Comprehensive Traffic Engineering Analysis and Future Planning for the Tasluja-Chamchamal Road in Sulaymaniyah Governorate: Understanding Traffic Dynamics and Capacity Considerations

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Abstract

The proposed road segment, named "Tasluja-Chamchamal," which has a length of 50 kilometers, in the Sulaymaniyah Governorate. It's designed as a two-directional route (2 Direction), divided into four lanes, with two lanes designated for each traffic flow (2 Lane per direction) for every segment, allowing unhindered traffic flow.

The construction of the Tasluja-Chamchamal road aims to accommodate heavy traffic loads, specifically at full capacity traffic, which has caused congestion issues after a few years of operation due to a significant increase in vehicle numbers on the road.

The project underwent data collection through interviewing and subsequent data adjustment, focusing on aspects related to heavy vehicle usage, lane width, and lane clearance.

The outcome of this specific approach to planning resulted in congestion on the Tasluja-Chamchamal road after 14 years of operation.

It's necessary, therefore, for the Directorate of Road and Bridges in Sulaimanyah to consider increasing the number of lanes (Lane) for each direction (Direction) on the Tasluja-Chamchamal road to alleviate congestion issues anticipated in the future.

Keywords:

Traffic volume; Flow rate; Peak Hour Factor; Level of Service; Heavy-Vehicle.

Introduction

Transportation Engineering involves the application of scientific principles and technology to effectively plan, design, operate, and manage transportation facilities for various modes of travel, ensuring safe, swift, comfortable, cost-effective, and environmentally sustainable movement of people and goods.

Furthermore, Traffic Engineering, a subset of transportation engineering, focuses on the planning, geometric design, and operational aspects of roads, streets, highways, their interconnected networks, terminals, and their integration with other transportation modes.

The paramount objective within these disciplines is safety, given that traffic accidents claim over 1.3 million lives annually worldwide. Strategies involving proactive programs, best practices, knowledge dissemination, and adherence to proper procedures significantly contribute to ensuring public safety.

Moreover, the emphasis on economical systems is pivotal. While constructing and maintaining transportation systems, substantial financial resources are required, often funded through general taxation and user fees. Engineers must optimize these resources to provide efficient and cost-effective systems.

Environmental compatibility is also a critical concern. Despite all transportation systems causing some form of air and noise pollution and utilizing valuable land resources, sustainable transport systems aim to minimize these adverse environmental impacts.

Speed is desirable in travel, yet it's limited by technology, human factors, and the necessity of ensuring safety. However, higher speeds, synonymous with shorter travel times, are often facilitated by interstate highways, promoting long-distance travel.

Comfort in transportation involves the physical attributes of vehicles and roadways and is influenced by safety perceptions, facilitating ease in making trips and accommodating diverse travel needs.

The fundamental components of traffic systems encompass road users, vehicles (both private and commercial), roadways (comprising streets and highways), and control devices.

Various modes of transportation exist, including road, rail, air, water, and pipelines. The selection of transportation modes is contingent upon multiple factors influencing vehicle or person movement, such as mode type, roadway characteristics, and traffic composition.

Vehicular movement studies, also known as traffic movement studies, involve the traditional method of counting vehicle movements on roads within specific time frames. This count, termed as Passenger Car Unit (P.C.U), varies throughout the day due to non-uniform traffic patterns. These studies are crucial for future road expansion and pollution control in developing areas, necessitating comprehensive traffic data collection, planning, and design to accommodate standard vehicular movement.

In addition, traffic data collection and projection play a fundamental role in road development and management planning, enabling insights into passenger and goods movement essential for both governmental and private sector transportation policies. Understanding traffic flow patterns, often seemingly random, aids in planning road networks and subsequent maintenance.

The proposed project site in the Sulaimaniyah Governorate, specifically on the Tasluja-Chamchamal road in both directions, witnessed an estimated traffic volume exceeding 1339 vehicles per hour. This data collection and analysis aimed to understand traffic flow for comprehensive planning and development of the transportation infrastructure.

In the Region of Kurdistan, efficient and systematic road planning can significantly enhance the knowledge and convenience for drivers, thereby facilitating substantial improvements and clarifications for the roadways. Particularly, in this project, a pivotal route within the Sulaymaniyah Governorate was selected to establish a comprehensive management plan that entails the Tasluja-Chamchamal road.

The project aimed to undertake a thorough monitoring endeavor for vehicles traversing this road section, with the intent to conduct operational supervision within a designated project, which underscores the Sulaymaniyah-Chamchamal route and its vicinity.

Furthermore, within this project's scope, a fleet of automobiles, meticulously chosen, was registered during a week-long period, from the 7th to the 13th of December 2022, under the administration of a dedicated team appointed by the Sulaymaniyah Road and Transport Authority, employing an interview-based methodology.

Moreover, a substantial prelude to the execution phase involved the formulation of strategies to gauge the service level index (SLI) of the roadway based on the Level of Service (LOS) scale, graded from A to F and further delineated by specific thresholds.

Upon registration of pertinent details by the supervisory team of the Sulaymaniyah Road and Transport Authority, a total of 1339 registered vehicles were documented traversing the designated route within a single day, marking the highest registration tally recorded during the monitoring phase.

