# CHAPTER 7. Applications

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## 1. Introduction

[revise:] This chapter presents a set of case studies in which the HCM methods are applied and interpreted. The case studies are intended to illustrate ways in which the methods can be applied and interpreted in various situations commonly found in practice. In some cases you will use the computational engines that you developed in Chapters 2, 3, and 4. In other cases, you will use results generated by software tools that implement the HCM methods. You will also use the approach suggested by the HCMAG suggested by the HCMAG and adapted for use in this book.

No adjustment factors.

## 2. Studies of an AWSC Intersection

 With sensitivity analysis.

The AWSC model is the most basic (and no-frills) of the HCM intersection modules. The basic model has the following components:

* Vehicles on each approach face differing degrees of conflict (# of vehicles present on the other approaches). The HCM describes five such cases, each with a given saturation headway.
* We can compute the probability of each of these five cases occurring, given the volumes or flow rates on each approach, and the expected value of the departure headway for each approach.
* From this departure headway, we can calculate the capacity and the delay.

### Study 1

In this first study, we consider the effect of an increasing volume on one approach on the degree of utilization (equivalent to the volume-capacity ratio) on that approach. Consider a four leg intersection, with one lane on each approach, that is controlled by stop signs on all approaches. The volumes on each approach are 250 vehicles per hour. Now suppose that we increase the volume on the northbound approach in increments of 25 vehicles per hour, until we reach capacity on that approach.

Figure x shows the results of these changes. As the northbound volume is increased, the degree of utilization on the northbound approach increases. Capacity is reached at a volume of 562 veh/hr when the degree of utilization reaches 1.0. If the demand volume continues to increase, the degree of utilization increases as well. However, the number of vehicles that can be served remains at 562 vehicles per hour, the maximum flow rate (capacity) possible, given the volumes (and degrees of conflict on the other approaches. Note also that the increasing volume on the northbound approach has little effect on the degrees of utilization on the other approaches, increasing from 0.41 when the northbound volume is 250 veh/hr to about 0.50 when the volume reaches 550 veh/hr. Above 550 veh/hr (actually, above the northbound capacity of 562 veh/hr), the degrees of utilization on these other approaches remains constant. Why? The actual flow rate on the northbound approach remains at 562 veh/hr, even if the demand volume continues to increase.

### Study 2

In this second study, we consider the effect of an increasing volume on one approach on the degree of utilization on the other approaches. The volume and geometric conditions remain the same as in Study 1. As the volume on the northbound approach increases from 250 veh/hr to 550 veh/hr, the departure headway on that approach increases from 5.9 sec to 6.4 sec. But once the approach reaches capacity (562 veh/hr), the departure headway remains the same at 6.4 sec. No additional vehicles can be served.

On the other approaches, the departure headways increase from 5.9 sec to 7.1 sec on the southbound approach and to 7.4 sec on the eastbound and westbound approaches. The increasing volume on the northbound approach increases the degree of conflict on the other approaches, evidenced by this increase in the departure headways on these approaches. But again, once capacity is reached (562 veh/hr), the departure headways remain constant on these other approaches.

[more explanation or discussion]

### Study 3

One of the most important aspects of traffic analysis is the interpretation of the results. In this study, consider a four leg intersection with four legs. The given volumes are:

* NB approach:450 veh/hr
* SB approach 425 veh/hr
* EB approach: 250 veh/hr
* WB approach: 300 veh/hr

The capacity of the northbound approach is calculation to be 465 veh/hr, when the degree of utilization reaches 1.0.

At these given volumes, the resulting degrees of utilization are:

* NB approach: 0.95
* SB approach 0.90
* EB approach: 0.59
* WB approach: 0.69

How do we interpret these results? The degree of utilization tells us what the probability is of observing a vehicle on an approach. When X is one, we know that the approach is at capacity because there is always a vehicle present on that approach. We are operating at capacity. In the case of the northbound approach, X is 0.95. While not at capacity flow, the approach is nearly always busy. It is very little (or practically no) room for accommodating additional vehicles. The same can be said for the southbound approach, where X is 0.90. Again, 90 percent of the time we expect to see a vehicle on that approach and the approach is little room to accommodate additional traffic. For this reason, we should consider changing to another form of traffic control. In the next section, we will consider these same conditions under two-way stop-control, with the northbound and southbound approaches constituting the major street, and the eastbound and westbound approaches with stop control. Signal control will also be considered in a subsequent section of this chapter.

