Introduction to Transportation Planning

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1. Background

Corridor traffic forecasting and project design traffic forecasting projects require forecasts of Annual Average Daily Traffic (AADT) and Design Hourly Volume (DHV). AADT and DHV are related to each other by the ratio known as the K-factor.

The Association of State Highway and Transportation Officials (AASHTO) suggests and the Federal Highway Administration (FHWA) requires that K_{30} be used for all design hour traffic projections. The overall truck volume and AADT are related to each other by the T-factor. The total impact of traffic on pavement design is expressed in units of ESALs, which represent truck axle weights converted into 18,000 pound loads carried by a single, four-tire axle.

2. Forecasting

2.1. Project Design Traffic Forecasting

The project design traffic forecasting process estimates traffic conditions used for determining the geometric design of a roadway and/or intersection and the number of 18 KIP ESALs that pavement will be subjected to over the design life. Project design traffic forecasting is required for reconstruction, resurfacing, adding lanes, bridge replacement, new roadway projects and major intersection improvements. The process is site specific and covers a limited geographic area.

2.2. Corridor Traffic Forecasting

Corridor traffic forecasting is used to determine the required number of lanes within a corridor or system to meet anticipated traffic demands. It is required prior to the establishment of a new alignment or the widening of existing facilities. Corridor traffic models are usually calibrated for forecast traffic for a specific corridor and are usually more specific than the urban area or statewide models and more general than a project specific model.

2.3. Equivalent Single Axle Loading (ESAL) Forecasting

The equivalent single axle loading (ESAL) forecasting process is necessary for pavement design for new construction, reconstruction or resurfacing projects. The pavement design for new alignment and reconstruction projects requires a structural loading forecast using the 18 KIP ESAL forecasting process. Structural design is primarily dependent upon the heavy axle loads generated by commercial traffic. The pavement design of new roadway construction,

reconstruction or resurfacing is based on accumulated 18 KIP ESALs. Truck traffic and damage factors are needed to calculate axle loads expressed as ESALs.

3. Traffic Data Sources

3.1. Traffic Adjustment Data Sources

3.1.1. Permanent Continuous Counts

Traffic data is collected through permanently installed traffic counters. These Telemetry Traffic Monitoring Sites (TTMSs) continuously record the distribution and variation of traffic flow by hours, of the day, days of the week and months of the year from year to year and transmit the data remotely. The TTMSs collect data 365 days a year. For these TTMS sites, actual AADT, K, D and T are measured. This information provides a statistical basis for estimating AADT, K, D and T for all other traffic counts where short-term traffic counts are obtained.

Permanent traffic counters use inductive loops to detect vehicles and record the traffic volumes for each hour. A single loop is required to collect traffic volume data. Two loops are required to collect speed data. Two loops and an axle sensor are required to collect vehicle classification data and two loops with a weight sensor (piezo or bending plate) are required to collect vehicle weight data.

3.1.2. Permanent Continuous Classification Counts

These classification counts are collected daily and are used to produce AADT, K, D and T. These counts are also used to calculate axle correction factors, K_{30}, D_{30} and T for design applications

3.1.3. Portable Seasonal Classification Counts

Portable Traffic Monitoring Sites (PTMSs) are automatic traffic recorders that are temporarily placed at specific locations throughout the state to record the distribution and variation of traffic flow. Seasonal classification counts are used to develop the axle correction factors and truck percentages during the year. These counts are performed one or more times a year (24 – 48 hours each) as deemed necessary to capture the seasonal truck variation. The classification counts will be used to estimate the axle correction factor and percentage of trucks.

3.2. Short-Term Traffic Counts

These counts are primarily performed by local agencies and consultants. They are responsible for field counts using various portable traffic counting devices. These counts are collected using axle counters, vehicle counters and/or video detection.