Volume signifies the count of vehicles passing a specific point or segment of a lane or roadway within a defined timeframe. It encompasses metrics such as Average Annual Daily Traffic (AADT) and Average Daily Traffic (ADT), representing the total yearly or specified period volume divided by the respective number of days. Additionally, parameters like Maximum Annual Hourly Volume and the Thirtieth Highest Annual Hourly Volume detail the highest and specific ordinal hourly traffic volumes in a given year. Density, expressed as vehicles per mile, indicates the number of vehicles occupying a unit length of a moving lane at a given moment or over a specific duration. It's crucial to differentiate between volume and density, as they represent distinct aspects of traffic flow.

The fundamental components governing traffic flow include volume (V), speed (S), and density (D). Their relationship, particularly when volume is articulated in vehicles per hour ($V = DS$), elucidates how density, calculated as vehicles per mile and influenced by space mean speed in miles per hour, can vary independently of volume. This leads to scenarios where high traffic density might coexist with very low traffic volume, particularly when vehicles are nearly stationary, approaching zero volume. Thus, density potentially offers a more comprehensive measure of roadway service, intensifying with escalating congestion levels. Analyzing density vis-a-vis volume aids in evaluating flow efficiency, as lower densities correlate with swifter traffic movement and heightened flow efficiency. Critical density denotes the traffic density when a roadway or lane operates at full capacity, impacting traffic volume, which decreases at densities diverging from this critical point.

The study of highway capacity extends beyond merely assessing the maximum potential of different facilities. It also involves examining how facilities function at varying levels below their full capacity. This study combines quantitative and qualitative aspects, enabling an evaluation of both the sufficiency and the standard of vehicle service offered by the facility in question. The Highway Capacity Manual, a comprehensive and authoritative resource on this subject, relies heavily on empirical data rather than theoretical frameworks, akin to its original edition. Capacity analyses serve as crucial inputs in numerous traffic engineering evaluations:

Assessing shortcomings in the current highway system involves comparing recorded traffic volumes with the capacities of existing facilities.

Evaluating proposed alterations in street systems—such as changes in layout, signaling, parking regulations, implementing one-way traffic, or imposing turn restrictions—necessitates a scrutiny of their impact on capacity.

The planning of new facilities always integrates capacity analyses alongside anticipated demands.

Comparing the efficiency of different transportation modes in meeting specific demands often relies partly on capacity analyses.

The initial Capacity Manual introduced the notions of fundamental capacity, potential capacity, and operational capacity to define the highest rate of passenger car flow in various traffic and roadway situations. Basic capacity refers to the maximum throughput achievable under optimal conditions, whereas feasible capacity takes into account the present road and traffic conditions.

The practical capacity refers to the highest possible flow rate that may be achieved without resulting in excessive delays or dangers.

The revised Manual, however, condenses both notions into the terms "capacity" and "level of service." The term "capacity" currently refers to the maximum amount of vehicles that can flow over a road under existing road and traffic conditions, which is closely related to the earlier concept of potential capacity. It pertains to the maximum amount of traffic that may be accommodated without changing the current conditions, including both the characteristics of the road and the characteristics of the traffic, which may vary.

The previous understanding of fundamental capability now corresponds with the idea of capability in optimal circumstances. The key features emphasized are continuous traffic flow, the presence of passenger cars alone, specific lane widths, sufficient shoulders, and excellent highway alignment to facilitate greater speeds.

The substitution of current capacity with the notion of level of service defines specific operational situations determined by different traffic volumes. Level of service refers to a subjective assessment that considers several elements such as speed, travel time, traffic disturbances, ease of maneuvering, driver satisfaction, safety, and operational costs associated with a transportation facility.

The new guidebook incorporates the notion of service levels, which applies to all aspects of roadways. There are six levels of service, labeled A to F, which represent a range from the most satisfactory to the least satisfactory driver experience. Service levels are selected across different parts of a highway infrastructure to provide appropriate operational characteristics. These conditions should ideally align with one another, aiming for a reasonable level of acceptability among average drivers.

Various components of highways and types of facilities, such as intersections, ramps, weaving sections, terminal ramps, speed-change lanes, freeways, multi-lane highways, arterial streets, and downtown roads, have specific factors to be taken into account within this service level framework.

It is essential to differentiate between capacity and degree of service. Although a particular lane or roadway may have varying levels of service dependent on factors such as speed and volume, its capacity remains constant. Practically, a highway or its parts can function at different levels of service, which can be affected by factors such as the time of day, day of the week, or season.

Service volume refers to the highest number of vehicles that pass through a lane or segment of a roadway within a certain period, considering the chosen service level and operational conditions. Typically, service volume is measured on an hourly basis, unless stated differently.

In the context of roadways, the term "Control of Access" refers to the many levels of control that can be exercised: complete control, partial control, and lack of control. These levels determine the extent to which authorities regulate the entry and exit locations. Full control prioritizes the movement of traffic by restricting access to specific public roadways and forbidding intersections with railway tracks or private driveways. Partial control allows for certain intersections at ground level and restricted access to private driveways while giving priority to the flow of traffic. Uncontrolled access refers to a situation where there are very few constraints on entering or leaving an area, except when it is necessary for public safety, which can be achieved through controlled placement and geometry of connections.

