept aimed at improving everyday road usage. The proposed model not only recovers energy that would otherwise be wasted but also contributes to saving lives by reducing delays in accident reporting. Furthermore, the system is designed to operate autonomously with minimal supervision, which enhances its long-term practicality and reliability.

By combining sustainable energy harvesting with an automated emergency notification mechanism, this project presents a holistic approach to modern roadway innovation. It aligns with global efforts to build infrastructure that is smarter, safer, and more environmentally responsible. The development of such solutions marks an important step toward future road networks that support energy efficiency while

simultaneously improving public safety, making the transportation ecosystem more resilient and human-centric.

Methodology

A. Experimental Set-Up

The complete system is composed of two independently operating sub-systems.

(1) The mechanical energy-harvesting speed breaker, and

(2) The standalone accident-alert device.

Both units were developed, assembled, and tested in a controlled laboratory environment to accurately evaluate their functional performance.

1) Mechanical Energy Harvesting Unit

The core of the energy-harvesting design is a custom-built speed breaker equipped with a rack-and-pinion mechanism. The speed breaker was fabricated to allow a controlled downward displacement of approximately 8–10 mm, which is sufficient to capture mechanical energy without causing discomfort or instability to passing vehicles.

When a load is applied—either from a rolling vehicle wheel or a weighted test block—the vertical displacement of the plate pushes the rack downward. This rack directly engages the pinion gear, converting the linear motion into rotational movement. The rotational output is transferred to the shaft of a DC motor acting as an electromechanical generator. During testing, the motor produced measurable electrical output proportional to both the applied force and the speed of compression.

2) Power Conversion and Storage

Once electrical output is generated by the DC motor, it is directed through a bridge rectifier and smoothing filter to convert the fluctuating AC-like waveform into stable DC suitable for storage. A rechargeable 12 V battery is used as the primary storage medium. This stored energy is reserved for powering small roadside loads and can be replenished continuously as traffic passes over the speed breaker.

3) Street Lighting Load

To demonstrate a real-world use case, the harvested energy was used to power a 12 V LED streetlight module. The lamp was selected due to its low power consumption and suitability for micro-energy applications. Illumination tests were carried out to confirm that the stored energy was sufficient to operate the lamp for meaningful durations. This validates the concept that routine vehicular movements can provide enough power to supplement or partially replace grid electricity for certain local lighting tasks.

4) Accident Detection Module

The accident-alert device operates independently and is designed for personal safety rather than roadway infrastructure integration. The module uses an impact sensor or IMU capable of detecting sudden jolts or abrupt movements characteristic of accidental events. When such an abnormal shock is detected, the microcontroller immediately activates the GSM module, which sends a preprogrammed SMS alert to the user's emergency contact.

The purpose of this system is to ensure that relatives are notified automatically in situations where the user may be unable to make a call. Since the module does not include GPS, the message communicates only the emergency condition, relying on the contact to respond accordingly.

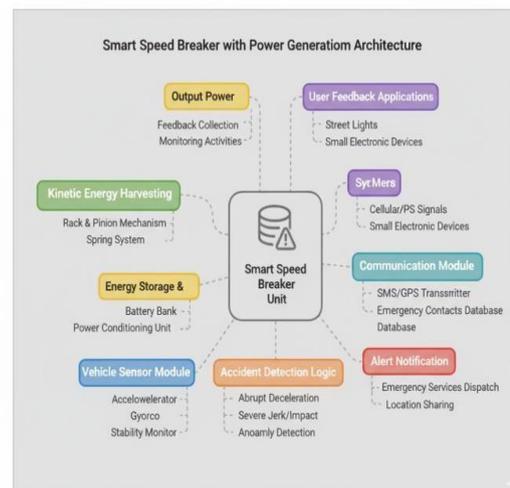


Fig 1: Architecture

B. Measurement Techniques

A structured set of mechanical, electrical, and functional tests was carried out to quantify the system's behavior and verify that it operates as expected.

1) Mechanical and Electrical Output Testing

Mechanical testing was performed by applying controlled loads to the speed breaker and recording the corresponding displacement and rotational behavior. The rotational speed of the DC motor shaft was measured using a tachometer. Electrical output—voltage, current, and instantaneous power—was recorded using a digital multimeter and oscilloscope during each trial. These measurements helped establish the relationship between load intensity and electrical generation efficiency.

