Enhancing Transportation Efficiency with the Aid of GNSS-RTN Technology

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Abstract

Modern cities are confronted with the problem of satisfying the increasing need for mobility while having limited infrastructural capacity. GNSS-RTN is a crucial technology that is dependent on a satellite's precise positioning for tracking traffic engineering patterns and enhancing transportation efficiency. The accurate location and the real-time data updating are the main elements for route optimization, safety raising, and cost-effectiveness in achieving integration with smart cities. The current research presents a new approach to enhancing the efficiency of the transportation system of Erbil City by implementing a GNSS-RTN application that can aid in overcoming many problems and obstacles in transportation and traffic issues. Issues like delay mitigation, accident rate reduction, fuel usage, and carbon emission reduction can be addressed by combining GNSS with Real-Time Networks (RTN). The proposed application concerns the establishment of a central server of data processing and an effective database for monitoring and granting the required support for cases of road accidents or any other problems.

Keywords: GNSS-RTN, Traffic enhancement, CORS, Delay, Congestion

1. Introduction

Cities are dealing with the challenge of addressing the growing demand for effective mobility within the constraints of limited infrastructural capacity due to the growing urban population [1]. Vehicle probe technology based on the Global Navigation Satellite System (GNSS) is becoming famous for monitoring traffic flow and upgrading traffic control [2]. The acronym "GNSS" is a global coverage describing a group of satellites that send signals for timing and positional information from orbit. Systems like United States NAVSTAR GPS, Russian GLONASS, European Galileo, and Chinese BeiDou are among them [3]. These signals are used in satellite navigation, which allows electronic receivers to use radio signals sent by satellites to calculate accurate positions (longitude, latitude, and altitude). It is employed in time synchronization, tracking, and navigation [3]. A central processing unit and a network of ground receivers, sometimes known as continuously operating reference stations or CORSs, are the two main components of the Global Navigation Satellite System-Real-Time Network (GNSS-RTN), a satellite-based positioning system. It offers consumers real-time, extremely accurate location services across an extensive geographic area. Anywhere in the network that uses GNSS-RTN technology can provide centimeter-level precision [4].

2. Objective of the research

The presented article aims to highlight the role of global navigation satellite systems (GNSS) applications in enhancing transportation efficiency. The subsequent are the main objectives of this research:

1- Reviewing the different experiences over the world to explain the interference of modern technologies to enhance and evolve transportation efficiency.

2- Investigation of the potential of using the GNSS-RTN technology to enhance the efficiency of the transportation system in Erbil city as a sample of urban territory.

3- Show the extent of the positioning accuracy contribution to evolving the transportation system performance.

3. Methodology

The methodology of this research is about reviewing the commonly published research concerning the matter of application the of GNSS technologies in traffic engineering firstly. Secondly, suggest a GNSS-RTN application that aids in enhancing the transportation and traffic engineering system in Erbil city.

3.1 GNSS – RTN Application

Reviewing the worldwide studies and experiences of the GNSS-RTN can be determined as one of the studies carried out in the United States at Montana State University by the Western Transportation Institute [4]. To escalate the precision of positioning data, the study concentrated on employing a network of ground receivers, also known as base stations or continuously operating reference stations (CORS). These networks reduce the effects of atmospheric and satellite orbit biases, improve geospatial positioning accuracy, and offer accurate location services across a larger geographic area. Integrity, also known as a reliability indicator, is essential for safety applications [5]. Differential GPS satellite systems (DGPS) offer adjustments to boost accuracy and integrity [5]. Examples of these include the European Geostationary Navigation Overlay System (EGNOS), the WIDE Area Augmentation System (WAAS), and the Multifunctional Transport Satellite Based Augmentation System (MSAS). These systems enhance the performance of satellite navigation systems, particularly in urban areas. Integration with other technologies (such as map matching and dead reckoning) guarantees adequate integrity. [6] evaluated the significance of GNSS continuity for automobile and railway control systems, the authors examined the need for continuity in several ways of transportation (air, rail, sea, and road) using a comparative approach. The role of current GNSS (such as GPS and GLONASS) and the anticipated impact of upcoming systems (like GALILEO) were the subjects of a study by [7] from the National Telecom Regulatory Authority (NTRA) in Egypt. The study focused on applications related to precise ground locations, earth observation, rescue operations, mobile phone technology, and more, as well as the necessity of integrating with other techniques to achieve better positioning precision, reliability, and accuracy. [8] carried out research in Pakistan, more precisely in the area surrounding Islamabad and Faisalabad. The suggested system uses a combination of Global Positioning System (GPS) and Global System for Mobile

