Maximum Theoretical Person Capacity in a 24 Hour Period

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Problem Statement

The Oregon Department of Transportation's (ODOT's) Rail and Public Transit Division (RPTD) approached ODOT's Transportation Planning Analysis Unit (TPAU) with several questions around the theoretical maximum capacity of a given section of road. After a series of emails and discussions between the RPTD and TPAU the questions being asked were defined as follows:

1. *How many people use the busiest section of roadway in Oregon?*
2. *How many people use the busiest section of roadway in the world (approximate)?*
3. *What is the theoretical maximum number of people that could use a section of roadway in a 24 hour period (how much daily capacity is not used, due to the fairly consistent daily cycle of sleeping, work, and play)?*
4. *For illustrative purposes, what is the theoretical maximum number of buses that could use a section of roadway in a 24 hour period? If those buses were completely full, how many people could use a given section of roadway in a 24-hour period traveling by bus?*
5. *Similarly, how many people could use a given section of roadway in a 24-hour period traveling by walking?*

RPTD finds that when taking a fresh look at a problem it is often useful to start by finding theoretical limits. In this case, with existing technology, what is the theoretical maximum capacity of a roadway to carry people, and how does that compare with real-world conditions. TPAU agreed to calculate these values with the understanding that they are impractical and irrational scenarios that would never occur in real world conditions. The values produced are strictly for illustrative purposes to help explain that even on the busiest sections of road there is still theoretical capacity available across time periods that are not fully utilized; and that traveling by bus has some potential to increase person capacity on our busy roadways.

The calculations presented here are on an exclusively theoretical basis and extreme care should be taken when presenting any of the information provided outside of this document. Capacity is typically reported in a passenger cars per hour per lane (pcphpl), but for the purpose of this exercise it is being reported on a persons per day (pcphpl *24*occupancy). For this reason and others listed throughout this document it is important that the user fully understand the meaning of the numbers within this document.

Capacity Basics

According to the 2010 Highway Capacity Manual (HCM), capacity is defined as "the maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of lane or roadway during a given time period under prevailing roadway, environmental, traffic and control conditions."[1] Transit capacity on the other hand, does not deal with "persons *or* vehicles", rather it deals with both people and vehicles. Transit capacity depends on many different elements, including, but not limited to: vehicle carrying capacity, highway capacity, schedule of the transit route, the transit agency's policies, and many more. For this reason the concept of capacity applied to personal vehicles must be broadened.

There are two main factors that affect bus facility capacity; they are: loading area capacity and bus stop capacity. In bus transit capacity analysis a scheduled or design person capacity is typically used. The scheduled person capacity is defined as the number of persons that "*can* be reliably served in an hour under the current schedule"[2]; the design person capacity is defined as the number of persons that "*could* be served if the facility was operated at capacity given a set of design criteria or assumptions."[3]

Cautions/Considerations

The calculations in this document assume that the section of freeway under consideration runs at capacity for 24 hours a day. This is also assuming that at no point does this section of freeway become oversaturated. Along with these assumptions some simplifying assumptions were also made. Rather than looking at an entire bus transit route, it was decided to only look at a section of freeway. It was decided to do a straight comparison on purely a passenger car equivalency and a person per vehicle estimation. Table 1 shows the theoretical maximum person-flow rates for buses on downtown and arterial streets suggested by the Transit Capacity and Quality of Service Manual (TCQSM).

Table 1: Suggested maximum person-flow for buses.

	Max Capacity pplphpl	Seated Capacity pplphpl
Downtown Streets	6,450	4,300
Arterial Streets	8,700	5,800

[1] 2010 Highway Capacity Manual Volume 1:Concepts
[2] Transit Capacity and Quality of Service Manual, 3rd Edition
[3] Transit Capacity and Quality of Service Manual, 3rd Edition

These numbers assume that these passengers are being served by standard buses, in exclusive bus lanes. It also assumes 106-135 buses per hour for arterial streets and 81-100 downtown streets. The seated capacity assumes a passenger load factor of 0.76-1.0 passengers per seat. On the other hand, the max capacity is also known as the crush capacity. The crush capacity is when as many people are crowded into a vehicle as physically possible. This condition is not normally accepted by North American passengers.[4] The TCQSM also warns that these values are assuming a "uniform flow that rarely occurs and indicates underservicing of demand when it does occurs." As such, "appropriate peak-hour factors should be used to reduce these values to design levels to reflect passenger flow variations within the 15-min peak period."[5]

Methodology

A comparison was made between the theoretical person capacity as well as some calculated person capacities on freeways throughout the world. The list below states the assumptions made in order to calculate the 24 hour person capacities.

