Proceedings of the 10th North American International Conference on Industrial Engineering and Operations Management, Orlando, Florida, USA, June 17-19, 2025

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/NA10.20250075
Published: June 17, 2025

Critical Path Method and Economic Analysis for Implementing Intelligent Accident Management System in Bisha, Saudi Arabia

Lama A Alshahrani, Lina T Alhamza, Ghina S AlShahrani and Elaf M Alhadi
Undergraduate Student in the Industrial Engineering
Department, College of Engineering
University of Bisha
Bisha 61922, Saudi Arabia
441802813@ub.edu.sa , 441802814@ub.edu.sa, 441802819@ub.edu.sa
441802804@ub.edu.sa

Khaled Ali Abuhasel
Full Professor in the Industrial Engineering Department
College of Engineering, University of Bisha
Bisha 61922, Saudi Arabia
kabuhasel@ub.edu.sa

Abstract

In Saudi Arabia, traffic accidents are a major source of death and serious injury, with a significantly impacting public safety, emergency response efficiency, and the local economy. The city of Bisha faces challenges with managing emergency response effectively. The goal of this project is to develop a smart accident management system that improves accident detection, emergency response, and system implementation efficiency by utilizing Geographic Information Systems (GIS), Internet of Things (IoT) sensors, and AI-driven automation in conjunction with project management concepts. The suggested system combines GPS and GSM modules with vibration and ultrasonic sensors to relay exact location data, identify accidents in real time, and automatically notify emergency services without the need for human participation. The Critical Path Method (CPM) and other project management approaches were used to identify critical activities to avoid delays and to ensure efficient scheduling and resource allocation. The project was found to take 28 weeks in total. The system's design and functionality were evaluated using simulation tools like Arena, Proteus, and SolidWorks. System sustainability and dependability were improved by implementing risk management techniques like Fault Tree Analysis (FTA) and Failure Mode and Effects Analysis (FMEA). The cost-benefit analysis used to determine economic feasibility showed a 1.35-year payback period. The study confirms two key findings: (1) applying CPM optimizes project scheduling and deployment efficiency, and (2) the system is economically viable, demonstrating financial sustainability and long-term benefits The goal of this intelligent system is to enhance emergency response management by integrating cutting-edge technologies and carrying out projects effectively.

Keywords
Traffic Accident Management, Accident detection, Critical Path Method (CPM), Risk Management, Economic study

1. Introduction

One of the primary reasons for the high death rates in Saudi Arabia and around the world is traffic accidents, which also result in a higher number of both temporary and permanent injuries as well as substantial damages that impact both victims and governmental institutions (Kumaresh 2021). The World Health Organization data for 2018 indicated that traffic accidents rank eighth globally in terms of causes of mortality and are predicted to move up to the fifth position by 2030 (WHO, 2018) and according to a Ministry of Health report, vehicle accidents in Saudi Arabia resulted in 16,159 fatalities and 89,050 injuries between 2018 and 2020 and more than a fifth of the cases reported to the Red Crescent Authority were classified as traffic accidents although safety and road monitoring systems such as Saher or Najm have been introduced to directly handle accidents and the percentage of accidents in major cities has decreased by 35%, it is still a large number compared to the aspirations of the Kingdom of Saudi Arabia for 2030, with the Kingdom of Saudi Arabia ranking thirty-fourth globally with a death rate of 36.13 per 100,000 people (WHO 2020)(Ministry of Health, 2021)(World Health Organization 2023). Road accidents have a significant financial impact on people, communities, and national economies according to study by (Gorea RK 2016).

Indirect costs include missed productivity, future income lost as a result of the victim's injury, and accident-related legal fees. Direct costs include the victim's medical care and repairs. Road accidents incur annual losses of up to $20 billion in India and $784 per capita in the US (1.6% of GDP), and they account for 5% of GDP in low- and middle-income nations, compared to 3% globally. In order to improve the effectiveness of the safety management system, a previous study was conducted by the same research team aiming to develop a smart accident management system in Bisha and identify high-risk areas using Geographic Information Systems (GIS) and a survey conducted on the people of Bisha city to analyze the spatial distribution and develop a smart system using several simulation programs to reduce the response time of emergency teams by 60-30 minutes for the traditional system. The effectiveness of using these tools based on the information provided by GIS and the survey to identify high-risk areas has been proven. During the study conducted by (Moradi et al. 2016), spatial analysis of 198 accidents was used, and the entrances and exits of Tehran were successfully identified as high-risk areas. In addition, a study conducted by Harifaroosh et al. 2017) on the city of Sherbrooke used two GIS-based methods to analyze the city's risk areas, both of which effectively identified critical and problematic locations and identified priority hotspots. The results show that accidents are more frequent in the central and southern regions of Bisha, and the response time is reduced to 11-15 minutes, indicating that road accidents are not randomly distributed but concentrated in certain areas. This result is important for road safety management and preventive measures.