For the eastbound and westbound approaches under all-way stop-control, there is considerable unused capacity with the degrees of utilization less than 0.70 for these two approaches.



Figure



Figure

## 3. Studies of a TWSC Intersection

 With sensitivity analysis.

## 4. Studies of a Pretimed Signalized Intersection

 With sensitivity analysis.

## 5. Studies of an Actuated Controlled Signalized Intersection

 With sensitivity analysis.

## 6. Case Study

### Introduction

In this section, we consider a case study adapted from the Highway Capacity Manual Applications Guide (HCMAG) [xx]. While we have previously focused on the components of the HCM intersection analysis models and methods, this case study considers some of the issues that arise when we apply the methods to a real world problem and interpret the results produced by the methods. The HCMAG was developed to provide guidance to users of the HCM in the following three areas:

* Defining and scoping the problem to be addressed,
* Identifying and using the appropriate analysis tools, and
* Interpreting results and understanding what they mean.

### The Situation

The Idaho Transportation Department is responsible for the operation of U.S. 95, the major highway running north-south in the state of Idaho, from the Canadian border on the north to the Oregon border in the southwest part of Idaho, a distance of 540 miles. In the city of Moscow, U.S. 95 is the major north-south route, serving both local traffic within the city as well as through traffic originating and/or destined outside of the city.

 The intersection of U.S. 95 and Styner Avenue currently operates with stop control for Styner Avenue (the minor street) and no control on U.S. 95 (the major street). As traffic volumes have increased at the intersection, residents of the city have asserted that delays have increased and safety has been degraded. A school located near the intersection generates an increasing number of students crossing U.S. 95. Limited sight distance on Styner for drivers entering the intersection from the east further adds to the safety problem. In addition, a grade of xx percent on the NB approach presents problems for heavy trucks who would be required to stop and then restart on an upgrade, a possibly difficult maneuver during winter conditions. The city of Moscow, responding to citizen complaints, has request that ITD install a traffic signal so that traffic can be more effectively and safely controlled.

 U.S. 95 currently carries about 20,000 vehicles per day through the city of Moscow. The city has a population of nearly 25,000 and is the home to the state’s land grant university, the University of Idaho, with a student population of nearly 12,000. Traffic on this section of U.S. 95 has been increasing at three percent per year. Traffic signals control the intersections to the immediate north and south of the U.S. 95/Styner intersection.

[figure of street system]

 The traffic engineer for the Idaho Transportation Department must consider the performance of the intersection under today’s conditions as well as how the intersection is predicted to perform in the future as she considers the city’s request to signalize the intersection. Both today’s control (TWSC) as well as two future control operations (signal control, AWSC) must also be considered in this evaluation.

### The Approach

Determining whether the existing intersection control is adequate or not depends on a number of factors, including:

* The delays experienced by users of the intersection,
* Analysis of crashes that have occurred at the intersection,
* The sufficiency of the intersection’s capacity to accommodate the traffic volumes, and
* [add].

While a complete analysis would include all of the factors listed above, as well as consideration of whether the warrants for signal control as specified by the Manual of Uniform Traffic Control Devices, we will focus our work on the operation of the intersection, both present and future, as measured by delay and by the sufficiency of capacity. We will consider the existing conditions under two-way stop-control, as well as present and future performance under all-way stop-control and signal control. This analysis will provide important information for the traffic engineer as she decides which control type is best for this intersection.

The analysis tools that we will use are the computational engines that we developed in earlier chapters in this book.

