MITIGATING ESCALATOR ACCIDENTS: A MODERN APPROACH TO PASSENGER PROTECTION

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1. ABSTRACT

This paper delves into the critical safety challenges posed by escalators, which are integral to modern urban infrastructure, facilitating efficient pedestrian movement in bustling environments. Despite their ubiquity and convenience, escalators are associated with numerous accidents globally, primarily due to user errors such as slips, trips, and falls, rather than mechanical failures. The paper underscores the importance of incorporating safety features from the design phase, adhering to stringent maintenance protocols, and educating passengers on safe usage practices to mitigate these risks.

The study explores the implementation of innovative safety measures, including anti-fall protection sensors and AI (Artificial intelligence) -powered systems. Anti-fall sensors are designed to monitor passenger movements along escalators, establishing a safe movement zone. Any deviation from this zone triggers alerts, thereby preventing potential falls. These sensors represent a significant advancement in passenger safety technology by providing immediate feedback and warnings to passengers, enhancing awareness of their positioning relative to the safe area.Furthermore, the integration of AI technology offers sophisticated solutions for real-time monitoring of passenger behavior and environmental conditions. AI-enabled systems can distinguish between actual incidents and false positives, ensuring timely interventions. These systems utilize advanced data analysis techniques to predict potential hazards and trigger proactive safety measures, including audio and visual alerts and emergency stops when necessary.

This paper emphasizes the transformative potential of these technologies in enhancing escalator safety. By continuously monitoring and addressing safety concerns, these innovations not only reduce the likelihood of accidents and injuries but also increase passenger confidence. As urban environments continue to evolve, the adoption of such advanced safety measures is crucial for ensuring the safe and efficient operation of escalators, ultimately contributing to safer public transportation infrastructure.

2. INTRODUCTION

Escalators are indispensable components of modern urban infrastructure, facilitating the efficient movement of large numbers of people in bustling environments such as shopping malls, airports, and public transit stations. Despite their convenience, escalators present significant safety challenges. Accidents can occur due to a variety of factors, including unsafe passenger behaviour, overcrowding, or mechanical malfunctions. Globally, escalator-related accidents result in numerous injuries each year, highlighting the urgent need for enhanced safety measures (Michael McCann, 2013).

Dr. Lutfi Al Sharif, in his paper "Escalator Human Factors: Passenger Behaviour, Accidents & Design," identified three critical factors contributing to escalator passenger accidents (Al-Sharif, 2016):

Design: The importance of ensuring safety through the design and production phases, with strict safety and quality measures.

Maintenance, Inspection & Operation: The necessity of regular maintenance to prevent issues and ensure safe operation.

Passenger Behaviour: The need to address unsafe behaviours through initiatives.

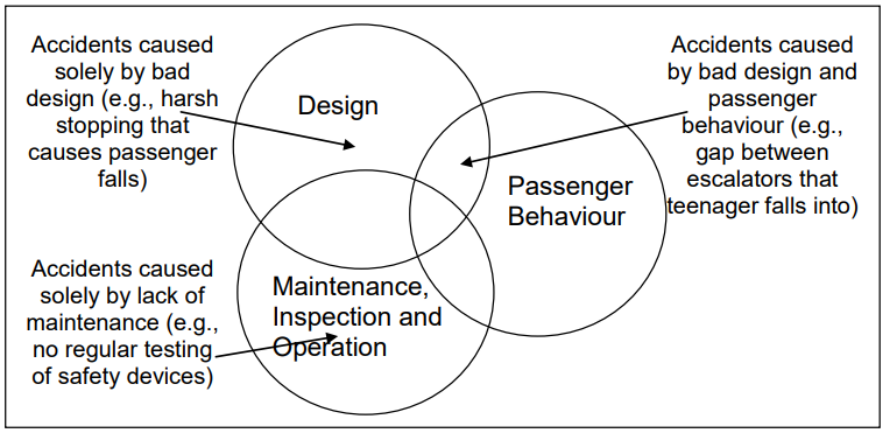

Figure 1. *Passenger Accident Model.* (Al-Sharif, 2016)

Comprehensive, worldwide statistical data on escalator accidents specifically caused by misuse is limited, but the available global evidence consistently shows that many escalator injuries are due to improper use or user error, rather than mechanical failure. Here's a summary of the best international data, with a breakdown suitable in Table 1 (Kaczmarczyk, 2015).