Functional Types categorize various parts and configurations within the road network.
An arterial highway is a road designed for smooth traffic flow, usually with no controlled entry points, allowing vehicles to go without interruption.
An expressway is a type of road designed for uninterrupted traffic flow. It is separated into separate lanes and allows for controlled entry and departure locations. Expressways sometimes have overpasses or underpasses at significant crossings.
Freeway: A high-speed road that has full control over entry and exit locations, enabling continuous traffic flow without any intersections at the same level.
A parkway is a major road constructed for noncommercial vehicles, with controlled entry and exit points, sometimes created to provide a more enjoyable driving experience through attractive areas.

A major street or major highway is a primary route that has crossings at the same level and provides direct access to nearby properties. It is designed with specific geometric features and traffic management techniques to ensure smooth and safe traffic flow.

A "Through Street" or "Through Highway" refers to a route or a specific part of a road where cars must come to a complete stop or surrender to traffic before entering or crossing from intersecting roads.

A local street or local road is a thoroughfare primarily designed to provide access to residential, commercial, or neighboring properties.

A frontage road is a thoroughfare that runs alongside and typically runs parallel to expressways, freeways, parkways, or through streets. The purpose of this system is to intercept, collect, and distribute the flow of traffic that is intended to cross, enter, or exit the major route. This road provides connectivity to properties that may otherwise be isolated due to the restricted access of the main road. Intermittently known as a service road.

Level terrain: Any combination of gradients, length of grade, or horizontal or vertical alignment that permits trucks to maintain speeds that are equal to, or approach the speeds of, passenger cars.

Rolling terrain: Any combination of gradients, length of grade, or horizontal or vertical alignment that causes trucks to reduce their speeds substantially below that of passenger cars on some sections of the highway, but which does not involve a sustained crawl speed by trucks for any substantial distance.

Mountainous terrain refers to a combination of steep slopes, long inclines, and curved paths that force trucks to travel at very slow speeds over long distances or at frequent intervals. Continuous level: A continuous highway with a significant length and a consistent or almost consistent slope. Glossary of Traffic Operations Terminology Peak-hour traffic refers to the maximum volume of cars observed traveling through a specific lane or roadway over a continuous 60-minute period. This term can be used to refer to either a daily peak hour or an annual peak hour. Flow rate: The hourly measurement of the volume of vehicles that traverse a specific segment of a lane or roadway within a time period shorter than one hour. The hourly rate is calculated by multiplying the number of vehicles within a particular time period by the ratio of 60 minutes to the number of minutes during which the flow occurred. Disrupted traffic flow: A situation where a vehicle traveling in a lane or road is compelled to stop due to external factors, such as traffic signs or

Signals at a crossroads or junction. The interruption of traffic flow caused by internal factors inside the traffic stream does not qualify as a stoppage of cars. Uninterrupted flow refers to a situation when a vehicle traveling down a lane or road does not need to stop due to any exterior factors, yet it may still be necessary to halt due to internal factors inside the traffic stream.

Peak hour factor refers to the ratio of the maximum number of users or vehicles present during a specific time period to the average number of users or vehicles during that same period. The volume-to-capacity ratio is defined as the ratio of the volume of traffic happening during the peak hour to the highest rate of flow during the peak hour. It is a metric that quantifies the degree of peaking, with a maximum achievable value of one. The term must be specified with a defined brief duration within the hour; typically, this duration is 5 or 6 minutes for freeway operation and 15 minutes for intersection operation. Glossary of Land Use and Development Terminology The Central Business District (CBD) refers to the primary area inside a city where there is a high concentration of commercial and business activities. This district is distinguished by a substantial volume of pedestrians, significant commercial vehicle loadings of products and people, a substantial demand for parking space, and a high turnover rate for parking. Fringe area refers to the section of a city that is directly adjacent to the central business district (CBD) and exhibits a diverse range of business activities. It typically encompasses small enterprises, light manufacturing, storage facilities, automotive service operations, and mixed-use development, along with certain densely populated residential zones. This region has a modest volume of people walking and a slower rate of parking turnover compared to the central business district (CBD). However, it is possible for this area to encompass sizable parking facilities that cater to the CBD. An outlying business district refers to a specific location inside or near a municipality that is physically distant from the central business district (CBD) and its surrounding areas. This district is primarily characterized by its predominant use for business activities. This district exhibits a notable inclination towards increased parking demand and turnover, along with a modest level of pedestrian traffic. A residential area refers to a part of a municipality or an area influenced by a municipality where the primary use of land is for residential development, but modest business areas may also be present. This region is distinguished by a scarcity of pedestrians and a minimal rate of parking turnover.

Roadway stream characteristics refer to the capacity of a road to handle traffic. The capacity of a roadway is primarily influenced by its physical features, but there are additional elements unrelated to these features that also play a significant role in determining the roadway's capacity. Several of these elements pertain to fluctuations in the traffic demand and the interplay of cars in the traffic flow. Comprehending the attributes of a stream is fundamental to gaining a comprehensive understanding of capacity analysis approaches. Characteristics of Spacing and Headway Spacing refers to the physical distance between the front of one vehicle and the front of the next vehicle, whereas headway refers to the time gap between individual cars as they pass a specific spot. These two metrics quantify the spatial positioning of vehicles in a traffic flow.