With accident analysis and system simulation, this study deals with project management analysis and principles with emphasis on risk management, economic feasibility, reliability, maintainability, and scheduling. Risk management will assess potential threats and vulnerabilities within the proposed incident management system by preparing a risk management plan. An economic analysis will be conducted to assess the cost-benefit ratio of implementing the system, ensuring its financial feasibility and sustainability. Reliability and maintainability considerations will be integrated to design a system that ensures continuous performance with minimal downtime using FTA and FMEA, according to a study by (Abdulrahman et al. 2024), FMEA is used to analyze traffic accidents in order to determine the underlying causes of risks, particularly when there is a deficiency of precise information. By determining the frequency (O), severity (S), and detectability (D) of failures, it aids in preventive maintenance by assisting in the development of proactive strategies like vehicle inspection, infrastructure improvement, and the use of safety technologies to stop accidents before they happen, thus maximizing efficiency and effectiveness. Scheduling techniques using CPM will be applied to ensure timely implementation and deployment of the system, improving resource allocation and operational readiness(Rakasyiwi et al. 2022).

1.1 Objectives

1- To develop an optimized implementation plan for the intelligent accident management system in Bisha using the Critical Path Method (CPM) to ensure efficient scheduling and resource allocation.
2- To evaluate the economic feasibility of the system through Cost-Benefit Analysis (CBA) and Payback Period Calculation, assessing its financial sustainability and long-term impact on accident response efficiency.

1.2 Problem Statement

The Kingdom of Saudi Arabia's Bisha city has a difficult time controlling traffic accidents, which lead to high death rates, property damage, and a burden on emergency services. Accident response times are still significantly delayed, averaging between 30 and 60 minutes, despite initiatives like the installation of traffic monitoring systems and apps like "Najm." In addition to making injuries more severe, this delay has a detrimental effect on local economies, public safety, and the effectiveness of emergency infrastructure. Areas with high accident rates, especially in Bisha's center and southern regions, emphasize the necessity of focused measures. Manual reporting is a major component of traditional accident management systems, which results in ineffective resource allocation and delays in emergency response. Furthermore, these problems are made worse by the lack of integrated, real-time accident detection technologies. In order to bridge this gap, an intelligent, automated accident detection and management system that can quickly identify events, send precise location data, and notify emergency services without the need for human interaction is desperately needed. Advanced sensor technologies, GPS, GSM communication modules, and spatial data analysis tools should all be used in this system to speed up response times, increase road safety.

2. Area of Study

This study centers on the city of Bisha in Saudi Arabia, situated within the Asir region. Bisha stretches 185 km in length from north to south. Its width changes from east to west, with the narrowest part noted in the south at roughly 48 km and the widest part in the north at around 120 km, encompassing a total area of 659 km². In 2022, the population totals 248,452. Bisha holds importance because it is situated along Wadi Bisha, the largest and most vital valley in the Kingdom. This valley houses Saudi Arabia's biggest dam, boasting a storage capacity of 325 million m³. The city is famous for its farming, especially the growing of date palms. Bisha benefits from excellent connectivity to surrounding cities, featuring a robust road network, particularly the Khamis Mushait-Bisha-Raniyeh-Khurmah road, which serves as an essential connection between the Asir and Makkah regions, shown in figure (1).

When compared to other governorates in Asir, Bisha is a warm area, with typical temperatures varying from 25 to 42 degrees Celsius. Spring brings rainfall, and as temperatures increase, drought conditions worsen in the east.

Figure 1. The location of Bisha city

3. The hypotheses of the study

Hypothesis 1: Applying the Critical Path Method (CPM) optimizes the implementation timeline of the smart accident management system, reducing delays and improving project efficiency.
Hypothesis 2: The intelligent accident management system is economically viable, with a favorable cost-benefit ratio and a short payback period. It is a cost-effective solution for enhancing road safety in Bisha.

4. Research Methodology

The Smart Accident Management System integrates IoT sensors, GIS spatial analysis, and AI automation to enhance accident detection and emergency response in Bisha City, Saudi Arabia. The system employs real-time monitoring, automated alerts, and predictive analytics to reduce response times and improve safety. The project utilizes computer-aided design, simulation, and smart automation, incorporating SolidWorks for mechanical modeling, Proteus for circuit design, and Arena for response time simulation. The Critical Path Method (CPM) is applied for project scheduling, ensuring efficient task sequencing and timely implementation.

The system features ultrasonic, vibration, GPS, and GSM sensors for accident detection, managed by an Arduino-based control unit that automates emergency reporting. A structured algorithm flowchart governs the response process, classifying accident severity and dispatching emergency teams accordingly.

Risk management is structured through a Risk Breakdown Structure (RBS) and Risk Assessment Matrix, which help identify and mitigate potential failures in sensors, network connectivity issues, and regulatory compliance risks. The SWOT analysis provides a strategic evaluation, highlighting the system's strengths, such as real-time detection and automated emergency response, while also addressing challenges like implementation costs and network dependence. The economic feasibility of the project is analyzed using cost-benefit analysis (CBA) and payback period analysis. These techniques assess the system's financial viability by comparing initial costs with expected savings. The payback period is estimated at 1.35 years, demonstrating the project's cost-effectiveness by reducing accident-related losses and emergency response costs.