Global Causes of Escalator Injuries. Based on aggregated international studies and recent government reports (Kaczmarczyk, 2015):

Cause of Escalator Injury	Approximate Share(%)
Falls (user error, slips, trips, not holding handrail, etc.)	75–89
Entrapment (clothing/body parts caught)	7–20
Other (sudden stops, mechanical issues, etc.)	3–5

Table 1. *international studies on escalator incidents* (Dhanasekaran, 2016)

3. PASSANGER PROTECTION

3.1 Anti-fall protection sensor:

In this research paper, we will focus on improving the safety of passengers to prevent accidents resulting from falls on escalators. In recent years, we have seen that most accidents involve falls, resulting in serious injuries and fatalities (Chi, 2016). The study will explore the implementation of anti-fall protection devices on escalators. Protection sensor (device) which cover passenger movement from start to end of escalator (Bress, 2018).

In figure 2 shows fall protection sensors which are mounted on escalator.

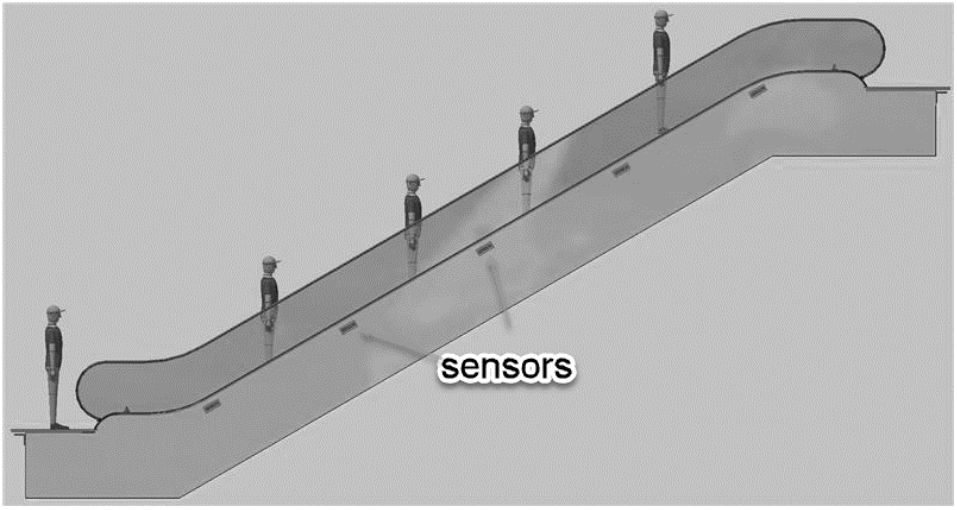

Figure 2. *Anti-fall sensor mounted on escalator.*

The integration of modern technology plays a pivotal role in addressing these safety concerns. New systems offer sophisticated solutions for detecting and mitigating potential risks associated with escalator use.

The anti-fall protection device is design to monitor passenger movements along the handrail of escalators. It establishes a specific pattern covering the safe movement area. When passengers stay within this designated zone, the sensor does not activate.

However, if a passenger crosses this boundary, indicating a potential fall risk, the system engages a feedback mechanism. This mechanism triggers an alarm, buzzer, or voice announcer to alert nearby individuals. This alert system plays a crucial role in preventing falls by providing immediate warnings. It enhances safety by ensuring that passengers are aware of their positioning relative to the safe area. This initiative-taking approach is vital for minimizing the risk of falls, which can lead to serious injuries or fatalities.

