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by Mr Adnan

Using Graph Theory to Optimise Emergency Response Routes in Johannesburg

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Research Aims:
This research examines how mathematical graph theory can be applied to improve emergency response systems in Johannesburg, where traffic and potholes delay life-saving services. This study will specifically analyse the following issues/aspects:

1. Current emergency response systems and their limitations in Johannesburg.

2. Graph theory algorithms being used to minimise response times and delays.

3. Incorporating real-time traffic into GPS systems and routes.

4. Recommendations for incorporating graph-based models to optimise emergency services efficiency in South Africa.

Research Questions:

1. What are the current challenges that emergency response units in Johannesburg face regarding delayed arrival times?

2. What is the effectiveness of the graph algorithms in making emergency routes on Johannesburg's busy roads?

3. What improvements can be made by including real-time traffic data and optimisation techniques?

4. How can the use of mathematics be used to optimise and reduce the average response times by emergency response?

Introduction:

Emergency response time is a factor that is vital in all our lives: in times of crisis such as medical issues, fires, or crime-related emergencies. In a city like Johannesburg, characterised by traffic, potholes and traffic lights not working, quick response times are essential yet they tend to be frequently delayed, putting countless lives in danger. According to the Johannesburg Roads Agency, emergency vehicles repeatedly fail to meet international response standards, with trends of arrival times being higher than 10-15 minutes.

Mathematics provides for numerous different methods in which optimisation and modelling can be used on urban roads such as Johannesburg's. Graph-based algorithms allow for the shortest and fastest routes to be calculated in a network, whilst taking in factors such as road length and traffic. While this does exist in smart-city development and planning, very little research has shown how this can be used and adapted in South African urban areas such as Johannesburg.

The main issue lies at human cost: every second saved could significantly increase survival rates and decrease destruction such as fires. By applying mathematics to this issue, this study aims to bridge the gap between non-existent problem solving and real-life implementation to save lives..

Literature Review:

Research on Graph Theory and Routing: Graph theory has been exceptional in finding the shortest-path possible by using Dijkstra's algorithm introduced in 1959 [1]. Extensions like the A* algorithm improves efficiency by using heuristics to guide search [2]. In transportation systems, these methods have been used to optimise efficiency by reducing fuel use and shortening delivery time .

Applications in Emergency Response: Research in global cities such as New York, Beijing, and London shows that optimised routing systems can reduce emergency response times significantly [3][4]. Studies also highlight the integration of real-time traffic data as a key factor in improving accuracy [5].

Limitations in African Contexts: Although these systems have been implemented, resulting in global success, there is still a lack of studies on its use and effectiveness in the urban areas of South Africa. Johannesburg faces many challenges: traffic congestion, traffic lights not working, and road closures due to maintenance. These factors are not included in GPS systems due to routing systems being dependent on static maps. This creates the issue of no real-time issues, thus allowing the routing system to find a better and more efficient route [6].

Gap in Prior Research: Current literature confirms the use and effectiveness of graph-based optimisation globally, however, in South Africa there are a lack of case studies regarding the implementation of these systems. This research will address this gap by testing how classical and advanced graph theory methods can be adapted to local conditions.

Research Methodologies:

This research will adopt a quantitative simulation-based approach:

1. **Data Collection:**

- Road network data from OpenStreetMap and Johannesburg Roads Agency reports.
- Historical and live traffic data from open APIs (only if accessible).
- Emergency response times and their accompanying statistics from government or public records.

2. **Graph Modelling:**
   - A constructed graph of Johannesburg's roads and connections.
3. **Algorithm Testing:**
   - Apply Dijkstra's and A* algorithms to set minimum standards of performance and efficiency.
   - Implement advanced algorithms such as real-time data..
   - Simulate scenarios such as heavy traffic.
4. **Evaluation:**
   - Compare how long response times should take to the current average times of emergency responses.
   - Perform statistical analysis to determine significance of improvements.

Conclusion:

This research addresses a pressing issue: delays in Johannesburg's emergency response system..The application of using thisystem would not only save countless lives, but it would reduce costs and improve the trust the public have in emergency services and in government. This study also looks at how this could be applied in a South African context, defeating current urban challenges.

References:

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