Improving traffic management and reducing congestion in the municipality of Hebron: an integrated engineering approach and data governance for sustainable development

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Abstract— **Traffic congestion is a global challenge, and it is exacerbated in Palestinian cities such as Hebron due to rapid population and urban growth and a lack of strategic planning. This paper aims to explore and analyze the root causes of the traffic crisis in the municipality of Hebron, with a particular focus on the poor utilization of available traffic data and structural and administrative complexities within the organisational structure of the municipality of Hebron. Through an exploration, descriptive, and analytical methodology based on field observations, semi-structured interviews with municipal officials, and analysis of the existing organisational structure, the paper presents an integrated engineering and administrative framework. This framework includes a proposal to establish a traffic data governance committee, develop a centralised traffic information system (GIS-based), and formulate a comprehensive traffic plan, with an emphasis on improving effective coordination between the relevant departments. The recommendations aim to enable the Municipality of Hebron to make informed, data-driven engineering decisions, contributing to sustainable traffic flow and enhancing the quality of life in the city.**

Keywords: traffic management, transport engineering, traffic congestion, Hebron Municipality, data governance, transport planning, Palestine, geographic information systems (GIS), sustainable transport.

I. INTRODUCTION

The transport sector is a vital artery for urban and economic development in any urban agglomeration, and the efficiency of the road network and traffic management is an indicator of a city's progress. However, many cities around the world, including Palestinian cities, face increasing challenges in coping with traffic congestion caused by rapid population growth, unplanned urban expansion, and increased vehicle ownership. Hebron, one of the largest and most commercially and demographically vibrant Palestinian cities, with a complex geographical and urban nature, suffers from a severe traffic crisis that negatively affects quality of life and economic productivity and increases environmental pollution.

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Preliminary observations and field experience indicate that the roots of this crisis in the municipality of Hebron lie not only in the lack of road infrastructure or poor driver behaviours, but also in administrative and planning shortcomings. The most prominent of these aspects is the poor use of available traffic data and the absence of a comprehensive strategic plan for traffic management, supported by effective structural coordination between the relevant departments within the municipality. These administrative and data gaps hinder the implementation of effective engineering solutions and limit their sustainability.

This paper aims to provide an in-depth exploration and analytical study of the traffic situation in the municipality of Hebron from an engineering and administrative perspective, with a focus on the role of data and its governance. The study seeks to diagnose the root causes of the problem and propose an integrated framework that goes beyond partial solutions, towards a comprehensive data-driven traffic management strategy that activates institutional coordination to ensure the sustainable development of the city.

II. STUDY OBJECTIVES:

- Analyse the current state of traffic data management in the municipality of Hebron and assess its current usefulness.
- Identify the root causes of the traffic crisis in Hebron from an administrative and structural perspective.
- Propose an integrated framework for traffic management, including data governance and the development of a comprehensive traffic plan for the municipality of Hebron.

III. THEORETICAL FRAMEWORK AND PREVIOUS STUDIES

1) Modern Traffic Management Systems

Modern Traffic Management Systems (MTMS) refer to the integration of advanced technologies, policies, and infrastructure strategies to monitor, control, and optimize traffic flow in urban and interurban networks. These systems leverage real-time data, communication technologies, and automated decision-making to improve road safety, reduce

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congestion, and enhance environmental sustainability [9] Recent developments in MTMS include adaptive signal control, automated incident detection, and coordinated traffic control strategies. By utilizing intelligent sensors, IoT devices, and predictive analytics, cities can dynamically adjust traffic operations to match demand patterns, reducing delays and improving travel time reliability [12].

2) Intelligent Transport Systems (ITS)

Intelligent Transport Systems (ITS) are the application of information and communication technologies (ICT) in transport infrastructure and vehicles to enhance traffic efficiency, safety, and sustainability. ITS encompasses solutions such as connected vehicles, real-time traffic monitoring, and electronic toll collection systems [2], ITS improves road network performance by enabling data exchange between vehicles, infrastructure, and control centers, leading to optimized routing, reduced congestion, and improved road safety. Furthermore, ITS supports the integration of emerging technologies like autonomous driving and vehicle-to-everything (V2X) communication [14].

3) Demand Management

Demand management in transportation refers to strategies aimed at influencing travel behavior to reduce traffic congestion, improve mobility, and minimize environmental impacts. These strategies can include congestion pricing, carpooling incentives, flexible work hours, and promoting non-motorized transport[6].
By managing demand rather than solely expanding infrastructure, cities can achieve more sustainable and cost-effective mobility solutions. For instance, congestion pricing has been proven to shift travel to off-peak hours, reduce vehicle kilometers traveled, and lower greenhouse gas emissions [5].

