A Model To Minimize Non-Revenue Costs In Bus Transit Operations

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ABSTRACT

This paper derives from feasibility studies for a proposed Bus Division of the Mass Transit Administration (MTA) to serve northeastern Baltimore. The study objective was to determine the comparative savings or additional costs between using existing versus new locations. The focus of the analysis was non-revenue operating costs which are affected by location because of vehicle deadhead travel, associated operator travel and other operator travel for relief purposes.

Based on the ***premise*** that "*the optimal location of a storage facility is that which minimizes pullout and pull-in distances and times plus relief travel time between the facility and various terminal points*", the model was constructed with detailed data on existing operations and applied to each candidate site. The procedure involved microscopic calculation of each individual pullout and pull-in which mark the beginning and end respectively of bus transit operations.

Compared to existing operations data, the model projected deadhead operations to within 4 percent of actual data and relief travels to within 10 percent. When components were aggregated, the overall margin of error was 1 percent.

Various operating scenarios were tested by distributing combinations of services to existing and proposed facilities with the objective of minimizing non-revenue operations costs. One existing and one new site were identified as the two top choices. An analysis involving the combined cost of construction and operation subsequently aided in the final choice of a site.

The model can serve as a tool for both site selection and distribution of units among various locations. Beyond transit operations, the model is extendable to governmental and municipal facilities.

A. INTRODUCTION

This paper derives from a technical task conducted as part of the feasibility studies for a proposed new Northeast Bus Division of the Mass Transit Administration (MTA) in the Baltimore metropolitan area. The MTA, Maryland's transit operating agency, has been considering either expanding and modernizing one existing bus storage and maintenance facility or developing a new site to replace two existing facilities in northeastern Baltimore. Initially, twenty-five sites were under consideration. From preliminary investigations based on adequacy of available acreage and discussions on environmental and social issues, all sites were eliminated except five.

Authorities were aware of the fact that location of a facility affected operating costs and thus were interested in finding out the comparative savings or additional costs between using existing versus new locations. Since existing bus services, routes and operating procedures were to remain essentially the same, the focus of the analysis was non-revenue operating costs. Location affects these types of costs because of vehicle deadhead travel time and distance, associated operator travel costs and other operator travel for relief purposes.

A model was developed and applied in determining the non-revenue costs. The following sections describe the premises, assumptions, development and application and results of the model.

B. MODEL CONCEPT

The model was first conceptualized as a microscopic calculation of each individual pullout and pull-in that marks the beginning and end respectively of the transit vehicle operating unit called a block. Figure 1 is a conceptual diagram for pull-in and pullout operations. It illustrates how pull-in and pullout distances vary between a pair of revenue service terminals and two hypothetical facility locations. The second part of the model involved assignment of service blocks to existing facilities or candidate sites with the objective of minimizing total non-revenue operating costs.

The model was developed with detailed data from existing operations and then applied to each candidate site. Ordinarily, routing of transit services is determined by the need for service measured in levels of patronage or projected demand volumes. Thus, the configuration of transit routes and selection of beginning and ends of service are separate from the choice of the site to store the fleet of vehicles. Model development was based on the following ***premise***: *The optimal location of a storage facility is that which minimizes pullout and pull-in distances and times plus relief travel time between the facility and various terminal points.*

Because the three relevant aspects of non-revenue operations (*pullout, pull-in, and relief*) involve personnel and vehicles, the non-revenue operating cost items that need to be minimized are the following:

- operator travel time between the facility and relief points;
- operator labor time during pullouts from the facility;
- vehicle operating distances during pullouts;

- operator labor time during pull-in to the facility;
- Vehicle operating distances during pull-in.

To construct the model, a typical day of transit bus operations was segmented into the following three parts:
1. *A pullout* from the bus storage facility to the starting point of a revenue service route;
2. Revenue service *runs*;
3. *A pull-in* to the facility from the end of a revenue service route.

A summary of daily bus operating activities is presented in Table 1. The first and the third segments are highly dependent on proximity of the facility to the start and ends of service routes. These segments of non-revenue operation are called *deadhead*. Closely related to deadhead travel is individual operator travel between the Facility and specified points along the service route for *relief* purposes.

Note that other non-revenue cost items are incurred during revenue service operations that are not ordinarily affected by location of a facility but the actual run construction. These items are therefore not included in the non-revenue operating cost calculations. As identified in Table 1, these items include layovers and interlining. *Layovers* may involve killing time at a station to conform to a schedule; this may also be a built-in buffer to be absorbed by delays during scheduled service. *Interlining* is travel between different lines to give relief.

