

A Review on Smart Energy Management in Elevator Systems Using machine learning

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Abstract—Modern elevator systems face challenges such as long waiting time, unnecessary movement, and high energy consumption. This project proposes EcoLift, an intelligent elevator dispatching system that uses Genetic Algorithm (GA)-based optimization and sensor-based passenger verification to improve elevator efficiency. The system aims to reduce passenger waiting time, optimize journey time, and minimize energy consumption. The proposed solution combines software-based optimization with low-cost hardware components for practical implementation.

Index Terms—Elevator Dispatching System, Energy Optimization, Genetic Algorithm, Artificial Intelligence, Smart Elevator, Waiting Time Reduction, Journey Time Optimization, IoT, Intelligent Transportation System, Energy Efficient System

I. INTRODUCTION

Imagine standing in a busy office building during the morning rush—dozens of people waiting, multiple elevator buttons lit up, and the system blindly stopping at every floor regardless of whether anyone is actually there. This is the everyday reality of conventional elevator systems, and it points to a much larger problem hiding in plain sight: our buildings are wasting energy, wasting time, and frustrating the very people they are meant to serve.

Over the past few decades, elevators have quietly become one of the most critical components of modern infrastructure. From towering skyscrapers to mid-rise hospitals and university campuses, vertical transportation is no longer a luxury—it is a necessity. According to industry estimates, elevators account for a significant share of a building's total energy consumption, sometimes as much as 3–8%, depending on usage patterns and building type [1]. In high-traffic environments, inefficient scheduling can amplify this figure considerably.

The root of the problem lies in how most traditional elevator systems are designed. They operate on fixed, rule-based logic—responding to every call without questioning whether a passenger is genuinely waiting. There is no intelligence behind the decision-making, no way to adapt to real-world conditions, and no mechanism to distinguish a phantom button press from an actual request. The result is a system that wastes trips, strains mechanical components, and leaves passengers waiting longer than necessary during peak hours.

This is not merely an inconvenience. In large commercial buildings, hospitals, or educational institutions where time and energy are both precious, these inefficiencies add up quickly. An elevator that makes five unnecessary stops per hour may seem trivial in isolation, but scaled across hundreds

of operating hours and multiple elevator banks, the cumulative cost—in kilowatt-hours, maintenance wear, and passenger frustration—becomes substantial.

What if elevators could *think*? What if, instead of blindly responding to every request, a system could evaluate which calls are genuine, determine the most efficient route, and continuously improve its decisions over time? This is the central idea behind intelligent elevator scheduling, and it is precisely the challenge that this paper addresses.

To build such a system, two complementary technologies are brought together: real-time sensor-based passenger detection and Genetic Algorithm (GA) optimization. Sensors serve as the system's eyes—detecting whether a passenger is genuinely present at a floor before committing an elevator to travel there. Genetic Algorithms, inspired by the process of natural selection, serve as the system's brain—evaluating multiple scheduling strategies simultaneously and evolving toward the solution that minimizes energy use and waiting time.

The resulting system, EcoLift, is designed from the ground up to be practical, scalable, and intelligent. Rather than replacing existing elevator hardware entirely, EcoLift acts as a smart scheduling layer that monitors real-time occupancy data and continuously optimizes dispatch decisions. The system targets three core performance metrics: *reduction in average passenger waiting time*, *minimization of unnecessary elevator travel*, and *overall improvement in energy efficiency*.

In the sections that follow, this paper presents the design, implementation, and evaluation of EcoLift. The related literature on elevator scheduling and genetic algorithms is reviewed in Section. The system architecture and algorithmic approach are described, results are presented and analyzed and the paper concludes with a discussion of practical implications and future research directions.

Ultimately, EcoLift is more than an engineering prototype—it is a demonstration that thoughtful, algorithm-driven design can transform a mundane piece of infrastructure into an intelligent, energy-aware system that genuinely improves everyday life.

II. LITERATURE REVIEW

The literature survey for the proposed EcoLift system is carried out by analyzing various recent research papers related to intelligent elevator optimization, Artificial Intelligence, Machine Learning, energy-efficient scheduling, smart transportation systems, and real-time monitoring techniques. The

reviewed papers mainly focus on reducing passenger waiting time, minimizing journey time, improving traffic handling, and decreasing overall energy consumption in elevator systems.