4) Multimodal Transport Planning

Multimodal transport planning involves designing and managing transportation systems that integrate various modes of travel, such as walking, cycling, public transit, and private vehicles, into a cohesive network [1],A multimodal approach enhances connectivity, accessibility, and sustainability by encouraging travelers to use the most efficient and environmentally friendly mode for each trip segment. Effective multimodal planning also incorporates intermodal hubs, unified ticketing systems, and seamless transfers between modes [10].

5) Big Data in Transportation

Big data in transportation refers to the collection, processing, and analysis of massive datasets from sources such as GPS devices, traffic sensors, social media, and mobile apps to improve transportation planning and operations [15]. Using big data analytics, transport authorities can predict congestion patterns, optimize public transit schedules, and detect incidents in real-time. Additionally, big data enables personalized travel recommendations and demand-responsive transport services [7].

6) Data Governance in Transport

Data governance in transportation is the framework of policies, standards, and processes that ensure the quality, security, privacy, and accessibility of transportation-related data [4].
Effective data governance supports better decision-making by ensuring that transportation data is accurate, up-to-date, and shared appropriately among stakeholders. It also addresses legal and ethical challenges related to data ownership, sharing, and protection [3].

7) Geographic Information Systems (GIS) in Transportation

Geographic Information Systems (GIS) in transportation involve the use of spatial data analysis tools to capture, store, manipulate, and visualize geographic information related to transportation networks [11].
GIS enables planners and engineers to map traffic flows, analyze accessibility, model infrastructure scenarios, and monitor real-time network performance. Its integration with other intelligent systems enhances spatial decision-making and supports long-term transport planning [13].

8) Municipal Challenges in Smart Traffic Management

Municipal challenges in implementing smart traffic management systems include financial constraints, technological limitations, data privacy concerns, and institutional resistance to change [8].
Other barriers include interoperability issues between different systems, lack of skilled personnel, and public acceptance of new technologies. Addressing these challenges requires multi-stakeholder collaboration, clear policy frameworks, and sustainable funding models [16].

IV. METHODOLOGY

This study relies on a descriptive, analytical, exploratory methodology to assess the current situation and propose practical solutions. Data was collected from primary and secondary sources to provide a comprehensive understanding of the problem.

A. Primary data

Field observations: Qualitative observations were collected through field inspections of major congestion points and the road network in Hebron, and preliminary discussions with an engineer specializing in the city to understand the daily challenges and practical realities of traffic management.

Semi-structured interviews: Interviews were conducted with a number of officials and experts in the Hebron Municipality

from various departments related to traffic management, such as: the Traffic and Transportation Department, the Roads and Maintenance Department, the Projects Department, and the Planning and Organization Department within the Engineering and Public Works Department, in addition to representatives from the Computer and Communications Department and the Strategic Planning Unit. The interviews aimed to gather their views on the problem, data management challenges, and current coordination mechanisms.

B. Secondary data

Analysis of the organisational structure of the Municipality of Hebron: The organisational structure of the Municipality of Hebron (as shown in Figure 1) was analyzed to identify the main departments, their relationships, and the location of departments related to traffic, in order to understand the administrative hierarchy and its potential impact on information flow and decision-making.

V. Current Situation Analysis in Hebron Municipality

The city of Hebron suffers from a worsening traffic crisis that hinders daily movement and causes economic, environmental and social damage.

A. The traffic crisis in Hebron: symptoms and effects

The traffic crisis in Hebron manifests itself in several major bottlenecks (e.g. Ibn Rushd roundabout, Bab al-Zawiya area, main street of Ein Sara), where vehicles experience significant delays and long queues during rush hour. The limited capacity of some roads, poor urban planning that has not kept pace with population growth, and the lack of optimal design or smart traffic light systems at some intersections contribute to the problem. Field observations and municipal data show the existence of black spots where accidents are frequent due to dangerous intersections or high conflict points, highlighting the urgent need for engineering intervention. This crisis translates into wasted time and fuel, increased polluting emissions, and a negative impact on the productivity of individuals and businesses.

B. Traffic-related administrative structure

The organizational structure of the Municipality of Hebron, shown in Figure 1, reflects the distribution of roles and responsibilities.

Figure 1: Organizational structure of the Municipality of Hebron

Through analysis of this structure and interviews with officials, the following becomes clear:

Engineering Department: Under the supervision of the Director of Engineering, this department is the technical and engineering hub for managing the city's infrastructure. The department includes vital sections directly related to traffic, namely:

1) Traffic and Transportation Section: Directly responsible for regulating traffic and certain operational aspects.
2) Roads and Maintenance Section: Responsible for maintaining and developing the road network.
3) Projects Section: Responsible for implementing road infrastructure projects.
4) Planning and Organization Department: concerned with urban planning that affects traffic.
5) Surveying and Design Department: provides spatial data and preliminary designs.