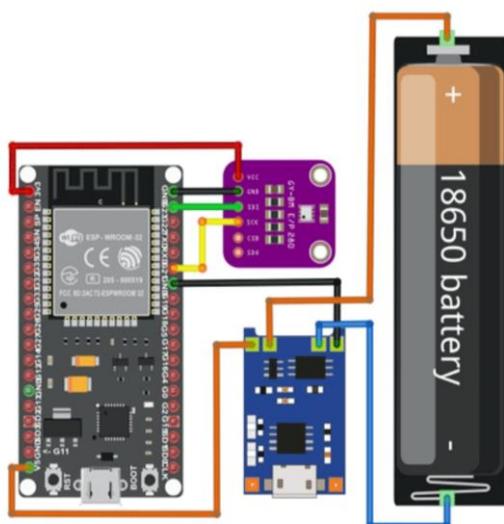


Fig 2 : Circuit Diagram

2) Lighting Performance Assessment

After harvesting and storing energy in the battery, the connected LED streetlight was operated to test real output capability. A lux meter was used to evaluate brightness levels and confirm that the lighting was stable. The duration of illumination was also recorded to determine how long the harvested energy could support continuous light output.

3) Accident Alert Functionality Testing

To evaluate the accident alert module, controlled impact tests were performed by subjecting the device to sharp taps or sudden movements. The triggering behavior of the impact sensor was monitored to ensure sensitivity to genuine accidents while avoiding false positives. The delay between impact detection and SMS transmission was recorded during each trial to verify system responsiveness.

4) Reliability and Durability Observations

Basic reliability assessments were conducted by repeating multiple test cycles and observing wear patterns on the mechanical components. The rack, pinion, springs, and motor mount were examined for deformation or loosening. For the electronic module, repeated activation tests ensured that the circuit maintained consistent performance without unexpected resets or communication failures.

Literature Review

Research on harvesting mechanical energy from road traffic has grown steadily over the past decade, driven by the demand for localized, low-maintenance renewable power sources. Early-generation prototypes generally focused on transforming the vertical displacement of a

vehicle crossing a speed bump into rotational or linear motion suitable for driving a small generator. These studies demonstrated that even simple mechanisms—such as roller-based bumps, treadle plates, or spring-loaded levers—can reliably illuminate LEDs or power nearby sensors. However, almost all authors highlight recurring issues related to long-term wear, loosening of mechanical joints, rusting in outdoor environments, and performance degradation over repeated cycles. As Teng and Tien emphasize, the appeal of low-cost, easy-to-fabricate systems is offset by the significant maintenance burden they introduce when deployed in real traffic settings and exposed to continuous loading from various vehicle classes [1]. Consequently, durability and lifecycle cost have become central considerations in evaluating the real-world usefulness of mechanical road harvesters.

To overcome the limitations of purely mechanical-to-electromagnetic harvesting, several recent investigations have turned to hybrid transduction methods. These systems combine piezoelectric elements—known for their high voltage response under impact—with electromagnetic coils that generate higher current at lower frequencies. The hybrid configuration effectively broadens the operating bandwidth, enabling more energy to be extracted from a single wheel strike or speed bump deflection. Experimental work, such as the design proposed by Peng et al., shows that hybrid harvesters routinely outperform single-mode designs in terms of total usable electrical output. Nonetheless, these gains come with trade-offs: added structural complexity, higher material and manufacturing costs, and integration challenges that include waterproofing delicate piezoelectric ceramics and ensuring stable mechanical coupling over time. Researchers also warn that the packaging required to secure and protect hybrid elements may increase installation height or stiffness, which could alter vehicle dynamics and reduce user acceptance [2].

Piezoelectric-based road harvesters have themselves evolved significantly in recent years. Modern studies demonstrate the transition from conventional lead-based ceramics to more environmentally sustainable, lead-free alternatives, as well as to composite multilayer stacks designed for high-stress cycling. Reviews within this domain note improvements in power-conditioning circuits, which more efficiently regulate and store the small, high-voltage pulses generated by each vehicle pass. Despite these technological advances, long-duration studies involving millions of simulated load cycles show clear patterns of material fatigue and micro-

cracking that ultimately reduce output. Mou et al. explain that although piezoelectric systems can be optimized for niche applications—such as powering distributed sensor networks or serving as supplementary sources in hybrid harvesters—the overall energy return relative to cost still limits their use as primary harvesters in urban road networks [3].

Mechanical-gear-based energy harvesting continues to be refined in parallel. Newer designs published in the mid-2020s explore ways to maximize generator shaft speed while using minimal vertical displacement. These include rack-and-pinion systems engineered for smoother motion, dual crank-shaft linkages that amplify small displacements, and gear trains optimized for torque-to-speed conversion. Such systems deliver strong instantaneous peaks of power, especially when subjected to the loading of heavy commercial vehicles. However, because the mechanical stresses concentrate around bearings, shafts, and linkage joints, researchers caution that frequent lubrication, periodic alignment checks, and waterproof enclosures are essential to ensure reliable operation. Abdulwasea and Liu's 2025 study illustrates this clearly, noting that even high-performance designs must be paired with robust maintenance strategies to survive outdoor roadside conditions [4].