C. MODEL ASSUMPTIONS

At the background of model development and application were the following assumptions:
- Bus operations, including in-service routes, service frequency, conditions of service plus peak and off-peak operating vehicles would remain at existing levels for all candidate sites.
- Bus operations policies and procedures would remain unchanged.
- Deadhead routes for all of the candidate sites should follow the shortest distance travel route appropriate for bus use.
- Since buses can operate for 18 hours before returning to the facility, deadheading of concern is that related to pull-ins and pullouts of vehicles from service. Deadheading due to interline relief would remain unchanged despite facility location and thus was not considered.
- For each candidate site (whether existing or proposed), alternative relief points were selected to ensure convenience of travel for relief via existing transit service routes. These lists constituted a set of alternative relief plans
- Operator relief travel times were estimated according to standard MTA procedure as half the off-peak (10:00 a.m. to 2:00 p.m.) headway of the service route used plus the actual running time of the bus.
- The maximum efficient size of a bus storage and maintenance facility was set at 300 buses.
- Unit operating costs in the Baltimore area were \$29.55 per hour for labor and \$0.81 per kilometer (\$1.35 per mile) for buses.

D. MODELING PROCESS

Data

To develop the model, detailed, block-level operational data was obtained from the MTA on the two existing facilities at Kirk Avenue and Eastern Avenue that were under study for possible consolidation into a new Northeast Facility. The primary data-set was provided via a standard MTA report entitled *Scheduled Miles and Hours Report*, which among other items, contained pullout and pull-in times and miles by individual routes and blocks operating out of each facility. Another standard MTA report, *The Block Summary,* identified service terminals by individual routes and blocks.

Relief travel data was provided via the *Run Break Data* which identified the routes, time of day, relief points and allowable relief times for existing facilities. The MTA provided a set of plans suggesting alternative relief points with allowable times for each of the five candidate sites studied. Geographical coordinates were determined for each existing and proposed facility and for all service terminals. These coordinates enabled GIS application in the development and application of the model and eased the repetitive calculations required.

A database was created which combined the various items of data identified. All required calculations used this database.

Steps

Figure 2 is a flowchart of the overall modeling procedure. In summary, model steps are the following:

- Key data items in the compiled database were used to estimate such vital data as circuity factor, route miles, travel speeds and travel times.
- The vital data were used to project quantities of cost components including pullout and pull-in distances and times.
- Unit costs were applied to the components to obtain individual cost elements. Table 2 shows the derivation of the five cost elements.
- The final non-revenue operating cost was determined for the service block as a simple summation of the five cost elements.

This entire procedure was applied to each individual service block and repeated for each of four schedules and then summed to obtain the yearly cost of operating various blocks of service. Table 3 identifies the schedules and periods covered. The yearly costs of the appropriate collection of service blocks were added to obtain the cost of operating out of various sites.

Equations

1. Determine **distances** (d_r) between pairs of origins and destinations comprising service terminals and divisions.

2. Determine travel **speeds** (s_{b0}) or (s_{bi}) using existing distance [(d_{eo}) or (d_{ei})] and time [(t_{eo}) or (t_{ei})] data for individual pullout and pull-in operations respectively.

$$S_{bo} = (d_{eo}) / (t_{eo}) \quad \textbf{(1)}$$
$$S_{bi} = (d_{ei}) / (t_{ei}) \quad \textbf{(2)}$$

3. Calculate **travel time**s for *pullout* (t_o) *and pull-in* (t_i) *respectively*.

$$t_o = d_r / s_{bo} \quad \textbf{(3)}$$
$$t_i = d_r / s_{bi} \quad \textbf{(4)}$$

4. Calculate **relief travel times** from service schedule as half off-peak headway (*hd*) plus bus run time (t_{ij})

$$t_r = 0.5hd + t_{ij} \quad \textbf{(5)}$$

5. Calculate **non-revenue operating cost** as the sum of the following:

Bus operation cost for pullout (c_{bo}) & pull-in (c_{bi})

$$C_{bo} = (d_{ro}) \times (b_c) \quad \textbf{(6)}$$
$$C_{bi} = (d_{ri}) \times (b_c) \quad \textbf{(7)}$$

where $b_c = \$1.35$

Labor cost for pullout (c_{lo}) & pull-in (c_{li})

$$C_{lo} = (t_o) \times (l_c) \quad \textbf{(8)}$$
$$C_{li} = (t_i) \times (l_c) \quad \textbf{(9)}$$

where $l_c = \$.29.55$

Labor cost for relief travel

$$C_r = (t_r) \times (l_c) \quad \textbf{(10)}$$

so that

$$C_k = C_{bo} + C_{lo} + C_{bi} + C_{li} + C_r \quad \textbf{(11)}$$

6. Calculate **yearly non-revenue operations cost** as the sum of costs (C_k) for schedules (z) used over various numbers of days (D_k) through the year.

$$C_y = \sum_z (C_k \times D_k) \text{ . . summed over z schedules in the year} \quad \textbf{(12)}$$

7. Assign service blocks to Divisions or candidate sites with the objective of minimizing total non-revenue operating costs. This is expressed as

$$min \sum_{k}\sum_{j}\sum_{i} (C_{ij}) \quad \textbf{(13)}$$

where:
$i = 1, \ldots, n$ -- *number of service blocks under study*
$j = 1, \ldots, m$ -- *number of Divisions under study*
$k = 1, \ldots, z$ -- *number of schedules used in the year*

$$C_{ij} = \sum_{z} (C_k \times D_k) \quad \text{summed over z schedules in the year} \quad \textbf{(14)}$$

E. MODEL APPLICATION

Sites

The modeling procedure was applied to the following group of five sites:

- The existing *Kirk Facility* and *Eastern Facility* that were under consideration for possible consolidation;
- The existing *Bush Facility* which was included to absorb potential overflow of buses and services from the northeast;
- Two new locations: one is off *Biddle Street* east of Edison Highway; the other is called the *Abandoned Vehicle* site east of Interstate 895 and south of Moravia Road.