Several researchers have proposed optimization techniques such as Genetic Algorithms, Differential Evolution, Reinforcement Learning, Fuzzy Logic, and Deep Learning for improving elevator dispatching efficiency. Other studies have focused on sensor-based passenger verification, occupancy detection, energy-aware motor control systems, IoT-based monitoring, and smart building integration. These methods demonstrated significant improvements in elevator performance, energy savings, and intelligent traffic management.

The literature survey also highlights the limitations of existing systems, such as high computational complexity, expensive hardware requirements, implementation difficulty, and lack of low-cost practical solutions. Based on the analysis of these research works, the proposed EcoLift system combines Genetic Algorithm-based scheduling, sensor-based passenger verification, energy optimization, and real-time monitoring to develop a cost-effective and intelligent elevator optimization system suitable for smart buildings, educational institutions, and commercial environments.

A. Genetic Algorithm-Based Elevator Scheduling

Genetic Algorithms (GA) are widely used in elevator group control systems because they provide efficient optimization for multiobjective problems such as reducing waiting time, journey time, and energy consumption simultaneously. Corte's *et al.* [1] proposed a constrained multiobjective optimization model for elevator group control. The system optimized passenger waiting time and elevator movement using evolutionary optimization techniques. Their work proved that intelligent optimization methods can reduce unnecessary elevator trips and improve traffic handling in high-rise buildings.

Silva and Moreno [10] studied heuristic and optimization approaches for elevator group control systems. Their research highlighted the effectiveness of Genetic Algorithms in handling multiple elevator requests and traffic conditions dynamically. The authors explained that GA-based scheduling improves elevator allocation efficiency by finding near-optimal solutions within a short time.

Suzuki and Yamamoto [12] applied Deep Q Learning and optimization-based scheduling for elevator systems. Although their main focus was reinforcement learning, the research showed that intelligent optimization algorithms can significantly improve elevator dispatching efficiency and reduce energy usage under dynamic traffic conditions.

The proposed EcoLift system adopts the concept of intelligent optimization from these works and implements a Genetic Algorithm-based scheduler to optimize elevator allocation, reduce unnecessary movement, and improve overall energy efficiency.

Best Features of GA-Based Methods:

- Efficient multiobjective optimization
- Reduced passenger waiting time
- Reduced unnecessary elevator movement

- Better traffic handling during peak hours
- Improved energy efficiency

Limitations / Worst Features:

- High computational complexity
- Requires powerful processing hardware
- Difficult real-time implementation in low-cost systems
- Optimization performance depends on parameter tuning

B. Sensor-Based Passenger Verification

Passenger verification plays an important role in reducing false elevator calls and unnecessary elevator movement. Abdullah and Khan [16] proposed the Intellevator system, which used smart passenger detection and proactive traffic control mechanisms. Their system verified passenger presence before processing elevator requests, thereby reducing energy wastage caused by accidental or false button presses.

Kim and Choi [14] developed a computer vision-based intelligent elevator information system for efficient demand-based operation. Their work used camera-based occupancy detection and passenger monitoring to analyze traffic patterns and optimize elevator scheduling.

Chen *et al.* [15] introduced occupancy-aware deep learning techniques for smart elevator dispatching. The system collected real-time occupancy information and used it for intelligent elevator allocation and traffic prediction.

The EcoLift system adopts the concept of passenger verification from these works by integrating IR sensors or ultrasonic sensors to confirm passenger presence before activating elevator movement. This helps reduce unnecessary energy consumption and improves scheduling efficiency.

Best Features of Sensor-Based Methods:

- Reduces false elevator calls
- Minimizes unnecessary elevator movement
- Improves scheduling accuracy
- Enhances passenger management
- Reduces energy wastage

Limitations / Worst Features:

- Camera-based systems increase implementation cost
- Requires continuous monitoring
- Privacy concerns in public areas
- Sensor failure may affect system accuracy

C. Energy Optimization and Power Saving Techniques

Energy optimization is one of the major objectives of modern elevator systems. Singh and Verma [6] proposed an energy-efficient permanent magnet motor drive system for elevators. Their research demonstrated that optimized motor control mechanisms can significantly reduce elevator power consumption compared to conventional systems.

Martínez and González [7] developed a Differential Evolution Algorithm for optimizing energy usage in vertical transportation systems. Their work focused on minimizing unnecessary elevator movement and reducing total operational energy consumption.

