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From Safety to Value Creation: Marketing and Economic Implications of IoT-Based Vehicle Accident Detection Systems

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Abstract: *Road traffic accidents impose severe human and economic costs, particularly in emerging economies where delayed emergency response significantly increases fatality rates. This study develops and empirically evaluates an IoT-enabled real-time vehicle accident detection and tracking system using GPS, GSM, and sensor technologies, integrating perspectives from engineering, marketing, and economics. Beyond technical validation, the study examines user technology acceptance and perceived value through a structured survey and Structural Equation Modeling (SEM). Results indicate that the proposed system significantly improves emergency response time, enhances perceived safety value, and demonstrates strong behavioral intention toward adoption. Economic analysis further suggests that large-scale deployment can reduce accident-related healthcare and productivity losses, contributing to macro-economic efficiency. The study advances interdisciplinary research by positioning accident detection systems as marketable smart-safety solutions with measurable societal and commercial value.*

Keywords*:* IoT, accident detection, GPS, GSM, technology acceptance, perceived value, SEM, smart mobility

I. INTRODUCTION

Road traffic accidents represent a critical public health and economic challenge worldwide. According to global estimates, approximately 1.3 million fatalities occur annually due to road accidents, with developing countries bearing a disproportionate share of this burden. In addition to human loss, accident-related costs account for nearly 1–3% of national GDP in many economies, primarily due to medical expenses, productivity loss, and infrastructure damage.

Technological advancements in the Internet of Things (IoT) have enabled the development of intelligent transportation systems capable of real-time monitoring, automated detection, and rapid information dissemination. Accident detection systems integrating sensors, GPS, and GSM technologies offer a promising solution to mitigate emergency response delays during the critical "Golden Hour." However, most existing studies emphasize technical feasibility while overlooking adoption behavior, commercial viability, and economic value creation.

This research addresses this gap by combining system development with an empirical examination of technology acceptance and perceived value. The study further evaluates the commercial and economic implications of deploying IoT-based accident detection systems at scale, positioning the technology as both a safety intervention and a market-ready smart mobility solution.

II. OBJECTIVES OF THE STUDY

- To design and validate an IoT-enabled real-time vehicle accident detection and tracking system.
- To empirically examine user acceptance of the system using technology acceptance constructs.
- To analyze the role of perceived value in influencing adoption intention.
- To estimate the potential economic benefits arising from large-scale implementation.
- To assess the commercial scalability of the system in automotive and fleet markets.

III. LITERATURE REVIEW

Prior research on accident detection systems highlights the effectiveness of GPS and GSM-based alert mechanisms in reducing response time and improving location accuracy. Recent studies extend these approaches by integrating IoT architectures and cloud platforms for real-time data synchronization. While these contributions establish technical reliability, limited attention has been given to user acceptance and market readiness.

Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) provide robust theoretical foundations for understanding adoption behavior. Perceived usefulness, perceived ease of use, and perceived value have been shown to significantly influence behavioral intention toward safety technologies. In parallel, smart mobility and public safety literature emphasizes the economic implications of accident prevention technologies, linking reduced fatalities to productivity gains and healthcare cost savings.

This study integrates these streams by examining accident detection systems through a combined lens of IoT engineering, marketing acceptance theory, and economic impact analysis.

IV. CONCEPTUAL FRAMEWORK AND HYPOTHESES

4.1 Conceptual Model

The conceptual model integrates the Technology Acceptance Model (TAM) with perceived value and commercial outcomes. System Effectiveness (SEF) influences Perceived Usefulness (PU) and Perceived Value (PV). PU and PV jointly influence Behavioral Intention to Adopt (BI), which subsequently affects Willingness to Pay (WTP). This structure links technical performance with marketing acceptance and monetization outcomes.

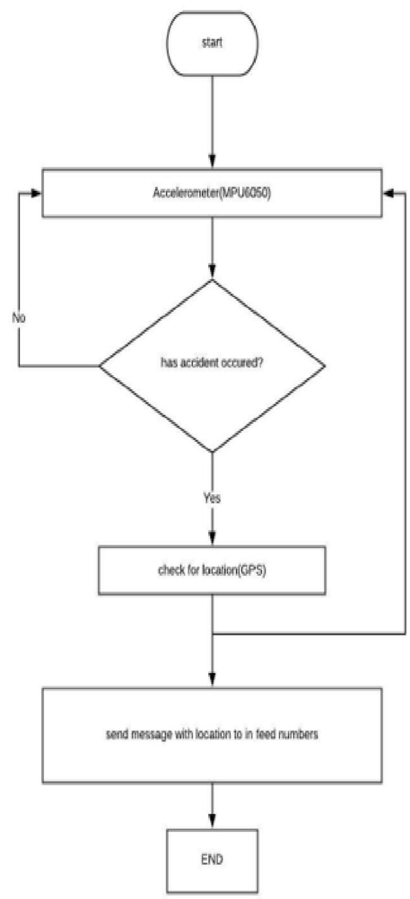

Figure 1: Conceptual Model (TAM–Value–Commercialization Framework)