Communication (GSM) technologies to track vehicle speed in real-time. Violations like speeding are identified by comparing the vehicle's speed to the relevant traffic laws. This method can increase traffic safety and generate income for the agencies in charge of traffic management. Continually operating Reference Stations (CORS) that present precise and real-time positioning have been installed all over the world in response to the requirement to monitor and measure utilizing GNSS technology [9]. According to [10] Static baseline, real-time kinematics (RTK), and the continuously operating reference system (CORS) are the three main GNSS observation techniques. One stationary receiver and at least one mobile receiver, referred to as a rover, are used in the static baseline mode. During the survey, reference receivers remain at the same control points and watch the same satellites concurrently. Throughout the network, the rover antenna travels from one location to another. Every five to twenty minutes, they pause briefly at each new location, and their data finally provides vectors between them and reference receivers. High-precision coordinates of traverse stations in three dimensions are frequently calculated using the static baseline mode of observation. The technology provides millimeter-level point coordinates in horizontal and vertical components. [4] state that a network of ground receivers, additionally referred to as base stations, reference stations, or continuously operating reference stations (CORSs), is used by the GNSS-RTN, a satellite-based positioning system, to escalate the precision of corrections in positioning data. This idea is displayed in Fig. 1.

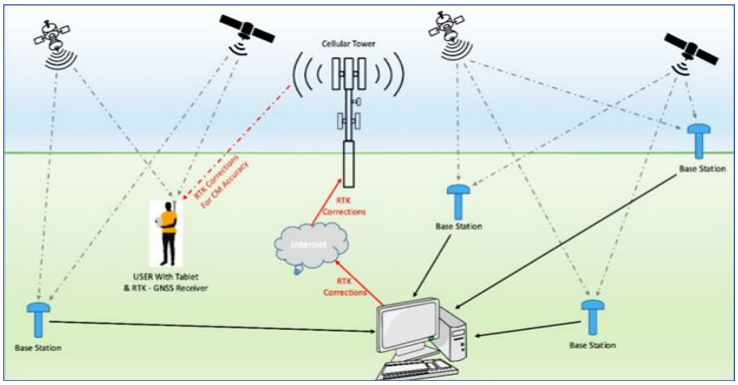

Figure 1: Concept of GNSS-RTN Operation, Reprinted from Anatum [4]

It is worth mentioning that [11] showed the rate of victims due to traffic accidents in Erbil city for the years 2021, 2022, and 2023 increased to about 109 persons and he expected that will be at the same rate for 2024. The data on traffic accidents in Erbil City - Iraq, were analyzed using R programming and STATA version 17. An effective statistical model for predicting accident rates was constructed using these instruments. The findings suggested that the Iraqi Kurdistan Traffic Department could utilize the created model to forecast accident trends in the future. As shown in Table 1, Fig. 2, and Fig. 3 below.

Table 1: Forecasting traffic accidents from 2021 to 2024 [11]

Year	Average Injury Rate	Average Death Rate
2021	93.315	15.405
2022	101.596	16.031
2023	101.609	16.031
2024	101.609	16.031

The data of Table 1 can be illustrated in the following diagrams (Fig. 2 and Fig. 3)