Accuracy

To assess the accuracy of the model, its results were compared with existing operations data for the Kirk and Eastern facilities. Figure 3 shows a comparison of modeled versus actual cost component data. The following are noteworthy:

- The non-revenue operations cost model projected individual components of deadhead operations to within 4 percent of actual data.
- The model underestimated relief travels by approximately 10 percent of actual data. Note that certain inaccuracies spotted in actual data could account for some difference.
- When components were aggregated, the overall margin of error was 1 percent.

Comparisons

Table 4 provides the cost components of deadhead and relief operations and compares total yearly costs by Facility. Under the first level ranking shown in Table 4, cost comparisons assume hypothetical relocation of all the four hundred existing buses and associated services from Kirk and Eastern to each of the five potential locations. Results offer the following overview: (a) Overall Facility ranking by yearly non-revenue operating cost identified Kirk and Biddle Street as the most favorable locations; the Abandoned Vehicle site was the least favorable. (b) Despite overall ranking, various services could operate out of each potential location at the least deadhead and relief cost as shown in Figure 4.

Under existing operations, relief travel accounted for less than 10 percent of the non-revenue operations cost. Modeled costs depicted a range of nine to 12 percent in relief travel excluding the Abandoned Vehicle site where it would be approximately 40 percent if all required relief travel were feasible via existing bus service routes. This is so because existing services that served the Abandoned Vehicle site were limited to peak periods with long headways which meant allowable relief travel time to this site would start at two hours and 40 minutes.

F. RESULTS OF COST MINIMIZATION SCENARIOS

For realistic assessments, various operating scenarios were tested that involved distribution of services to combinations of existing and proposed facilities. The objective was to minimize non-revenue operations costs. Table 5 shows cost comparisons based on various operating scenarios. Each of these scenarios is further compared with existing operations cost to assess potential cost savings or extra expenditure. In an outline, results depict the following:

- Scenarios that involve expansion of Bush, by moving all 100 excess buses to that location, were the least rated of all tested scenarios. Refer to scenario 8 and 9.

- Scenarios that involve use of Bush by moving only those few services (14 blocks) which could operate at the least cost out of that location, were among the best rated. Refer to scenario 1, 3 and 5.

- Reconstruction of the existing Kirk facility showed a slight edge, in terms of non-revenue operating cost, over new construction at the Biddle site.

- If reconstruction of Kirk were the selected option, the most promising scenario would be scenario 1:
  - a new Kirk with 270 buses;
  - downsize Eastern to a 120-bus facility;
  - assign approximately 14 bus services (10 buses) to Bush.

- If construction of Biddle were the selected option, the most promising scenario would be scenario 3 that resulted from tweaking scenario 5:
  - construct Biddle to replace Eastern and operate 170 buses out of Biddle (similar to Northwest which is the newest of the existing facilities);
  - maintain the existing size of Kirk as a 220-bus facility;
  - assign approximately 14 bus services (10 buses) to Bush;
  - close Eastern.

- Scenarios 1 and 2, which hinge around Kirk as the major facility without construction of a new site, showed potential yearly cost savings over existing operations. All others suggested varying degrees of additional expenditure.

- The yearly cost differential of scenario 3 from existing non-revenue operating cost was 0.5 percent which was within the overall margin of error of the model; this could be considered a "break-even" scenario when compared with existing operations.

- Scenario 4 was within a 4 percent margin while 5 and 6 were within a 5 percent margin. The remainders of the scenarios projected cost differentials above 10 percent.

- It was concluded therefore that scenarios number 1 through 6 were worth further consideration.

G. CONCLUDING OBSERVATIONS

Application of the *Non-Revenue Operations Cost Model* helped with the following:

- Identification of one existing facility site at Kirk Avenue and a new site off Biddle Street as the two top choices for a modern bus facility for northeast Baltimore. A full economic analysis will aid in the final choice of a site based on total cost of construction and operation. That analysis will include both the non-revenue operations costs from the model and capital costs of real estate acquisition, site development and construction.

- Identification of the particular bus transit services to place between the selected site and existing facilities to ensure the least cost of non-revenue operations. The cost minimizing benefits are also obtainable if the model is applied to existing facilities without consideration of a new site.

- Determination of the number of buses and associated services to redistribute among both existing and proposed facility locations.

H. MODEL APPLICABILITY

The author believes that this model could be widely applied to various transit operations nationwide. It will use data that is readily available on existing transit operations. It is simple in concept but detailed enough in scope to ensure a high level of accuracy. The efficiency gained by reducing operating costs is not envisioned to result in loss of jobs. Considering the common goal of transit operating agencies to attain greater efficiency in transit operations and such specific requirements as 50 percent farebox recovery, the need to evaluate operations with this type of model cannot be overemphasized.