Portable traffic counters frequently use rubber hoses that record by sensing the number of axles. These counters are small enough to be transported, contain a power source and may be easily secured to a telephone pole, fence post, signpost, tree, etc. They may include time period recording or cumulative counts. Most traffic volume counters utilize electronic storage and require software and/or hardware to download the collected data. The downloaded data can be transferred directly to a computer or may be printed in a report format. Video detection can also be used to collect the same data.

3.2.1. Portable Axle Counters

If the counting device measures the "number of axles," an axle factor is assigned to the specific count location based on the trucking characteristics of that location. The axle correction factor is applied to the count and then the count is seasonally adjusted.

3.2.2. Portable Vehicle Counters

If the counting device counts the "number of vehicles," the count site will require no axle corrections.

3.2.3. Seasonal Adjustments

All short-term counts must be adjusted to reflect the seasonal changes in traffic volumes. The seasonal factors, K and D are used to estimate the average K_{30} and D_{30} for system level analysis.

4. Traffic Adjustment Factors

4.1. Seasonal Factor (SF)

The Monthly Seasonal Factor (MSF) for a particular month in a particular location is derived from the Annual Average Daily Traffic (AADT) for a location divided by the Monthly Average Daily Traffic (MADT) for a specific month at that count site:

$$MSF = AADT/MADT$$

Weekly Seasonal Factors (SF) are developed by interpolating between the monthly factors for two consecutive months. The Seasonal Factors are calculated for each week of the year for each permanent count station. The SF and Axle Correction Factors are used to convert ADT to AADT.

4.2. Axle Correction Factor

The Axle Correction Factors are determined by using the data from continuous classification counts and portable seasonal classification counts following the guidelines described in the FHWA Traffic Monitoring Guidelines.

For design traffic purposes, the data collected on a road system is used to measure the values identified as AADT, K, D and T. AADT, K and D are the three critical numbers which determine the geometric design of a road. T is the critical value for pavement design. AADT is the most important value used in design traffic forecasts because K, D and T are key factors which are related to AADT.

4.3. Annual Average Daily Traffic (AADT)

The Annual Average Daily Traffic (AADT) is the estimate of typical daily traffic on a road segment for all days of the week, Sunday through Saturday, over the period of one year. AADT is determined by dividing the total volume of traffic on a highway segment for one year by the number of days in the year. The AADT is the best measure of the total use of a road, because it includes all traffic for an entire year.

Average Daily Traffic (ADT) is obtained by a short-term traffic count. Short-term counts are commonly referred to as "raw counts" or simply "traffic counts." ADT is typically a 72-hour traffic count collected on Tuesday, Wednesday and Thursday divided by three. However, ADT can be based on the simple average of any short-term traffic count at least 24 hours long. 24-hour and 48-hour traffic counts are often taken to measure ADT and converted to AADT for design traffic projects. For design traffic forecasts, the Weekly Correction Factor (SF) and Axle Correction Factor should be used to convert ADT to AADT.

$$AADT = ADT \times SF \times Axle\ Correction\ Factor$$

When the ADT is multiplied by the seasonal factor and axle correction factor assigned to that site, it will provide a statistically accurate count for the entire year at that site known as AADT.

4.4. K-Factor

K is the proportion of AADT occurring in an hour. The K-factor is critical in design traffic forecasts because it defines the peak hours of road use, typically traffic going to work and coming home. Since this is when the roads will be the most used, it is appropriate to design the system to handle this level of congestion.

It may not be financially feasible to build for the peak hour of the year, therefore the 30th highest hour of the year has been chosen as the design hour. K_{30} is the proportion of AADT occurring during the 30th highest hour of the design year. Traffic projections are expressed as AADT and Design Hour Volume (DHV). AADT and DHV are related to each other in the following equation:

$$DHV = AADT \text{ x } K_{30}$$

The K-factor is the ratio of hourly two-way traffic to the two-way AADT. The design hour factor (K_{30}) is the relationship between the 30th highest hour volume and the AADT for the design year. FHWA requires that the K_{30} be used for all traffic projections used for design projects. K_{30} is used to determine the design hour volume (DHV).