Methodology

Traffic volume

Traffic volume refers to the method of measuring the quantity of traffic or number of cars traveling on a specific section of roadways within a specific time frame. The time period can be measured in units such as 'minutes', 'hours', or 'days'.

Methods for conducting a Traffic Survey / Techniques for studying Traffic Volume

The methods for conducting a traffic survey are as follows:

1. Through the process of toll plaza ticketing.
2. Offices for registration.
3. Utilizing a statistical methodology.
4. Through conducting interviews.
5. Through the use of checkpoints.
6. Contemporary Global Positioning Systems.

Presented below is an elaborate exposition of the theory of TVS.

1. Toll Plaza Ticketing: Toll plazas are currently being built to generate income from road users. This procedure is highly efficient for revenue collection as it requires payment from a large number of road users, hence playing a crucial role in the development of the economy. The Toll Plaza can also serve as a location for performing the traffic study. Every vehicle that passes through the city is required to pay a tax and receive a receipt. By tallying the number of receipts for each type of

vehicle, it is possible to determine the total number of automobiles, buses, trucks, and other vehicles that have entered or departed the city.

2. Statistical Approach: This method is suitable when the historical data for countries is successfully and efficiently maintained. Therefore, employing statistical methods of approximation can be utilized to forecast future traffic patterns on the route.

3. Registration Offices: Each newly purchased car must undergo government registration by its owner. Registration offices are present at each district level, and those living in close proximity are required to register their vehicles at the designated office. To perform a traffic survey, data can be obtained from these offices for a specific year. This data will allow us to ascertain the number of newly introduced automobiles on the roads.

Nevertheless, this approach has several limitations as the vehicle, previously owned by an individual, may be relocated to a different area after being sold, despite being initially registered in a specific district.

4. Through conducting interviews: Interviews are an effective approach for gaining insight into a person's everyday routine. A traffic survey interview necessitates an understanding of the daily traffic volume at several locations at different times throughout the day. This can be accomplished by a team of individuals stationed at various entry points of a city, systematically questioning each person about their daily activities. This would enable the collection of accurate data on traffic density at specific locations. By utilizing this data, the respective departments can implement more effective traffic management techniques.

This procedure is somewhat laborious due to the reluctance of many transporters to pause even momentarily for individuals.

5. Inspection Points: Inspection points are stationed at the entry and exit locations of a city or province. The major objective of these measures is to ensure lawful ingress and egress to minimize the occurrence of thefts and other criminal incidents. Inspections can also be employed to carry out traffic surveys. Maintaining accurate records of vehicle entry and exit enables a straightforward calculation of the daily number of cars entering and exiting the city.

6. The Global Positioning System (GPS), originally called the Navstar Global Positioning System, was established in 1973 to assist navigation systems. GPS's ability to surpass the limits of other navigation systems made it appealing to a wide range of users. The success of GPS in navigation

applications can be attributed to its accessibility through compact and affordable devices. GPS has also been instrumental in other new uses, such as highway design. This technique is currently being used in traffic surveys in major countries such as the USA, China, and other industrialized nations. This technology is fitted with integrated microchips and a centralized navigation control room. The chip is installed in the vehicle and continuously records data that is stored in the control room. Therefore, there is a constant availability of accurate data regarding the number of vehicles on a specific road in the city. This technique is often referred to as "Automated Surveillance Technique".

The significance of conducting a traffic volume study is in its ability to enhance the effectiveness and longevity of road infrastructure.

1. Decreases the amount of traffic at a specific section
2. Enhance the mechanisms for the advancement of infrastructural development.
3. Enhance the available options for utilizing alternative routes during major events in the city.
4. Offer an estimation of the ratio between the number of vehicles and the number of individuals.

Volume and flow rate are two metrics used to estimate the quantity of traffic that passes through a specific place on a lane or route within a specified time period. The following terms are defined as:

• Volume refers to the overall number of vehicles that traverse a specific place or segment of a lane or roadway within a specified time interval. Volumes can be measured in terms of yearly, daily, hourly, or sub-hourly periods.

• Flow rate refers to the number of vehicles that pass over a specific place or part of a lane or roadway over a time interval of less than 1 hour, often 15 minutes.

Volume and flow are metrics that measure demand, namely the number of vehicle occupants or drivers (often represented as the number of cars) who wish to utilize a particular facility within a defined timeframe. Congestion has the ability to affect demand, and the volumes that are observed may sometimes be a result of limitations in capacity rather than actual demand. The contrast between volume and flow rate is significant. Volume refers to the quantity of vehicles that are observed or projected to traverse a specific location within a given time period. Flow rate is a measure of the number of cars that pass a specific site within a time interval of less than 1 hour, although it is expressed as if it were the number of vehicles passing in one hour. Flow rate refers to the ratio of the number of vehicles observed within less than an hour to the duration of the observation, measured in hours. For instance, if there were 100 automobiles spotted within 15 minutes, this would indicate a flow rate of 100 vehicles per 0.25 hours or 400 vehicles per hour.