The *Non-Revenue Operations Cost Model,* which estimates and compares relevant non-revenue operating cost items therefore has the following applications: (a) As a tool to evaluate existing operations by determining the optimal distribution of services and vehicles between storage and maintenance facilities; and (b) as a tool for identifying the location with the lowest non-revenue operating cost from among a set of candidate sites either for expansion or for new construction.

Beyond transit operations, the model is extendable to governmental and municipal facilities for storage and maintenance of vehicle fleet and other equipment used in street cleaning, snow removal, highway maintenance and incident management as a tool for both site selection and distribution of units among various locations.

ACKNOWLEDGMENT

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TABLE 1
Summary of Daily Bus Operating Activities

SEGMENT		ACTIVITY	COSTS INVOLVED	
			OPERATOR	VEHICLE
1. PULLOUT				
Begin		pullout from facility to beginning of service route	Y	Y
2. REVENUE SERVICE				
Runs	N/A	ply service route according to a schedule, pick up and drop off patrons at specified stops	Y	Y
Layover	N/A	kill time at a station to conform to a schedule; could be a buffer to absorb delays during runs	Y	
Relief		get relief at the facility	Y	
		give relief at the facility	Y	
	N/A	travel between lines to give relief (interlining)	Y	
3. PULL-IN				
End		pull-in to facility from the end of service route	Y	Y

Y--*Yes (involves non-revenue operation and cost)*
N/A--*Not applicable in scope of cost calculations*

TABLE 2
The Individual Cost Elements

COMPONENT		UNIT COST	COST ELEMENT
ITEM	**UNIT**		
Operator Relief Travel Time	hour	$29.55	Relief Labor Cost
Bus Pullout Time	hour	$29.55	Pullout Labor Cost
Bus Pullout Distance	kilometer	$0.81	Pullout Bus Operating Cost
Bus Pull-in Time	hour	$29.55	Pull-in Labor Cost
Bus Pull-in Distance	kilometer	$0.81	Pull-in Bus Operating Cost
Summation	**block**	----	**Non-Revenue Operating Cost**

Notes:
1 kilometer = 0.6 mile
bus operation = $0.81 per kilometer ($1.35 per mile)

TABLE 3
Yearly Cost Derivation

SCHEDULE	PERIOD COVERED	NUMBER OF DAYS
Fall Weekday Summer Weekday Saturday Sunday	Fall and Winter (Labor Day to Mid-June) Mid-June to Labor Day Saturdays Sundays and Holidays	200 54 53 58
TOTAL	**ALL-YEAR**	**365**

TABLE 4
Comparative Costs of Operating from Alternative Locations
(YEARLY COST OF NON-REVENUE OPERATION)

LOCATION	TOTALS							
	BUS NON-REVENUE KILOMETERS	DEADHEAD LABOR TIME (hours)	RELIEF LABOR TIME (hours)	BUS COST (DEADHEAD)	LABOR COST (DEADHEAD)	LABOR COST (RELIEF)	GRAND TOTAL COST	OVERALL RANK
BIDDLE/CHASE DIVISION								
EASTERN SERVICES	848,562	33,194	*11,059*	*$687,405.70*	*$980,999.86*	*$326,813.70*	*$1,995,219.26*	
KIRK SERVICES	1,502,686	55,529	*9,596*	*$1,217,277.91*	*$1,641,099.38*	*$283,599.50*	*$3,141,976.79*	
COMBINED SERVCES	2,351,248	88,723	*20,656*	*$1,904,683.61*	*$2,622,099.24*	*$610,413.20*	***$5,137,196.05***	*2nd*
ABANDONED VEHICLE DIVISION								
EASTERN SERVICES	949,227	38,616	*64,514*	*$768,959.00*	*$1,141,207.87*	*$1,906,389.06*	*$3,816,555.93*	
KIRK SERVICES	1,725,337	66,023	*57,653*	*$1,397,453.91*	*$1,951,135.03*	*$1,703,656.00*	*$5,052,244.94*	
COMBINED SERVCES	2,674,563	104,639	*122,168*	*$2,166,412.91*	*$3,092,342.90*	*$3,610,045.06*	***$8,868,800.87***	*5th*
KIRK DIVISION								
EASTERN SERVICES	1,015,141	41,541	*14,039*	*$822,286.31*	*$1,227,659.97*	*$414,871.37*	*$2,464,817.65*	
KIRK SERVICES	1,256,528	44,199	*6,523*	*$1,017,898.11*	*$1,306,222.29*	*$192,753.63*	*$2,516,874.03*	
COMBINED SERVCES	2,271,668	85,739	*20,562*	*$1,840,184.42*	*$2,533,882.26*	*$607,625.00*	***$4,981,691.68***	*1st*
EASTERN DIVISION								
EASTERN SERVICES	856,594	31,662	*5,734*	*$693,810.53*	*$935,634.19*	*$169,384.18*	*$1,798,828.90*	
KIRK SERVICES	1,833,954	68,024	*12,222*	*$1,485,568.91*	*$2,010,214.10*	*$361,216.60*	*$3,856,999.61*	
COMBINED SERVCES	2,690,549	99,686	*17,956*	*$2,179,379.44*	*$2,945,848.29*	*$530,600.78*	***$5,655,828.51***	*3rd*
BUSH DIVISION								
EASTERN SERVICES	1,362,875	55,560	*15,273*	*$1,103,967.82*	*$1,641,866.80*	*$451,267.93*	*$3,197,102.55*	
KIRK SERVICES	1,990,271	69,857	*9,779*	*$1,612,204.25*	*$2,064,416.92*	*$288,970.27*	*$3,965,591.44*	
COMBINED SERVCES	3,353,146	125,417	*25,052*	*$2,716,172.07*	*$3,706,283.72*	*$740,238.20*	***$7,162,693.99***	*4th*
EXISTING CONDITIONS								
EASTERN SERVICES	856,594	31,662	*5,734*	*$693,810.53*	*$935,634.19*	*$169,384.18*	*$1,798,828.90*	
KIRK SERVICES	1,256,528	44,199	*6,523*	*$1,017,898.11*	*$1,306,222.29*	*$192,753.63*	*$2,516,874.03*	
TOTAL SEPARATE SERVCES	2,113,122	75,861	*12,257*	*$1,711,708.64*	*$2,241,856.48*	*$362,137.81*	***$4,315,702.93***	*