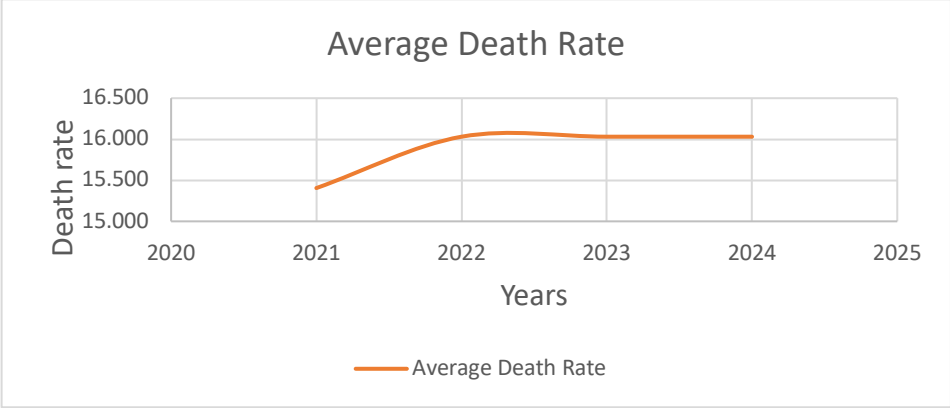

Figure 2: Average death rate from 2021 to 2024

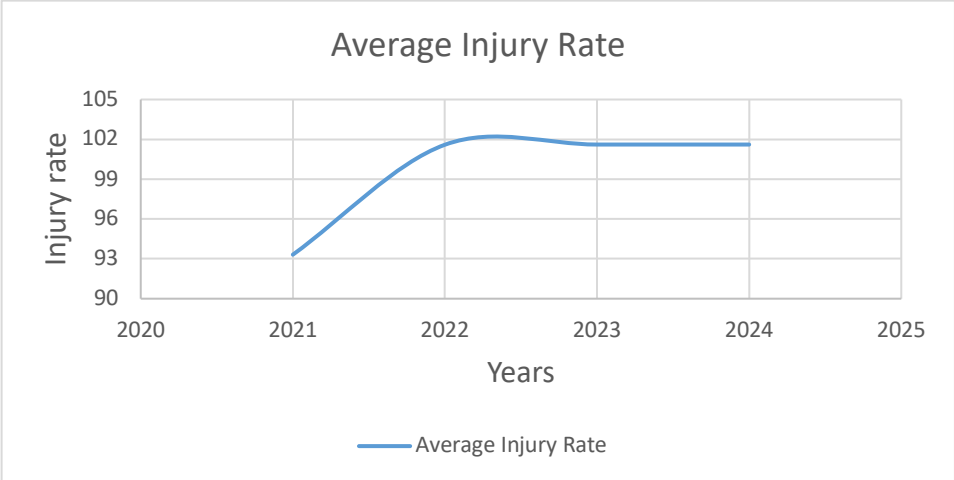

Figure 3: Average injury rate from 2021 to 2024

The curves in Fig. 2 and Fig. 3 show that the number of accidents in Erbil City is increasing year by year, and it is expected that the increasing number of vehicles is one of the main reasons for the increasing number of accidents. This matter requires an active solution for such issues as soon as possible. The authors of the current paper suggest applying the GNSS-RTN technologies to enhance the efficiency of the transportation system in Erbil City.

3.2 Proposed GNSS-RTN for Erbil City

The accurate position and updated information are the most important pillars of establishment any effective transportation system in modern cities. The current paper presents a new application of GNSS technologies for solving the problem of traffic accidents and enhancement the transportation efficiency in Erbil city. The proposed GNSS-RTN application will serve to enhance the efficiency of the transportation system and increase the effectiveness of traffic engineering in the city through using the existing GNSS CORS stations in the study area of the administration boundaries of Erbil. According to the information obtained from the Iraq Surveying website, in the vicinity of Erbil city, there is only one CORS station available and it is located in the district of "Daratwo", south part of the city near Kirkuk Road, (Fig. 4). The standard range of communication to this station is within a radius of 60km, which means that the station can provide a real-time positioning corrections for the user's overall territory of Erbil city [12].

Figure 4: Location of (CORS) in Erbil city (Iraq Surveying)

The main components of the proposed application are:
I- GNSS CORS station which covers all the administration territory of Erbil city.
II- Central server of data processing (CSDP).
III- Communication towers distributed to guarantee success and secure data transformation.
IV- Mobile monitoring groups, which take takeover real-time the transformation of the desired data.
The structure of this application is presented in (Fig. 5) below.