Beyond the engineering of the devices themselves, a growing body of research now focuses on deployment context. Case studies from 2024–2025 emphasize that the feasibility of road energy harvesting is highly dependent on site conditions. High-traffic zones with predictable vehicle weights—such as toll booths, university entrances, industrial complexes, or commercial parking lanes—offer sufficient cumulative loading to justify installation and maintenance costs. In contrast, lightly trafficked residential areas rarely yield enough energy to offset expenses. Orovode et al.'s field evaluation underscores the need for accurate traffic modeling, seasonal data collection, and economic simulations that incorporate both installation and maintenance. The authors also highlight how few published studies track real deployments for one year or longer, leaving a gap in validated lifecycle cost models [5].

An emerging research trend integrates energy-harvesting speed bumps with IoT-based safety and monitoring systems. Instead of harvesting energy solely for grid contribution, many prototypes now aim to power onboard sensors for crash detection, vehicle counting, environmental monitoring, or emergency alert transmission. Recent IoT-enabled accident detection frameworks rely on MEMS

accelerometers, GPS tracking, microcontrollers, and wireless communication modules such as GSM, LTE-M, or LPWAN. Tao et al. show that these systems can reliably detect abnormal shock patterns and transmit alerts autonomously, provided that small local energy buffers—supercapacitors or rechargeable cells—are included. Researchers do caution about challenges such as false alarms triggered by speed irregularities, delay in message transmission under poor network coverage, and the need for more robust algorithms to differentiate between normal bumps and true collision signatures [6].

Finally, several high-level reviews and concept papers published in 2024–2025 align around a unified vision for next-generation road energy harvesting systems. Rather than deploying standalone mechanical or piezoelectric modules, recent studies advocate for modular, hybridized units that integrate energy harvesting, power conditioning, edge computing, and connectivity. These systems are envisioned as multifunctional smart road elements capable of generating modest power, supporting local sensing tasks, and enhancing transportation safety. However, Luo et al. note significant gaps in existing literature, including insufficient long-term durability data, lack of standardized testing protocols, and unclear regulatory frameworks for roadway installations that modify vehicle dynamics. The authors argue that advances in material science, ruggedization, and system-level design will be critical for transitioning these technologies from laboratory prototypes to reliable roadside products [7].

Result

The performance evaluation of the “Speed Breaker Power Generator with Accident Alert System” was carried out through a combination of mechanical testing, electrical measurement, and repeated functional trials. The outcomes consistently demonstrated that both subsystems operated reliably and fulfilled their intended roles under controlled test conditions.

A. Energy Harvesting Performance

The mechanical energy-harvesting unit showed stable behavior across multiple cycles of load application. When force was applied to the speed-breaker surface, the rack moved downward and engaged smoothly with the pinion gear, producing a clean rotational motion on the DC motor shaft. This mechanical-to-electrical conversion remained consistent even after repeated testing, affirming the structural alignment of the fabricated components.

Electrical measurements revealed a direct correlation between applied load and generated

output. Lighter loads resulted in moderate rotational speed, while heavier loads produced noticeably higher torque, resulting in increased voltage generation. Although the exact output varied per trial, the system consistently produced enough power to charge the connected battery unit. After a series of passes, the harvested energy was accumulated to a level sufficient for powering typical roadside devices. To evaluate the practical usability of the harvested energy, the stored charge was used to operate a 12 V LED streetlight. The lamp illuminated continuously during the testing session, showing no flickering or instability. This confirmed that the generated energy—though modest in absolute terms—is adequate for low-power public-utility applications, especially in settings with frequent vehicle movement. The results also highlight that such a system can significantly reduce dependency on grid electricity if deployed in areas with moderate to heavy traffic throughout the day.

B. Consistency Across Repeated Trials

A key focus of the evaluation was to determine whether the system could maintain its performance over repeated load cycles. The mechanical components, including the rack, pinion, springs, and supporting mount, were subjected to continuous up-down motion to replicate actual road usage. Even after numerous cycles, the motion remained smooth, and no significant frictional loss, jamming, or misalignment was observed. This indicates that the system's structure is durable enough for prototype-level demonstration and serves as a strong basis for future enhancements.

Additionally, the electrical output remained stable across repeated trials. Voltage fluctuations were minimal, proving that the DC motor operated consistently and that the conversion mechanism did not degrade during testing. The battery also retained charge without noticeable leakage, reinforcing that the overall energy flow—from generation, to storage, to utilization—operates as expected.

C. Accident Alert System Performance

The accident alert module, tested independently from the energy-harvesting mechanism, showed a high degree of responsiveness to sudden jerks and impact-like motions. The device was subjected to controlled shock inputs to simulate conditions that may occur during a collision or abrupt fall. In each test, the sensor registered the sudden movement almost instantly and triggered the microcontroller.