Novak and Horvat [17] studied energy-saving prediction techniques in elevator systems. Their work analyzed traffic

conditions and passenger demand to estimate future energy usage and optimize elevator operations.

The proposed EcoLift system extracts the concept of energy-aware scheduling and optimized elevator movement from these studies. By minimizing idle movement and avoiding false requests, the system reduces overall energy consumption.

Best Features of Energy Optimization Methods:

- Significant reduction in power consumption
- Improved energy efficiency
- Reduced idle elevator movement
- Better resource utilization

Limitations / Worst Features:

- Requires accurate traffic prediction
- Specialized motor drives increase system cost
- Complex synchronization mechanisms
- Maintenance complexity is higher

D. Machine Learning and Traffic Prediction

Machine Learning and Deep Learning techniques are increasingly used for elevator traffic prediction and intelligent scheduling. Sharma and Gupta [19] proposed a machine learning-based elevator traffic prediction system for energy optimization. Their model analyzed passenger movement patterns to improve scheduling efficiency and reduce waiting time.

Zhou *et al.* [22] developed a deep learning-based passenger flow prediction system for elevator operations. Their work demonstrated that predictive traffic analysis improves elevator performance in high-rise buildings.

Yavas, [13] explored reinforcement learning approaches for elevator group control systems and compared traditional scheduling methods with AI-based adaptive learning models. The study concluded that intelligent learning systems provide better adaptability in dynamic traffic environments.

The EcoLift system adopts the idea of intelligent traffic analysis and adaptive scheduling from these studies to improve elevator efficiency during peak traffic conditions.

Best Features of ML-Based Methods:

- Accurate traffic prediction
- Adaptive scheduling capability
- Improved passenger service quality
- Better handling of dynamic traffic conditions

Limitations / Worst Features:

- Requires large training datasets
- High computational requirements
- Complex model training process
- Difficult implementation in low-budget systems

E. Real-Time Monitoring and Smart Building Integration

Real-time monitoring systems improve elevator management and performance analysis. Ibrahim and Hassan [9] developed an engineering energy measurement and data analysis system for electric elevators. Their work provided real-time monitoring of elevator energy usage and system performance.

Liu and Chen [18] discussed AI-assisted intelligent transportation systems in smart buildings and emphasized the importance of IoT-based monitoring and automation for improving transportation efficiency.

Lee and Park [4] integrated energy-aware elevator control systems with smart building infrastructure to improve overall building energy efficiency.

The EcoLift system adopts real-time monitoring concepts from these works by including a monitoring dashboard for tracking elevator status, traffic conditions, and power-saving statistics.

Best Features of Real-Time Monitoring Methods:

- Continuous system monitoring
- Easy performance analysis
- Better maintenance support
- Improved traffic management

Limitations / Worst Features:

- Requires IoT infrastructure
- Increased implementation complexity
- Continuous internet connectivity required
- Higher installation and maintenance cost

Overall, the reviewed literature indicates that intelligent optimization algorithms, passenger verification systems, energy-aware scheduling, and real-time monitoring techniques can significantly improve elevator efficiency. The proposed EcoLift system combines these methods into a low-cost, energy-efficient, and practical elevator optimization system suitable for educational institutions and small commercial buildings.

III. WORKING MECHANISM / SYSTEM DESIGN

A. Existing System

Feature	Existing	Proposed EcoLift
Scheduling	Traditional	GA-Based
Passenger Detection	No	Yes
Energy Optimization	Low	High
Waiting Time	High	Reducing
Journey Time	High	Optimizing
False Requests	Not handled	Cancelling
Monitoring	Limited	Real-Time
Traffic Handling	Basic	Intelligent

The comparison table shows the major differences between traditional elevator systems and the proposed EcoLift system. Existing elevator systems mainly use traditional scheduling methods that do not consider real-time traffic conditions, passenger occupancy, or energy optimization. As a result, they often experience high waiting time, increased journey time, unnecessary elevator movement, and poor handling of peak traffic situations.

Traditional elevator systems mainly use fixed scheduling or simple duplex control algorithms. These systems respond immediately whenever a hall-call button is pressed without verifying whether passengers are actually present. This causes unnecessary elevator operations, increased electricity consumption, and reduced operational efficiency. Most existing

systems also lack intelligent traffic prediction and adaptive scheduling mechanisms, which limits their ability to handle dynamic passenger demand efficiently.

