FINAL REPORT

HIGHWAY COST ALLOCATION STUDY

FOR

THE MARYLAND TRANSPORTATION AUTHORITY

TOLL FACILITIES

SUBMITTED TO

MARYLAND TRANSPORTATION AUTHORITY
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APRIL 2009

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HIGHWAY COST ALLOCATION STUDY

EXECUTIVE SUMMARY

A Highway Cost Allocation Study (HCAS) was conducted for each of the Maryland Transportation Authority's (the Authority's) seven toll facilities. The objective of this study was to evaluate the relative share of facility costs that is attributable to each vehicle class in the Authority's toll structure. A thorough literature review of past federal and state HCAS was conducted in order to develop an appropriate analysis procedure for the Authority's facilities. The HCAS procedure implemented for the Authority is based on the 1997 Federal HCAS with supplementary material from other state HCAS. Technical details of the approach are described in the *Phase I Interim Report: Pilot Implementation of Cost Allocation Methodology*.

A thorough HCAS requires extensive and detailed information in the following categories:

1. Facility Inventory Data: These include pavement type, length, and number of lanes and bridge type, span, and structural configuration for each highway infrastructure component at each facility. Other infrastructure features such as toll plazas, guard rails, light poles, etc. are also included.

2. Traffic Data: These include vehicle miles of travel (VMT), passenger car equivalent (PCE) values, and vehicle/axle weight distributions by vehicle class for each facility.

3. Expenditure Data: These include costs for initial construction, periodic rehabilitation, maintenance activities, and administrative overhead for each facility (past and future).

4. Revenue and Toll Data: These include total toll revenue, nominal toll structure, and average effective toll rate after discounts by vehicle class for each facility.

A thorough search of all data available from the Authority was conducted at the start of this study. Where necessary, relevant information from the literature was obtained to supplement the Authority's data. Vehicle axle load distributions, in particular, were estimated using data from the FHWA Long Term Pavement Performance database.

Project expenditure data, often dating back to each facility's initial construction, were compiled from construction, rehabilitation, and repair contracts at each facility. The Authority also provided projected future preservation and enhancement expenditure data in three categories: Programmed Funded Projects (2008-2013), Unfunded Capital Needs (2008-2013), and Unfunded Long Range Needs (2014-2026). All costs were adjusted to 2005 dollars using the *Engineering News Record* (ENR) time series of material and labor construction costs.

Routine maintenance activities performed by Authority staff were also included in the HCAS. Average annual maintenance expenditures compiled for 2001 through 2005 were assumed to be typical for all years in the study period, with appropriate adjustments for inflation.

Toll data were based on traffic and revenue data by vehicle class for fiscal year 2006. This information was used to determine the average effective toll rate currently paid by each vehicle class after deducting

commuter and truck discounts. Tables 1 and 2 show percents of traffic and percents of revenue by class for all facilities for fiscal year 2006, respectively.

Table 1. Percent of Traffic by Class for All Facilities for Fiscal Year 2006

Traffic in 2006	JFK	WPL	HWN	BHT	FSK	TJH	FMT	All Facilities
Two-Axle	87.03%	91.61%	90.69%	96.61%	89.80%	95.00%	91.21%	91.95%
Three-Axle	1.61%	1.16%	1.29%	1.33%	2.11%	1.95%	1.36%	1.46%
Four-Axle	1.21%	1.01%	1.46%	0.48%	1.31%	0.50%	0.90%	0.90%
Five-Axle	9.90%	6.10%	6.34%	1.57%	6.60%	2.53%	6.43%	5.57%
Six(+)-Axle	0.26%	0.12%	0.21%	0.01%	0.18%	0.03%	0.10%	0.11%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 2. Percent of Revenue by Class for All Facilities for Fiscal Year 2006

Revenue in 2006*	JFK	WPL	HWN	BHT	FSK	TJH	FMT
Two-Axle	64.09%	71.76%	68.67%	86.32%	56.91%	31.11%	68.24%
Three-Axle	2.42%	2.16%	2.41%	3.49%	5.13%	10.77%	2.73%
Four-Axle	2.73%	2.83%	4.12%	1.89%	4.79%	8.10%	2.71%
Five-Axle	29.79%	22.71%	23.79%	8.21%	32.09%	49.03%	25.80%
Six(+)-Axle	0.98%	0.54%	1.00%	0.09%	1.09%	0.98%	0.52%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
* based on traffic & current toll w/discounts							

Across all Authority facilities, two-axle vehicles currently pay 68% of post-discount toll revenues (FY 2006) while vehicles with three or more axles pay 32%. These percentages can be compared to national statistics from the 1997 Federal HCAS which found that 60% of highway construction and maintenance costs are attributable to passenger vehicles and the remaining 40% to trucks. Combined cost allocations across all Authority facilities suggested by the HCAS based on historical expenditures and various combinations of projected future costs range from 49 to 64% for two-axle vehicles and 36 to 51% for vehicles with three or more axles (Table). In all cases, five-axle trucks are responsible for the major portion of costs attributable to vehicles with three-axles or more.

Table 3. Summary of percentage of combined costs by vehicle toll classes

Study	Number of Axles				
	2	3	4	5	6+
Current (2006) Revenue w/Discounts	68.3%	2.9%	2.9%	25.2%	0.7%
HCAS w/Historical Costs	64.3%	2.4%	1.8%	31.2%	0.3%
HCAS w/Historical Costs and Future A	59.9%	2.4%	1.7%	35.8%	0.3%
HCAS w/Historical Costs and Future A+B	54.7%	2.3%	1.7%	41.0%	0.2%
HCAS w/Historical Costs and Future A+B+C	48.9%	2.6%	1.6%	46.7%	0.2%

Notes: Future A costs = Programmed Funded Projects (2008-2013)
Future B costs = Unfunded Capital Needs (2008-2013)
Future C costs = Unfunded Long Range Needs (2014-2026)

Figure 1 depicts the ratios of the "fair share" revenues (i.e., the revenues suggested by the HCAS based on the contribution of the vehicle class to overall costs) to current post-discount revenues by toll class (two-axle vs. three-axles or more) and expenditure scenario (historical only or historical plus various combinations of projected future costs). Ratios higher than 1.0 correspond to vehicle classes that are responsible for more costs than they currently pay—i.e., that are currently undercharged. Ratios lower

than 1.0 represent vehicle classes that have a lower cost responsibility than they currently pay—i.e., that are currently overcharged. Overall, two-axle vehicles currently pay more than their fair share of historical costs while trucks (5 axle trucks, in particular) pay less. This disparity increases when future outlays are included, with two-axle vehicles paying progressively more than their fair share and trucks paying progressively less.

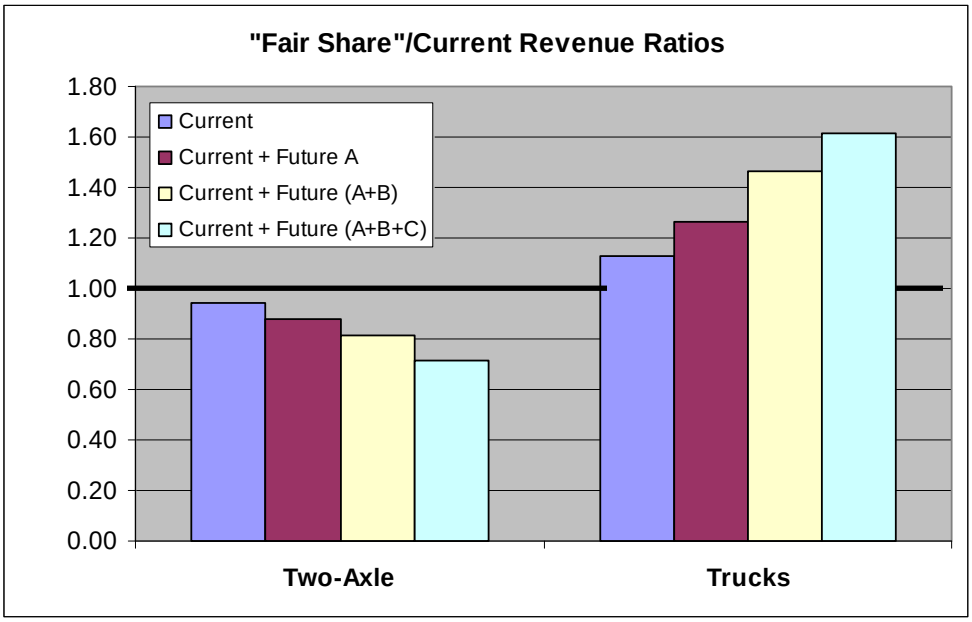

Figure 1. System-wide revenue ratios. "Fair Share" Revenues correspond to HCAS findings, "Current" revenues correspond to FY 2006 totals after all discounts.

As detailed in the body of the report, a separate HCAS analysis is performed for each of the Authority's seven toll facilities. Results for each facility include:

(a) Current nominal (pre-discount) and effective (post-discount) tolls by vehicle class;
(b) Nominal and effective tolls as determined by HCAS allocation of historical facility costs to each vehicle class;
(c) Nominal and effective tolls after HCAS allocation of historical and projected future facility costs by vehicle class; and
(d) Percent share of total facility costs (historical and historical plus future) by vehicle class.

The HCAS toll allocations are adjusted to be revenue-neutral for each facility. That is, the total projected revenue that would be generated by the HCAS-allocated toll structure for the specific vehicle mix at that facility is set equal to the actual FY 2006 revenue reported for that facility.

Table 4 summarizes the percentage toll changes by vehicle class for each facility that are suggested by the HCAS analysis results for the case of historical expenditures only. "Current tolls" are FY 2006 effective tolls after all discounts, and "HCAS tolls" are scaled to provide total revenues equal to the actual FY 2006 totals for each facility. Although the detailed results vary by facility, the overall trend is an increase in HCAS tolls for five-axle trucks and a decrease for all other vehicle classes for revenue neutral conditions. The exceptions to this trend are the Key and Hatem Bridges, both of which have a significant proportion of truck and commuter transactions and currently offer substantial toll discounts, including commuter plans for two-axle vehicles.