NOTES:

1 kilometer = 0.6 mile

bus operation = $0.81 per kilometer ($1.35 per mile)

labor rate = $29.55 per hour

TABLE 5
Comparison of Alternative Operating Scenarios
(YEARLY COST OF NON-REVENUE OPERATION)

#	ALTERNATIVE SCENARIO	LOCATION		NON-REVENUE OPERATING COST BLOCKS	BUSES	COST	RANK
1	NEW KIRK	MAIN	KIRK	405	270	$2,925,730.51	
	- DOWNSIZE EASTERN	MINOR	EASTERN	176	120	$1,072,556.00	
	& USE BUSH	OTHER	BUSH	14	10	$89,778.69	
			total			$4,088,065.20	1ST**
2	NEW KIRK	MAIN	KIRK	405	270	$2,936,807.46	
	& DOWNSIZE EASTERN	MINOR	EASTERN	190	130	$1,164,559.13	
		OTHER					
			total			$4,101,366.59	2ND**
3	CONSTRUCT BIDDLE TO REPLACE EASTERN	MAIN	KIRK	322	220	$2,307,356.84	
	- KEEP KIRK	MINOR	BIDDLE	259	170	$1,903,323.69	
	- CLOSE EASTERN & USE BUSH	OTHER	BUSH	14	10	$89,778.69	
	(tweak #5)		total			$4,300,459.22	3RD
4	CONSTRUCT BIDDLE	MAIN	BIDDLE	405	270	$3,214,537.35	
	- DOWNSIZE KIRK & DOWNSIZE EASTERN	MINOR	KIRK	66	45	$484,750.94	
		OTHER	EASTERN	124	85	$731,501.27	
			total			$4,430,789.56	4TH
5	CONSTRUCT BIDDLE	MAIN	BIDDLE	405	270	$3,122,929.94	
	- DOWNSIZE KIRK	MINOR	KIRK	170	115	$1,188,189.73	
	- CLOSE EASTERN & USE BUSH	OTHER	BUSH	20	15	$148,082.71	
			total			$4,459,202.38	5TH
6	CONSTRUCT BIDDLE	MAIN	BIDDLE	405	270	$3,115,647.80	
	- DOWNSIZE KIRK	MINOR	KIRK	190	130	$1,344,584.01	
	& CLOSE EASTERN	OTHER					
			total			$4,460,231.81	6TH
7	CONSTRUCT BIDDLE	MAIN	BIDDLE	450	300	$3,919,922.66	
	- DOWNSIZE EASTERN	MINOR	EASTERN	145	100	$832,280.18	
	& CLOSE KIRK	OTHER					
			total			$4,752,202.84	7TH
8	CONSTRUCT BIDDLE	MAIN	BIDDLE	450	300	$3,682,123.94	
	- USE BUSH	MINOR	BUSH	145	100	$1,286,008.69	
	- CLOSE KIRK & CLOSE EASTERN	OTHER					
	(tweak #10)		total			$4,968,132.63	8TH
9	NEW KIRK & USE BUSH	MAIN	KIRK	450	300	$3,792,430.36	
	& CLOSE EASTERN	MINOR	BUSH	145	100	$1,275,377.22	
		OTHER					
			total			$5,067,807.58	9TH
10	CONSTRUCT BIDDLE	MAIN	BIDDLE	595	400	$5,137,196.05	
	- CLOSE KIRK & CLOSE EASTERN	MINOR					
		OTHER					
			total			$5,137,196.05	10TH
			KIRK	336	220	$2,500,334.95	
0	CONTINUE OPERATION AS EXISTING		EASTERN	259	180	$1,779,717.94	
			total			$4,280,052.89	AFTER 2ND