- Capacity = 2,250 passenger cars per hour per lane (pcphpl)
- 1 bus = 1.5 passenger vehicles
- Bus capacity = 1500 buses per hour per lane (bphpl)
- When theoretical bus capacity was analyzed, buses were the only vehicles on the roadway under question
- When theoretical vehicle capacity was analyzed, vehicles were the only vehicles on the roadway under question
- Buses travel at the same speed and headway as vehicles
- Volumes remained at capacity for 24 hours (this theoretically possible but not a practical or reasonable assumption)
- Traffic flows smoothly all 24 hours at capacity without entering an unstable (slowing) condition.
- Vehicles carry an average of 1.4 persons per vehicle
- TCQSM buses carry an average of 40 persons per vehicle
- Oregon buses carry an average of 55 persons per vehicle
- No weaving, diverging, or merging occurred in the analysis segment
- Buses do not stop within the analysis area
- Buses are able to fill and discharge outside the study area without facility capacity issues.
- There are no upstream bottle necks impeding the flow

[4] Transit Capacity and Quality of Service Manual, 3rd Edition, Chapter 1
[5] Transit Capacity and Quality of Service Manual, 3rd Edition, pg 6-21& 6-22.

The chart below shows a comparison of three extreme real world examples the number of daily vehicles (per lane) for some of the busiest sections of roadway in the world. The chart also has 6 examples of theoretical daily capacity limits including: theoretical examples for all personal vehicles, all walk, and all buses. The columns that are red in color indicate a theoretical maximum value. The blue columns indicate values that have been calculated with real world AADTs for the appropriate roadway.

This comparison over a 24 hour period is unusual and requires a detailed description (as is provided in this document). For ease of calculation the buses were calculated using a passenger car equivalency of 1.5 to one. Without an accurate and detailed description this graphic can be confusing and misleading. A comparison was done between three different real locations and six theoretical exercises. The descriptions of each comparison shown on the bar chart are listed after the chart.