The implementation of such devices on escalators represents a significant advancement in passenger safety technology. By continuously monitoring the movement patterns, the device ensures that any deviation from the safe zone is promptly address. This not only improves safety but also increases passenger confidence while using escalators. The technology underpinning this system is sophisticated, allowing for precise detection and timely alerts. Its effectiveness lies in its ability to seamlessly integrate with existing escalator systems. As a result, the anti-fall protection device significantly contributes to reducing escalator-related accidents. Through ongoing innovation and refinement, such devices expected to become standard features in public transportation infrastructure.

3.2 Anti-fall protection with Artificial intelligence (AI):

In the section 3.1, the emphasis is on the anti-fall device without AI. (Cooper) In this section, the focus is on AI-powered cameras that continuously monitor passenger behaviour and environmental conditions in real-time. These systems are capable of distinguishing between actual incidents such as slips, trips, or falls and false positives, such as someone bending down or adjusting their position (Jiang, 2024). This distinction is critical to avoid unnecessary alerts and to ensure timely intervention when real risks are detects.

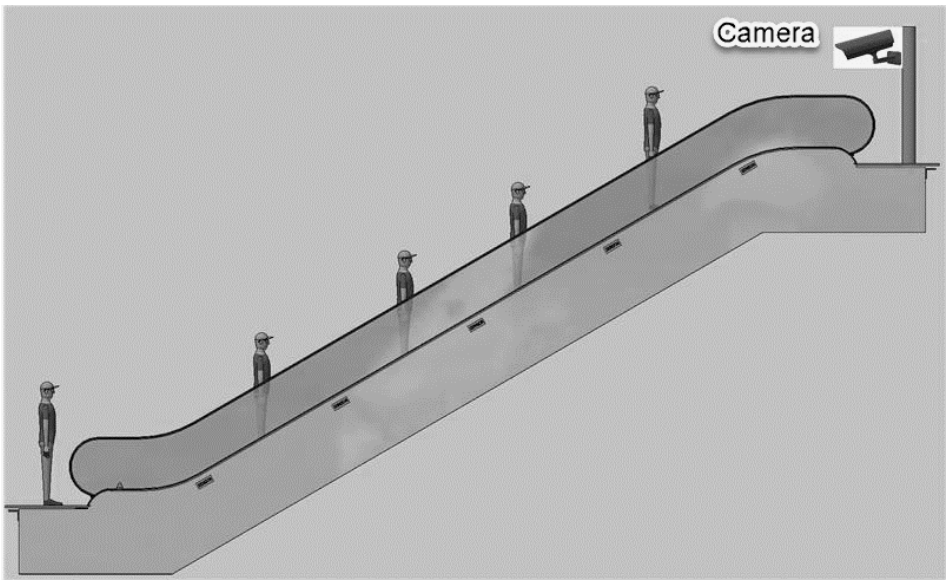

***Figure 3**. Anti-fall sensor mounted on escalator with AI.*

The AI enabled Architecture is divide into three main components:

Input to Controller: This section gathers data through devices such as cameras, sensors, and switches, capturing the current state and environment of the escalator.

Controller and Drive Mechanism: This is the central part of the system, where the controller processes the input data and activates outputs. It employs algorithms to determine the appropriate corrective actions, ensuring the escalator operates smoothly and safely.

Output and Safety Features: This section includes elements like alarms, buzzers, stopping mechanisms, and customized announcements, which activated to ensure passenger safety and provide information.