To maintain system reliability, Failure Mode and Effects Analysis (FMEA) is used to assess potential failure points and implement preventive maintenance strategies. A routine maintenance schedule ensures the long-term functionality of sensors, communication modules, and control units, minimizing downtime and optimizing performance.

5. Data Collection

The data for this research were collected from various sources, including international organizations, simulation tools, government records, academic studies, and surveys conducted in the study area. These sources provided crucial data for analyzing traffic patterns, response times, and accident hotspots in the region.

- SolidWorks was used to develop a virtual model, offering valuable insights into the design and operation of the smart system.
- Proteus was utilized to design and simulate the electronic circuits that form an integral part of the smart system. These circuits include sensors for accident detection and communication modules for data transmission. Proteus also features a visual designer tool for Arduino, which facilitated rapid prototyping of system components. Simulating the electrical circuits in Proteus ensured accuracy and reliability in the analysis.
- Arena software was employed to simulate traffic response times, enabling the evaluation of system efficiency and the identification of bottlenecks in accident response operations.

By integrating data from multiple sources and leveraging advanced simulation tools, this research ensures a comprehensive analysis and enhances the effectiveness of the proposed smart system.

6. Results and Discussion

6.1 Project Management

6.1.1 Project scheduling

The Critical Path Method (CPM) is a key project scheduling technique that identifies activities affecting project duration. Activities with zero slack form the critical path, directly impacting progress. Delays in these activities delay the entire project, while speeding them up accelerates completion (Mahardika et al. 2019)(Adibhesami et al. 2019).

Table 1. The basic activities and schedule of the project

Activity Code	Activity Description	Predecessors	Estimated Duration (By Week)
A	Project Initiation	None	3
B	Assignment of task and responsibility among team members	A	1
C	Gathering initial data and requirement	B	3
D	Design system architectrue	C	4
E	SolidWorks Simulation	D	2
F	Proteuos Simulation	D	8
G	Collect HotSpot Data	C	1
H	Arena Simulation	D,G	2
I	Testing and Validation	E,F,H	2
J	Analysis and Optimization	I	3
K	Project Documentation and Presntation	J	3
L	Scientific Research papers	J	2
M	Project Closure	K	1

Using the Precedence Diagramming Method (PDM), also known as Activity on Node (AON), we can calculate the critical path, identify critical and non-critical activities, determine slack time, and estimate project completion. In this method, activities are represented as nodes connected by arrows, illustrating sequence and dependencies (Romadhona et al. 2021). Table (1) outlines the schedule of activities, what they depend on, and the time required to complete each of them.

Forward Pass (Calculating Earliest Times). The Earliest Start (ES) is determined, where the first activity starts at zero, and subsequent activities start at the maximum Early Finish (EF) of predecessor activities. The Earliest Finish (EF) is calculated by adding the activity duration to its ES. The EF of the last activity represents the minimum project duration as shown in Figure (2).

ES = max (EF of all predecessor activities) …….......…………………………………….………………….… (1)
EF = ES + Activity Duration ...……………………………………………………….………………..... (2)

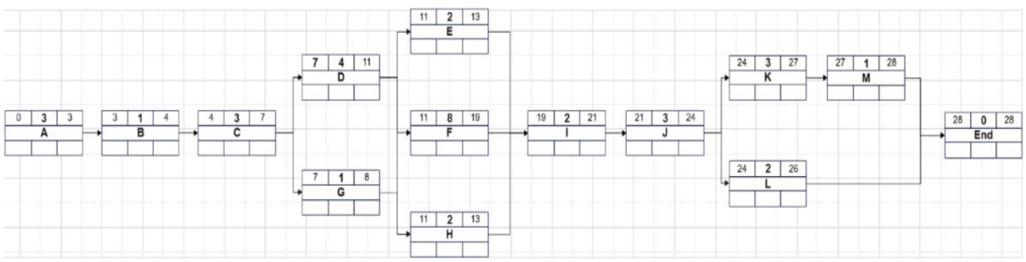


Figure 2. Network modeling and Forward pass (ES , EF and D)

Backward Pass (Calculating Latest Times) & Slack Calculation. The Latest Finish (LF) of the last activity is initially set to its EF, then the LF of each activity is determined by taking the minimum LS of successor activities. The Latest Start (LS) is calculated by subtracting the activity duration from LF. Then, Total Float (Slack - TF) is determined to see how much delay is allowed without impacting project completion, as shown in Figure(3) the project duration was found and calculated.

LS = LF - Activity Duration ....(3)
LF = min (LS of all successor activities) .... (4)
TF = LS - ES or TF = LF – EF .... (5)

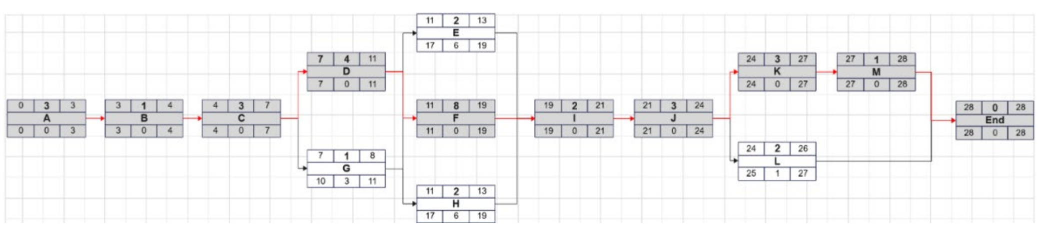


Figure 3. Backward Pass and Critical Path

The results. Any activity with TF equal to zero is considered a critical activity and must be considered it will avoid any lack or delayed the entire project progress, for other activities total float value shows how delay is permissible without causing any impact on the start times of subsequent activities or the project completion duration.