Capacity analysis focuses on the traffic monitored at an intersection or along a highway during a particular peak hour. The peak hour most frequently used to design roads and intersections is the 30th highest hour occurring during the design year. The amount of traffic occurring during this hour is called the design hour volume (DHV). K_{30} is the ratio of the DHV to the AADT. DHV is derived by multiplying the AADT by the estimated K_{30} (for the design year) based on data collected at telemetered traffic monitoring site surveys.

K_{30} should be measured and not artificially computed using a mathematical equation. However, it is not possible to measure K_{30} at every count site, so the information gathered by the permanent count sites is used to estimate K_{30} when short-term traffic counts are used. The basic assumption is that K_{30} is based on roadway type and land use characteristics and remains relatively constant over time (as long as the roadway type and land use characteristics stay constant). Therefore, an accurate estimate of K_{30} for the current roadway system will be a reasonable estimate of K_{30} for the design year.

The K-factor represents typical conditions found around the state for relatively free-flow conditions and are considered to represent typical traffic demand on similar roads. The magnitude of the K-factor is directly related to the variability of traffic over time. Rural and recreational travel routes which are subject to occasional extreme traffic volumes generally exhibit the highest K-factor. The millions of tourists traveling on interstate highways during a holiday are typical examples of the effect of recreational travel periods. Urban highways, with

their repeating pattern of home-to-work trips, generally show less variability and have a lower K-factor.

The HCM notes that when the K-factor is based on the 30th highest hour of annual traffic, it has the following characteristics:

1. The K-factor generally decreases as the AADT on a highway increases.
2. The K-factor generally decreases as development density increases.
3. The highest K-factor generally occurs on recreational facilities, followed by rural, suburban and urban facilities in descending order.

4.5. Directional Distribution (D)

A highway with a high percentage of traffic in one direction during the peak hours may require more lanes than a highway having the same AADT but with a lower percentage. This percentage of traffic in one direction is referred to as directional distribution (D).

During any particular hour, traffic volume may be greater in one direction than the other. An urban route, serving strong directional demands into the city in the morning and out of it at night, may display as much as a 2:1 imbalance in directional flows.

Directional distribution is an important factor in highway capacity analysis. This is particularly true for two-lane rural highways. Capacity and LOS vary substantially based on directional distribution because of the interactive nature of directional flows on such facilities. Queuing, slowness of traffic, land use impact and capacity are some of the considerations which affect the directional distribution.

The Directional Distribution (D) of traffic is also important in determining the LOS for a road. D is the percentage of total, two-way peak hour traffic which occurs in the peak direction. D_{30} is the proportion of traffic in the 30th highest hour of the design year traveling in the peak directions. D_{30} is a measured value which is assumed to remain constant over time.

The directional distribution (D) is the percentage of the total, two-way peak hour traffic traveling in the peak direction. D_{30} is the proportion of traffic in the 30th highest hour of the design year traveling in the peak directions. The directional distribution is an essential parameter used to determine the directional design hour volume (DDHV). The DDHV should be the basis of geometric design.

The Directional Design Hourly Volume (DDHV) for the design year should be the basis of the geometric design. The DDHV is the product of the following equation:

$$DDHV = DHV \text{ x } D_{30}$$

Recommended D-factors (D_{30}) for Design Traffic				
Road Type	**Low**	**D_{30} Average**	**High**	**Standard Deviation**
Rural Freeway	52.3%	54.8%	57.3%	1.73
Rural Arterial	51.1%	58.1%	79.6%	6.29
Urban Freeway	50.4%	55.8%	61.2%	4.11
Urban Arterial	50.8%	57.9%	67.1%	4.60

4.6. Percent Trucks (T)

The most critical factor to pavement design is the percentage of trucks (T) using a roadway. The structural design is primarily dependent upon the heavy axle loads generated by commercial traffic. The estimated future truck volume is needed for calculating the 18 KIP ESALs for pavement design. Design traffic calculations use the factor T, the percentage of trucks for 24 hours (one day).