Key concepts regarding traffic volume:

1-Speed: Single-speed Vehicle speed is the measure of the distance it covers within a specific period. It is the reciprocal of the duration it takes for a vehicle to travel a specific distance.

$$\text{Speed (km/h)} = \frac{Distance}{Time} \quad \text{Eq.1}$$

Types of Speed:

a. Travel (Journey) speed: it is the length of a highway section divided by the overall travel time (including stopping time).

$$Travel\ (journey) speed = \frac{Distance\ Overall}{Time} \quad \text{Eq.2}$$

b. Running speed refers to the ratio of the length of a highway section to the time a vehicle requires to travel through that particular section

$$Running\ speed = \frac{Distance}{Overall\ travel\ time - Stopping\ tim} \quad \text{Eq.3}$$

c. Design speed represents a chosen velocity utilized to ascertain different geometric design attributes of the road, typically ranging from 20 to 130 kilometers per hour.

d. Operating speed denotes the velocity at which drivers are seen operating their vehicles under free-flowing conditions. In Iraq, this often aligns with the 85th percentile of observed speeds, falling between 56 to 88 kilometers per hour.

2. Volume (vpd, vph): The aggregate number of vehicles that traverse a specific place or segment of a lane or route within a defined time period (often one day or one hour).

Traffic Volume can be quantified using several words, including flow rate, Average Daily Traffic (ADT), Annual Average Daily Traffic (AADT), Annual Average Weekday Traffic (AAWT), and Design Hourly Volume (DHV). Rate of flow the flow rate is the volume of a substance that passes through a point in a certain time interval, often less than one hour (15 minutes).

Sub hourly volume refers to the fluctuation in traffic during the peak hour.

The Peak Hour Factor (PHF) is a metric used to measure the level of traffic congestion during peak hours.

The peak hour factor is determined by comparing the peak flow rate to the hourly quantities in the following manner:

$$PHF = \frac{Volume\ hourly}{flow\ rate\ (4 * V15)} \qquad 0.25 \leq PHF \leq 1 \quad \text{Eq.4}$$

Where:

PHF =peak hour factor.

V15=volume for peak 15-minute period.

The peak hour factor (PHF) serves to estimate the peak rate of flow within an hour by converting the peak hourly volume (PHV). It's calculated as V = Peak hourly volume / PHV, where V represents the peak rate of flow within an hour in vehicles per hour. The PHF's maximum value is 1.0, achieved when the volume in each interval remains constant.

Current traffic, referred to as existing or attracted traffic, encompasses the volume of traffic anticipated to use a new or improved highway upon its opening. It includes the traffic already utilizing the highway and traffic shifting to the new route from less attractive pathways.

Generated traffic represents the vehicle trips that would have occurred if the new facility had not been provided.

Current ADT (Average Daily Traffic) signifies the average number of vehicles per day over a specified period (spanning more than one day but less than a year).

$$Current\ ADT = \frac{Total\ No.of\ \ vehicles\ (Period\ more\ than\ 1\ day\ and\ less\ than\ 1\ year)}{Time\ period\ (days)} \quad \text{Eq.5}$$

$$Units = \frac{vpd}{both.dic}$$

Future (forecasted traffic)

The design of new roadways or renovation of existing highways should be determined not solely by current traffic levels, but rather by the projected future traffic that will utilize the infrastructure.

The Future Average Daily Traffic (AADT) can be calculated by adding the Current Average Daily Traffic (AADT) to the normal rate of traffic growth.

Normal traffic growth refers to the incremental rise in the existing traffic volume resulting from the overall increase in the number and use of vehicles.

The formula for normal traffic growth is the product of the current traffic (existing traffic) and the Traffic Projection Factor (TPF).

$$TPF = (1 + r)^{\prime + n} \quad \text{Eq. 6}$$

Where: r represents the annual rate of traffic increase, which might range from 0% to 10%.
n represents the designated lifespan, which typically ranges from 20 to 50 years.
x represents the duration of the construction period, which typically ranges from 2 to 4 years.
The Future Average Daily Traffic (AADT) is appropriate for pavement structural design but not for geometric design.
The average weekly traffic (AWT): is the average 24-hours traffic volume occurring on weekdays at a given location for a period of time less than a year.
The Average Annual Weekly Traffic (AAWT) refers to the volume of traffic that occurs during a 24-hour period on weekdays across an entire year. The Average yearly Weekday Traffic (AAWT) is often calculated by dividing the total traffic on weekdays throughout the year by the number of yearly weekdays, which is usually 260 days. This amount is significant due to the typically diminished weekend traffic.
Hourly volume for design purposes: The peak hour volume utilized for design purposes is:

* Infrequently surpassed. * Seldom acquired.

The Thirtieth Highest Hourly Volume (30HV) refers to the design hourly volume that is surpassed for just 29 hours annually.

Capacity and Level of Service refer to the ability of a system to handle a certain amount of demand and the quality of service provided to users, respectively.
Capacity refers to the maximum amount of traffic that a highway can handle.
Level of Service (LOS)

Level of Service (LOS) refers to a qualitative assessment of the operational condition of a traffic stream based on the existing demand. The measure of effectiveness (MOE) is determined by many factors, including travel time, speed, wait time, and safety, which are used to describe the level of service. The highway capacity manuals categorize six levels of service, labeled A through F. The level A denotes the utmost level of service, whereas F signifies the lowest and most unsatisfactory service. The following table provides detailed information regarding the operational condition and operating speed for each level of service category.

Table 1: The operational state and speed at which the different level of service categories operate.

