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Optimization Modeling at the Happy Valley Transit Company: An Analytical Methods Teaching Case

Author:

Keith A. Willoughby
Department of Finance and Management Science
Edwards School of Business
University of Saskatchewan
Saskatoon, SK Canada S7N 5A7
Phone: (306) 966-2128
Fax: (306) 966-2515
E-mail: willoughby@edwards.usask.ca

Introduction

It had been 45 minutes since the meeting concluded, but Ken Wilson was still jotting down his ideas regarding this newest project. Wilson, a young operations analyst, had been hired eight months previous to systematically analyze various features of the Happy Valley Transit Company (HVTC). With some success, he had examined such issues as transit routes, fare setting and driver scheduling. However, this latest project appeared to be especially intriguing.

With a sigh of relief, Ken put down his pen and tried to let it all sink in. During this latest meeting, he had met with Paul Green, Vice-President of Capital Projects, and Mary Andrews, Scheduling Supervisor. They indicated that HVTC was at a critical point in its development. One of their transit centers, located in a prime commercial area, was severely overcrowded. Another was at its capacity. (Transit centers, particularly large structures, served as depots or garages where buses were parked overnight or various maintenance activities performed. Besides parking spots for buses, they housed offices, conference rooms and lounges for transit staff). Both Paul and Mary wondered if other locations ought to be considered as potential transit centers. Mary, in particular, worried about how the current public transit infrastructure could handle future population shifts.

Happy Valley Transit Company Structure

The Happy Valley Transit Company, owned by the Happy Valley Economic Authority (HVEA), was responsible for providing efficient, reliable transit service to the 750,000 residents of the Happy Valley metropolitan area. Without an efficient public transit service, road congestion and pollution would become an increasing problem. With this in mind, Ken knew that successful implementation of this current project could provide substantial benefits to all Happy Valley residents.

He again glanced at his notes. The transit company currently operated three transit centers. Based on some information gathered by Mary, he observed the total allocation and capacity of each respective garage (see Table 1).

The 9th Street location proved a particularly troublesome issue for transit personnel. Besides being severely overcrowded (drivers were forced to park buses with minimal spaces between them), this transit garage was positioned within a high-priced commercial real estate area. The Lakeridge garage was at its current capacity, while the Cotters' Creek facility seemed to be under-utilized.

Ken then decided to look at the individual routes operated by the transit company. Currently, HVTC operated 12 bus routes. Service was provided on weekdays only, roughly 260 service days annually. (Due to the smaller passenger demands on weekends and holidays, the Happy Valley Economic Authority had decided to sub-contract this portion of transit service to a private company. This organization provided service with a fleet of smaller vans).

The routes, due to specific passenger demand and route length, did not all require the same number of buses per day. Ken was able to obtain the information provided in Table 2 of the Appendix. The first seven routes were considered "urban" routes (they operated solely within Happy Valley proper), while the remaining five routes were "suburban" (service extended into Happy Valley's metropolitan areas).

Analyzing the Problem

In order to understand the particular nature of transit operations, Ken reviewed some of the material he had received from Mary's scheduling group. Undoubtedly the largest cost associated with transit center location involved the cost of "deadheading" buses to and from their assigned routes. Buses do not begin revenue service from the moment of departure from their transit center. Likewise, buses do not undertake revenue service to the garage at the end of the service period. A certain amount of time is required to travel "not-in-service" between the garage and route (initiation of service) and the route and garage (termination of service). This time is referred to as "deadhead" time. Since such travel earned no revenue but still consumed resources (driver wages, fuel costs, etc.), it was the desire of transit planners to reduce this deadhead cost as much as possible.

Obviously, deadhead costs could be reduced by simply building several bus garages and positioning them relatively close to specific routes. However, the construction of these facilities incurred substantial expense. Deadhead and construction costs epitomized the tradeoffs that transit planners were required to make.

Paul's Capital Projects group had determined three potential locations for future transit centers. These locations offered sufficient land area for bus garage construction, and also permitted suitable roadway access. The respective locations were in the subdivisions of Bridgepoint, Montgomery and Clearwater.

Mary's staff provided the data depicted in Table 3. This matrix shows the number of hours required to deadhead one bus of a specific route from a given transit center. (Much of this data, particularly for the combination of routes and existing transit centers was already available. Consequently, the bulk of the work required by Mary's group focused on accurately estimating the deadhead times associated with the new (potential) bus garages). Both Mary and Paul indicated that the data in Table 3 provided accurate deadhead times. Current transit policy was to cost the deadhead time at a rate of $70 per hour. This amount was felt to be sufficient to cover the principal components of deadhead cost; namely, driver salary and vehicle operating expenses.