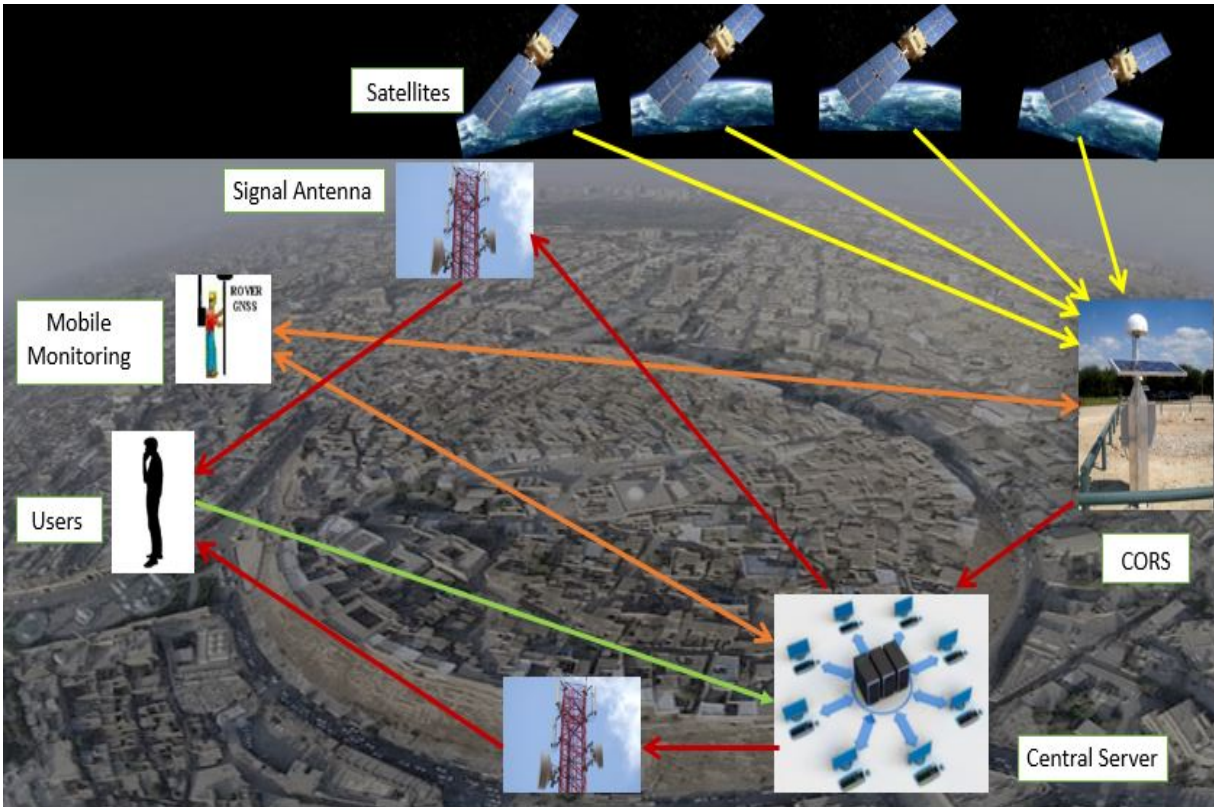

Figure 5. The suggested structure of the GNSS-RTN application in Erbil City

Furthermore, the description of the relationships between the application's components and the mechanism of data and information trading is illustrated in the following flowchart in Fig. 6.