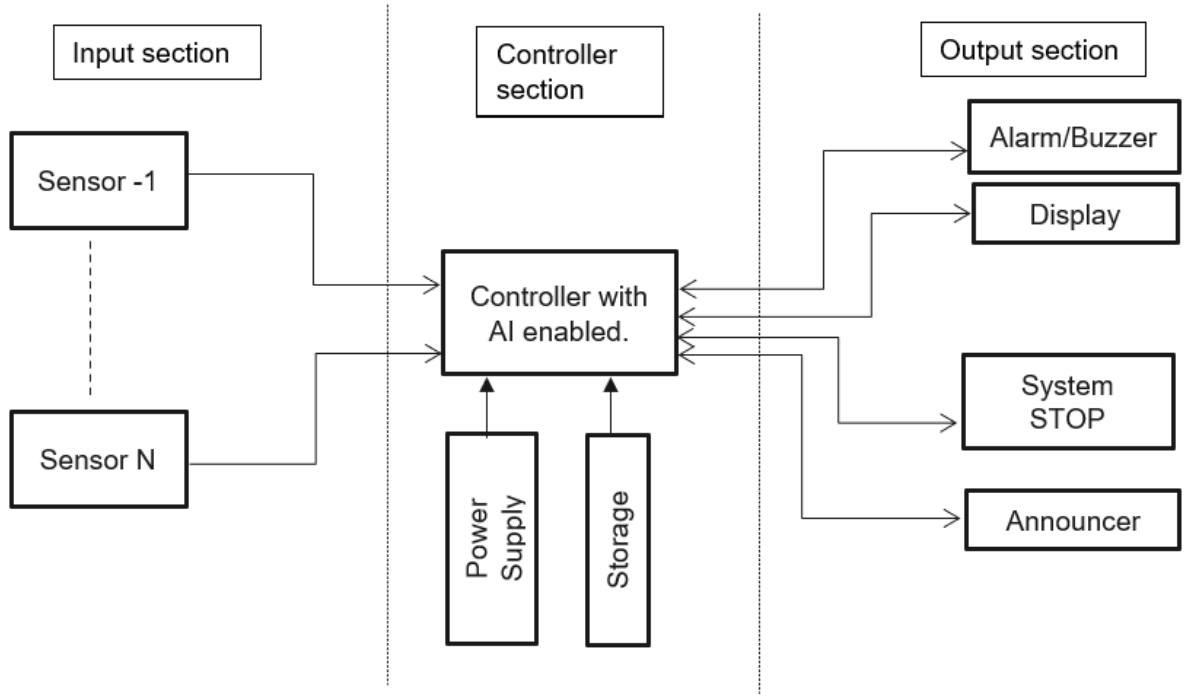

Figure 4. *AI enabled Architecture of escalator control system.*

To process and interpret the vast amount of data generated by these systems, advanced data analysis techniques must be employed. Data classification helps categorize behaviours into safe or unsafe actions. Regression analysis used to identify trends and predict the likelihood of future incidents based on historical data. Predictive algorithms further enhance the system's ability to foresee potential hazards before they occur, enabling initiative-taking safety measures.

In figure 3. Shows architecture about escalator control system. Which help us to get corrective action on incident which is going to happen (Zhang, 2024).

When a potential risk detected, the system can trigger immediate responses, including audio and visual alerts to warn passengers of the danger. In more critical situations, the system can initiate an emergency stop to prevent accidents. This initiative-taking approach not only enhances the safety of escalator users but also significantly reduces the likelihood of accidents and injuries.

Cities across world are beginning to implement these advanced safety measures to ensure. (Bress, 2018)

4. CONCLUSION

Escalators are crucial in modern urban environments, significantly improving accessibility and pedestrian flow. However, safety concerns, primarily due to improper use and mechanical failures, need advanced safety measures.

A patent has filled on above research work of using an Anti-fall protection device in escalator. This paper highlights the importance of anti-fall protection devices and AI-powered systems in enhancing escalator safety. These innovations effectively check passenger behaviour, promptly detect risks, and trigger alerts to prevent accidents. As these technologies continue to evolve, they promise to become standard features in public infrastructure, significantly reducing escalator-related injuries and boosting user confidence. Continued investment in safety innovations and awareness campaigns is vital to ensure escalators stay safe and efficient transportation solutions in bustling urban settings.

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