Table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Intersection Control** | **Computational Engine** | **Configuration Assumed** | **Source in Book** | **Performance Measures Predicted** |
| TWSC | S2 | T intersection | Chapter x, page x | v/c ratio, movementDelay, approach/movementDelay, intersection |
| AWSC | S2 | 4 leg | “” | Degree of utilization, approachDelay, approachDelay, intersection |
| Signal | S2S1S3S6 | 4 legApproachApproachApproach | “”“”“”“” | Capacity utilization of intersectionCapacity of approachUniform delay, approachNon-uniform arrivals, approach |

Our analysis will include xx problems:

* Problem 1. Performance of existing intersection, existing control
* Problem 2. Performance of existing intersection with AWSC
* Problem 3. Performance of existing intersection with signal control
* Problem 4. Performance of intersection with project future volumes

Table 2 shows …

Table

|  |  |  |
| --- | --- | --- |
| **Intersection control** | **Analysis tool** | **Performance measure** |
| TWSC T-intersection |  | v/c ratio: movementDelay: approach/movementDelay: intersection |
| AWSC 4 legs |  | Degree of utilization: approachDelay: approachDelay: intersection |
| Signals-CMA (S2)Signals-Uniform delay (S3)Signals-Capacity (S1) |  | Capacity of approach (S1)Capacity utilization of intersection (S2, CE)Uniform delay: approach (S3, CE)Non-uniform arrivals (S6) |

[Scope and problem definition

Analysis methods used

Interpreting results

Location of current intersection

Effects of adjacent signalized intersection

Future traffic growth]

In short, the goal of this analysis is to help the state traffic engineer make a decision: keep the existing two-way stop-control or change to signal or all-way stop-control.

### Data Required

The primary data required for this analysis are the intersection geometry and the current and projected traffic volumes. Figures x and x show the intersection geometry and lane configuration as well as the current and project traffic volumes for the afternoon peak hour. The afternoon peak hour is the most intensive period of traffic during the day.



[note: 10 yr = 1.3439, 20 yr = 1.8061]

|  |  |  |  |
| --- | --- | --- | --- |
| **Movement** | **Current** | **10 year** | **20 year** |
| NBTH | 450 | 605 | 815 |
| SBLT | 300 | 400 | 540 |
| SBTH | 10 | 15 | 20 |
| EBLT | 100 | 130 | 180 |
| EBRT | 10 | 15 | 20 |

### Problem 1 – Performance of Existing Intersection (TWSC)

* Data
* Analysis tool (and assumptions)
* Results
* Interpretations and key issues

In Problem 1, we consider the existing TWSC intersection with current traffic volumes. The computational engine developed for a TWSC T-intersection (see pages xx-xx) will be used to predict the volume/capacity ratio and the delay for the stop-controlled approaches. Since the computational engine is based only on three movement (NBTH, SBLT, and EBLT), we will ignore the SBTH and EBRT movements. This can be justified since the volumes for these latter two movements are small, only 10 veh/hr.

Table x shows the results from the model predictions. The v/c ratio for the stop-controlled approaches are less than one, indicating sufficient capacity is provided for the existing traffic volumes. The average delay for all travelers using the intersection is relatively low, about 11 sec/veh. However, the average for the intersection hides what is a significant problem. For the EBLT movement, travelers wait over a minute at the stop sign, about 66 sec/veh. This level of delay, over an entire hour, lengthy and unacceptable, should provide justification for the traffic engineer to consider other forms of traffic control at this intersection.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **NB** | **SB** | **EB** |
| v/c ratio | - | 0.27 | 0.66 |
| Delay, approach | 0 | 9.4 | 65.8 |
| Delay, intersection | 11.1 |

### Problem 2 – Performance with AWSC

* Data
* Analysis tool (and assumptions)
* Results
* Interpretations and key issues

In problem 2, we consider the operation of the intersection with existing traffic volumes, but with AWSC. The computational engine developed for an AWSC intersection (see pages xx-xx) will be used to predict the degree of utilization and the delay for each approach. The computational engine considers only TH movements. But we will consider the LT volumes as part of the TH movement volumes, since the LT volumes are small compared to the TH movement volumes. [sensitivity with LT volumes]

Table x shows the results from the model predictions. The delay on each approach is comparable, ranging from just under 10 sec/veh on the EB approach to just over 13 sec/veh on the NB approach. The predictions for degree of utilization are well below one, ranging from 0.15 on the EB approach to 0.57 on the NB approach.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **NB** | **SB** | **EB** |
| Degree of utilization | 0.57 | 0.39 | 0.15 |
| Delay, approach | 13.3 | 10.6 | 9.6 |
| Delay, intersection | 11.9 |