FIGURE 1
CONCEPTUAL DIAGRAM FOR PULL-OUT AND PULL-IN OPERATIONS

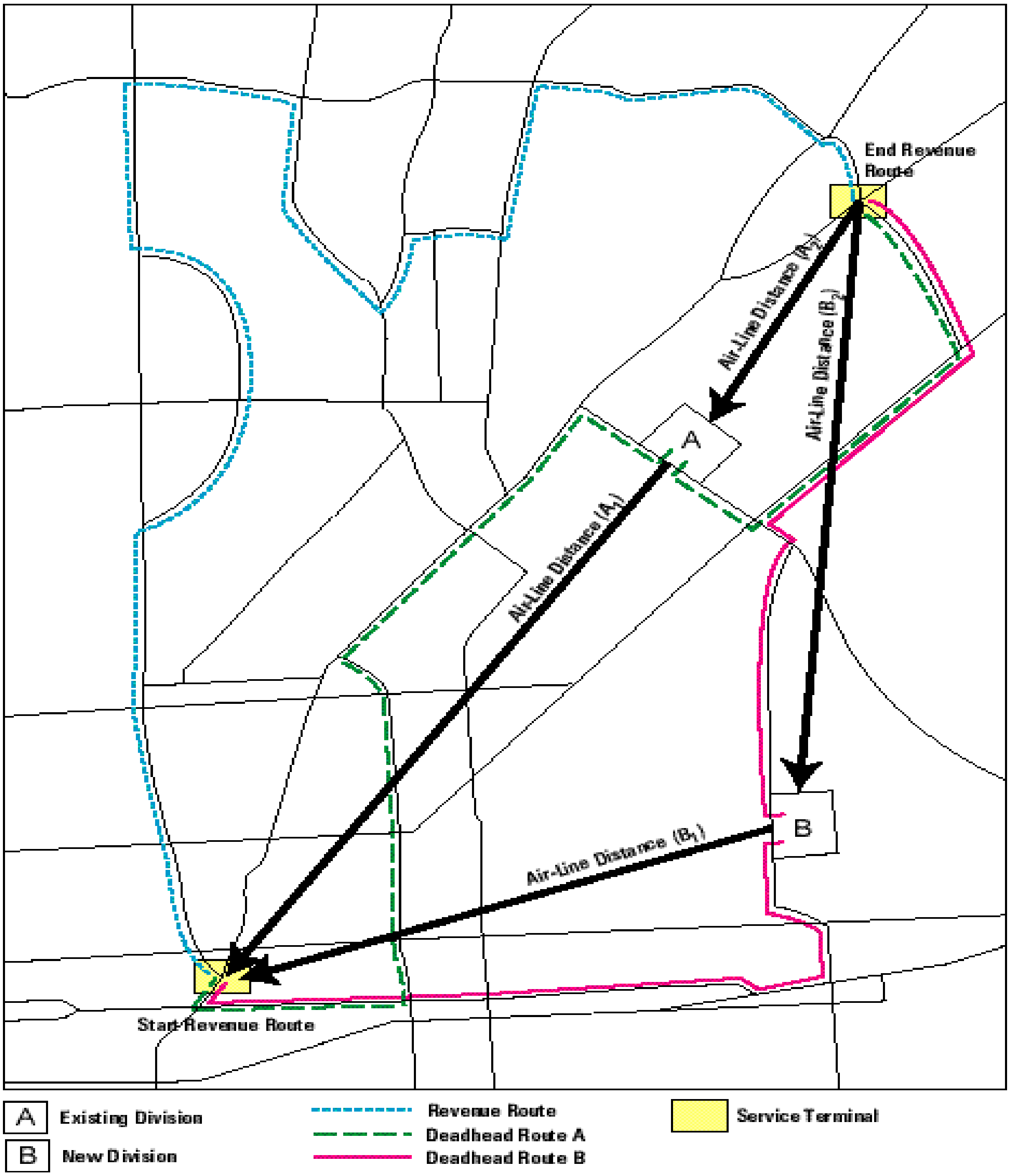


FIGURE 2
FLOWCHART OF THE MODELING PROCEDURE

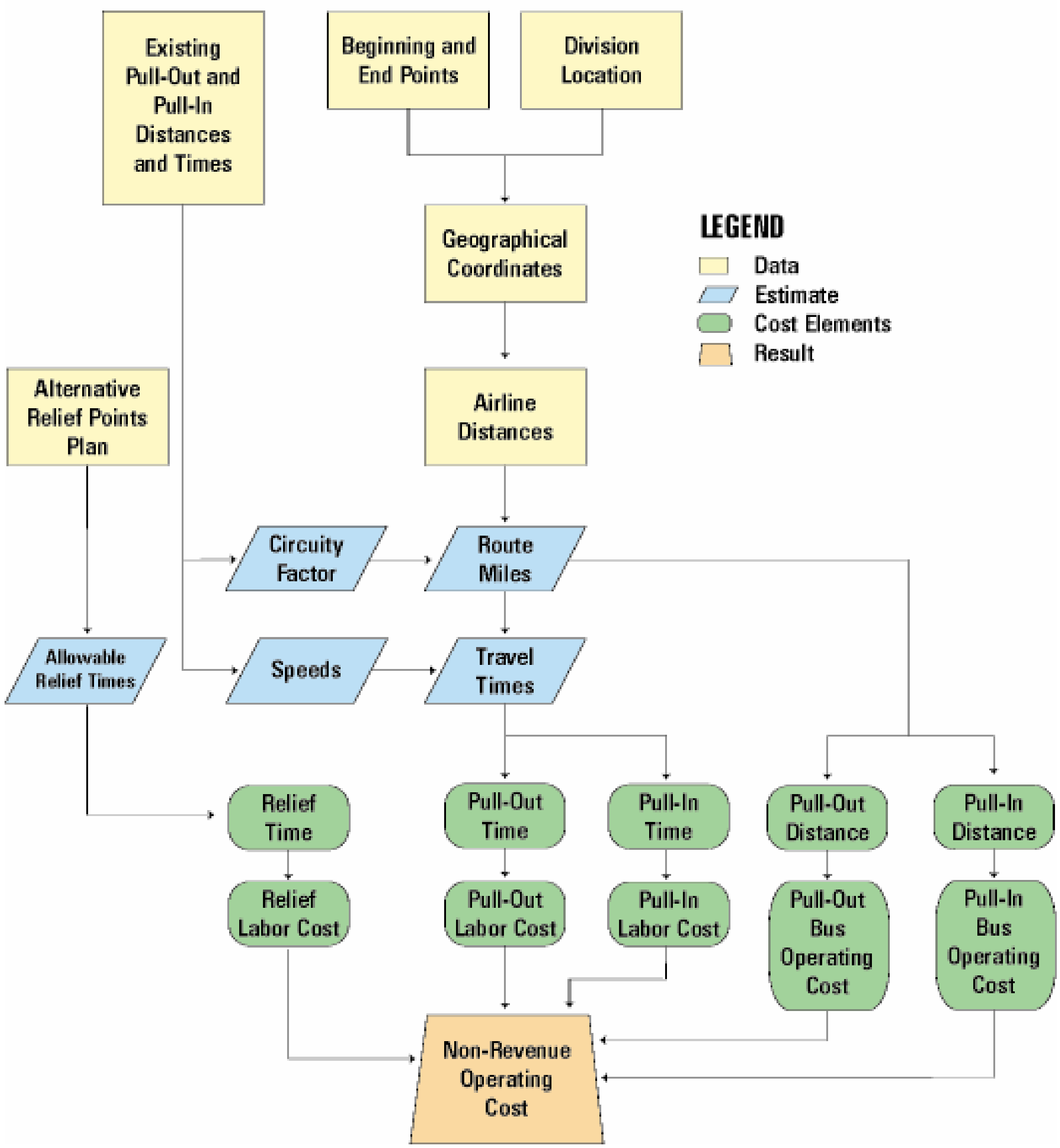


FIGURE 3

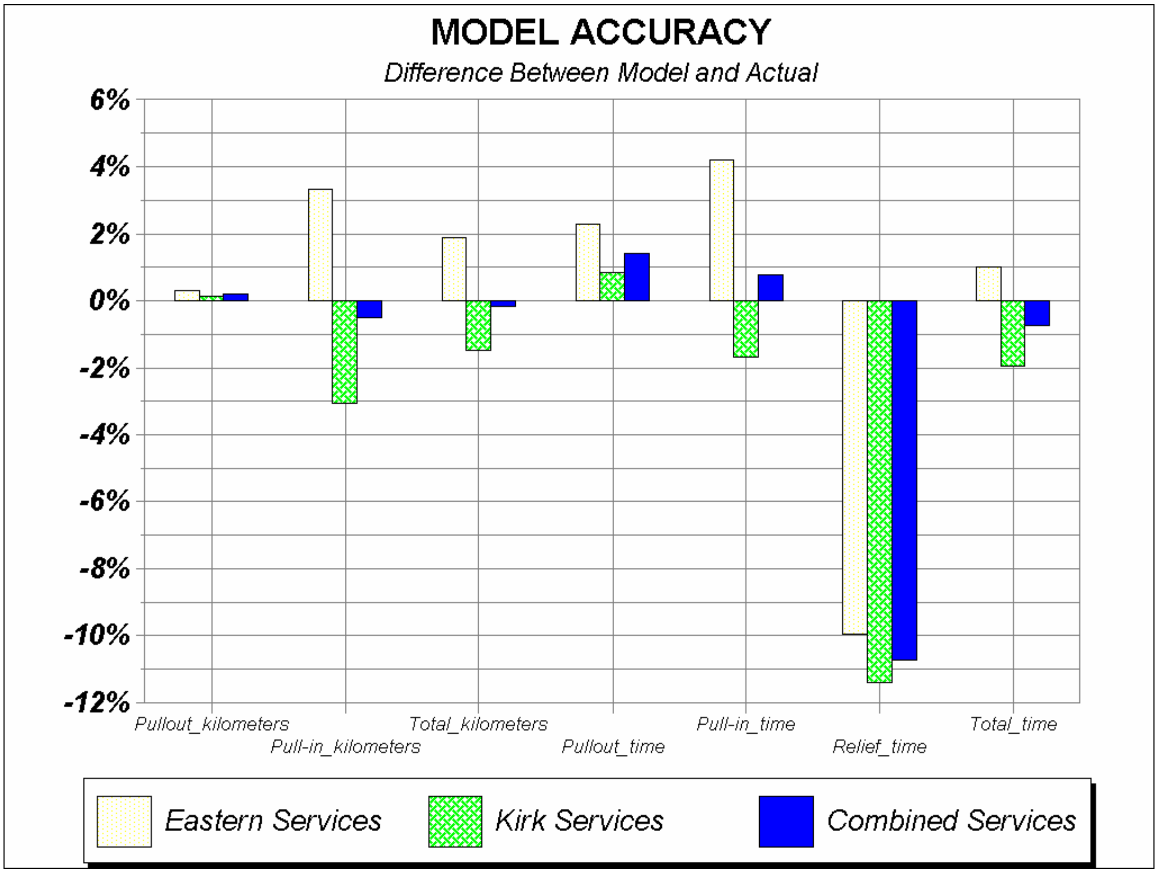