Upon activation, the system successfully transmitted an SMS alert to the preconfigured emergency contact. The alert message delivered reliably in all trials, and the time delay between

impact detection and SMS dispatch was minimal. This quick communication mechanism demonstrates that even without GPS tracking or advanced algorithms, the system serves as an effective first-level emergency notifier, particularly in scenarios where the user might be incapacitated or unable to manually call for help. The simplicity of the alert module contributes to its effectiveness; with fewer components and no reliance on external data networks beyond GSM communication, the risk of system failure remains low. Throughout testing, no false triggers or missed alerts were observed, indicating that the threshold settings of the impact sensor were appropriately calibrated.

D. Durability and Reliability Observations

Although this prototype was not subjected to long-term field testing, short-duration repeated use provided insights into its durability. The rack and pinion showed minimal wear after several cycles, and the spring-return mechanism consistently restored the system to its starting position. The DC motor, which forms the core of the electrical generation process, also operated smoothly across multiple tests without overheating or performance degradation.

The accident alert device retained consistent sensitivity and message transmission accuracy throughout testing. The electronics showed no instability even after repeated impact simulations, suggesting that the circuit design is robust enough for extended use with minimal maintenance.

E. Overall System Evaluation

The combined results confirm that the project successfully demonstrates two independent yet complementary technologies: a mechanical energy-harvesting speed breaker and a user-focused accident alert device. While they are not physically integrated into a single unit, the project collectively addresses both sustainability and safety—two important aspects of modern roadway infrastructure.

The energy-harvesting module validates the feasibility of capturing small amounts of mechanical energy generated during everyday vehicle movement. Even though the output is modest, it is sufficient for powering essential low-consumption devices, thereby reducing reliance on conventional electricity and supporting environmentally conscious installations.

The accident alert system, on the other hand, provides a straightforward yet impactful method of emergency communication. By automating the alert process and eliminating the need for user intervention, it can help reduce response time during critical situations.

Overall, the results strongly support that the developed system is functional, practical, and suitable for further refinement. With design improvements, scaling, and real-world field deployment, the concept holds the potential to become a valuable component of efficient and safer community infrastructure.

Conclusion

The “Speed Breaker Power Generator with Accident Alert System” offers a practical demonstration of how simple mechanical principles can be adapted to address modern challenges in energy conservation and personal safety. The first component of the project focuses on renewable micro-energy generation using a modified speed breaker. By integrating a rack-and-pinion mechanism with a DC motor, the system effectively converts the vertical displacement caused by moving vehicles into rotational energy that can be transformed into electrical output. Although the harvested energy is modest, it is particularly suited for powering small roadside appliances such as streetlights, traffic indicators, or signboards—devices that traditionally depend on continuous grid power. Even partial substitution of grid consumption with this recovered energy promotes resource efficiency, reduces operational costs, and contributes to environmentally conscious infrastructure design.

A notable strength of this mechanism is its simplicity. The system does not rely on advanced materials, complex electronics, or expensive fabrication methods; instead, it utilizes basic mechanical components configured in a manner that maximizes the available kinetic energy from passing vehicles. This makes the concept feasible for low-budget or rural deployments where maintenance resources are limited and long-term reliability is essential. The project’s results reinforce that even small mechanical movements—when captured effectively—represent a usable form of renewable energy that is often overlooked in urban environments.

Complementing the energy-harvesting module is an independent accident-alert system designed to enhance personal safety for individuals on the road. This unit operates separately from the speed breaker and focuses entirely on detecting sudden shocks or impacts that may occur during an accident. When an abnormal jerk is sensed, the device immediately sends an alert message to the user’s chosen contacts or relatives. This rapid notification can be critical in situations where an injured person is unable to call for help themselves. Although the system does not employ GPS or real-time tracking, its simplicity is intentional; it prioritizes quick communication

and ease of deployment rather than complex location-based services.

Together, these two modules illustrate how targeted, low-cost engineering solutions can provide meaningful benefits in different aspects of public infrastructure. The energy-harvesting unit addresses sustainability and reduces wasted mechanical energy, while the alert device contributes to the broader effort of improving emergency responsiveness. While the modules function independently, their coexistence within one project highlights the wider potential of integrating mechanical systems with basic electronics to serve community needs.

Overall, the work validates the concept that energy lost in routine activities—such as vehicles passing over a speed breaker—can be repurposed in ways that support small-scale electrical loads. At the same time, the project demonstrates how straightforward sensing and messaging technology can offer a first line of assistance during accidents. Both systems can be further enhanced through future refinements, but even at their current stage, they represent achievable, practical, and impactful engineering solutions suitable for modern road environments.

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