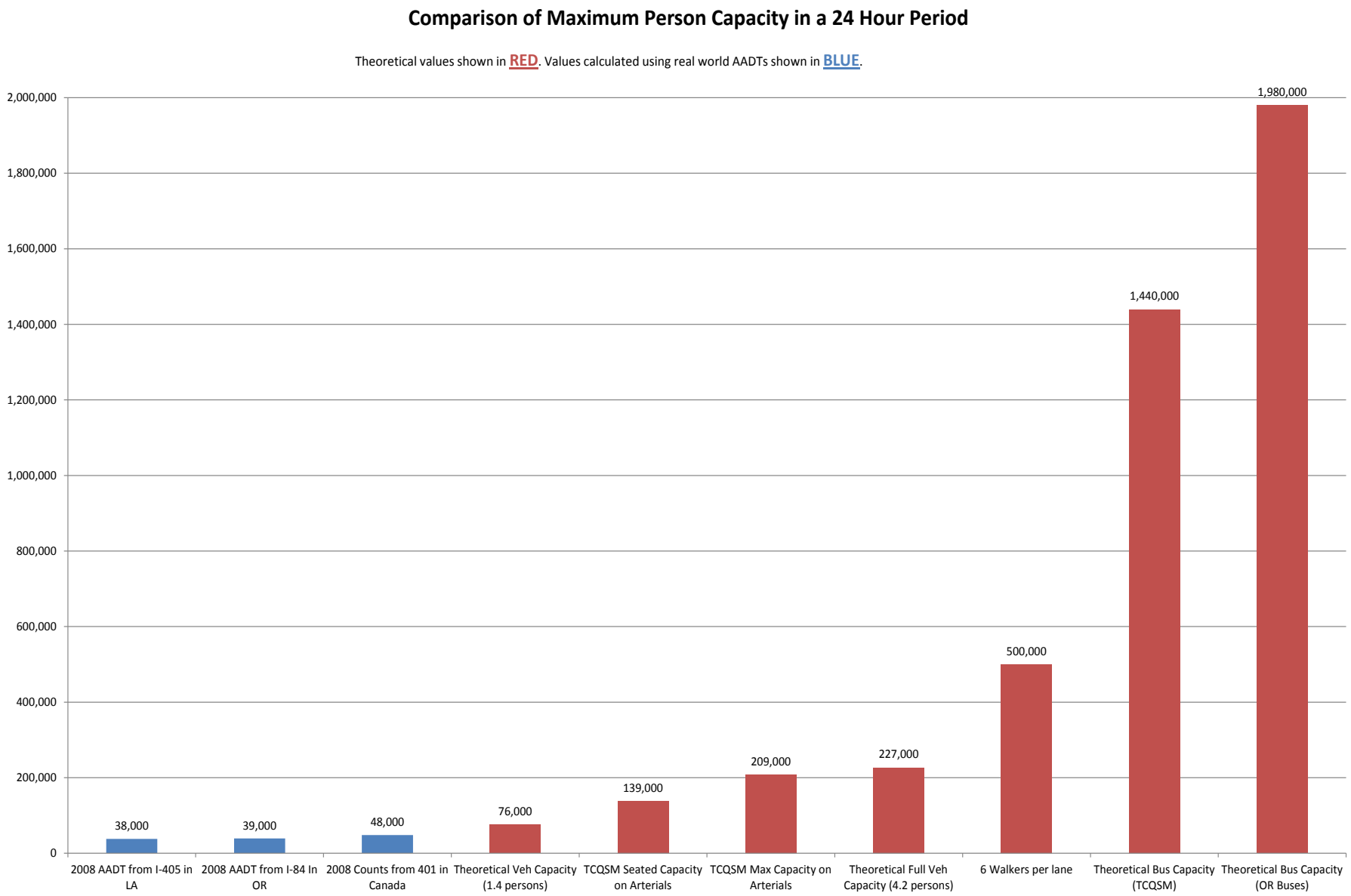

Figure 1: Comparison of Maximum Person Capacity in a 24 Hour Period

Table Breakdown

- 2008 AADT from I-405 in LA – The 35,000 people per day per lane(pplpdpl) was calculated using the 2008 AADT (about 375,000 with 14 lanes) of a section I-405 in Las Angeles. The segment between exit 21 and exit 22 is known to be the busiest freeway in the United States, and is often congested.
- 2008 AADT from I-84 in OR – the 36,000 pplpdpl was calculated using the 2008 AADT (about 165,000 with 6 lanes) of I-84 in Portland. This is known to be one of the busiest freeway sections in Oregon and is often congested.
- 2008 Counts from 401 in Canada – the 44,000 pplpdpl was calculated using an average of 2 AADT counts taken in 2008 (about 475,000 with 14 lanes) on 401 in Canada, outside of Toronto. This is known to be the busiest freeway in the world and is often congested.
- Theoretical Veh Capacity (1.4 persons) – the 70,000 was calculated using a "Perfect" capacity of 2250 pcphpl and 1.4 persons per vehicle for 24 hours. The 1.4 persons comes from the OHAS data set.
- TCQSM Seated Capacity on Arterials – this 139,000 was calculated using the seated capacity per lane suggested by the TCQSM (5800) multiplied by 24 hours in a day.
- TCQSM Max Capacity on Arterials – this 209,000 was calculated using the max capacity per lane suggested by the TCQSM (8700) multiplied by 24 hours in a day.
- Theoretical Veh Capacity (4.2 persons) – the 227,000 was calculated using a theoretical max capacity of 2250 pcphpl and 4.2 persons per vehicle for 24 hours.
- 6 Walkers Per Lane- this 500,000 was calculated using the assumption that walkers were walking 6 wide in a lane and were moving at 3.5 mph, with a headway of 5 ft.
    - 3.5 Miles/Hour * 5280 Feet / Mile * 6/5 Person / Foot * 24 hours/day
- TCQSM Theoretical Bus Capacity – this 1.4 million pplpdpl was calculated using a "perfect" bus capacity of 1500 bphpl and a TCQSM suggested max of 40 persons per bus for 24 hours.
- OR Theoretical Bus Capacity – this 1.98 million pplpdpl was calculated using a "perfect" bus capacity of 1500 bphpl and an assumed capacity for Oregon buses of 55 persons per bus for 24 hours.

Findings

This task compared real world situations to theoretical situations, and also compared Oregon's roadways to other known congested roadways in North America. In the completion of this task it was found that in comparison to the busiest freeway in the United States (I-405 in Los Angeles), the busiest roadway in Portland carries about the same number of passengers per lane. Compared to 401 in Canada, the busiest freeway in the world, both I-405 and I-84 carry about 10,000 less people per lane. The busiest freeway in the world carries about 26,000 less people per lane per day than it could theoretically carry; if it were to carry the full capacity of 2,250 pcphpl, and 1.4 people per vehicle for 24 hours a day. Table 2 shows each of the calculated values for this exercise.

Table 2: Calculated People per Day per Lane (pplpdpl)

Roadway	People per day per lane (pplpdpl)
2008 AADT from I-405 in LA	38,000
2008 AADT from I-84 In OR	39,000
2008 Counts from 401 in Canada	48,000
Theoretical Veh Capacity (1.4 persons)	76,000
TCQSM Seated Capacity on Arterials	139,000
TCQSM Max Capacity on Arterials	209,000
Theoretical Full Veh Capacity (4.2 persons)	227,000
6 Walkers per lane	500,000
Theoretical Bus Capacity (TCQSM)	1,440,000
Theoretical Bus Capacity (OR Buses)	1,980,000

Overall the number of passengers that Portland metro freeways carry per lane is comparable to similarly congested freeways within the United States, when a comparison is made between the roadways AADTs. Even so, Oregon's busiest roadway currently carries roughly 2% of the maximum theoretical person capacity per lane, equivalent to 39,000 pplpdpl. The difference between the observed and theoretical values imply there is potential to expand utilization of infrastructure by employing existing strategies of investing in transit, encouraging carpooling, and shifted trip times. Much of this difference can be attributed to the fact than most people have similar sleeping and waking patterns, are on the roadways during similar periods, and the time that the freeways spend in oversaturated (unstable flow) conditions. This exercise compares both real and theoretical values. For this reason it is important that graphics, and excerpts from this document be accompanied by a proper description.