The three sites selected for potential transit center locations varied in terms of their construction costs. In particular, land values at the different sites meant that some sites would be more affordable than others. Paul's Capital Projects staff felt that these construction costs could be denoted as a (linear) "per bus" cost over a specific range of transit center size - specifically, between 25 and 100 buses. These minimum and maximum values corresponded to the generally acceptable sizes of bus garages. Transit officials felt that it would be extremely inefficient to build a bus garage with a size less than 25 buses (this minimum size also applied to existing transit centers). Moreover, an allocation of 100 buses was considered to be the highest capacity one would ever devote to such a facility. This linearization of construction costs removed the necessity of incorporating fixed costs into the construction cost expressions.

Based on different land values, the following ("per bus") capital costs of transit center construction were:

- Bridgepoint: $60,000
- Montgomery: $55,000
- Clearwater: $47,500

During the recent meeting, Ken had learned that these construction costs would not be paid "up-front". Rather, HVEA would "annualize" the construction costs over a 25-year period, at an annual interest rate of 7%. This, as explained by Paul, was similar to a consumer taking out a mortgage on a piece of personal property. The entire cost was not paid at the outset of the agreement; instead, the consumer would make periodic payments throughout the life of the mortgage. Based on the given term and interest rate, the Bridgepoint location, for example, featured an annualized per bus capital cost of $5,149.

The closure of existing transit centers and concomitant sale of the land (thereby earning some revenue) were considered vital issues by Paul and Mary. The 9th Street location, in particular, appeared to offer some benefits in terms of its relatively large size and high-priced land value (it occupied 4.0 acres with a land value of $13 per square foot). The Lakeridge site consisted of 2.0 acres at $5 per square foot, while the Cotters' Creek transit center sat on 2.4 acres of land at $6 per square foot (Ken dug out an encyclopedia and found out that an acre consisted of 43,560 square feet). As with the construction costs of new bus garages, Ken learned that HVEA would annualize the salvage revenue obtained from the sale of any existing transit center facility (the term and interest rate would be the same as those used for the construction calculations).

Additional Scenarios

It was during this most recent meeting that Paul and Mary had suggested other scenarios that they would like Ken to consider. Paul wondered what would be the effect if one forced the closure of the 9th Street facility. Mary, concerned about the impact of future development, suggested that the number of allocated buses on suburban routes could soon double. This doubling of "demand" could alter the attractiveness of certain facilities. Both Paul and Mary knew that certain parts of their transit system were inefficient. They indicated that it would be interesting to know the best decisions if one had a "clean slate" before them. In other words, suppose that one could place the routes in any of the six possible transit centers. Suppose further that this decision was made solely on deadhead costs alone - that is, construction costs and salvage revenues were ignored. If one only limited the problem by garage capacity restrictions (minimum and maximum of 25 and 100 buses, respectively, at each facility), what would be the resulting effects?

Ken looked up from his notes. Rubbing his eyes, he glanced at the transit network map shown above his office desk. This was by no means a trivial project. Paul wanted a completed report in 8 days. He knew he had better get to work.

Suggested Assignment Questions

1. Determine the optimal number, location and size (bus allocation) of the transit centers. What annual savings are obtained by your optimal solution?

2. What implications does the optimal plan have on HVTC? What recommendations would you make to Paul and Mary?

3. Could HVTC alleviate the problem of over-crowding within the current network of transit garages? Why or why not?

4. Determine the effects of Paul and Mary's suggested (but separate) scenarios:
   - doubling the number of suburban buses
   - closing the 9th Street bus garage
   - the "clean-slate" approach

   Do these additional scenarios support or modify your recommendations provided in question 3?

Table 1
Current Transit Centers

Transit Center	Current Allocation	Capacity
9th Street	121	100
Lakeridge	50	50
Cotters' Creek	29	60

Table 2
Route Allocations and Requirements

Route Number	Route Name	Garage	Number of Buses Required
1	4th Avenue	9th Street	11
2	South Industrial	Cotters' Creek	8
3	Westview	9th Street	14
4	Baker Street	9th Street	12
5	North Heights	Lakeridge	25
6	Bailey Place	9th Street	30
7	Hillcrest	Lakeridge	25
8	Millwood	Cotters' Creek	5
9	Richfield	9th Street	12
10	Brocktown	9th Street	22
11	Cedar Junction	9th Street	20
12	White River	Cotters' Creek	16

Table 3
Deadhead Times (Hours)

Garage	Route											
	1	2	3	4	5	6	7	8	9	10	11	12
9th Street	0.25	0.75	0.50	0.50	0.65	0.80	1.25	0.80	0.60	0.50	0.60	1.50
Lakeridge	2.00	1.25	1.00	0.60	0.15	1.50	0.20	0.30	1.25	0.55	0.70	0.80
Cotters' Creek	1.25	0.60	1.25	1.00	2.00	0.90	1.00	0.75	0.60	2.50	0.90	0.50
Bridgepoint	0.50	1.00	0.75	0.50	0.30	1.25	0.60	1.25	2.00	0.15	1.00	1.25
Montgomery	0.60	0.20	1.00	0.75	0.75	0.60	0.30	0.75	0.90	2.00	0.10	0.40
Clearwater	2.25	1.25	1.75	1.25	1.00	0.75	0.45	0.50	0.40	2.25	0.40	0.10