Table 4. HCAS-suggested toll change percentages by vehicle class and facility (historical expenditures only).

Vehicle Class	JFK Highway	Bay Bridge	Nice Bridge	Baltimore Harbor Tunnel	Key Bridge	Hatem Bridge	Fort McHenry Tunnel
2 axle	-19%	-6%	-1%	-8%	21%	174%	0%
3 axle	-29%	-3%	-12%	32%	-35%	-64%	-25%
4 axle	-46%	-21%	-26%	-19%	-51%	-87%	-28%
5 axle	49%	24%	11%	77%	-22%	-81%	7%
6+ axle	-62%	-34%	-39%	-56%	-66%	-91%	-49%

HIGHWAY COST ALLOCATION STUDY

FINAL REPORT

1.0 PURPOSE

This report summarizes the Highway Cost Allocation Study (HCAS), conducted for each of the Maryland Transportation Authority's (the Authority's) seven toll facilities: John F. Kennedy Memorial Highway, William Preston Lane Jr. (Bay) Bridge, Governor Harry W. Nice Bridge, Baltimore Harbor Tunnel, Francis Scott Key Bridge, Thomas J. Hatem Memorial Bridge, and the Fort McHenry Tunnel.

The purpose of the HCAS is to evaluate the relative share of facility costs that is attributable to each vehicle class in the Authority's toll structure. The 1997 Federal Highway Cost Allocation Study found that while passenger vehicles account for 93% of total VMT and trucks account for 7%, 60% of highway construction and maintenance costs are attributable to passenger vehicles and the remaining 40% to trucks. The Authority's current 31% of net adjusted revenue from trucks is lower than the national average determined by FHWA.

The objectives of the proposed study are as follows:

1. Develop an analytical model based on current and accepted best practices to evaluate the relative cost of system development and degradation attributable to each vehicle class in the Authority's vehicle tolling structure. This cost allocation model must be sufficiently robust to be applicable for the entire diverse composition of the Authority's facilities and should use methodologies appropriate for assessing costs to individual vehicle classes.

2. Apply the cost allocation model to each toll facility individually to assess the infrastructure development and degradation costs attributable to each vehicle class and the corresponding share of maintenance and rehabilitation costs. This will require that the study team compile relevant Authority data for vehicle characteristics (e.g., classification and axle load distributions) and facility features (e.g., number and type of structures, length and type of paving, etc.).

This study shall focus only on determining a rational distribution of the costs of system preservation and system development attributable to each vehicle class for the vehicle mix and asset mix at each toll facility. The study will not include specific recommendations for remedying any current toll inequities should they exist.

The approach implemented in the HCAS is explained in the Phase I Interim Report: Pilot Implementation of Cost Allocation Methodology. A thorough literature review of past federal and state HCAS was conducted, in order to develop an effective procedure for the MdTA facilities. The applied approach is based on the 1997 Federal HCAS, with supplementary material from Oregon and other state HCAS.

2.0 DATA FOR STUDY

Proper implementation of a highway cost allocation study requires extensive and detailed information in the following categories:

1. Traffic Data: Data such as vehicle weight and classification as well as vehicle miles of travel (VMT), passenger car equivalent (PCE) values by vehicle class, and vehicle/axle weight distributions for each facility.

2. Expenditure Data: Costs for construction projects (past and future), highway maintenance activities, and administrative overhead for each facility.

3. Revenue and Toll Data: The total toll revenue, nominal toll structure, and average effective toll rate after discounts paid by each vehicle class for each facility.

A thorough search of all traffic and cost data available from the Authority was conducted at the start of this study. The key categories of data required for the HCAS are summarized in the following subsections.

2.1 Traffic

Traffic volume and vehicle classification data for this study were based on average from the MdTA toll collection records for the years 2001-2005. It should be noted that traffic volumes for 2002 are left out because the MdTA records do not consistently differentiate the number of electronic tolls paid by each vehicle class for this year. Traffic growth during the study period has been neglected for simplicity.

For cost allocation purposes, the traffic volume data was expanded into vehicle miles traveled (VMT) by FHWA vehicle class and weight category.

The Authority provided toll revenue sheets that document the traffic and revenue by vehicle class and payment method for its seven toll facilities. The current Authority classification system is axle-based with 6 categories: 2-axle, 3-axle, 4-axle, 5-axle, 6-axle, and “unusual” classes.

Because highway cost responsibility is so strongly influenced by vehicle axle configurations and axle weights, it is beneficial to base highway revenue and cost analyses on a wider range of vehicle configurations. Table 5 and Figure 2 describe the 20 vehicle classes used in the Federal HCAS. The Federal HCAS analysis method allows travel, Highway User Revenues (HURs), and highway cost responsibility to be estimated for up to thirty 5,000-pound weight intervals (ranging from 5,000 lbs or less to over 145,000 lbs) for each vehicle class. Frequency distributions for axle loads within each vehicle class are estimated using Maryland weigh station data and/or regional or national default distributions, e.g., as derived from the Long Term Pavement Performance database in NCHRP Project 1-37A (NCHRP, 2004).

In the end, however, cost allocations based on these more detailed vehicle and axle load distributions must be collapsed into a simpler vehicle classification for implementation at the Authority’s toll facilities. The mapping between the FHWA and MdTA vehicle classification is shown in Table 6.

Table 5. Federal HCAS Vehicle Classification Categories

VEHICLE CLASS	ACRONYM	*DESCRIPTION*
1	AUTO	Automobiles and Motorcycles
2	LT4	Light trucks with 2-axles and 4 tires (Pickup Trucks, Vans, Minivans, etc.)
3	SU2	Single unit, 2-axle, 6 tire trucks (includes SU2 pulling a utility trailer)
4	SU3	Single unit, 3-axle trucks (includes SU3 pulling a utility trailer)
5	SU4+	Single unit trucks with 4- or more axles (includes SU4+ pulling a utility trailer)
6	CS3	Tractor-semitrailer combinations with 3-axles
7	CS4	Tractor-semitrailer combinations with 4-axles
8	CS5T	Tractor-semitrailer combinations with 5-axles, two rear tandem axles
9	CS5S	Tractor-semitrailer combinations with 5-axles, two split (>8 feet) rear axles
10	CS6	Tractor-semitrailer combinations with 6-axles
11	CS7+	Tractor-semitrailer combinations with 7- or more axles
12	CT34	Truck-trailers combinations with 3- or 4-axles
13	CT5	Truck-trailers combinations with 5-axles
14	CT6+	Truck-trailers combinations with 6- or more axles
15	DS5	Tractor-double semitrailer combinations with 5-axles
16	DS6	Tractor-double semitrailer combinations with 6-axles
17	DS7	Tractor-double semitrailer combinations with 7-axles
18	DS8+	Tractor-double semitrailer combinations with 8- or more axles
19	TRPL	Tractor-triple semitrailer or truck-double semitrailer combinations
20	BUS	Buses (all types)

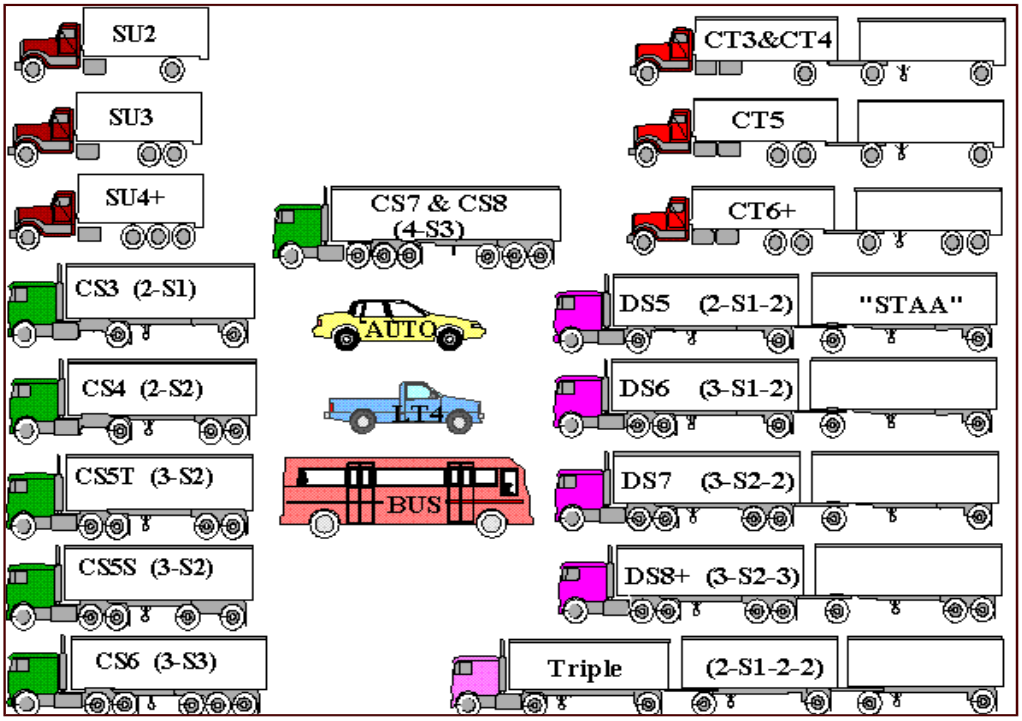

Figure 2. Federal HCAS Vehicle Classes

Table 6. Mapping of Federal Vehicle Classes to MdTA Axle Categories

PROPOSED VEHICLE CLASSIFICATION		
GROUPED CLASSES	**CLASSIFICATION**	*VEHICLE CLASSES TO BE INCLUDED*
1	Two-Axle	AUTO, LT4, SU2, BUSES
2	Three-Axle	SU3, CS3
3	Four-Axle	CS4, SU4+, CT34
4	Five-Axle	CS5T, CS5S, CT5, DS5
5	Six-Axle	CS6, CT6+, DS6
6	Unusual	CS7+, DS7, DS8+, TRPL

Since trucks and other heavy duty vehicles are larger than cars, typically have slower acceleration and require more room for maneuvering, lane changing, and braking, they consume more of the highway's capacity than do cars and light trucks. Traffic engineers account for the impact of these vehicles on highway capacity by assigning each class of vehicle a passenger car equivalent (PCE) value. This PCE represents the number of passenger cars that would consume the same percentage of the highway's capacity as the vehicles under consideration under prevailing roadway and traffic conditions.