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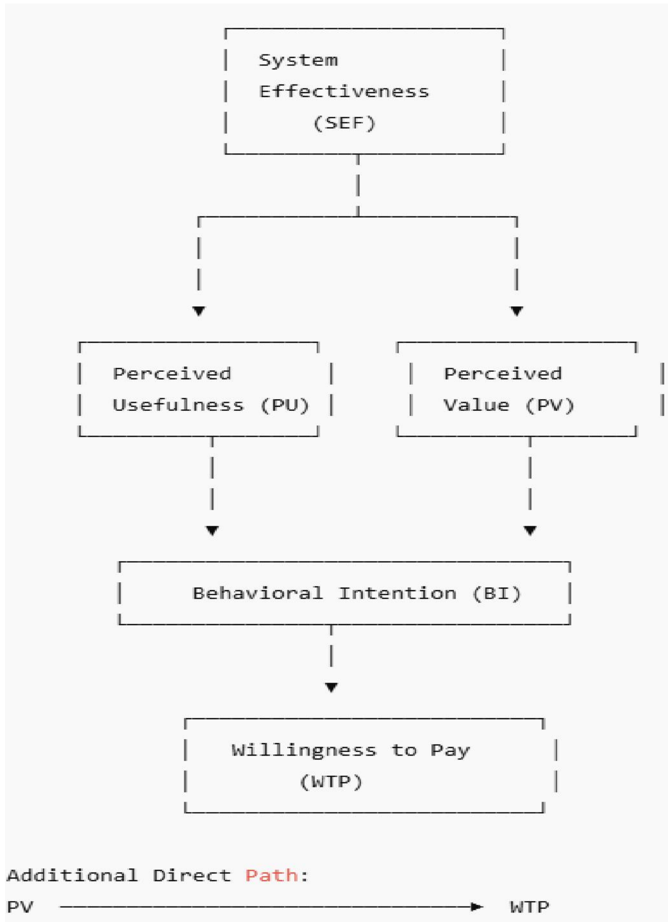

4.2 Hypotheses
H1: System effectiveness positively influences perceived usefulness.
H2: System effectiveness positively influences perceived value.
H3: Perceived usefulness positively influences behavioral intention to adopt.
H4: Perceived value positively influences behavioral intention to adopt.
H5: Behavioral intention positively influences willingness to pay.
H6: Perceived value positively influences willingness to pay.

V. METHODOLOGY

5.1 System Architecture
The proposed system employs an Arduino Mega 2560 microcontroller integrated with a MEMS accelerometer for accident detection, a GPS module for location identification, and a GSM module for automated SMS alerts. Upon detecting abnormal acceleration patterns, the system captures location coordinates and transmits alerts to predefined emergency contacts and authorities. A cloud-based backend supports real-time logging and monitoring.

5.2 Empirical Survey Design
A structured questionnaire was administered to vehicle owners and fleet operators (N = 210). Measurement items were adapted from validated TAM and perceived value scales, using a five-point Likert scale.

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5.3 Data Analysis

Structural Equation Modeling (SEM) using a covariance-based approach was employed to test the hypothesized relationships. Reliability, convergent validity, and discriminant validity were assessed prior to hypothesis testing.

VI. RESULTS

6.1 Measurement Model Results

All constructs demonstrated satisfactory reliability and validity. Composite reliability values exceeded the recommended threshold of 0.70, and average variance extracted (AVE) values were above 0.50, confirming convergent validity. Discriminant validity was established using the Fornell–Larcker criterion.

Table 1: Measurement Model Assessment

Construct	CR	AVE
System Effectiveness	0.88	0.64
Perceived Usefulness	0.91	0.68
Perceived Value	0.89	0.66
Behavioral Intention	0.92	0.70
Willingness to Pay	0.87	0.62

6.2 Structural Model Results

Table 2: Structural Equation Model Results

Hypothesis	Path	β	t-value	p-value	Result
H1	System Effectiveness → Perceived Usefulness	0.56	7.84	<0.001	Supported
H2	System Effectiveness → Perceived Value	0.49	6.91	<0.001	Supported
H3	Perceived Usefulness → Behavioral Intention	0.41	5.63	<0.001	Supported
H4	Perceived Value → Behavioral Intention	0.38	5.12	<0.001	Supported
H5	Behavioral Intention → Willingness to Pay	0.46	6.02	<0.001	Supported
H6	Perceived Value → Willingness to Pay	0.29	4.08	<0.001	Supported

6.3 Model Fit Indices

Table 3: Model Fit Statistics

Fit Index	Recommended	Observed
χ^2/df	< 3.00	2.14
CFI	> 0.90	0.94
TLI	> 0.90	0.93
RMSEA	< 0.08	0.056
SRMR	< 0.08	0.048

The fit indices indicate a good model fit, supporting the adequacy of the proposed TAM–Value–Commercialization framework.