- Project duration is 28 weeks.
- Critical Path includes A, B, C, D, F, I, J, K, and M activities.
- The near-critical paths are considered as subcritical paths; it is close to the critical path with small TF values and any impact on one of these activities may shift these values to zero, which turns them into critical paths. Therefore, these paths must be taken into consideration and monitored to avoid any sudden change that affects the project progress plan.

Critical Path (TF = 0) – Main Project Path:
A → B → C → D → F → I → J → K → M
Near Critical Path (TF = 1):
A → B → C → D → F → I → J → L

Third Critical Path (TF = 3):
A → B → C → G
Fourth Critical Path (TF = 6):
A → B → C → E
A → B → C → H

6.1.2 Risk Management

Risk management involves identifying, analyzing, and mitigating risks that could impact project goals. Risks can be threats or opportunities, and effective management reduces uncertainty to an acceptable level (Simon et al. 2020). A Risk Management Plan outlines potential risks, their likelihood, impact, and significance, along with preventive and contingency measures. It provides a structured approach to managing risks throughout the project lifecycle (Glama 2021).

6.1.2.1 Risk Breakdown Structure (RBS)

A Risk Breakdown Structure (RBS) is a diagram that categorizes project risks by significance and probability, ensuring all possible risks are considered (Simplilearn, 2024). It is a vital tool for systematically and effectively managing risks, improving project success (Hillson 2002). Figure (4) presents an RBS covering key risks in designing a smart system for accident management in Bisha, Saudi Arabia.

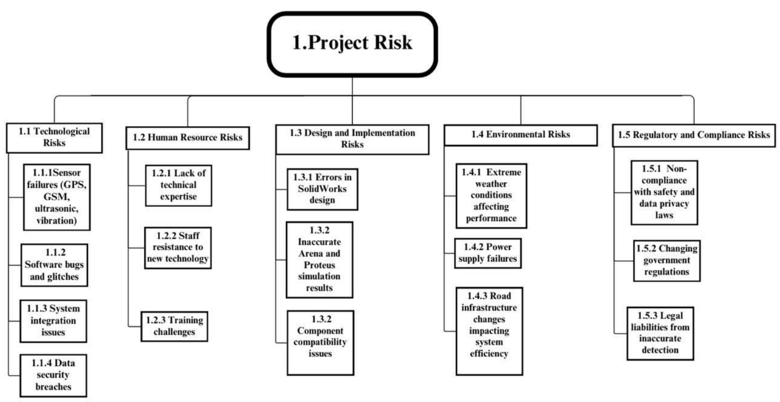


Figure 4. Risk Breakdown Structure (RBS)

6.1.2.2 Risk management plan

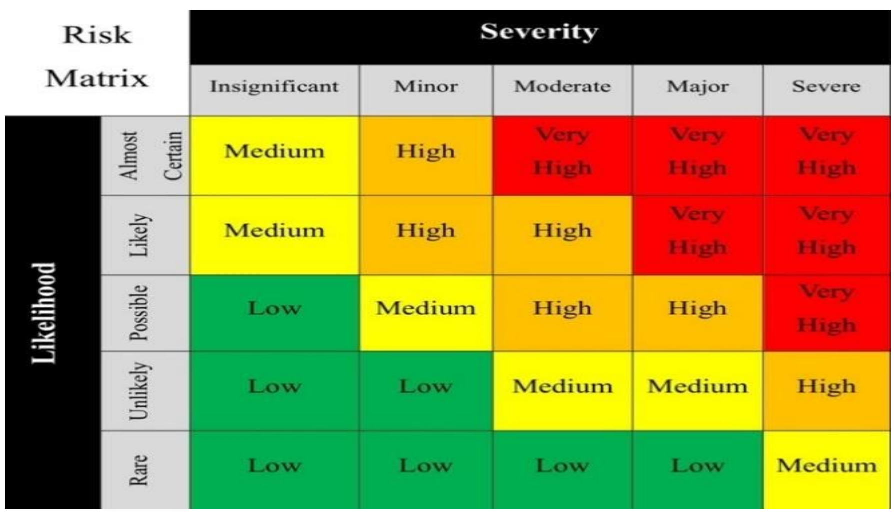
A Risk Management Plan is a crucial project management process that helps anticipate and mitigate potential risks (LogicManager, 2024). It outlines expected risks, preventive measures, and strategies to minimize their impact (Glama, 2021). Table (2) evaluates and ranks risks associated with designing a smart accident management system in Bisha, Saudi Arabia, while identifying mitigation strategies.