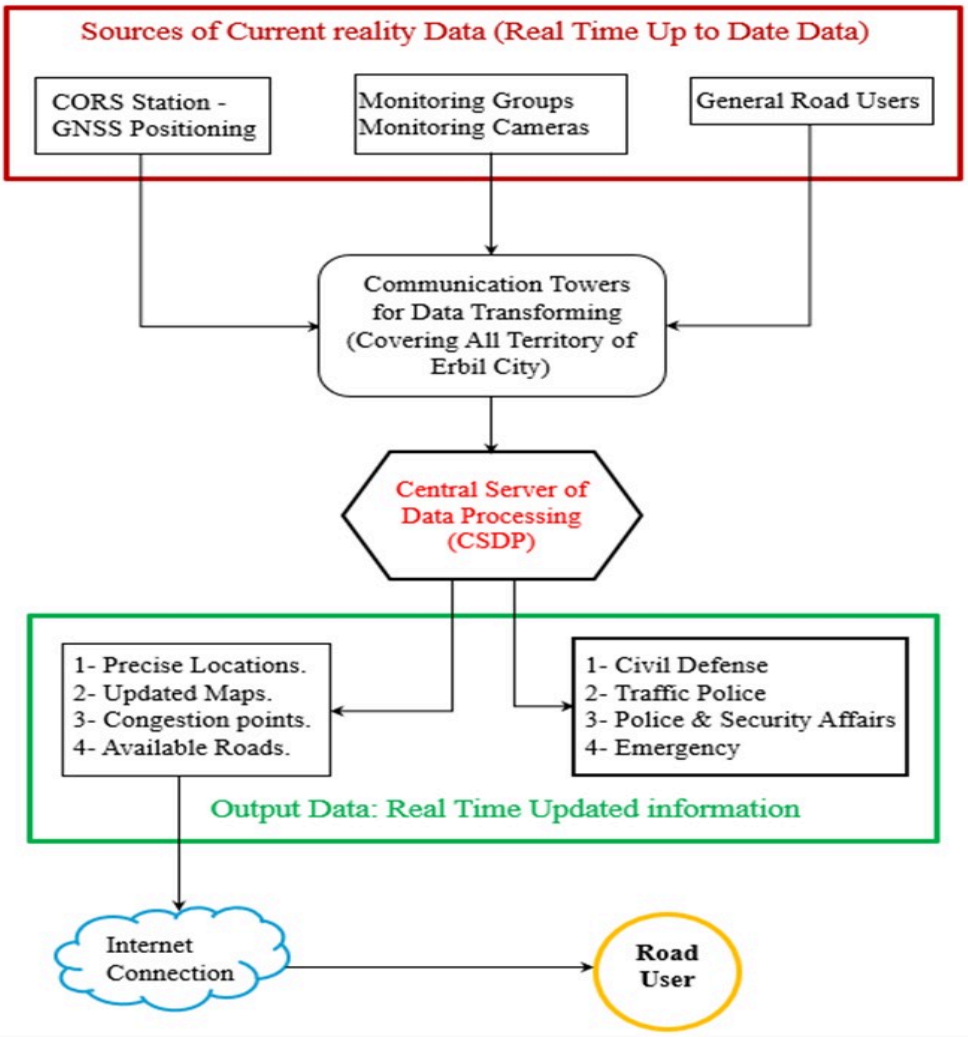

Figure 6. Process of data trading in the proposed GNSS-RTN application.

Generally, the factors that affect the traffic status assessment any time can be listed as in Table 2 below:

Table 2: Factors affecting the status of the highway

No.	Factor	Weight
1	Absent of precise information of roads real time situation.	30 %
2	Lack of accurate and updated maps of the city.	50 %
3	The roads' periodical and temporary maintenance works.	10 %
4	The sudden and unexpected road accidents.	10 %

The factors presented above (in Table 2) are the main causes of most road accidents, which are increasing the possibility of occurrence of traffic congestion and transportation delays.

It is worth noting that, the weights of those factors were assigned according to the information that we obtained by the traffic affairs in Erbil city.
Therefore, the researchers in this paper suggest to implement the proposed GNSS-RTN system that is an effective application for enhancing the transportation efficiency of Erbil city and that can find solutions to mitigate the effect of the factors above. Since the proposed GNSS-RTN is just a suggested system and does not exist in reality yet, so the authors cannot introduce any actual results currently. However, the researchers can provide a logical scenario as a kind of prediction to evaluate the proficiency of the application of the GNSS-RTN system.
The proficiency evaluation of the proposed GNSS-RTN system will be done based on finding the reduction percentage of the effect of each factor individually as it is shown in Table 3 below:

Table 3: Expected proficiency in the status of the road by using GNSS-RTN applications

No.	Factor	GNSS-RTN Solutions	Expected Enhancement
1	Absent of precise information of roads real time situation.	1- Assigning mobile monitoring groups. 2- Providing the communication tools for general road users with CSDP.	80 %
2	Lack of accurate and updated maps of the city.	1- Precise GNSS positioning. 2- GIS tools for map updating.	100 %
3	The roads' periodical and temporary maintenance works.	Coordinating between CSDP and the concerned organizations.	85 %
4	The sudden and unexpected road accidents.	1- Fast reacting of CSDP with the real-time received data. 2- The fast response from the related organizations.	85 %

The prediction results shown in the table above indicate the range of traffic efficiency enhancement that the proposed GNSS-RTN can provide to the transportation system in Erbil City. As a result, the accidents rate will be decreased then the potential of congestions is decreased also, furthermore the traffic delay is expected to be minimum.