LOS	**Description (operational Condition)**	**Operating Speed (km/hr)**
A	**Free Flow**	**96**
B	**Stable flow**	**88**
C	**Stable flow with restriction**	**72**
D	**Approaching unstable flow**	**56**
E	**Unstable flow**	**48**
F	**Forced flow (stop and go condition)**	**< 48**

Design Capacity (Design service flow rate): The maximum hourly rate at which vehicles can be expected to pass a point or section of a lane or roadway during one hour under prevailing roadway, traffic and control condition for a designated level of service.

Table 2: The design capacity for different level of service

LOS	Design Capacity (pcphpl)	Description Operational Condition
A	**660**	**Free Flow**
B	**1080**	**Stable flow**
C	**1550**	**Stable flow with restriction**
D	**1980**	**Approaching unstable flow**
E	**2200**	**Unstable flow**
F	**-**	**Forced flow (stop and go condition)**

Table 3: The desired LOS for varies terrain.

Highway	LOS			
	Level	**Level Rolling Mountain**	**Mountain**	**Urban and Suburban**
Principal Arterial	**B**	**B**	**C**	**C**
Minor Arterial	**B**	**B**	**C**	**C**
Collector	**C**	**C**	**D**	**D**
Local	**D**	**D**	**D**	**D**

Highway Capacity for uninterrupted flow (Basic Freeway Segment)

Estimating FFS: Free Flow Speed

$FFS = BFFS - FLW - FLC - 3.22\ TRD^{0.84}$ Eq. 7

$FFS = 75.4 - FLW - FLC - 3.22\ TRD^{0.84}$

Where:

FFS = free flow speed (mi /h).

FLW = adjustment for lane width (mi / h).

FLc = adjustment for lateral clearance (mi/ h).

TRD = total ramp density (ramps / mi).

The FFS should be rounded to the nearest 5 mile/hr. as follows:

* ≥72.5 mi/hr <77.5 mile/hr: use FFS = 75 mile/hr.

* ≥67.5 mi/hr <72.5 mile/hr: use FFS = 70 mile/hr.

* ≥62.5 mi/hr <67.5 mile/hr: use FFS = 65 mile/hr.

* ≥57.5 mi/hr <62.5 mile/hr: use FFS = 60 mile/hr.

* ≥52.5 mi/hr <57.5 mile/hr: use FFS = 55 mile/hr.

Table 4: Adjustment for lane width (F_{LW}).

Average Lane Width (ft)	**Reduction in FFS F_{LW}**
≥12	0.0
≥11-12	1.9
≥10-11	6.6

Table 5: Adjustment to FFS for right side lateral clearance, fLC (mph)

Right-Side Lateral Clearance	Lane in one Direction			
	2	3	4	≥5
≥6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

Table 6: Another source about Target level of Service (LOS):

FFS (mile / h)	**Target level of Service**					
	A	**B**	**C**	**D**	**E**	**F**
75	**820**	**1310**	**1750**	**2110**	**2400**	**-**
70	**770**	**1250**	**1690**	**2080**	**2400**	**-**
65	**710**	**1170**	**1630**	**2030**	**2350**	**-**
60	**660**	**1080**	**1560**	**2010**	**2300**	**-**
55	**600**	**990**	**1430**	**1900**	**2250**	**-**

Determining Flow Rate:

Tow adjustment must be made to hourly volume counts or estimates to arrive at the equivalent passenger-car flow rate used in LOS analyses . These adjustments are the PHF and the heavy vehicle adjustment factor. The number of lanes also is used so that the flow rate can be expressed on a per-lane basic. this adjustment are applied in the following manner using equation.

$$\mathbf{Vp} = \frac{\mathbf{V}}{\mathbf{PHF * N * FHV * FP}} \qquad \text{Eq. 8}$$

Where:

VP = demand flow rate under equivalent base condition (pc / h / In).

V = adjustment volume under prevailing conditions (veh / h).

PHF = Peak hour factor.

N = Number of lane in analysis direction,

FHV = adjustment factor for unfamiliar driver population.

Heavy-Vehicle adjustment

The presence of heavy vehicles in the traffic stream decreases the FFS because base conditions allow a traffic stream of passenger cares only. Therefore, traffic volumes must be adjusted to reflect an equivalent flow rate expressed in passenger cars per hour per lane (Pc/h/ln). this adjustment are applied in the following manner using equation.

$$FHV = \frac{\mathbf{1}}{1 + PT\ (ET - 1) + PR\ (ER - 1)} \qquad \text{Eq. 9}$$

Where:

FHV =Heavy vehicle adjustment factor.

PT =proportion of trucks and buses in traffic stream.

PR = proportion of RVs in traffic stream

ET =passenger- care equivalent (PCE) of one truck or bus in traffic stream.

ER =PCE of one RV in traffic stream.

$$\textbf{PT=} \quad \frac{\text{Number of Heavy Vehicles}}{\text{Total number of vehicles}} \qquad \text{Eq. 10}$$

$$\textbf{ET=} \quad \frac{\text{Number of Passenger Car}}{\text{Total number of vehicles}} \qquad \text{Eq. 11}$$

3. Density:

Density refers to the quantity of vehicles present on a specific section of road at a particular moment. The measurement of density is commonly denoted as the number of vehicles per kilometer (veh/km). High densities indicate a near proximity of automobiles, and low densities reflect a larger separation between vehicles. Measuring the density at the field is challenging. The measurement can be conducted using aerial photography, which is a costly approach, or it can be approximated theoretically based on the relationship between density, flow, and speed.

$$Spacing\ (m) = \frac{1 \rightarrow 1000}{Density\ (vpkm)} \qquad \text{Eq. 12}$$

Density (vpkm) = 1 (or 1000)/Spacing (m)

(Use 1 if the spacing in km, and use 1000 if the spacing in m).