The PCE value of a truck depends on its weight, length, engine, and other characteristics. The PCE value also depends on roadway characteristics such as the number of lanes and length and steepness of grades. The PCE values adopted for usage in the MdTA HCAS were obtained from a Battelle working paper prepared as part of a FHWA Truck Speed and Weight Study (Battelle, 1995).

The GVW distribution in the VMT data is sufficient for allocating load related costs for bridges. However, pavement deterioration is a function of axle loads rather than GVW. Representative axle load distribution data for rural interstates was obtained from the FHWA Long Term Pavement Performance (LTPP) traffic database as extracted by NCHRP Project 1-37A for the purposes of mechanistic-empirical design. These axle weight distributions for single, tandem, tridem and quad axle configurations are used in the MdTA HCAS. Note that for multiple axle configurations, the axle weight corresponds to the total weight for the axle group.

2.2 Expenditure Data

Project expenditure data for each facility was obtained from the MdTA Engineering Division and Finance Department. Dating back to each facility's initial construction date, the contracts include construction, rehabilitation, repair, and replacement projects. The MdTA also provided future preservation and enhancement project expenditure data in three categories: Programmed Funded Projects (2008-2013), Unfunded Capital Needs (2008-2013), and Unfunded Long Range Needs (2014-2026).

Given that the project expenditure data spans multiple decades, inflation factors must be applied to convert all expenditures to constant dollars. In the HCAS, all costs were adjusted to 2005 dollar amounts using the *Engineering News Record* (ENR) time series of actual material and labor construction costs since 1918.

Routine maintenance activities, which are usually performed by MdTA in-house staff, must also be included in the analysis. MdTA maintenance expenditures were obtained for the period of 2001 through 2005. The average annual maintenance cost derived from this data was assumed to be valid for all years in the study period, with appropriate adjustments for inflation.

2.3 Toll Discounts

In order to see the effects of commuter and truck discounts, the MdTA provided traffic and revenue data by vehicle class for the 2006 fiscal year. This information yields the average effective toll rate paid by each vehicle class. Using this average effective toll rate, the HCAS toll results are modified to account for discounts.

3.0 COST ALLOCATION PROCEDURES

3.1 Bridges

All load-related costs for new bridges, bridge replacement, and major rehabilitation for all bridge structures in the MdTA facilities are assigned using the Incremental Method of cost allocation. The Incremental procedure relates the increments of cost necessary to make the bridge incrementally stronger to the set of vehicles that occasion these increased costs. Since it would be computationally impractical to allocate the cost of every single bridge in each facility, the bridges are grouped by functional class. For each representative bridge within each functional class, the live load moment (or force in case of truss bridges) for each vehicle class/weight group is computed and sorted by increasing live load moment (or force). The incremental cost of the bridge structure for each vehicle class/weight group is defined as the difference in structure cost attributable to the increased live load moments (or forces) for each successive vehicle class/weight group.

The incremental cost of the bridge structure for each vehicle class/weight group is defined as the difference in structure cost attributable to the increased live load moments (or forces) for each successive vehicle class/weight group. The total cost C_i of any structural element i is given by the expression:

$$C_i = \sum_{j=1}^{n} Q_{ij} U_j \qquad i = 1 \ldots m \tag{1}$$

in which m is the number of elements comprising the structure (e.g., deck, stringer, pier, etc.), n is the number of materials are used to construct the elements, Q_i, is the quantity of each jth material for the ith structural element, and U_j is the unit cost for that material. Every vehicle class shares the cost of the first structural increment, which is not attributable to any vehicle loading. All vehicle classes except the lightest one pay the cost of the second increment, and so on. Each incremental cost is assigned to the responsible vehicle class according to its respective PCE-VMT value. Let the index i denote the vehicle class in increasing order of the GVW. Then the bridge costs assigned to vehicle class i are estimated by using the following equation:

$$U_i = \sum_{j=1}^{i} \frac{\Delta C_j}{Z_j} P_i X_i \tag{2}$$

and

$$Z_j = \sum_{i=j}^{l} P_i X_i \tag{3}$$

where

U_i	= cost assigned to vehicle class i
ΔC_j	= the jth incremental cost
P_i	= the PCE of vehicle class i
X_i	= the number of vehicles (or VMT) of class i per period
l	= number of vehicle classes analyzed

Minor rehabilitation and repair improvements are not a function of vehicle size and weight. Consequently, these are allocated to the various vehicle classes in proportion to VMT and PCE-VMT.

To demonstrate the bridge analysis Table 7 provides a summary of the type of elements and their total lengths including the member type, which were used to extract the necessary information for the bridge. Figure 3 gives a perspective view for the model bridge using VBDS software.

Table 7. Summary of the Suspension Bridge Model

Type of Elements	Total Length (IN FEET)	Number of Elements	Finite Element Member Type
Towers	1466.32	260	3-D Beam
Cables	6087.62	148	3-D Truss
Hangers	9037.77	142	3-D Truss
Floor Truss	30536.75	2046	3-D Truss
Main Truss	23547.98	1710	3-D Truss
Lateral Bracing	18140.95	868	3-D Truss

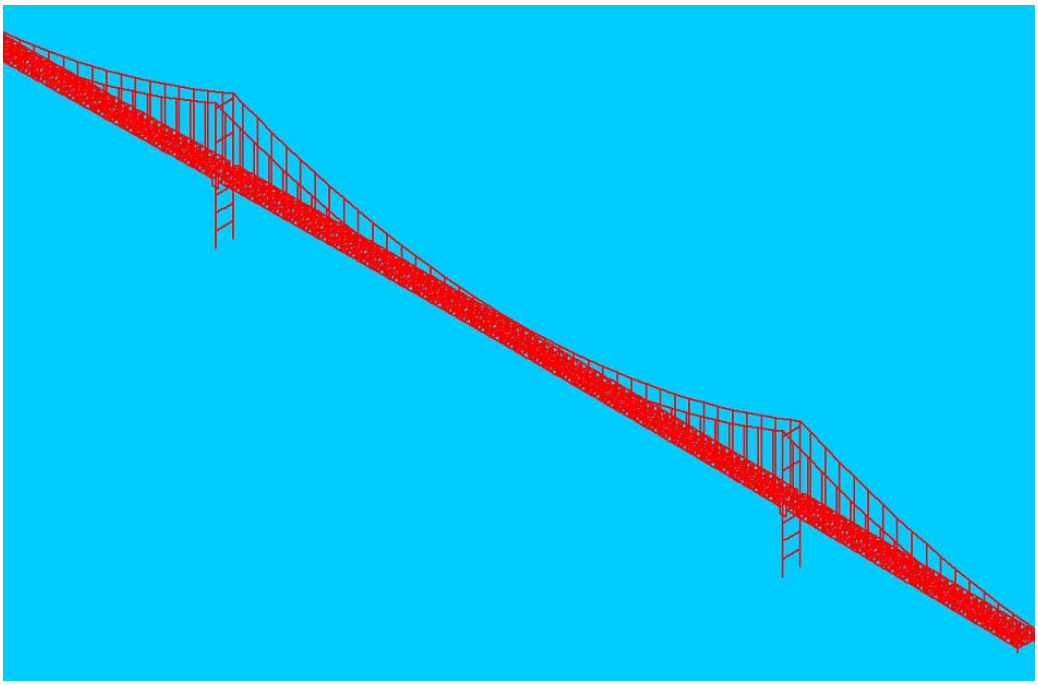

Figure 3. Perspective View for the Suspension Bridge Model

3.2 Pavements

The pavement cost allocation procedure employed in the present study is based on the 1997 Federal HCAS and the subsequent State HCAS guidelines developed by the FHWA. Load-related costs for pavement construction are allocated on the basis of equivalent single axle loads (ESALs) for each vehicle class. This approach allocates costs on the same technical basis used to design pavements, since total ESALs are the sole traffic input in the AASHTO pavement design procedures (AASHTO, 1993).

Load equivalency factors (LEFs) are used to convert physical axles to ESALs. In general, LEFs are functions of the axle type (single vs. tandem, e.g.), axle load, distress type, and pavement structure (thickness and pavement type). The State HCAS Guidelines provide an alternative of overall LEFs that depend only on highway functional class, axle type, and pavement type (flexible vs. rigid). The overall LEFs are defined as follows:

$$LEF = aW^b \tag{4}$$

in which W is the axle load in kips and a and b are factors that are a function of pavement type and axle configuration. The LEF values given by Eq. (4) represent an average over all distress types, which is appropriate for the purposes of the present study. Values for a and b extracted from the State HCAS spreadsheets for rural interstate conditions are summarized in Table 8. For simplicity, the averages of the flexible and rigid pavement coefficients for each axle type have been adopted for the MdTA HCAS. The total number of ESALs for any given vehicle can then be evaluated as:

$$ESAL = \sum_{i=1}^{n} LEF_i = \sum_{i=1}^{n} a_i W_i^{b_i} \tag{5}$$

in which i is the axle group, W_i is the load level for the axle group, a_i and b_i are the average coefficients for the axle group's type, and n is the total number of axle groups in the vehicle.