Table 2. Risk management plan

Risk Category	Identified Risks	Impact	Mitigation Strategy
Technological	Sensor failures	Delayed emergency response	Routine testing and redundancy
Technological	Software bugs	Incorrect accident detection	Regular code review and validation
Human Resource	Lack of expertise	Inefficient system operation	Conduct training programs
Human Resource	Resistance to adoption	Reduced system effectiveness	Awareness sessions and workshops
Design & Implementation	Inaccurate simulations	Performance issues	Use real-world data for validation
Design & Implementation	Component compatibility issues	System failure	Vendor assessments and pre-testing
Environmental	Harsh weather	Sensor damage	Weatherproof enclosures
Environmental	Power supply failures	System downtime	Solar-powered backups
Regulatory	Non-compliance with laws	Legal penalties	Regular audits and legal consultations
Regulatory	Policy changes	Additional cost & rework	Flexible system architecture

6.1.2.3 Risk Assessment Matrix

Risk assessment is a systematic approach to identifying and evaluating risks, ensuring safety by recognizing hazards and accidents. It is both a legal requirement and a critical tool for managing health, safety, and wellness in the workplace (BSC 2025). A risk assessment matrix, or Probability and Severity matrix, visually represents risks by comparing their likelihood and potential consequences, helping to prioritize risks based on their impact, shown in Figure(5) and Table(3) (Vicente 2024).



Risk Matrix	Severity				
Likelihood	Insignificant	Minor	Moderate	Major	Severe
Almost Certain	Medium	High	Very High	Very High	Very High
Likely	Medium	High	High	Very High	Very High
Possible	Low	Medium	High	High	Very High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Low	Medium

Figure 5. Risk Matrix

The risk assessment helped us evaluate the level and likelihood of each risk, allowing us to identify, prioritize, and assess their importance. Enhancing this assessment improves our understanding of potential challenges and supports effective decision-making for risk control and achieving objectives efficiently.

Table 3. Risk Assessment Matrix

Risk	**Likelihood**		**Severity**	**Risk Level**
Technological	Likely		Major	Very High
Human Resource	Unlikely		Minor	Low
Design & Implementation	Likely		Moderate	High
Environmental	Possible		Severe	Very High
Regulatory	Unlikely		Major	Medium
Risk	**Likelihood**		**Severity**	**Risk Level**
Technological	Likely		Major	Very High
Human Resource	Unlikely		Minor	Low
Design & Implementation	Likely		Moderate	High
Environmental	Possible		Severe	Very High
Regulatory	Unlikely		Major	Medium

6.1.3 Preventive Maintenance Strategies

The primary aim of maintenance and reliability is to ensure the efficient and seamless functioning of equipment, systems, and facilities (Rao 2025). To reach these objectives, we employed Fault Tree Analysis (FTA) and Failure Mode and Effects Analysis (FMEA). A combined approach that applies FTA at the system level (for analyzing accidents) alongside FMEA at the component level (to prevent vehicle failures) would provide the best comprehensive safety and reliability plan (Dziak 2023) (Dziak 2024). By executing a thorough preventive maintenance plan based on industry best practices, this approach guarantees the ongoing reliability and effectiveness of the smart system elements to manage incidents. This strategy for predictive maintenance is crucial for maintaining the ongoing performance of the system, storage, and operating system, aiding in minimizing unexpected failures and improving emergency response quality, thereby boosting safety and efficiency while driving (Emaint 2025).

6.1.3.1 Fault Tree Analysis (FTA)

Fault Tree Analysis (FTA): This is a method for determining the reasons behind system failure through the use of a diagram. The diagram illustrates the potential reasons and elements that contribute to the failure, aiding in the evaluation of likelihood and tackling the underlying causes. It is alternatively known as Event Tree Analysis. FTA is utilized to rank corrective measures and prevent negative results (Fiix Software 2025).

6.1.3.2 Failure Mode and Effects Analysis (FMEA)

Failure Mode and Effects Analysis (FMEA): This is a structured approach employed to recognize possible failure modes, their origins, and their impacts on the system. It also assists in identifying risks and creating strategies to mitigate them. It is also utilized in various industries and sectors to minimize mistakes and enhance processes (Parlatan & Van Der Burgt 2024). In light of the conducted research on the geographical distribution of traffic incidents and the emergency services' response time in Bisha city, we will implement linear fault tree analysis (FTA) to grasp the reasons behind accidents and find strategies to minimize them. Subsequently, we will employ failure mode and effect analysis (FMEA) to avert vehicle malfunctions that could result in accidents.