The truck volume and AADT are related to each other by a ratio commonly known as "T." The Daily Truck Volume (DTV) can be derived from the following equation:

$$DTV = AADT \text{ x } T$$

For design traffic purposes, the Design Hour Truck (DHT) is defined as T divided by two, based on the assumption that only half as many trucks travel on the roadway during the peak hour. The DHT is derived from the following equation:

$$DHT = T/2$$

The truck percentage is usually assumed to be constant over time.

5. Precision of Data

To reflect the uncertainty of estimates and forecasts, volumes shall be reported according to the following AASHTO rounding standards:

Forecast Volume	Round to Nearest
<100	10
100 to 999	50
1,000 to 9,999	100
10,000 to 99,999	500
>99,999	1,000

6. Level of Service (LOS) Operational Analysis

6.1. Intersection Capacity and Quality of Service

The "capacity" of an intersection for any of its users (motor vehicles, pedestrians, bicyclists, transit vehicles) is the maximum rate of flow of users that can be accommodated through the intersection. Typically, capacity is defined for a particular user group without other user groups present. Thus, for example, motor vehicular capacity is stated in terms of hourly vehicles, under the assumption that no other flows (pedestrians, bicycles) are detracting from such capacity.

Multi-modal capacity is the aggregate capacity of the intersection for all users of the intersection. In some cases, the maximum multi-modal capacity may be obtained while some individual use flows are at less than their individual optimum capacity.

"Level of service" is defined, by the <u>Highway Capacity Manual</u>, for each type of intersection user. For each user, level of service is correlated to the amount of control delay encountered by the user at the intersection.

Control delay, a result of traffic control devices needed to allocate the potentially conflicting flows at the intersection, reflects the difference between travel time through the intersection at free flow, versus travel time under the encountered conditions of traffic control. For drivers, control delay consists of time "lost" (from free-flow time) due to deceleration, waiting at signals, stop or yield signs, waiting and advancing through queue of traffic and accelerating back to free-flow speed. For pedestrians and bicyclists, deceleration/acceleration times are insignificant, and control delay is largely the time spent waiting at signals, stop or yield signs. Levels of service are somewhat correlated to capacity in that levels of service decline as capacity is approached.

6.2. Mobility

Providing mobility for people and goods is transportation's most essential function.

Quantity reflects the collective value of mobility provided
- Understand the magnitude of mobility
- Quality alone does not matter

Quality is related to the conditions of travel (user perception)
- How good or bad is it

Accessibility describes the ease of engaging in activities
- Opportunities that can be reached in a given time
- Cumulative number of opportunities (modal choices)

Utilization relates demand to capacity
- How much of the transportation facility service is being utilized
- Evaluates efficiency

Quality of service and capacity analyses are at the heart of ensuring mobility of people and goods.

Definitions

- Quality of Service – a user-based assessment of how well a facility is operating

- Level of Service – a quantitative stratification of the "quality of service" of a facility into six letter grade levels with "A" describing the highest quality and "F" describing the lowest quality

- Highway – roadway with all transportation facilities (i.e., lanes, bus pull-outs, paved shoulders, sidewalks, signals) within the right-of-way

- Multimodal – more than one highway mode (auto, bicycle, bus, pedestrian, truck)

- Capacity – the maximum number of persons or vehicles that can pass a point on a roadway during a specified time period under prevailing roadway traffic and signalization conditions

6.3. Highway System Structure (Types of Roadways)

- Uninterrupted flow roadways
  - Freeways
  - Two-lane highways
  - Multilane highways

- Interrupted flow roadways
  - Arterials (typically ≥ 0.5 signalized intersections per mile)