Table 8. Overall LEF Factors Used in This Study (from State HCAS spreadsheets; FHWA, 2000)

Axle Type	Flexible		Rigid		Average	
	log *a*	b	log *a*	b	log *a*	b
Single	-3.2517	2.5904	-3.0983	2.4683	-3.175	2.529
Tandem	-4.6469	3.2430	-3.7011	2.5517	-4.174	2.897
Tridem	-4.5528	2.3065	-3.7864	2.4327	-4.170	2.370

Load-related costs for new construction and for 3R activities (reconstruction, rehabilitation, and resurfacing) typically represent 70 to 80% of the total project costs; for the purposes of the present MDTA HCAS, this portion is fixed at 75%. The remaining 25% of project new/3R project costs is allocated according to unweighted VMT.

Common costs for pavement construction and maintenance that are not related to vehicle load but that are related to increased highway capacity are allocated to vehicle classes according to PCE-VMT. Common costs unrelated to increased highway capacity are allocated according to unweighted VMT. General administrative and overhead costs are allocated in proportion to the composite allocations from all other costs.

3.3 Tunnels

Unlike bridges and pavements, the physical tunnel structure is not affected by vehicle load. Tunnel costs that are related to increased highway capacity, such as initial construction and ventilation fans/motors, are allocated using PCE-VMT. Tunnel costs that are not related to capacity are allocated according to unweighted VMT.

The tunnel pavement costs are allocated using the same method as highway pavements: 75% ESALs and 25% unweighted VMT.

3.4 Pilot Investigation

A partial segment of a facility was investigated to provide initial guidance to the overall study. The facility studied in this pilot implementation is the John F. Kennedy Memorial Highway from (and including) the Tydings Memorial Bridge to the Delaware state line, which can be found in Appendix A – Pilot Implementation of the Cost Allocation Methodology.

4.0 HCAS RESULTS BY FACILITY

4.1 John F. Kennedy Memorial (JFK) Highway

After completing the pilot investigation, study of the entire JFK Highway was completed in the second phase of the HCAS. Table 9 summarizes suggested relative toll structures for the entire JFK Highway based upon the HCAS analysis results. Five toll structures are included in the table:

(a) the existing toll structure;
(b) the average effective toll rates including discounts;
(c) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping the base toll for two-axle vehicles fixed at $5 (not including discounts);
(d) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2000-2004 traffic data and the current non-discounted toll rates); and
(e) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2006 traffic and revenue data including discounts).

The effective revenue-neutral tolls from the HCAS (i.e., revenue neutral with discounts—rightmost column in Table 9) are arguably the most realistic numbers to compare to the current effective tolls (i.e., current nominal tolls after discounts—3rd column in Table 9.) The HCAS effective revenue neutral tolls for two-axle vehicles are approximately 20% lower than the corresponding current effective toll. The revenue-neutral tolls for three, four, and six+ axle vehicles also decrease slightly, but the numbers of these vehicles using the JFK Highway are very small. The effective revenue neutral tolls for five-axle trucks, the highest volume truck category using the JFK, are approximately 50% greater than the current effective toll, a significant increase.

Table 9. HCAS Toll Rates

Vehicle Class	MdTA Current Tolls		HCAS Tolls		
	Nominal	Effective (w/ Discounts)	$5.00 Base	Revenue Neutral	Effective Revenue Neutral (w/ Discounts)
Two-axle	$5.00	$4.65	$5.00	$4.01	$3.77
Three-axle	$10.00	$9.51	$8.89	$7.12	$6.71
Four-axle	$15.00	$14.26	$10.14	$8.13	$7.65
Five-axle	$20.00	$19.01	$37.64	$30.15	$28.39
Six+ Axle	$25.00	$23.77	$11.99	$9.60	$9.04

The HCAS results are modified to include the future projects in three phases:

1. including the program funded projects (A);
2. adding the unfunded capital needs (A+B); and
3. adding the unfunded long range needs (A+B+C).

Table 10 shows the HCAS revenue neutral toll results (including discounts) for the three phases of future projects. The HCAS $5 base tolls and revenue neutral tolls without discounts are also updated to include future projects and can be found in the Appendix B - the John F. Kennedy Memorial Highway Report.

Table 10. HCAS Toll Rates Including Future Projects

Vehicle Class	MdTA Current Tolls		HCAS Effective Revenue Neutral Tolls (w/ Discounts)		
	Nominal	Effective (w/ Discounts)	A	A+B	A+B+C
Two-axle	$5.00	$4.65	$2.95	$2.76	$2.33
Three-axle	$10.00	$9.51	$5.89	$5.75	$5.34
Four-axle	$15.00	$14.26	$6.46	$6.29	$5.68
Five-axle	$20.00	$19.01	$35.96	$37.63	$41.60
Six+ Axle	$25.00	$23.77	$7.32	$7.10	$6.21

A key output from any HCAS is the assignment of highway and bridge costs to each vehicle class. The total costs allocated to each vehicle class by both the MdTA current toll structures and the HCAS scenarios are summarized in Table 11. According to the HCAS results, two-axle vehicles are responsible for approximately 51% of the combined pavement and bridge costs while trucks (three-axle vehicles and above) are responsible for the remaining 49% of costs. This can be compared against toll revenue shares currently paid by each vehicle class: two-axle vehicles currently pay 64% of total toll revenue and trucks (three-axle vehicles and above) pay the remaining 36%. The share of revenues by vehicle class from the HCAS revenue neutral analysis mirrors the toll changes, with share of total revenue decreasing by about 20% for two-axle vehicles, increasing by about 36% for all trucks (50% for five-axle vehicles, and changing insignificantly for the low volume three, four, and six+ axle vehicles). Adding the future projects to the study further decreases the two-axle vehicle cost responsibility and increases the truck cost responsibility. The results from the JFK HCAS therefore suggest that trucks are undercharged in the current toll structure in comparison to the costs they incur for the pavement and bridge infrastructure.

Table 11. Combined Highway and Bridge Cost Shares by Vehicle Class

Cost Shares	Two-axle	Trucks (Three-axle and above)
Current Revenue w/ Discounts	64%	36%
HCAS Revenue Neutral	51%	49%
HCAS w/ Future Projects (A)	40%	60%
HCAS w/ Future Projects (A+B)	38%	62%
HCAS w/ Future Projects (A+B+C)	32%	68%

4.2 William Preston Lane, Jr. (Bay) Bridge

Table 12 summarizes suggested relative toll structures for the Bay Bridge based upon the HCAS analysis results. Five toll structures are included in the table:

(a) the existing toll structure;

(b) the average effective toll rates including discounts;
(c) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping the base toll for two-axle vehicles fixed at $2.50 (not including discounts);
(d) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2001-2005 traffic data and the current non-discounted toll rates); and
(e) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2006 traffic and revenue data including discounts).

The effective revenue neutral tolls from the HCAS (i.e., revenue neutral with discounts—rightmost column in Table 12) are arguably the most realistic numbers to compare to the current effective tolls (i.e., current nominal tolls after discounts—3rd column in Table 12). The HCAS effective revenue neutral tolls for two-axle vehicles are approximately 7% lower than the corresponding current effective toll. The revenue neutral tolls for three, four, and six+ axle vehicles also decrease slightly, but the numbers of these vehicles using the Bay Bridge are very small. The effective revenue neutral tolls for five-axle trucks, the highest volume truck category using the Bay Bridge, are approximately 24% greater than the current effective toll, a significant increase.

Table 12. HCAS Toll Rates

Vehicle Class	MdTA Current Tolls		HCAS Tolls		
	Nominal	Effective (w/ Discounts)	$2.50 Base	Revenue Neutral	Effective Revenue Neutral (w/ Discounts)
Two-axle	$2.50	$2.00	$2.50	$2.23	$1.87
Three-axle	$5.00	$4.75	$6.12	$5.46	$4.59
Four-axle	$7.50	$7.13	$7.51	$6.69	$5.63
Five-axle	$10.00	$9.50	$15.66	$13.95	$11.74
Six+ Axle	$12.50	$11.88	$10.52	$9.37	$7.89

The HCAS results are modified to include the future projects in three phases:

1. including the program funded projects (A);
2. adding the unfunded capital needs (A+B); and
3. adding the unfunded long range needs (A+B+C).

Table 13 shows the HCAS revenue-neutral toll results (including discounts) for the three phases of future projects. The HCAS $2.50 base tolls and revenue-neutral tolls without discounts are also updated to include future projects and can be found in the Appendix C - the William Preston Lane, Jr. Memorial (Bay) Bridge Report.

Table 13. HCAS Toll Rates Including Future Projects

Vehicle Class	MdTA Current Tolls		HCAS Effective Revenue Neutral Tolls (w/ Discounts)		
	Nominal	Effective (w/ Discounts)	A	A+B	A+B+C
Two-axle	$2.50	$2.00	$1.87	$1.86	$1.23
Three-axle	$5.00	$4.75	$4.49	$4.52	$3.77
Four-axle	$7.50	$7.13	$5.49	$5.51	$4.67
Five-axle	$10.00	$9.50	$11.86	$11.99	$21.77
Six+ Axle	$12.50	$11.88	$7.59	$7.50	$5.05

A key output from any HCAS is the assignment of highway and bridge costs to each vehicle class. The total costs allocated to each vehicle class by both the MdTA current toll structures and the HCAS scenarios are summarized in Table 14. According to the HCAS results, two-axle vehicles are responsible for approximately 67% of the combined pavement and bridge costs while trucks (three-axle vehicles and above) are responsible for the remaining 33% of costs. This can be compared against toll revenue shares currently paid by each vehicle class: two-axle vehicles currently pay 71% of total toll revenue and trucks (three-axle vehicles and above) pay the remaining 29%. The share of revenues by vehicle class from the HCAS revenue neutral analysis mirrors the toll changes, with share of total revenue decreasing by about 7% for two-axle vehicles, increasing by about 14% for all trucks (26% for five-axle vehicles, and changing insignificantly for the low volume three, four, and six+ axle vehicles). Adding the future projects to the study further decreases the two-axle vehicle cost responsibility and increases the truck cost responsibility. The results from the Bay Bridge HCAS therefore suggest that trucks are undercharged in the current toll structure in comparison to the costs they incur for the pavement and bridge infrastructure.