B. Explanation of The System

The block diagram shows the working flow of the EcoLift system from user request to elevator movement.

It starts with **Passenger Request Buttons**, where the user selects a floor. Then **Sensor-Based Passenger Detection** checks whether a passenger is actually present, reducing false requests.

The request is processed by the **Microcontroller / Processing Unit**, which collects real-time data such as elevator position and traffic status. This information is sent to the **Genetic Algorithm Scheduler**, which selects the most suitable elevator based on minimum waiting time and energy efficiency.

After scheduling, the **Elevator Allocation and Control** unit assigns the elevator, and the **Motor Driver** executes the movement between floors.

Finally, the **Real-Time Monitoring Dashboard** displays system status, energy usage, and elevator performance for analysis and control.

C. Block Diagram

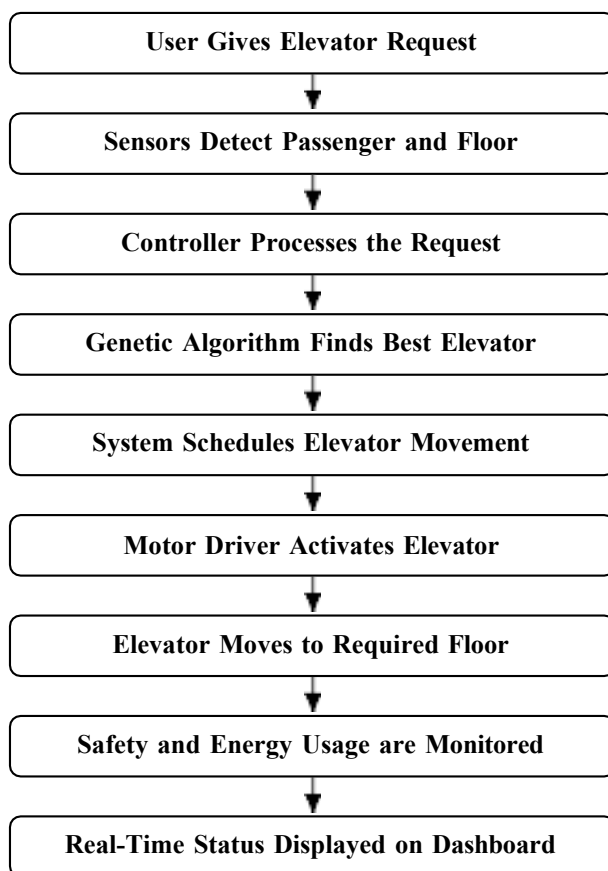


Fig. 1. Block Diagram of Intelligent Elevator System

IV. BASIC METHODOLOGY

The proposed EcoLift system follows an intelligent and energy-efficient methodology for elevator scheduling.

- **Passenger Detection and Verification**
Sensors verify passenger presence before elevator allocation.
- **Hall Call Registration**
Passenger requests are registered and sent to the scheduler.
- **Genetic Algorithm Scheduling**
The GA selects the best elevator based on waiting time, distance, traffic conditions, and energy consumption.
- **Smart Elevator Allocation**
The nearest and most efficient elevator is assigned.
- **Real-Time Monitoring**
A dashboard tracks elevator movement and energy usage.
- **Energy Optimization**
The system minimizes unnecessary trips and idle movement.
- **Performance Evaluation**
System performance is evaluated using waiting time, journey time, and energy efficiency.

V. EXPECTED OUTCOMES

The proposed EcoLift system is expected to reduce passenger waiting time, journey time, and unnecessary elevator movement through intelligent scheduling and passenger verification. The system improves scheduling efficiency, optimizes energy consumption, and supports real-time monitoring for better elevator management. By minimizing false requests and idle movement, EcoLift enhances passenger comfort and operational performance. The use of low-cost hardware and practical implementation methods also makes the system cost-effective and suitable for smart buildings, educational institutions, and commercial environments.

VI. CONCLUSION

EcoLift is an intelligent elevator dispatching system developed to improve energy efficiency and passenger comfort using Genetic Algorithm-based optimization and sensor-based passenger verification.

The project provides a low-cost and practical solution suitable for smart building applications.

Future enhancements may include:

- Machine Learning-based traffic prediction
- Multi-elevator coordination
- IoT cloud monitoring
- Mobile application integration

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