



CHART 2004 Performance Evaluation and Benefit Analysis

- Abridged Version -



Gang-Len Chang, Professor

Chih-Sheng Chou, Pei-Wei Lin

Research Assistants

University of Maryland, College Park

Steve Rochon

Traffic Engineer, MSHA



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<http://chartinput.umd.edu>



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- Module 2: Statistical Analysis and Comparison of Data Characteristics and Distribution
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Module 1

Evaluation of Data Quality



Contents

- Available Data for Year 2004
 - Available data in Year 2004 classified by Incident and by Disabled Vehicle
 - Available data in Year 2004 and comparison with the available data in Year 2003
- Data Quality Analysis
 - Data quality in Year 2004 and comparison with the data quality in Year 2003





Available Data for Year 2004

– classified by type

Year	Type		Total
	Disabled Vehicles	Incidents	
2002	19,062	13,752	32,814
2003	20,455	18,068	38,523
2004	21,412	19,127	40,539

Note: Data Format – CHART II Database



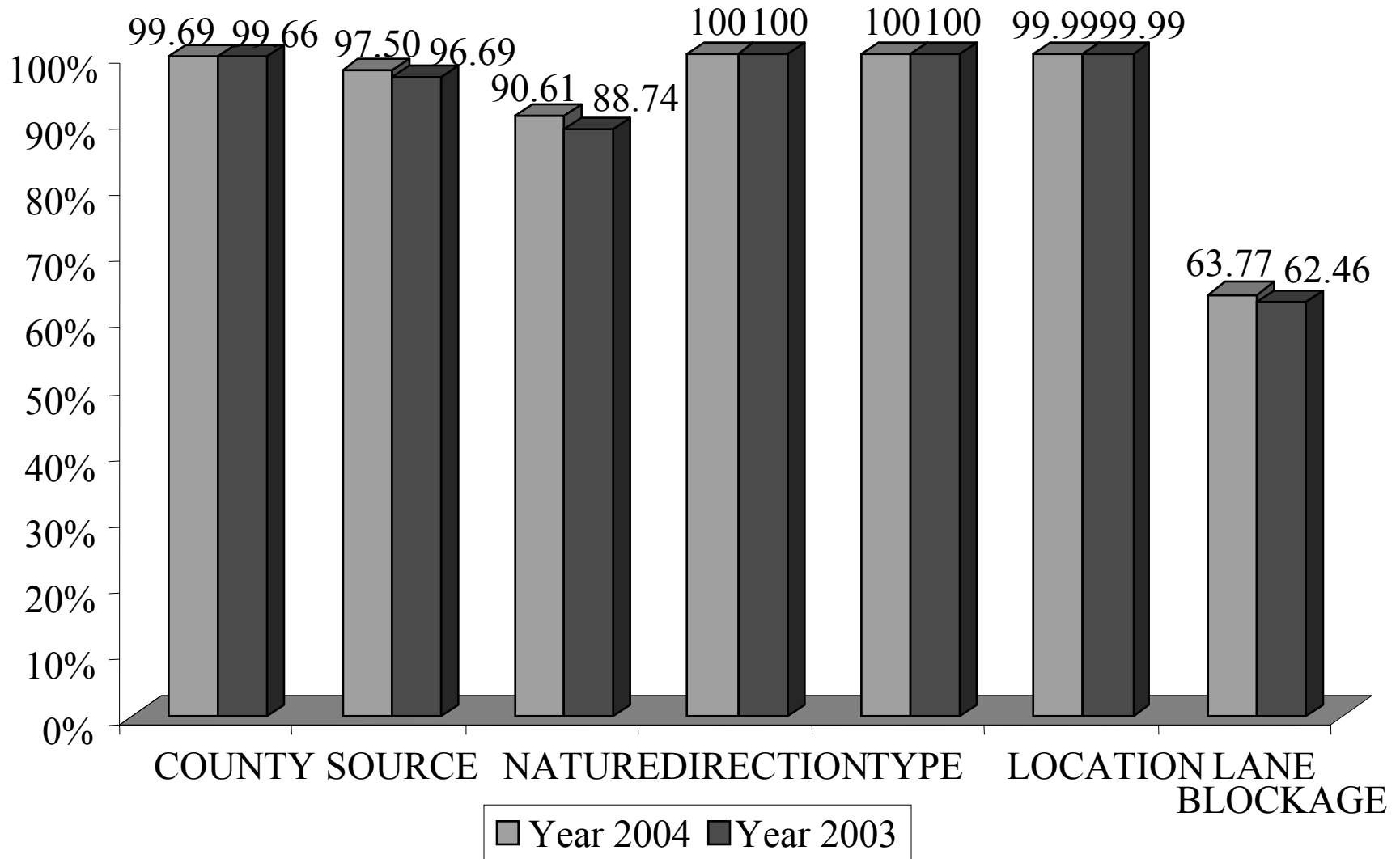
Available Data for Year 2004

– classified by type and operations center

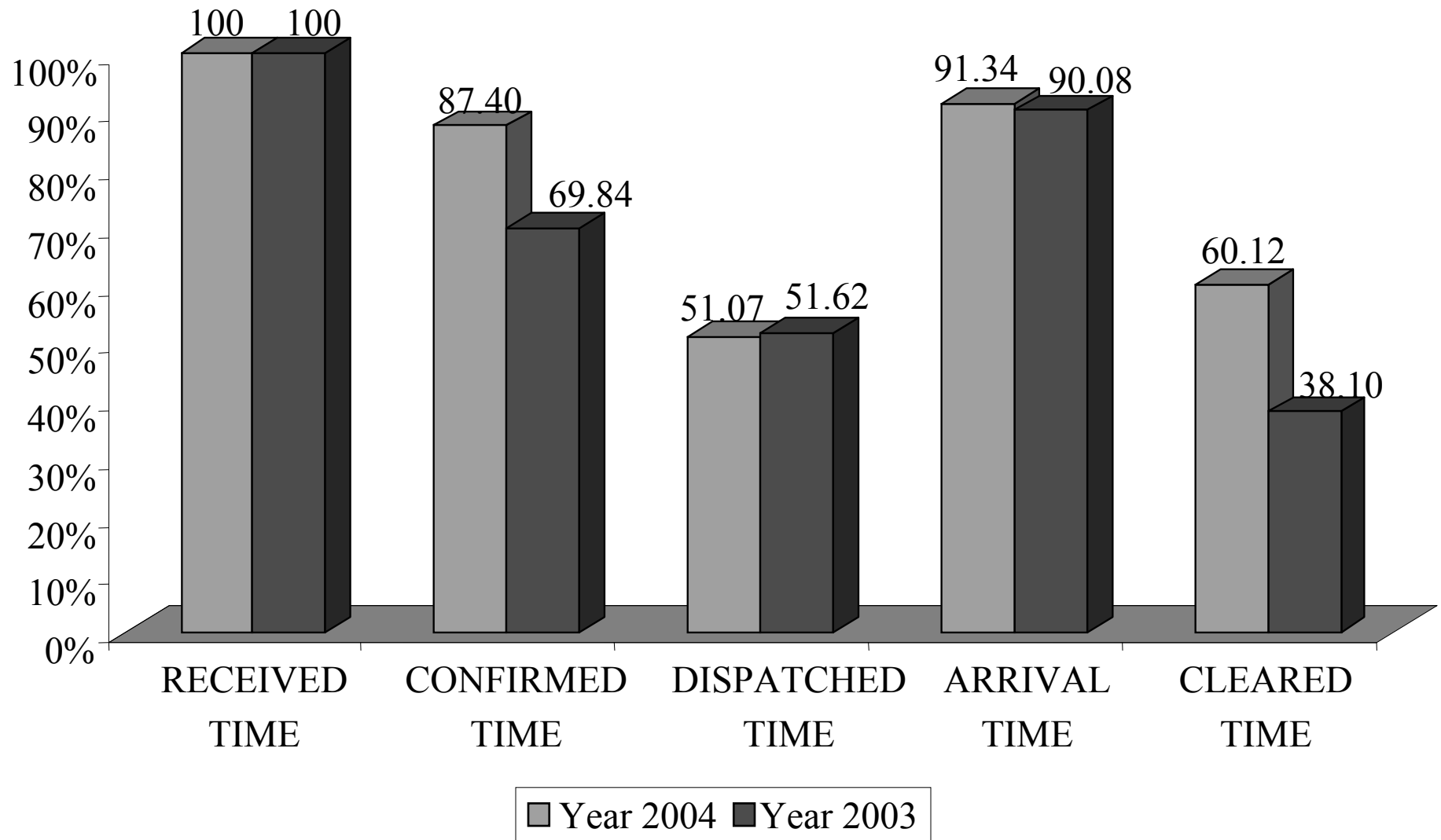
Operations Center	TOC3	TOC4	SOC	TOC5	Other	Total
Disabled Vehicles	8,551	9,750	932	904	1,275	21,412 (20,455)
Incidents	6,464	6,066	2,996	157	3,444	19,127 (18,068)
Total	15,015	15,816	3,928	1,061	4,719	40,539 (38,523)

Note: Number in each parenthesis shows the data from Year 2003.