Generalized HCM Highway System Structure

- Point – A boundary between segments, usually at signalized intersections
- Segment – A portion of roadway extending from one point to another
- Facility – A length of roadway consisting of points and segments
- Corridor – A combination of generally parallel facilities
- Areawide Analysis – A combination of all facilities in an area

6.4. Key Factors Affecting Level of Service and Capacity

Roadway Characteristics
- Lineage
- Turn Lanes
- Sidewalks
- Bicycle lanes

Traffic Characteristics
- Daily/hourly aspects
- Directional aspects
- Bus frequency

Control Characteristics
- Signalized intersections
- Green time

The Level of Service (LOS) analyses are to be performed in accordance with the most current Highway Capacity Manual (HCM) procedures. The HCM procedures for freeway level of service are based on the following equation:

$$SF_i = MSF_i \text{ x } N \text{ x } f_w \text{ x } f_{hv} \text{ x } f_p$$

SF_i = service flow rate
MSF_i = maximum service flow rate for LOS i under prevailing roadway and traffic conditions for one lane in one direction, in vehicles per hour (vph)
N = number of lanes in one direction of the freeway
f_w = factor to adjust for the effects of restricted lane widths and/or lateral clearances
f_{hv} = factor to adjust for the effect of heavy vehicles (trucks, buses and recreational vehicles) in the traffic stream
f_p = factor to adjust for the effect of driver population (tourist, student, seniors, etc.)

7. Number of Lanes Required

Design traffic forecasts ultimately are used to determine how many lanes a corridor or project may require. Using the current year data and projecting future values of DDHV, SF_i and Peak Hour Factor (PHF), the number of lanes can be estimated.

The DDHV estimate divided by the service flow rate per lane for a required LOS and PHF, will determine the number of lanes required in the peak direction. Using the HCM methodology to calculate the service flow rate per lane, the number of lanes can be determined by applying the following equation:

Number of Lanes = DDHV / (Service Flow Rate per lane x PHF)

8. Highway Capacity Manual (HCM)

The Transportation Research Board (TRB) publishes the Highway Capacity Manual (HCM). The HCM incorporates more than $5 million of funded research that has occurred since the previous publication. This manual significantly updates how engineers and planners assess the traffic and environmental effects of highway projects.
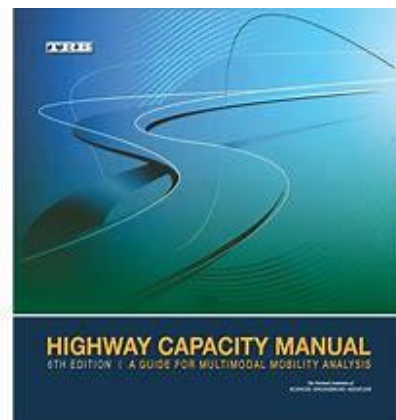
9. Highway Capacity Software (HCS)

McTrans produces the Highway Capacity Software (HCS). It implements the procedures defined in the <u>Highway Capacity Manual</u> (HCM). The software is updated periodically to maintain the updates from the HCM. The latest release of HCS 2010 includes updated modules to implement the new procedures for signalized intersections, roundabouts, basic freeway segments, freeway weaving segments, freeway merge/diverge segments, two-lane highways and multilane highways.

10.   Summary

This document discussed the basic principles of transportation planning. It provided the definition and objectives of project design and corridor traffic forecasting. It also examined how equivalent single axle loading (ESAL) forecasting plays into the planning process.

Traffic data sources were discussed such as permanent continuous counts, permanent continuous classification counts and portable seasonal classification counts.

Definitions were provided for traffic factors including seasonal factor (SF), axle correction factor, annual average daily traffic (AADT), K, directional distribution (D) and percent trucks (T). Equations were provided to show how each of these factors relate to traffic forecasting.

Level of service (LOS) as it relates to operational analysis was be covered. The level of service is correlated to the amount of control delay encountered by the user at the intersection. Mobility was also be discussed as to how quantity, quality, accessibility and utilization play a role in how road users move on the transportation system.