Table 14. Combined Highway and Bridge Cost Shares by Vehicle Class

Cost Shares	Two-axle	Trucks (Three-axle and above)
Current Revenue w/ Discounts	71%	29%
HCAS Revenue Neutral	67%	33%
HCAS w/ Future Projects (A)	68%	32%
HCAS w/ Future Projects (A+B)	67%	33%
HCAS w/ Future Projects (A+B+C)	44%	56%

4.3 Governor Harry W. Nice Memorial Bridge

Table 15 summarizes suggested relative toll structures for the Nice Bridge based upon the HCAS analysis results. Five toll structures are included in the table:

(a) the existing toll structure;
(b) the average effective toll rates including discounts;
(c) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping the base toll for two-axle vehicles fixed at $5 (not including discounts);
(d) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2000-2004 traffic data and the current non-discounted toll rates); and
(e) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2006 traffic and revenue data including discounts).

The effective revenue neutral tolls from the HCAS (i.e., revenue neutral with discounts—rightmost column in Table 15) are arguably the most realistic numbers to compare to the current effective tolls (i.e., current nominal tolls after discounts—3rd column in Table 15). The HCAS effective revenue neutral tolls for two-axle vehicles are approximately the same as the corresponding current effective toll. The revenue neutral tolls for three, four, and six+ axle vehicles also decrease slightly, but the numbers of these vehicles using the Nice Bridge are very small. The effective revenue neutral tolls for five-axle trucks, the highest volume truck category using the Nice Bridge, are approximately 11% greater than the current effective toll.

Table 15. HCAS Toll Rates

Vehicle Class	MdTA Current Tolls		HCAS Tolls		
	Nominal	Effective (w/ Discounts)	$3.00 Base	Revenue Neutral	Effective Revenue Neutral (w/ Discounts)
Two-axle	$3.00	$2.35	$3.00	$2.79	$2.32
Three-axle	$6.00	$5.82	$6.59	$6.13	$5.10
Four-axle	$9.00	$8.73	$8.37	$7.79	$6.48
Five-axle	$12.00	$11.64	$16.66	$15.50	$12.89
Six+ Axle	$15.00	$14.55	$11.52	$10.72	$8.91

The HCAS results are modified to include the future projects in three phases:

1. including the program funded projects (A);
2. adding the unfunded capital needs (A+B); and
3. adding the unfunded long range needs (A+B+C).

Table 16 shows the HCAS revenue neutral toll results (including discounts) for the three phases of future projects. The HCAS $3.00 base tolls and revenue neutral tolls without discounts are also updated to include future projects and can be found in the Appendix D - the Governor Harry W. Nice Memorial Bridge Report.

Table 16. HCAS Toll Rates Including Future Projects

Vehicle Class	MdTA Current Tolls		HCAS Effective Revenue Neutral Tolls (w/ Discounts)		
	Nominal	Effective (w/ Discounts)	A	A+B	A+B+C
Two-axle	$3.00	$2.35	$2.31	$1.14	$0.92
Three-axle	$6.00	$5.82	$5.04	$4.44	$4.25
Four-axle	$9.00	$8.73	$6.38	$6.56	$6.49
Five-axle	$12.00	$11.64	$13.17	$30.10	$33.29
Six+ Axle	$15.00	$14.55	$8.69	$5.13	$4.21

A key output from any HCAS is the assignment of highway and bridge costs to each vehicle class. The total costs allocated to each vehicle class by both the MdTA current toll structures and the HCAS scenarios are summarized in Table 17. According to the HCAS results, two-axle vehicles are responsible for approximately 65% of the combined pavement and bridge costs while trucks (three-axle vehicles and above) are responsible for the remaining 35% of costs. This can be compared against toll revenue shares currently paid by each vehicle class: two-axle vehicles currently pay 69% of total toll revenue and trucks (three-axle vehicles and above) pay the remaining 31%. The share of revenues by vehicle class from the HCAS revenue neutral analysis mirrors the toll changes, with share of total revenue decreasing by about 6% for two-axle vehicles, increasing by about 13% for all trucks (8% for five-axle vehicles, and changing insignificantly for the low volume three, four, and six+ axle vehicles). Adding the future projects to the study further decreases the two-axle vehicle cost responsibility and increases the truck cost responsibility. The results from the Nice Bridge HCAS therefore suggest that trucks are undercharged in the current toll structure in comparison to the costs they incur for the pavement and bridge infrastructure.

Table 17. Combined Highway and Bridge Cost Shares by Vehicle Class

Cost Shares	Two-axle	Trucks (Three-axle and above)
Current Revenue w/ Discounts	69%	31%
HCAS Revenue Neutral	65%	35%
HCAS w/ Future Projects (A)	67%	33%
HCAS w/ Future Projects (A+B)	33%	67%
HCAS w/ Future Projects (A+B+C)	27%	73%

4.4 Baltimore Harbor Tunnel

Table 18 summarizes suggested relative toll structures for the Baltimore Harbor Tunnel based upon the HCAS analysis results. Five toll structures are included in the table:

(a) the existing toll structure;
(b) the average effective toll rates including discounts;
(c) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping the base toll for two-axle vehicles fixed at $5 (not including discounts);
(d) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2000-2004 traffic data and the current non-discounted toll rates); and
(e) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2006 traffic and revenue data including discounts).

The effective revenue neutral tolls from the HCAS (i.e., revenue neutral with discounts—rightmost column in Table 18) are arguably the most realistic numbers to compare to the current effective tolls (i.e., current nominal tolls after discounts—3rd column in Table 18). The HCAS effective revenue neutral tolls for two-axle vehicles are approximately 8% lower than the corresponding current effective toll. The revenue neutral tolls increase for three-axle vehicles and decrease for four and six+ axle vehicles, but the numbers of these vehicles using the Harbor Tunnel are very small. The effective revenue neutral tolls for five-axle trucks, the highest volume truck category using the Harbor Tunnel, are approximately 77% greater than the current effective toll, a significant increase. The increase for five-axle tolls is noticeably higher than in the previous facility HCAS. This can be attributed to the small number of trucks using the Harbor Tunnel: vehicles with three-axles or higher account for only 5% of the traffic. As a result, the truck-related costs must be distributed among this smaller number of vehicles, causing a higher toll rate.

Table 18. HCAS Toll Rates

Vehicle Class	MdTA Current Tolls		HCAS Tolls		
	Nominal	Effective (w/ Discounts)	$2.00 Base	Revenue Neutral	Effective Revenue Neutral (w/ Discounts)
Two-axle	$2.00	$1.21	$2.00	$1.75	$1.11
Three-axle	$4.00	$3.55	$8.45	$7.38	$4.70
Four-axle	$6.00	$5.32	$7.71	$6.74	$4.29
Five-axle	$8.00	$7.09	$22.58	$19.72	$12.55
Six+ Axle	$10.00	$8.87	$7.10	$6.20	$3.94

The HCAS results are modified to include the future projects in three phases:

1. including the program funded projects (A);
2. adding the unfunded capital needs (A+B); and
3. adding the unfunded long range needs (A+B+C).

Table 19 shows the HCAS revenue neutral toll results (including discounts) for the three phases of future projects. The HCAS $2.00 base tolls and revenue neutral tolls without discounts are also updated to include future projects and can be found in the Appendix E - the Baltimore Harbor Tunnel Report.

Table 19. HCAS Toll Rates Including Future Projects

Vehicle Class	MdTA Current Tolls		HCAS Effective Revenue Neutral Tolls (w/ Discounts)		
	Nominal	Effective (w/ Discounts)	A	A+B	A+B+C
Two-axle	$2.00	$1.21	$1.08	$1.08	$0.91
Three-axle	$4.00	$3.55	$5.16	$5.10	$7.60
Four-axle	$6.00	$5.32	$4.45	$4.41	$5.24
Five-axle	$8.00	$7.09	$14.04	$13.85	$22.24
Six+ Axle	$10.00	$8.87	$3.77	$3.74	$2.93

A key output from any HCAS is the assignment of highway and bridge costs to each vehicle class. The total costs allocated to each vehicle class by both the MdTA current toll structure and the HCAS scenarios are summarized in Table 20. According to the HCAS results, two-axle vehicles are responsible for approximately 78% of the combined pavement and bridge costs while trucks (three-axle vehicles and above) are responsible for the remaining 22% of costs. This can be compared against toll revenue shares currently paid by each vehicle class: two-axle vehicles currently pay 87% of total toll revenue and trucks (three-axle vehicles and above) pay the remaining 13%. The share of revenues by vehicle class from the HCAS revenue neutral analysis mirrors the toll changes, with share of total revenue decreasing by about 10% for two-axle vehicles and increasing by about 70% for all trucks (88% for five-axle vehicles, and changing insignificantly for the low volume three, four, and six+ axle vehicles). Adding the future projects to the study further decreases the two-axle vehicle cost responsibility and increases the truck cost responsibility. The results from the Baltimore Harbor Tunnel HCAS therefore suggest that trucks are undercharged in the current toll structure in comparison to the costs they incur for the pavement and bridge infrastructure.

Table 20. Combined Highway and Bridge Cost Shares by Vehicle Class

Cost Shares	Two-axle	Trucks (Three-axle and above)
Current Revenue w/ Discounts	87%	13%
HCAS Revenue Neutral	78%	22%
HCAS w/ Future Projects (A)	77%	23%
HCAS w/ Future Projects (A+B)	77%	23%
HCAS w/ Future Projects (A+B+C)	65%	35%

4.5 Francis Scott Key Bridge

Table 21 summarizes suggested relative toll structures for the Francis Scott Key Bridge based upon the HCAS analysis results. Five toll structures are included in the table:

(a) the existing toll structure;
(b) the average effective toll rates including discounts;
(c) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping the base toll for two-axle vehicles fixed at $2.00 (not including discounts);

(d) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2001-2005 traffic data and the current non-discounted toll rates); and
(e) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2006 traffic and revenue data including discounts).