(It may include other departments such as the Water and Sewerage Department and the Construction Department, whose work may affect traffic).

6) Computer and Communications Department: Under the supervision of the Director of the Computer and Communications Department, this department is the main provider of technical support and technological infrastructure. Its sections, such as the Networks Section and the Software and Applications Section, are essential for any traffic data system.
7) Strategic Planning Unit: This unit reports directly to the mayor and is responsible for formulating the city's future visions and plans, including those related to transportation.

C. Problems with the administrative structure and their impact (from the analysis of the diagram):

- Complexity and centralisation: There are multiple administrative levels and centralised decision-making, which leads to slow approval of engineering projects and traffic solutions and delays in their implementation.
- Lack of formality and clarity of roles: There is a lack of clarity in job descriptions and written procedures for some tasks related to traffic data collection and exchange, which may lead to overlapping responsibilities or gaps.
- Weak horizontal coordination: Although the technical departments are grouped together in the Engineering Department, effective coordination between these departments, with the Computer Department (especially in data projects) and with the Strategic Planning Unit, faces challenges due to structural separation and a lack of formal coordination mechanisms.

D. Reality of traffic data management

The municipality suffers from a lack of effective use of data, which leads to its fragmentation and lack of availability. There is no centralised system for managing this data, making it difficult for different departments (e.g. roads, projects, planning) to access or analyse it effectively to make informed engineering decisions. Data ownership and access rights are a challenge, with each department or division keeping its data in 'information silos'. Employees also often lack adequate training in the latest traffic data analysis tools or specialised GIS software.

E. Lack of a comprehensive plan

As a result of data fragmentation and poor coordination, the Municipality of Hebron lacks a comprehensive long-term strategic traffic plan. The solutions implemented are often a reaction to specific problems or public pressure, rather than part of an integrated vision for the city's future traffic network, leading to partial solutions that may create new problems elsewhere.

F. Root causes of the problem

The worsening traffic problem in Hebron is directly linked to the following administrative and structural weaknesses: poor horizontal and vertical coordination between departments and divisions, lack of a data governance framework, shortage of trained human resources and specialised technical tools, and lack of a comprehensive vision and long-term strategic planning for traffic based on data.

VI. Proposed Framework for Solutions

To address traffic challenges in Hebron, an integrated engineering and administrative framework combining technical solutions and institutional reforms is proposed, based on data governance.

A. Strengthening Traffic Data Governance

Objective: To build a centralised and reliable data system that enables evidence-based engineering and administrative decisions.

1) Proposed implementation mechanism

Establish and activate a 'Traffic Data Governance Committee': This committee should be the cornerstone of this framework. The committee will include high-level representatives from:

a) *Engineering Department (Department Director, Heads of Traffic and Transportation, Roads and Maintenance, Projects, Planning and Organisation, Surveying and Design).*

b) *Computer and Communications Department (Department Director and Head of Software and Applications and Networks).*

c) *Strategic Planning Unit.*

d) *Internal Control Unit (to ensure compliance with quality and security policies).*

e) *Police representative (to ensure the integration of accident and violation data).*

The pivotal role of the committee: The committee will work to: Develop uniform policies and standards for data collection, storage, processing, and security. Defining 'data ownership' for each type of data and clarifying access rights for each department (data owner, data producer, data consumer). Overseeing data quality and accuracy, and overcoming 'information islands' through an institutional framework for coordination.

2) Development of a 'Central Traffic Information System' (GIS-based Traffic Information System):

- The Computer and Communications Department is responsible for the technical aspects of creating, developing and maintaining this system, which must be based on geographic information systems to link data to geographical locations.
- The Traffic and Transportation Department will be the main owner of operational data content (such as traffic volume, accidents, and signals).
- The system will be used as a common platform for all relevant departments to exchange and analyse traffic data, ensuring the availability of accurate and standardized information for engineering and administrative decision-making.
- Human capacity building: Implement specialised and ongoing training programmes for employees in the engineering, traffic, projects, planning, and information technology departments on the use of GIS systems, traffic data analysis tools, and simulation software.

B. Developing and implementing a comprehensive traffic plan for the municipality of Hebron:

Vision: To provide a safe, efficient, and sustainable traffic system in the city of Hebron that contributes to enhancing the quality of life and supports urban development.

Strategic objectives: Improving traffic flow, enhancing traffic safety, improving the experience of road users, and supporting sustainable development.