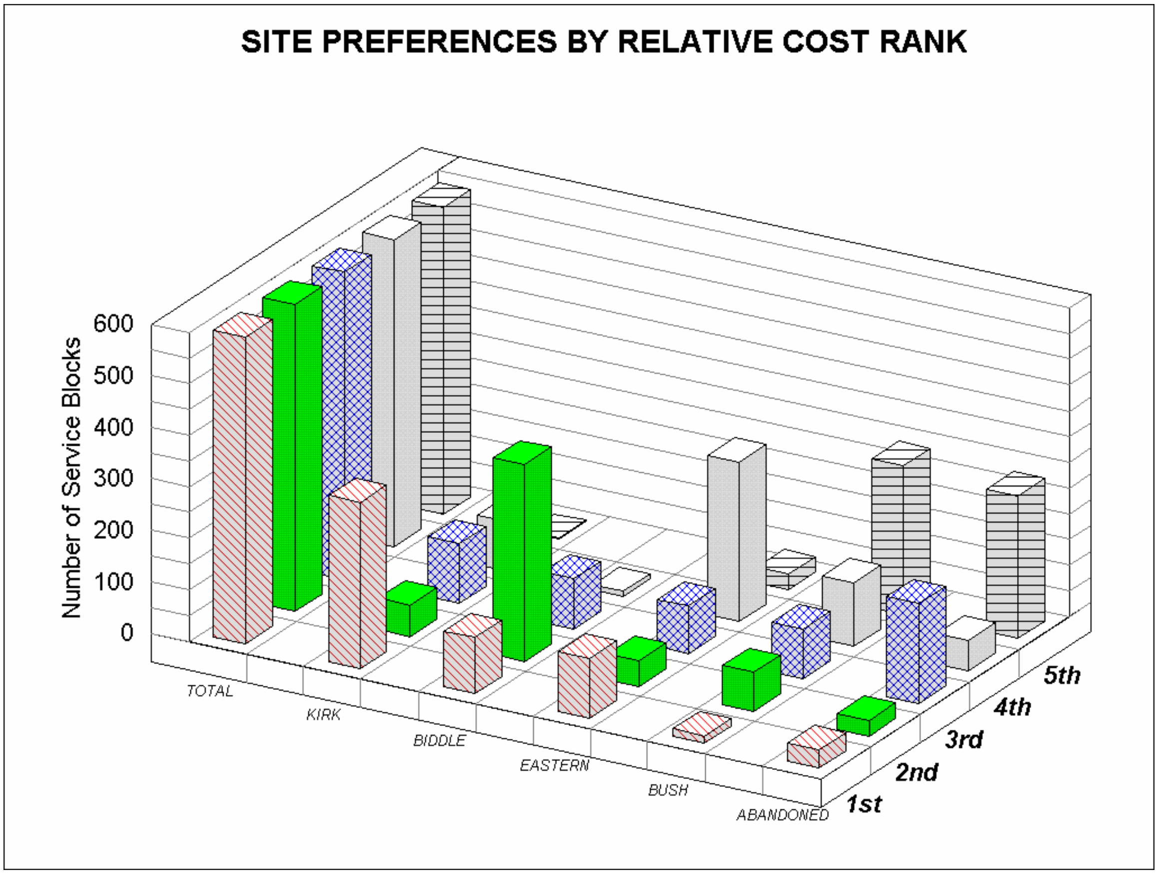

MODEL ACCURACY
Difference Between Model and Actual
6%
4%
2%
0%
-2%
-4%
-6%
-8%
-10%
-12%
Pullout_kilometers
Pull-in_kilometers
Total_kilometers
Pullout_time
Pull-in_time
Relief_time
Total_time
Eastern Services
Kirk Services
Combined Services

FIGURE 4


SITE PREFERENCES BY RELATIVE COST RANK
Number of Service Blocks
600
500
400
300
200
100
0
TOTAL
KIRK
BIDDLE
EASTERN
BUSH
ABANDONED
1st
2nd
3rd
4th
5th

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