The effective revenue neutral tolls from the HCAS (i.e., revenue neutral with discounts—rightmost column in Table 21) are arguably the most realistic numbers to compare to the current effective tolls (i.e., current nominal tolls after discounts—3rd column in Table 21). The HCAS effective revenue neutral tolls for two-axle vehicles are approximately 21% higher than the corresponding current effective toll. The revenue neutral tolls decrease for three, four and six+ axle vehicles, but the numbers of these vehicles using the Key Bridge are very small. The effective revenue neutral tolls for five-axle trucks, the highest volume truck category using the Key Bridge, are approximately 22% lower than the current effective toll. This result shows that discounts make a significant impact on the MdTA's revenue at the Key Bridge. For example, the current effective toll rate for two-axle vehicles is $1.00, which is only half of the $2.00 nominal toll.

Table 21. HCAS Toll Rates

Vehicle Class	MdTA Current Tolls		HCAS Tolls		
	Nominal	Effective (w/ Discounts)	$2.00 Base	Revenue Neutral	Effective Revenue Neutral (w/ Discounts)
Two-axle	$2.00	$1.00	$2.00	$1.92	$1.21
Three-axle	$4.00	$3.84	$4.10	$3.94	$2.49
Four-axle	$6.00	$5.76	$4.68	$4.49	$2.84
Five-axle	$8.00	$7.69	$9.89	$9.49	$6.00
Six+ Axle	$10.00	$9.61	$5.38	$5.16	$3.26

The HCAS results are modified to include the future projects in three phases:

1. including the program funded projects (A);
2. adding the unfunded capital needs (A+B); and
3. adding the unfunded long range needs (A+B+C).

Table 22 shows the HCAS revenue neutral toll results (including discounts) for the three phases of future projects. The HCAS $2.00 base tolls and revenue neutral tolls without discounts are also updated to include future projects and can be found in the Appendix F - the Francis Scott Key Bridge Report.

Table 22. HCAS Toll Rates Including Future Projects

Vehicle Class	MdTA Current Tolls		HCAS Effective Revenue Neutral Tolls (w/ Discounts)		
	Nominal	Effective (w/ Discounts)	A	A+B	A+B+C
Two-axle	$2.00	$1.00	$1.19	$1.19	$1.07
Three-axle	$4.00	$3.84	$2.46	$2.46	$2.64
Four-axle	$6.00	$5.76	$2.78	$2.78	$2.90
Five-axle	$8.00	$7.69	$6.28	$6.28	$7.87
Six+ Axle	$10.00	$9.61	$3.14	$3.14	$2.98

A key output from any HCAS is the assignment of highway and bridge costs to each vehicle class. The total costs allocated to each vehicle class by both the MdTA current toll structure and the HCAS scenarios are summarized in Table 23. According to the HCAS results, two-axle vehicles are responsible for approximately 70% of the combined pavement and bridge costs while trucks (three-axle vehicles and above) are responsible for the remaining 30% of costs. This can be compared against toll revenue shares currently paid by each vehicle class: two-axle vehicles currently pay 57% of total toll revenue and trucks (three-axle vehicles and above) pay the remaining 43%. The share of revenues by vehicle class from the HCAS revenue neutral analysis mirrors the toll changes, with share of total revenue increasing by about 23% for two-axle vehicles and decreasing by about 30% for all trucks (22% for five-axle vehicles, and changing insignificantly for the low volume three, four, and six+ axle vehicles). Adding the future projects to the study slightly decreases the two-axle vehicle cost responsibility and increases the truck cost responsibility. The results from the Key Bridge HCAS suggest that trucks are overcharged in the current toll structure in comparison to the costs they incur for the pavement and bridge infrastructure.

Table 23. Combined Highway and Bridge Cost Shares by Vehicle Class

Cost Shares	Two-axle	Trucks (Three-axle and above)
Current Revenue w/ Discounts	57%	43%
HCAS Revenue Neutral	70%	30%
HCAS w/ Future Projects (A)	69%	31%
HCAS w/ Future Projects (A+B)	69%	31%
HCAS w/ Future Projects (A+B+C)	61%	39%

4.6 Thomas J. Hatem Memorial Bridge

Table 24 summarizes suggested relative toll structures for the Thomas J. Hatem Memorial Bridge based upon the HCAS analysis results. Five toll structures are included in the table:

(a) the existing toll structure;
(b) the average effective toll rates including discounts;
(c) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping the base toll for two-axle vehicles fixed at $5 (not including discounts);
(d) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2000-2004 traffic data and the current non-discounted toll rates); and
(e) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2006 traffic and revenue data including discounts).

The effective revenue neutral tolls from the HCAS (i.e., revenue neutral with discounts—rightmost column in Table 24) are arguably the most realistic numbers to compare to the current effective tolls (i.e., current nominal tolls after discounts—3rd column in Table 24). The HCAS effective revenue neutral tolls for two-axle vehicles are approximately 174% higher than the corresponding current effective toll. The revenue neutral tolls decrease for three, four and six+ axle vehicles, but the numbers of these vehicles using the Hatem Bridge are very small. The effective revenue neutral tolls for five-axle trucks, the highest volume truck category using the Hatem Bridge, are approximately 81% lower than the current effective toll. This means that after including discounts, two-axle vehicles are underpaying, while five-axle trucks are overpaying. This result can be attributed to the fact that the Hatem Bridge operates a substantial

discount program: the facility's revenue in 2006 after discounts was $3.6 million, while without discounts, the facility would collect approximately $28 million per year.

Table 24. HCAS Toll Rates

Vehicle Class	MdTA Current Tolls		HCAS Tolls		
	Nominal	Effective (w/ Discounts)	$5.00 Base	Revenue Neutral	Effective Revenue Neutral (w/ Discounts)
Two-axle	$5.00	$0.23	$5.00	$4.98	$0.63
Three-axle	$10.00	$3.88	$10.96	$10.92	$1.39
Four-axle	$15.00	$11.38	$11.89	$11.84	$1.50
Five-axle	$20.00	$13.63	$20.97	$20.89	$2.65
Six+ Axle	$25.00	$24.36	$17.68	$17.61	$2.23

The HCAS results are modified to include the future projects in three phases:

1. including the program funded projects (A);
2. adding the unfunded capital needs (A+B); and
3. adding the unfunded long range needs (A+B+C).

Table 25 shows the HCAS revenue neutral toll results (including discounts) for the three phases of future projects. The HCAS $5.00 base tolls and revenue neutral tolls without discounts are also updated to include future projects and can be found in the Appendix G - the Thomas J. Hatem Memorial Bridge Report.

Table 25. HCAS Toll Rates Including Future Projects

Vehicle Class	MdTA Current Tolls		HCAS Effective Revenue Neutral Tolls (w/ Discounts)		
	Nominal	Effective (w/ Discounts)	A	A+B	A+B+C
Two-axle	$5.00	$0.23	$0.63	$0.61	$0.61
Three-axle	$10.00	$3.88	$1.37	$1.59	$1.60
Four-axle	$15.00	$11.38	$1.58	$1.59	$1.62
Five-axle	$20.00	$13.63	$2.60	$3.42	$3.31
Six+ Axle	$25.00	$24.36	$2.38	$2.27	$2.29

A key output from any HCAS is the assignment of highway and bridge costs to each vehicle class. The total costs allocated to each vehicle class by both the MdTA current toll structure and the HCAS scenarios are summarized in Table 26. According to the HCAS results, two-axle vehicles are responsible for approximately 87% of the combined pavement and bridge costs while trucks (three-axle vehicles and above) are responsible for the remaining 13% of costs. This can be compared against toll revenue shares currently paid by each vehicle class: two-axle vehicles currently pay 31% of total toll revenue and trucks (three-axle vehicles and above) pay the remaining 69%. The share of revenues by vehicle class from the HCAS revenue neutral analysis mirrors the toll changes, with share of total revenue increasing by about 181% for two-axle vehicles and decreasing by about 81% for all trucks (82% for five-axle vehicles, and changing insignificantly for the low volume three, four, and six+ axle vehicles). Adding the future projects to the study slightly decreases the two-axle vehicle cost responsibility and increases the truck cost responsibility. The results from the Hatem Bridge HCAS suggest that trucks are overcharged in the current toll structure in comparison to the costs they incur for the pavement and bridge infrastructure.

Table 26. Combined Highway and Bridge Cost Shares by Vehicle Class

Cost Shares	Two-axle	Trucks (Three-axle and above)
Current Revenue w/ Discounts	31%	69%
HCAS Revenue Neutral	87%	13%
HCAS w/ Future Projects (A)	86%	14%
HCAS w/ Future Projects (A+B)	83%	17%
HCAS w/ Future Projects (A+B+C)	83%	17%

4.7 Fort McHenry Tunnel

Table 27 summarizes suggested relative toll structures for the Fort McHenry Tunnel based upon the HCAS analysis results. Five toll structures are included in the table:

(a) the existing toll structure;
(b) the average effective toll rates including discounts;
(c) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping the base toll for two-axle vehicles fixed at $5 (not including discounts);
(d) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2000-2004 traffic data and the current non-discounted toll rates); and
(e) a relative toll structure based on the proportion of costs incurred by each vehicle class, keeping total toll revenue fixed (based on 2006 traffic and revenue data including discounts).

The effective revenue neutral tolls from the HCAS (i.e., revenue neutral with discounts—rightmost column in Table 27) are arguably the most realistic numbers to compare to the current effective tolls (i.e., current nominal tolls after discounts—3rd column in Table 27). The HCAS effective revenue neutral tolls for two-axle vehicles are equal to the corresponding current effective toll. The revenue neutral tolls decrease for three, four and six+ axle vehicles, but the numbers of these vehicles using the Fort McHenry Tunnel are very small. The effective revenue neutral tolls for five-axle trucks, the highest volume truck category using the Fort McHenry Tunnel, are approximately 7% greater than the current effective toll.