Table 7: PCEs Heavy Vehicle in General Terrain:

Right-Side Lateral Clearance	PCE by type of terrain		
	Level	Rolling	Mountainous
Truck and Bus	1.5	2.5	4.5
RVs, ER	1.2	2.0	4.0

$$D = \frac{Vp}{S} \qquad \textbf{Eq.13}$$

Where: D represents density, measured in particles per cubic mile per natural logarithm.

Vp represents the demand flow rate, measured in picoliters per hour per logarithmic natural unit.

S is the average velocity of the traffic flow under normal circumstances, measured in miles per hour (mi/h).

Passenger Car Units (PCUs) refer to the number of vehicles on the road that are equivalent to a single passenger car in terms of their impact on traffic flow and capacity. Various types of vehicles possess distinct road space requirements and exert varying impacts on the capacity of highways and intersections due to differences in size and performance. The impact of any vehicle on traffic operations can be quantified by comparing it to the impact of a standard unit, often a passenger automobile. The determination of equivalence between the Passenger Car Unit (PCU) and other vehicles divided in classes is based on conversion factors that quantify the relative impact of different vehicle types on traffic flow. The table below displays the passenger car unit equivalents for large vehicles under various topographic circumstances.

Table 8: Criteria for Basic Freeway Segment as defined by the Level of Service (LOS)

LOS	Density (pc/mi/ln)
A	**≤11**
B	**>11-18**
C	**>18-26**
D	**>26-35**
E	**>35-45**
F	**Demand exceeds capacity >45**

4. Headway

There are two sorts of headways that represent traffic characteristics which are time headway and space headway.

1. Time Headway (ht): The duration between the arrivals of consecutive vehicles at a given time. The time gap between two vehicles can be calculated by subtracting the arrival time of the first vehicle (t1) from the arrival time of the following vehicle (t2) at the same place on the roadway. The measurement is typically denoted in seconds.

The average distance between vehicles in a lane is directly proportional to the rate at which vehicles pass through.

$$ht = \frac{1 \rightarrow 3600}{Volume\ (vph)} \quad \text{Eq. 14}$$

$(1\ in\ hour\ unit, 3600\ in\ second\ unit)$

ht = SEC

2. Space headways (hs) refer to the distance between the leading edge of a vehicle and the leading edge of the vehicle following it, usually measured in meters. The spacing between vehicles in a

traffic lane is inversely proportional to the lane density. This relationship can be expressed as Hs = 1000 / D, where D represents the lane density measured in vehicles per kilometer per lane.

Gap is the distance between vehicles in a mainstream, as seen by a driver in a smaller stream who wants to merge. The measurement can be expressed either in terms of time intervals or in terms of spatial intervals.

Time lag refers to the disparity in arrival times between a merging vehicle and a vehicle in the mainstream when they both reach a particular point on the highway.

Space lag, measured at a specific moment, refers to the difference between the distance of a merging vehicle from the reference point in the merging region and the distance of a vehicle in the mainstream from the same location.

Free-flow speed refers to the average speed at which vehicles typically move on a specific road when there is minimal traffic and drivers can travel at their desired speed without experiencing any delays or restrictions.

Results and Discussion:

The findings derived from the examination of the Tasluja-Chamchamal road section in the Sulaymaniyah Governorate highlight significant concerns regarding traffic congestion and road capacity. The analysis primarily examined numerous crucial variables, such as the width of the lanes, the rate at which traffic flows, the concerns for heavy vehicles, and how these factors affect the Level of Service (LOS).

A notable discovery concerns the correlation between the width of lanes and the decrease in Free Flow Speed (FFS) Flow. It was noted that lanes that were 12 feet wide or wider did not have any decrease in FFS Flow, however narrower lanes had a significant reduction. The lane width of the Tasluja-Chamchamal road is 3.75 meters, which is roughly 12.3 feet. This belongs into the group of lanes that are equal to or greater than 12 feet. This lane width is associated with a lack of reduction in FFS Flow.

An analysis of Traffic Flow during peak hours, specifically from 13:00 to 14:00, uncovered a significant surge in the volume of vehicles moving along the road. During this timeframe, there was a peak in the Flow Rate, which suggests a large concentration of vehicles on the road.

Additional modifications were implemented to accommodate Heavy Vehicles and Passenger Cars, ultimately leading to the inclusion of factors related to Future Volume. The assessment revealed an expected rise in transportation demand, underscoring the necessity for proactive steps to alleviate congestion in the future. The assessment of the LOS Criteria determined that the current level of service falls within category C, suggesting the need for improvement to address potential future limitations.

These findings highlight the significance of proactive road planning measures, particularly in relation to adjusting lane width and capacity, in order to handle the anticipated rise in traffic volume. The statement emphasizes the need for a prompt evaluation and possible enlargement of the Tasluja-Chamchamal road section to efficiently handle the anticipated future traffic requirements.