### Problem 3 – Performance with Signal Control

* Data
* Analysis tool (and assumptions)
* Results
* Interpretations and key issues

Xc = 0.512

In problem 3, we consider the operation of the intersection with existing traffic volumes but with pretimed signal control. The computational engine developed for S2, S3, and S6 will be used, as well as the capacity ?? for S1 on pages xx. The engines will be used to predict the v/c ratio and the delay for each movement.

Table x shows the result of the critical movement analysis using the computational engine for S2. The model allocates green time based on the relative flow ratios for each movement. This produces v/c ratios that are nearly the same, about 0.42. We note that this means there is sufficient capacity. The overall utilization of capacity for the entire intersection is 0.51, again showing there is sufficient capacity at the intersection to accommodate the existing traffic volumes.

Table x shows the predicted delays for each approach, assume no effect from the adjacent upstream intersection and producing uniform arrivals at the intersection. While the average delay for all users of the intersection is predicted to be xx sec/veh, the delay for one of the movements is significantly higher. The average uniform delay for the EBLT movement is predicted to be 36 sec/veh. [add non-uniform arrival and delay prediction?]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Movement 1** | **Movement 3** | **Movement 4** | **Sum/Total** |
| Flow ratio, Y | 0.053 | 0.158 | 0.211 | 0.422 |
| Proportion | 0.1256 | 0.3744 | 0.5000 |  |
| Green split, sec | 11.3 | 33.7 | 45.0 | 90.0 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **NBTH** | **SBLT** | **EBLT** |
| Flow ratio, Y | 0.211 | 0.158 | 0.053 |
| Split proportion | 0.5000 | 0.3744 | 0.1256 |
| Split time | 33.7 | 33.7 | 11.3 |
| g/C | 0.5000 | 0.3744 | 0.1256 |
| Capacity | 950 | 711 | 239 |
| Volume | 400 | 300 | 100 |
| v/c ratio | 0.421 | 0.422 | 0.418 |
| Delay | 14.3 | 20.9 | 36.3 |

### Problem 4 – Performance with Future Conditions for Three Control Types

* Data
* Analysis tool (and assumptions)
* Results
* Interpretations and key issues

In problem 4, we consider the operation of the intersection with future volumes under each of the three control types. Table x shows the volumes for today, for 10 years in the future, and for 20 years in the future. The future volumes assume a 3 percent annual growth rate.

Tables x, x, and x show the predicted v/c ratios (or degrees of utilization) and the average delay for the future volumes under TWSC, AWSC, and pretimed signal control. Again, the two movements with low volumes (EBRT and SBTH) are ignored in this analysis.

[v/c ratios]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Period** | **Control** | **NBTH** | **SBLT** | **EBLT** |
| 10 years | TWSC |  |  |  |
| AWSC |  |  |  |
| Signal control |  |  |  |
| 20 years | TWSC |  |  |  |
| AWSC |  |  |  |
| Signal control |  |  |  |

[Similar table with delays]

### Synthesis of Results, Issues, Discussions

Interpreting results.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **AWSC** | **TWSC** | **Signals** |
| EBLT | 9.6 | 65.8 | 36.3 |
| SBLT | 10.6 | 9.4 | 20.9 |
| NBTH | 13.3 | 0 | 14.3 |
| Intersection | 11.9 | 11.1 | 19.5 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **AWSC** | **TWSC** | **Signals** |
| EBLT | 0.15 | 0.66 | 0.42 |
| SBLT | 0.39 | 0.27 | 0.42 |
| NBTH | 0.57 | - | 0.42 |
| Intersection |  |  | 0.51 |

### Further Thoughts

## 7. Summary

## 8. Glossary

Table . Terms used in this chapter

|  |  |
| --- | --- |
| **Term** | **Definition** |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

Table . Variables used in this chapter

|  |  |  |
| --- | --- | --- |
| **Variable** | **Description** | **Units** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

## 9. References

## 10. Problems