1) *Main pillars of the plan (with an engineering focus):*

a) *Pillar 1: Traffic data management and governance: (as detailed in the previous point).*

b) *Pillar 2: Improving traffic infrastructure (engineering solutions):*

- Intersection and traffic light management: Conduct detailed engineering studies to analyse the performance of major intersections (using simulation software) and redesign them to increase their capacity and efficiency. Upgrade existing traffic lights to intelligent adaptive systems that respond to actual traffic volume, thereby reducing delays.
- Road network development: Includes engineering design for the development and expansion of main streets in congested areas, opening new lanes or alternative routes to relieve bottlenecks, and improving road quality and maintenance.
- Parking management: Developing engineering solutions for parking, such as designing and building multi-storey car parks and implementing smart systems to manage parking occupancy.

Note: Specific projects such as 'feasibility study for replacing roundabouts with intersections/bridges' may emerge as one of the main projects within this axis and require in-depth engineering feasibility studies.

c) *Pillar 3: Traffic management and operation (Intelligent Transportation Systems - ITS):*

- Implementation of intelligent transportation systems (ITS) to monitor traffic in real time and provide up-to-date information to drivers (e.g. variable message signs).
- Development of a rapid response system for traffic accidents to manage accident sites effectively.
- In cooperation with the relevant authorities, improving the public transport network and routes to make them more efficient and attractive.

d) *Pillar 4 : Awareness and community participation: Organizing traffic awareness campaigns targeting all road users and promoting a culture of sustainable transport.*

2) *Implementation and follow-up mechanism*

- Formation of a high-level steering committee chaired by the mayor to oversee the implementation of the plan.
- Identification of measurable key performance indicators (KPIs) (e.g., percentage reduction in travel time, number of accidents per 1,000 vehicles).
- Periodically evaluate and adjust the plan based on performance and changing circumstances.
- Allocate the necessary financial resources for projects, systems, and training.

C. Strengthen structural and administrative coordination:

Considering the current organisational structure, permanent and effective coordination mechanisms should be activated at the horizontal level between:

- Engineering Department divisions (especially traffic and transportation, roads and maintenance, projects, planning and organisation, surveying and design).
- Computer and Communications Department.
- Strategic Planning Unit.
- External entities such as the police.

It is recommended that modern management principles be applied to reduce complexity and increase clarity of tasks and (formal) procedures in the organisational structure, simplify communication channels and delegate authority to enable technical departments to make faster and more effective decisions based on data.

VII. 7. Conclusion & Recommendations

This exploratory analytical study shows that the traffic crisis in the municipality of Hebron is a complex challenge that goes beyond purely engineering aspects to include issues of data management and structural and administrative coordination. The current approach, which lacks a comprehensive strategy and optimal use of data, leads to partial and unsustainable solutions.

The paper recommends adopting an integrated framework based on the following pillars to ensure sustainable traffic flow in Hebron:

- Immediate initiative to establish and activate a 'Traffic Data Governance Committee' as an administrative structure that ensures data

coordination between key departments in the municipality and relevant authorities, such as the police, which will enable engineers to access unified data.

- Investing in the construction of a 'centralised traffic information system supported by GIS technologies to be developed and maintained by the Computer and Communications Department, with the Traffic and Transportation Department designated as the main data owner, to serve as a basis for analysis and engineering design.

- Develop and adopt a 'comprehensive strategic traffic plan' for the municipality of Hebron, based on a thorough analysis of data obtained from the central system, including clear and specific engineering projects with priorities.

- Allocate the necessary resources (financial and human) and train and qualify human resources in all relevant departments (Engineering and Public Works Department and its divisions, Computer and Communications Department) on the latest practices in traffic data management and analysis and transport engineering.

- Strengthen coordination and cooperation mechanisms within the Municipality of Hebron (particularly between the Engineering and Public Works Department, the Computer and Communications Department, and the Strategic Planning Unit) and between the Municipality and relevant external entities such as the police and the Ministry of Transport and Communications, to ensure the efficient implementation of engineering projects.

- Conduct comprehensive engineering and economic feasibility studies for proposed major projects, such as converting congested roundabouts into intersections with traffic lights or bridges, before beginning their design and implementation.

VIII. Future Research Directions

- Conduct detailed traffic modelling and simulation studies for specific intersections in Hebron to evaluate proposed engineering solutions using specialised software.

- Conduct a detailed feasibility study for the application of intelligent transport systems (ITS) in Hebron, including an assessment of engineering costs and operational benefits.

- Analyse the role of public transport in alleviating congestion in Hebron and propose an engineering plan for its development.

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