4. Conclusions

1. Many ways exist through which the GNSS technology could be utilized in transportation to enhance the efficiency, safety, and effectiveness of the transportation system.

2. The GNSS-RTN offers extremely accurate positioning data, which is crucial for the spatial updating of the city's base map and the traffic database as well. Adoption of GNSS positioning technology will lead to precisely monitoring, controlling, and managing road crises.

3. Being able to reduce field observation time considerably, real-time data updating management, live traffic monitoring and dynamic routing are possible in today's world as well. This real-time information in transportation industry enhances operational efficiency and supports decision-making.

4. In table 3 above, what is indicated by the results of prediction is an estimation of how much improvement on traffic efficiency can be made by using GNSS-RTN in Erbil City Transport System (ECTS). Thus, it will definitely result into less accidents happening and decreasing chances of the congestions occurrence plus minimizing the expected delay as much as possible.

5. The proposed GNSS-RTN application for Erbil City will contribute to evolving the traffic engineering performance by increasing the efficiency of the transportation system in this city. So, this application can provide safe and adequate information about the road's accidents and any other traffic crises real time.

6. GNSS-RTN can provide a precise event's position to ensure a rapid response, which in turn will leads to mitigation of the possible damages and fatalities during any emergency cases by utilizing a network of active communications with the data managing center in a central server for data processing department (CSDP) as a fast and secure system.

7. The suggested GNSS-RTN application for Erbil city should reduce the rate of transportation accidents and meanwhile, increase the safety factor of road users. This is will achieved through the following:
a- Using an accurate and updated maps that define the precise position of the road's accidents.

b- Establishing the effective central server of data processing (CSDP) for Erbil City that can process the received data in real time based on accurate locations and reliable information.

c- Effective accessibility to the operation center in CSDP by the mobile monitoring groups or other road users to send the required information about the accidents or other road's events.

d- GNSS-RTN application for Erbil City will aid in improving the efficacy of the current security system since it can provide different kinds of support through the services of the operation center that exists in the CSDP of the city.

8. GNSS-RTN can effectively contribute to improving the aspect of future performance of the transportation systems in modern cities. The development of advanced driver assistance systems of autonomous cars (CAVs) can be achieved with the aid of GNSS technologies hence improving the autonomous transportation system's safety and efficacy.

5. Recommendations

To increase the accuracy of corrections for positioning data, the GNSS-RTN, a satellite-based positioning system, that uses a network of ground receivers, also known as base stations, reference stations, or continuously operating reference stations (CORSs) is highly recommended. Through real-time corrections delivered from a central server of data processing to the users (rover), the network of CORS stations increases the accuracy and precision of geospatial location, while mitigating the spatially correlated atmospheric and satellite orbit biases. When ground sensors are used, systems can achieve an accuracy range of 1 to 5 cm, as opposed to 1 to 10 m when sensors are not used. Thus, For Erbil City, we recommend the following:

1. Establishment and implementation of the central server of data processing (CSDP) for securely managing and controlling the transportation issues and traffic system in Erbil city based on using the exist CORS stations or even utilizing other densified reference stations.

2. The responsibility of managing CSDP and traffic operation leadership should be entrusted to the Erbil Traffic Directorate. That will be done using a specialized technical team qualified to work on digital maps updating and other related data processing operations.

3. To ensure the effective operations of the proposed GNSS-RTN application, the territory of Erbil City should be distributed into four zones. For each zone there is a Mobile Monitoring group will be specified to take the responsibility of the zone individually. Thus, these groups will cooperate directly with the CSDP to monitor every event in its precise location and real time.

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7. Conflict of interest

1. Geomatics engineering
2. GNSS technologies
3. Transportation
4. Traffic engineering
5. GIS and mapping

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