Table 27. HCAS Toll Rates

Vehicle Class	MdTA Current Tolls		HCAS Tolls		
	Nominal	Effective (w/ Discounts)	$2.00 Base	Revenue Neutral	Effective Revenue Neutral (w/ Discounts)
Two-axle	$2.00	$1.41	$2.00	$1.83	$1.41
Three-axle	$4.00	$3.79	$4.04	$3.70	$2.85
Four-axle	$6.00	$5.69	$5.83	$5.34	$4.11
Five-axle	$8.00	$7.59	$11.50	$10.53	$8.12
Six+ Axle	$10.00	$9.48	$6.82	$6.25	$4.81

The HCAS results are modified to include the future projects in three phases:

1. including the program funded projects (A);
2. adding the unfunded capital needs (A+B); and
3. adding the unfunded long range needs (A+B+C).

Table 28 shows the HCAS revenue neutral toll results (including discounts) for the three phases of future projects. The HCAS $2.00 base tolls and revenue neutral tolls without discounts are also updated to include future projects and can be found in the Appendix H - the Fort McHenry Tunnel Report.

Table 28. HCAS Toll Rates Including Future Projects

Vehicle Class	MdTA Current Tolls		HCAS Effective Revenue Neutral Tolls (w/ Discounts)		
	Nominal	Effective (w/ Discounts)	A	A+B	A+B+C
Two-axle	$2.00	$1.41	$1.39	$1.40	$1.27
Three-axle	$4.00	$3.79	$2.81	$2.80	$2.66
Four-axle	$6.00	$5.69	$4.00	$3.98	$3.59
Five-axle	$8.00	$7.59	$8.40	$8.37	$10.27
Six+ Axle	$10.00	$9.48	$4.62	$4.59	$3.88

A key output from any HCAS is the assignment of highway and bridge costs to each vehicle class. The total costs allocated to each vehicle class by both the MdTA current toll structure and the HCAS scenarios are summarized in Table 29. According to the HCAS results, two-axle vehicles are responsible for approximately 68% of the combined pavement and bridge costs while trucks (three-axle vehicles and above) are responsible for the remaining 32% of costs. This can be compared against toll revenue shares currently paid by each vehicle class: two-axle vehicles currently pay 67% of total toll revenue and trucks (three-axle vehicles and above) pay the remaining 33%. The share of revenues by vehicle class from the HCAS revenue neutral analysis mirrors the toll changes, with share of total revenue staying about the same for two-axle vehicles and trucks. Adding the future projects to the study slightly decreases the two-axle vehicle cost responsibility and increases the truck cost responsibility. The results from the Fort McHenry Tunnel HCAS therefore suggest that in the current toll structure, trucks are paying approximately their fair share of pavement and bridge infrastructure costs.

Table 29. Combined Highway and Bridge Cost Shares by Vehicle Class

Cost Shares	Two-axle	Trucks (Three-axle and above)
Current Revenue w/ Discounts	67%	33%
HCAS Revenue Neutral	68%	32%
HCAS w/ Future Projects (A)	67%	33%
HCAS w/ Future Projects (A+B)	68%	32%
HCAS w/ Future Projects (A+B+C)	61%	39%

5.0 HCAS RESULTS SUMMARY

The HCAS results can be summarized by looking at the ratio of the effective revenue neutral toll to the current effective toll for each vehicle class. This ratio represents the “fair share” toll to the currently paid toll, and it accounts for each facility’s discount programs. Figure 4 displays the ratio by vehicle class for the seven MdTA toll facilities. Figure 5 displays the ratio of revenue generated by the effective revenue neutral tolls to the current revenue (both including discounts). Ratios higher than 1.0 represent vehicle classes that are responsible for more costs than they currently pay (undercharged). Ratios lower than 1.0 represent vehicle classes that have a lower cost responsibility than they currently pay (overcharged).

The results show that for most of the MdTA facilities (JFK Highway, Bay Bridge, Nice Bridge, and Baltimore Harbor Tunnel), two-axle vehicles are currently overcharged for the costs they incur on the facility, while five-axle vehicles (the highest volume truck category) are undercharged.

It is clear that each MdTA facility has a unique discount program, which affects the results in different ways. For the Key Bridge and Hatem Bridge, the discounts significantly impact the results. For these two facilities with heavy use of commuter discount plans, two-axle vehicles are currently underpaying their fair share, while five-axle vehicles are currently overpaying.

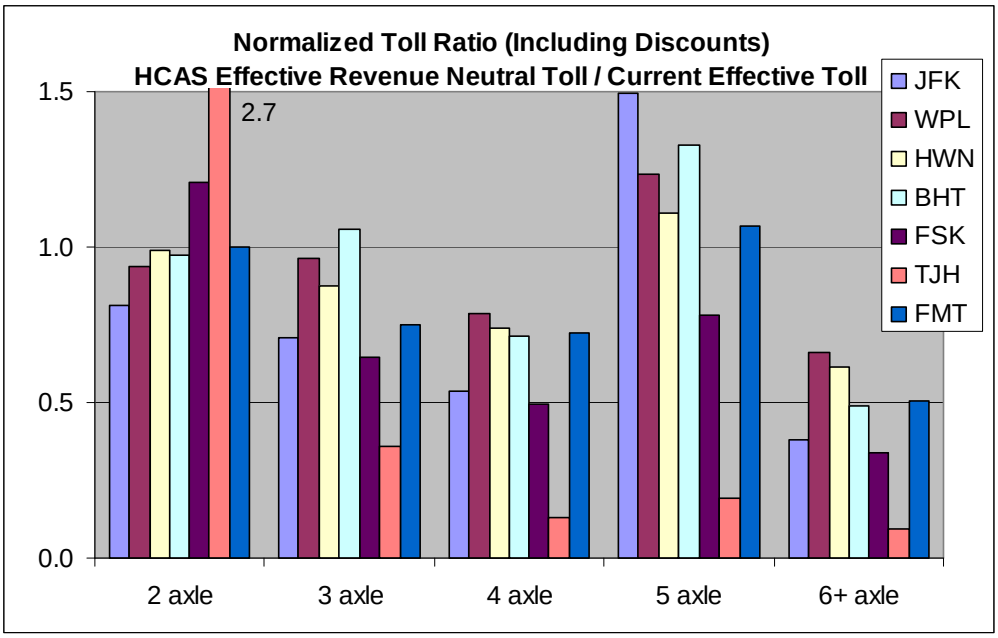

Figure 4. Normalized Toll Ratio (Including Discounts)

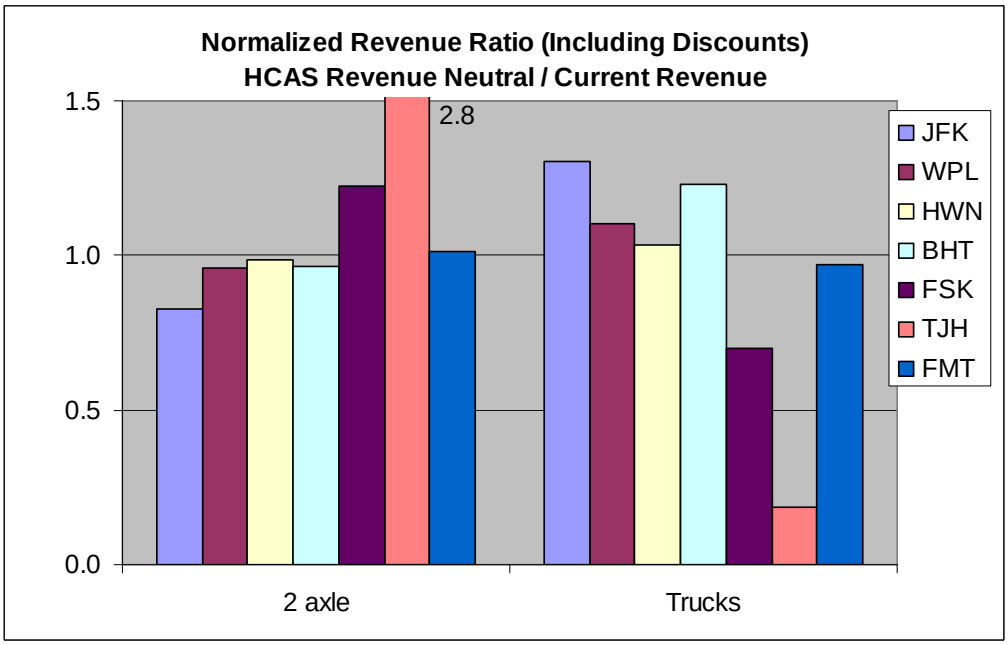

Figure 5. Normalized Revenue Ratio (Including Discounts)

6.0 HCAS SYSTEM-WIDE RESULTS

Initially, the HCAS were completed independently for each MdTA toll facility. In order to see system-wide results, the total revenues for each vehicle class were computed, based on 2006 traffic and MdTA revenue data. The total revenues for each vehicle class were also computed based on the HCAS results including toll discounts. These system wide total revenues by vehicle class are summarized in Table 30. The table also summarizes the ratio of the "fair share" to current revenues paid by each vehicle class. The data in Table 30 are also the basis for the pie chart distributions shown in Figures 6 and 7. The results show that two-axle vehicles are currently overcharged for the costs they incur (68% in Figure 6 vs. 65% in Figure 7, "fair share"/current toll ratio of 0.94), while five-axle trucks are currently undercharged (25% in Figure 6 vs. 31% in Figure 7, "fair share"/current toll ratio of 1.24). Three, four and six+ axle vehicles are slightly overpaying their fair share; however, the low volumes and varied characteristics of vehicles in these vehicle classes make it difficult to interpret their contribution to costs.