Section 1. Fault Tree Analysis (FTA) for Traffic Accidents

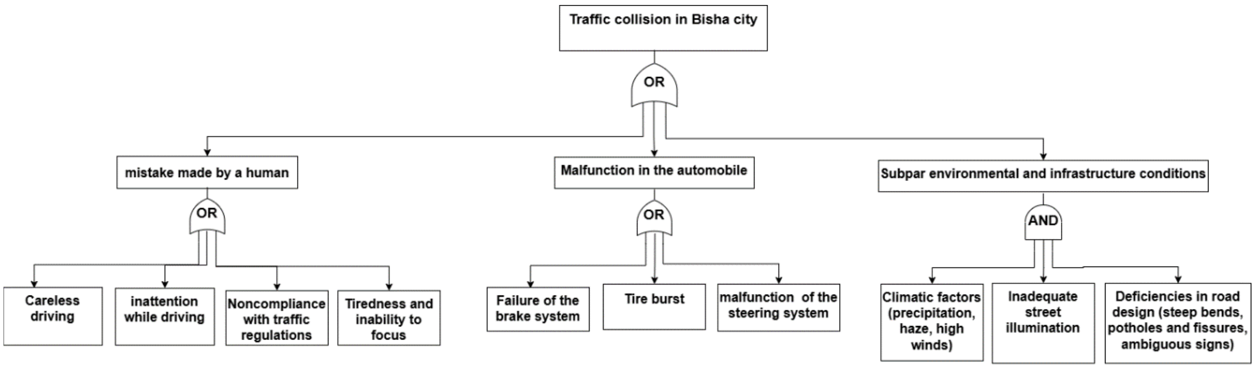


Figure 6. FTA for Traffic Accidents

Section 2: Failure Mode and Effects Analysis (FMEA) to Avoid Vehicle Malfunctions
Because vehicle malfunctions directly lead to accidents, employing FMEA aids in recognizing possible vehicle failures and implementing preventive actions to mitigate them.
I. Determine the fundamental elements of the vehicle for examination:
1- Brakes system
2-Car tires
3-Lighting system
4-Motor and fuel system
II. FMEA Assessment Table (4) for Preventing Vehicle Failures:

Table 4. Failure Mode and Effects Analysis

Failure Mode and Effects Analysis

Date:	3/2/2025
Prepared By:	Lina Alhamzah
Responsibility	the User
Model:	Current

Component	Mode of failure (potential failure)	Effect on vehicle	Severity (S)	Occurrence (O)	Detection (D)	RPN (S x O x D)	Preventive measure
Brakes system	Brakes malfunctioning	Inability to stop and possible accident	9	4	3	108	Regular brake inspections and changing brake pads when they are worn out.
Car tires	tire explosion	Losing control of the automobile	9	5	4	180	Inspect air pressure and change tires when there is any difference.
Lighting system	Headlight malfunction	Weak nighttime visibility, possible accident	6	3	5	90	Consistently inspect the lights and verify the condition of the wiring.
Motor and fuel system	The engine halted abruptly	Car breakdown on the road, collision risk	8	2	4	96	Routine engine upkeep and ongoing fuel system inspections

The Risk Priority Number (RPN) serves as a quantitative instrument utilized in Failure Modes and Effects Analysis (FMEA) to evaluate and rank possible risks (Six Sigma 2024).
III. Analyze results and set priorities

•RPN is computed by multiplying the three distinct ratings together: RPN = S x O x D. A greater RPN signifies a more serious risk (Six Sigma 2024).
•The highest RPN is 160 which is (tire explosion) so the tires need regular inspection and air pressure adjustment.
•The brakes system is a major hazard so regular maintenance should be ensured.
In our project, a maintenance schedule must be set for traffic safety as shown in Table 5.

Table 5. Routine maintenance schedule

Component	maintenance schedule
Brakes system	- Brake inspection every 6 months or every year. - Immediate examination if you hear strange noises or poor performance.
Car tires	- Routine calibration and examination every 3-6 months. - Replace your car tires every 2-3 years to ensure your safety.
Lighting system	- Inspect the lighting system biennially to confirm there are no deposits interfering with the illumination. - Replace your lighting system every 6-8 years to ensure the best lighting quality.
Motor and fuel system	- Replace the motor every 1.5 to 2 years to prevent unexpected failures. - Inspect the motor every 6-12 months to make sure it operates efficiently.

6.2 Economic Study

The study aims to analyze the economic study of a project (Lin & Huang, 2020). To design an smart system to deal with accidents in the city of Bisha in the Kingdom of Saudi Arabia using Geographic Information Systems (GIS) techniques and system simulation. The project reduces traffic accidents and improves emergency response time, which reduces the economic costs associated with accidents. Therefore, the analysis includes a detailed look at the initial costs of purchasing equipment as shown in Table 6.

Table 6. Equipment and Software

Equipment and software description	Unit price (SAR)	QTY	Total
Arduino	120	1	120
Arduino Mega 2560	220	1	220
GPS Module	40	1	40
SIM card	60	1	60
Terminal	66	3	198
Vibration Sensor	75	1	75
Sonar	77	1	77
Ultrasonic Sensor	37	1	37
Led Red	33	1	33
Sounder	40	1	40
Connecting Wires	28	13	364
Training	180	2	360
Total : 1624 SAR			

Total Initial Costs:
The initial costs of the new system include an investment in equipment of 1624 Saudi Riyals, including the purchase of equipment, its maintenance and programming. The installation cost is equivalent to 25% of the equipment cost.

Installation Cost : 1624 x 0.25 = 406 SAR

Covers the costs of labor required for installation and training on operating the new system.