Average Lane Width (ft)	**Reduction in FFS FLW**
≥12	0.0
≥11-12	1.9
≥10-11	6.6

Lane width Tasluja - Chamchamal = 3.75 m

3.75 m = 12.3 ft

12.3 ≥12

∴ Reducation in FFS (FLW) = 0.0

Right-Side Lateral Clearance (ft) = 12.3

No of lane = 2

12.3 ≥6

∴ FLC =0

$$TRD = \frac{Ramps}{mi}$$

$$TRD = \frac{20}{32} = 0.625$$

FFS = BFFS - FLW - FLC - 3.22 $TRD^{0.84}$

FFS = 75.4 - FLW - FLC - 3.22 $TRD^{0.84}$

FFS = 75.4 - 0 - 0 - 3.22 $(0.625)^{0.84}$

FFS = 73.24 mph

The FFS should be rounded to nearest.

∴ FFS = **75 mph**

Flow Rate

Between (13:00 - 14:00) PM more number of vehicle exceeded in the road.

Time interval	Volume per time interval	Flow rate for time interval(veh/h)
13:00 - 13:15	237	**237* 4 = 948**
13:15 - 13:30	342	**342 * 4 = 1365**
13:30 - 13:45	397	**397 * 4 = 1588**
13:45 - 14:00	363	**363 * 4 = 1452**
13:00 - 14:00 h	**1339**	**1588**

$$PHF = \frac{Volume\ hourly}{flow\ rate\ (4 * V15)}$$

$$PHF = \frac{1339}{1588}$$

$$PHF = 0.8432$$

Adjustment for Heavy Vehicle and Passenger Car

Total number of vehicles between (13:00 - 14:00) = 1339 vehicles

Total number of heavy vehicles = 543 vph

Total number of Passenger car = 796vph

$$\textbf{PT=} \frac{\text{Number of Heavy Vehicles}}{\text{Total number of vehicles}}$$

$$PT = \frac{543}{1588}$$

PT= **34.2%**

$$ET = \frac{\text{Number of Passenger Car}}{\text{Total number of vehicles}}$$

we will count ET zero

ET= **0.0%**

$$FHV = \frac{\mathbf{1}}{1 + PT\,(ET - 1) + PR\,(ER - 1)}$$

$$FHV = \frac{1}{1 + 0.342\,(2.5 - 1) + 0}$$

$$FHV = \frac{1}{1.513}$$

FHV= **0.66**

Adjustment Demand Volume

$$V_p = \frac{V}{PHF * N * FHV * FP}$$

$$V_p = \frac{1339}{0.84 * 2 * 0.66 * 1}$$

$$V_p = \frac{1339}{1.1088}$$

Vp = 1207.61

Vp = 1207 veh / h

$$D = \frac{V_p}{S}$$

$$D = \frac{1207}{65}$$

D = 18.57

LOS Criteria for Basic Freeway Segment

LOS	Density (pc/mi/ln)
A	≤11
B	>11-18
C	>18-26
D	>26-35
E	>35-45
F	Demand exceeds capacity >45

18.57 > 18-26

- **LOS Criteria suitable with C**

That is good level service (LOS)

Below table about Target Level Of Service (LOS):

FFS (mile/h)	Target level of Service					
	A	B	C	D	E	F
75	820	1310	1750	2110	2400	-
70	770	1250	1690	2080	2400	-
65	710	1170	1630	2030	2350	-
60	660	1080	1560	2010	2300	-
55	600	990	1430	1900	2250	-

$$V_p = \frac{V}{PHF * N * FHV * FP}$$

$$MSFE = \frac{SVE}{PHF * N * FHV * FP}$$

SVE = MSFE * PHF * N * FHV * FP

From upper exhibit the service flow rate (MSFE) for LOS D an basic freeway segment with 65 mile / h (100 km / h) FFS is 2,030 pc / h / ln.

SVE = 2110 * 2 * 0.84 * 0.66 * 1.0

SVE = 2340

V future =	**V * (rate of growth)^n**
2340 =	**1339 * (1+ 0.04)^n**
2340/1339=	**(1.04)^n**
n =	**14.26**
n =	**14 Years for full capacity**

Conclusion:

In analyzing the Tasluja-Chamchamal road segment in the Sulaymaniyah Governorate, it's evident that the current four-lane configuration, with two lanes allocated for each traffic direction, faces congestion issues during peak hours after 14 years of operation. The data collection methodology, employing interviews and adjustments, focused on heavy vehicle usage, lane width, and clearance.

The findings underscore the necessity for the Directorate of Road and Bridges in Sulaimanyah to consider expanding the number of lanes per direction on this road segment to alleviate anticipated future congestion. Keywords encompassing this study include traffic volume, flow rate, peak hour factor, level of service, and heavy-vehicle considerations.

The study emphasizes that effective road planning is crucial in enhancing drivers' convenience and road efficiency. It also outlines various methodologies for traffic volume measurement and the distinction between volume and flow rate metrics, underscoring their significance in traffic management.

In conclusion, this research offers vital insights into traffic engineering methodologies and highlights the imperative nature of considering traffic volume and flow rate dynamics in road planning and expansion, especially concerning the Tasluja-Chamchamal road segment.