Table 30. System-Wide Revenues by Vehicle Class

Vehicle Class	Revenues ($M)		Ratio:
	Current	HCAS	"Fair Share"/Current
Two-Axle	$187.1	$176.2	0.94
Three-Axle	$8.0	$6.5	0.82
Four-Axle	$7.9	$5.0	0.63
Five-Axle	$69.0	$85.3	1.24
Six(+)-Axle	$1.9	$0.8	0.44

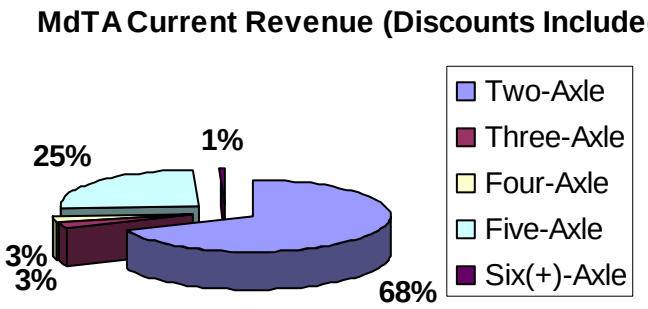

Figure 6. Percentage of Combined Highway and Bridge Costs by Vehicle Toll Class – Current Effective Toll Rates

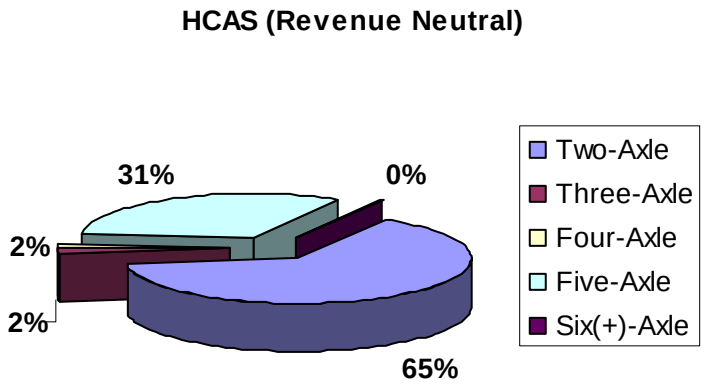

Figure 7. Percentage of Combined Highway and Bridge Costs by Vehicle Toll Class – HCAS Revenue Neutral Toll Rates

Figure 8 and Figure 9 display the ratios of the "fair share" revenue (i.e., the revenues from the HCAS) to current revenues (both including discounts). Figure 8 shows the ratio by MdTA vehicle classes, while Figure 9 groups three-axle vehicles and higher as trucks. Ratios higher than 1.0 represent vehicle classes that are responsible for more costs than they currently pay (undercharged). Ratios lower than 1.0 represent vehicle classes that have a lower cost responsibility than they currently pay (overcharged). Overall, two-axle vehicles are paying more than their fair share of costs and trucks (5 axle trucks, in particular) are paying less.

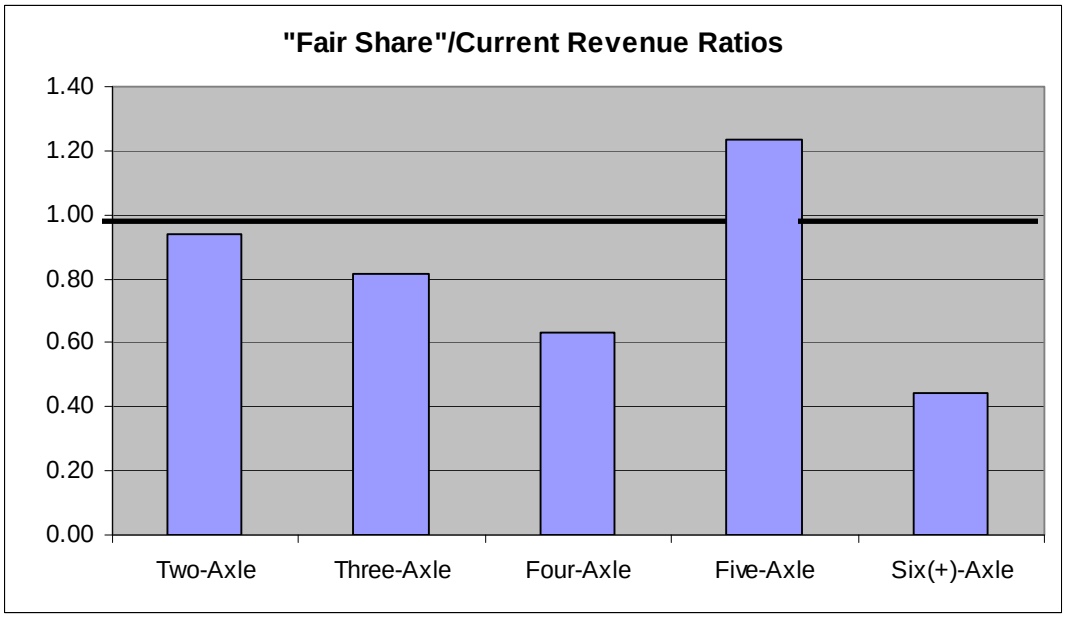

Figure 8. System-Wide Revenue Ratios (Including Discounts)

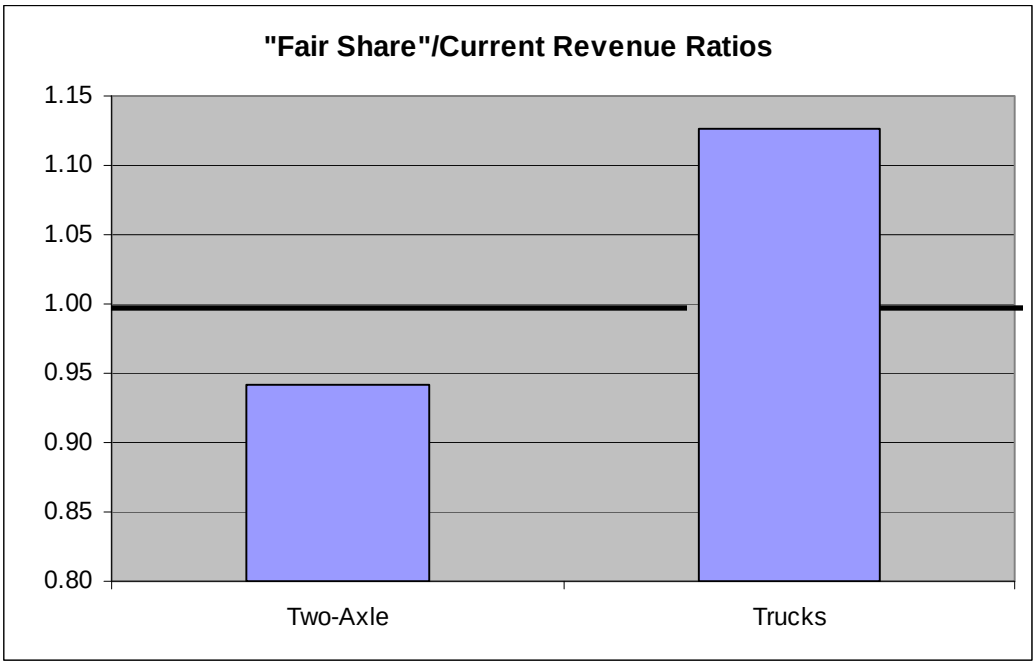

Figure 9. System-Wide Revenue Ratios (Including Discounts)

Similarly, Figure 10 displays the ratios of the HCAS "fair share" revenues to current revenues (both including discounts) when future costs are added to historical outlays. The data in this figure clearly show a growing disparity between two-axle's and trucks' revenues as future outlays are added to the analysis, with two-axle vehicles paying progressively more than their fair share and trucks paying progressively less.

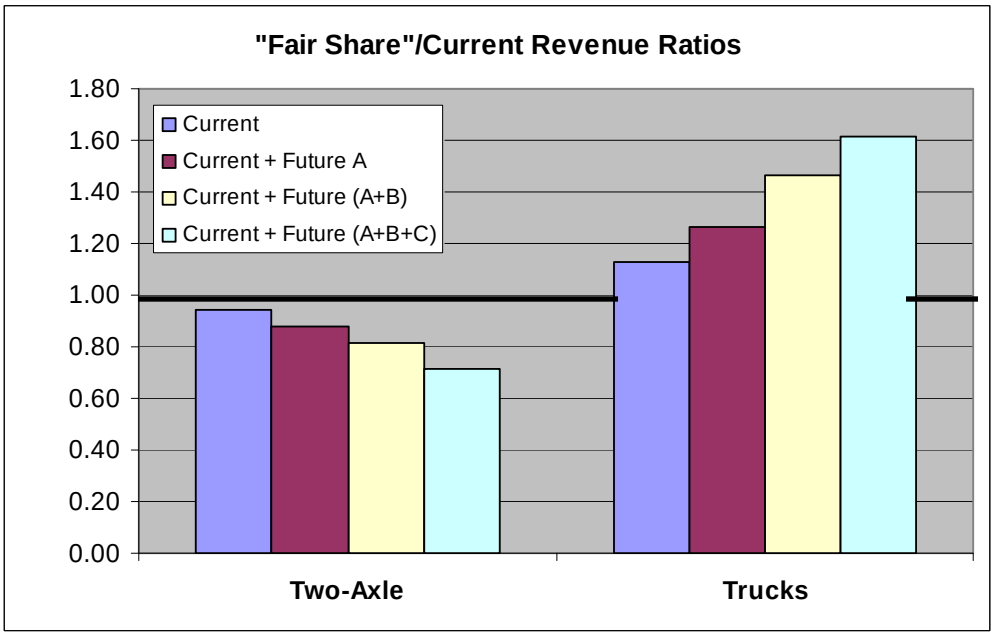

Figure 10. System-Wide Revenue Ratios With Future Costs (Including Discounts)