Total Initial Costs= Total Equipment Investment + Installation Cost

1624 + 406 = 2030 SAR

Annual Net Savings:
Implementing the system results in annual savings through reduced operating expenses:
Lower car equipment costs 1200 SAR
Lower maintenance costs 500 SAR
Total annual savings are calculated as follows = 1700 SAR

Annual operating costs work from total savings to annual return

Annual net saving = Total annual gross saving - total operational costs
1700 – 200 = 1500 SAR

Payback Period Calculation:
Payback period is a financial concept that denotes the duration required for an investment to recover the funds invested in it. The term refers to a metric for assessing the profitability of an investment; a shorter payback period indicates greater profitability (Ungvarsky 2024).

Payback period = Total initial costs \ Annual net savings
2030 \ 1500 = 1.35 years

Since it will take about a year, less than its expected life, for the system to pay for itself, the investment is worth the cost.

7. Conclusion
The successful implementation of an intelligent accident management system in Bisha City relies on a structured project management approach and economic feasibility assessment. This study confirms two key findings: applying the Critical Path Method (CPM) optimizes project scheduling, ensuring efficient system deployment with minimal delays, and the economic analysis demonstrates that the system is financially viable, with a favourable cost-benefit ratio and a short payback period.

By integrating CPM for structured scheduling and Cost-Benefit Analysis (CBA) for financial assessment, this research provides a practical roadmap for implementing smart traffic solutions efficiently and sustainably. The findings highlight that a well-managed implementation plan enhances emergency response efficiency and ensures long-term economic benefits by reducing accident-related costs and optimizing resource allocation.

Collaboration between government agencies, emergency services, and technology providers is essential for successful deployment. Public awareness campaigns can also maximize the system's impact by encouraging community engagement. As Bisha continues to expand, leveraging smart project management and economic strategies can serve as a model for other cities aiming to enhance traffic safety and urban resilience.

References
Abdulrehman, R., Almoshaoheh, M., Haider, H., Alharbi, F., and Jamal, A., Development and application of a risk analysis methodology for road traffic accidents , *Alexandria Engineering Journal*, vol. 111, no. 2025, pp. 293–305, October 2024.

Adibhesami, M. A., Ekhlassi, A., Mohebifar, A., and Mosadeghrad, A. M., Improving time-cost balance in Critical Path Method (CPM) using Dragonfly Algorithm (DA), *Proceedings of the 2019 International Conference on Industrial Engineering and Operations Management*, pp. xx-xx, Tehran, Iran, June 2019.

AuditBoard, What is a Risk Assessment Matrix?, Available: https://www.auditboard.com/blog/what-is-a-risk-assessment-matrix/, Accessed on January 31, 2025.

British Safety Council, Risk Assessment and Management: A Complete Guide, Available: https://www.britsafe.org, Accessed on January 31, 2025.

Glama, D. F., Project Management Plan for the Construction of Madang Christian Academy Perimeter Fence, Final Graduation Project, Master in Project Management (MPM), San Jose, Costa Rica, October 2021. Available: https://www.ucipfg.com/biblioteca/files/original/c4fe10b13b44412e89c3d1c1ae160f75.pdf.

Gorea, R., Financial impact of road traffic accidents on the society, *International Journal of Ethical Trauma and Violence*, vol. 2, no. 1, pp. 6–9, 2016.

Harirforoush, H., and Bellalite, L., A new integrated GIS-based analysis to detect hotspots: A case study of the city of Sherbrooke, *Proceedings of the Accident Analysis & Prevention Conference*, pp. 62–74, Sherbrooke, Canada, 2019.

Hillson, D., Use a Risk Breakdown Structure (RBS) to Understand Your Risks, *Proceedings of the Project Management Institute Annual Seminars & Symposium*, San Antonio, TX, USA, October 3, 2002. Newtown Square, PA: Project Management Institute. Available: https://www.pmi.org/learning/library/risk-breakdown-structure-understand-risks-1042.

Kumaresh, G., Saldanha, F., Lich, T., and Moennich, J., Estimation of Socio-Economic Loss due to Road Traffic Accidents in India, *SAE International Journal of Advances and Current Practices in Mobility*, vol. 4, no. 3, pp. 774–784, 2022.

LogicManager, What is a Risk Management Plan?, Last updated October 3, 2024. Available: https://www.logicmanager.com/resources/erm/what-is-a-risk-management-plan/.

Mahardika, A. G., Fadriani, H., Munityono, Afiyah, S., and Ramady, G. D., Analysis of time acceleration costs in level building using critical path method, *Journal of Physics Conference Series*, vol. 1424, no. 1, pp. 012025, 2019.

Ministry of Health, Road Traffic Injuries and Deaths, Available: https://www.moh.gov.sa/en/Ministry/Statistics/Pages/Traffic-accidents.aspx, 2021.

Moradi, A., Soori, H., Kavousi, A., Eshghabadi, F., Jamshidi, E., and Zeini, S., Spatial analysis to identify high risk areas for traffic crashes resulting in death of pedestrians in Tehran, *Proceedings of Med J Islam Repub Iran Conference*, pp. 450, Tehran, Iran, 2016.