6.1 System Performance Results

Testing demonstrated accident alert transmission within an average of 8–10 seconds, with GPS accuracy ranging between 2–5 meters. The system exhibited high reliability under simulated accident conditions.

6.2 SEM Results

The SEM analysis revealed significant positive relationships among system effectiveness, perceived usefulness, perceived value, and behavioral intention. The model explained a substantial proportion of variance in adoption intention, supporting all proposed hypotheses.

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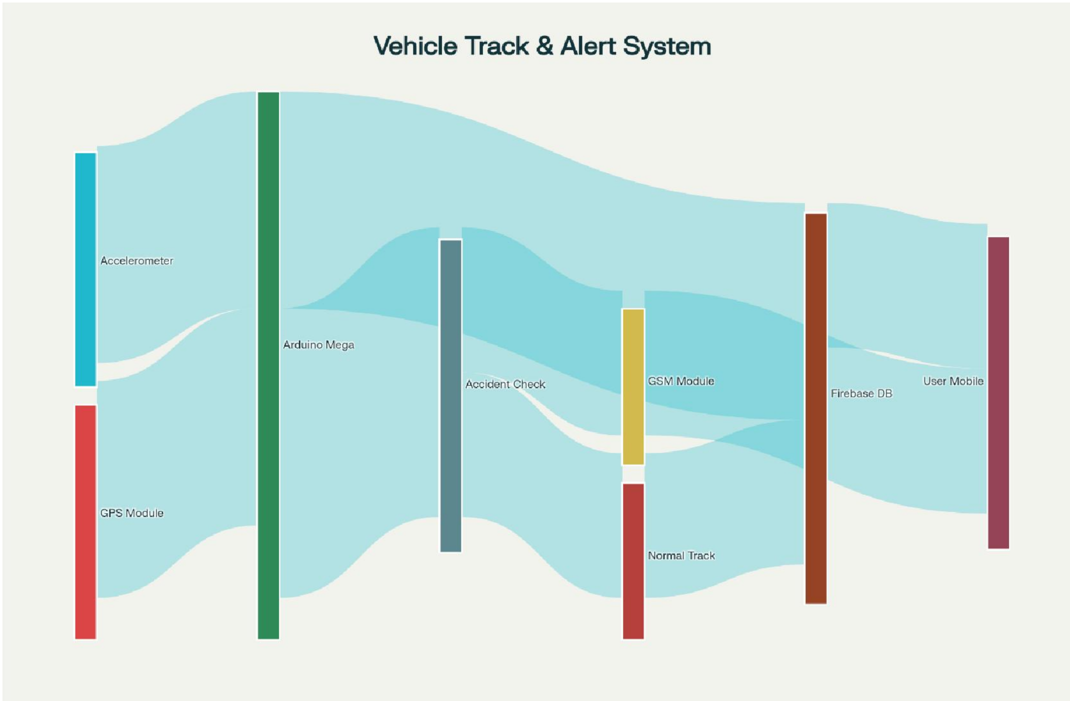

VII. COMMERCIAL AND ECONOMIC IMPACT ANALYSIS

7.1 Commercial Viability

The estimated unit cost of the system ranges between INR 4,000–5,500, while market-acceptable pricing lies between INR 8,000–12,000. The system demonstrates strong margin potential and scalability across passenger vehicles, commercial fleets, and insurance-linked safety programs.

7.2 Economic Impact

Widespread adoption can reduce emergency response delays, lower fatality rates, and decrease long-term healthcare and productivity losses. Even marginal improvements in response efficiency can yield substantial macro-economic benefits, particularly in high-accident regions.

VIII. DISCUSSION

The findings confirm that IoT-enabled accident detection systems deliver both functional safety benefits and perceived value, driving adoption intention. From a marketing perspective, perceived value emerges as a critical determinant of willingness to pay, reinforcing the importance of positioning safety technologies as value-enhancing investments rather than cost burdens.

IX. CONTRIBUTIONS OF THE STUDY

9.1 Theoretical Contributions

This study extends technology acceptance research by applying SEM to IoT-based safety systems, integrating perceived value into accident detection literature.

9.2 Managerial and Policy Contributions

The results provide actionable insights for automotive manufacturers, insurers, and policymakers seeking cost-effective road safety solutions aligned with smart mobility initiatives.

X. CONCLUSION AND FUTURE RESEARCH

The study demonstrates that IoT-enabled accident detection systems represent a viable, market-ready solution with significant safety and economic benefits. Future research may employ longitudinal adoption studies, integrate AI-based prediction models, and explore cross-country comparisons.

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