Rakasyiwi, G. R., Witjaksana, B., and Tjendani, H. T., Project scheduling analysis using the critical path method – Case study: subsidized house construction project in Hill Mulya Housing, Samarinda City, *International Journal on Advanced Technology Engineering and Information System (IJATEIS)*, vol. 1, no. 4, pp. 73–88, 2022.

Romadhona, S., Kurniawan, F., and Tistogondo, J., Project scheduling analysis using the precedence diagram method (PDM) case study: Surabaya's city outer east ring road construction project (Segment 1), *International Journal of Engineering, Science & Information Technology (IJESTY)*, vol. 1, no. 2, pp. 53–61, 2021.

Simplilearn, Risk Breakdown Structure: Explained Easily, Last updated August 13, 2024. Available: https://www.simplilearn.com.

Verbraeck, A., Bosch-Rekveldt, M., Rye, S., and Simon, P., The Asymmetry between Threats and Opportunities in Risk Management: Results from a Survey among APM Corporate Members, APM, Available: https://www.apm.org.uk/v2/media/frmga0fg/the-asymmetry-between-threats-and-opportunities-in-risk-management.pdf, 2023.

Vicente, V., What is a Risk Assessment Matrix?, AuditBoard Blog, February 15, 2024. Available: https://www.auditboard.com/blog/what-is-a-risk-assessment-matrix/.

World Health Organization, Global Status Report on Road Safety, Available: https://www.who.int/publications/i/item/9789241565684, 2018.

World Health Organization, Reducing Road Crash Deaths in the Kingdom of Saudi Arabia, Available: https://www.who.int/news/item/20-06-2023-reducing-road-crash-deaths-in-the-kingdom-of-saudi-arabia, 2023.

Biographies

Lama A.Alshahrani is undergraduate Industrial Engineer in final year at Bisha University with exceptional academic performance. She complete her coop-training with Saudi Aramco under Operational Excellence and Field Compliance Group as OE Coordinator. She was an active member during her time at the university, she held many position at IEOM including volunteer teacher , member at Social and Technology Team and Activity and Program team , also she worked as Director of Training and Development Committee in Engineering Club. Lama have certificates from Google in Data Analysis and Project Management as her research interests include optimization, risk management and Continuous Improvement.

Lina T.Alhamzah is undergraduate Industrial Engineering student in her final year at the University of Bisha, with diverse experiences and a passion for enhancing efficiency and innovation. Successfully completed her training program in the Project Management Department at Gold and Minerals Company, where she gained valuable skills in project planning, scheduling, and execution. Additionally, participated in a virtual work experience with the Misk Foundation as an Operational Risk Analyst Assistant. Actively volunteered as an engineer with IEOM UB and the Engineering Club at the University of Bisha, contributing to committees focused on volunteering, collaboration, and cultural activities, which strengthened her teamwork and event organization skills. Holds a Google Data Analytics Professional Certificate, which enhanced her abilities in data analysis and decision-making. Committed to leveraging her academic and practical expertise to contribute to innovative and sustainable projects that create real value.

Ghina S. Al-Shahrani is a final-year undergraduate student in Industrial Engineering at Bisha University. She completed her cooperative training at the Saudi Electricity Company (Abha Electricity Services Office - Safety Group), where she gained practical experience in safety operations and standards in one of the Kingdom's critical infrastructure sectors. her also volunteered as an the Engineering Club at the University of Bisha has also successfully

completed the “Data Analytics ” learning path at the Saudi Digital Academy (SDA) her earned the Google Data Analytics from Google and Data Visualization With from IBM On this path and participated in a virtual work experience program in project management and community initiatives offered by the Misk Foundation.
Her dedication to academics and professional development is further reflected, Her interests include safety engineering, data analytics , project management.

Elaf M. Alhadi is an undergraduate Industrial Engineering student in her senior year at Bisha University. She successfully completed her cooperative training at ALLAMAA Factory of Wood & Metal furniture manufacturing in Dammam, 2nd Industrial City of Saudi Arabia, Where she gained excellent knowledge, experience and practical skills in four departments (Inventory Control, Optimizing Processes, Workplace Safety, Maintenance Management). She gratefully accepted this generous training offer due to her passion for improvement, her interest in sustainability, and her creative performance. She’s also known for her active role in the IEOM branch of Bisha University since it was founded in 2022; she’s currently a member of the Research & Publication Team. She completed her unique journey with McKinsey’s Forward Program in 2024. She participated in a Virtual Work Experience with the Misk Foundation as a Project Officer in 2024 and as an Operational Risk Analyst Assistant with the Saudi Industrial Development Fund (SIDF) in 2023.

Khaled A. Abuhasel received the B.Sc. and M.Sc. degrees from the University of Central Florida, Orlando, FL, USA, in 2009 and 2010, respectively, and the Ph.D. degree from New Mexico State University, Las Cruces, NM, USA, in 2012, all in industrial engineering. He is currently a Professor in the Industrial Engineering Department at, the University of Bisha, Saudi Arabia. He holds three U.S. patents, and more than 75 publications in journals and proceedings of very reputable conferences. His research interests include optimization, systems engineering, healthcare systems, intelligent systems, artificial neural network methodologies, and statistical analysis.