Statistics Summary for Data Quality and Comparison



Statistics Summary for Data Quality and Comparison





Module 2

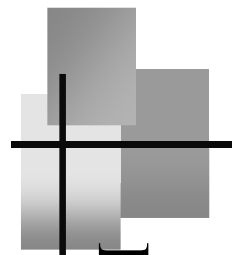
Statistical Analysis and Comparison of Data Characteristics and Distribution



Contents

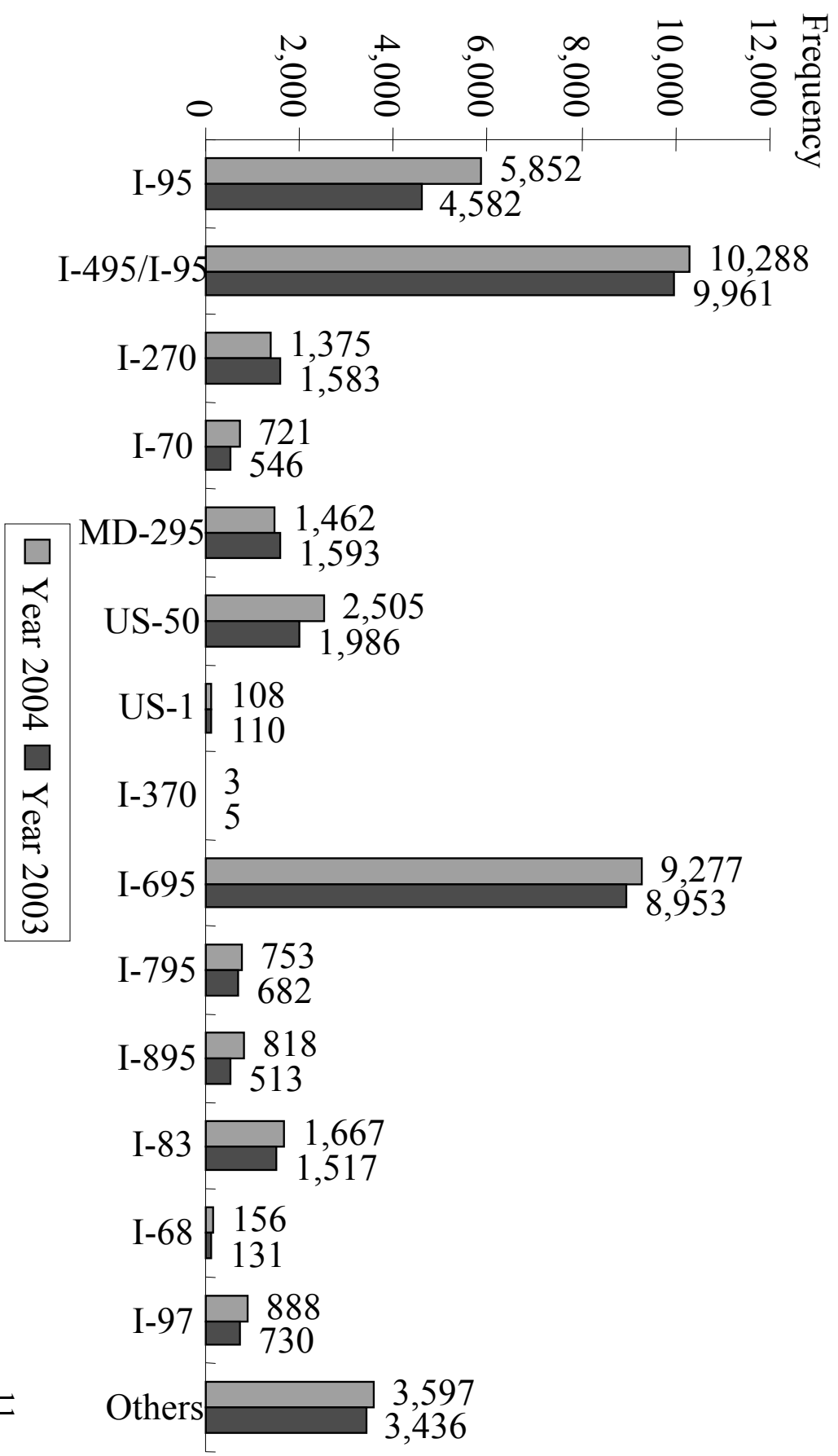
- Distribution of Incidents and Disabled Vehicles by
 - Road
 - Peak and Off-Peak Hours
 - Weekday and Weekend
 - Lane Blockage
 - Location
 - I-495/95, I-95, I-270, and I-695
 - Detection Source
 - Duration
 - Cleared Time – Received Time





Distribution of Incidents and Disabled Vehicles

- by Road -



Distribution of Incidents and Disabled Vehicles

- by Peak* and Off-Peak Hours -

	TOC 3		TOC 4		TOC 5	
	2004	2003	2004	2003	2004	2003
Peak*	44%	43%	46%	45%	16%	15%
Off-Peak	56%	57%	54%	55%	84%	85%
	SOC		Other		Total	
	2004	2003	2004	2003	2004	2003
Peak*	20%	22%	26%	24%	39%	40%
Off-Peak	80%	78%	74%	76%	61%	60%

Note: * Peak Hours – Weekdays 7:00 am to 9:30 am and 4:00 pm to 6:30 pm



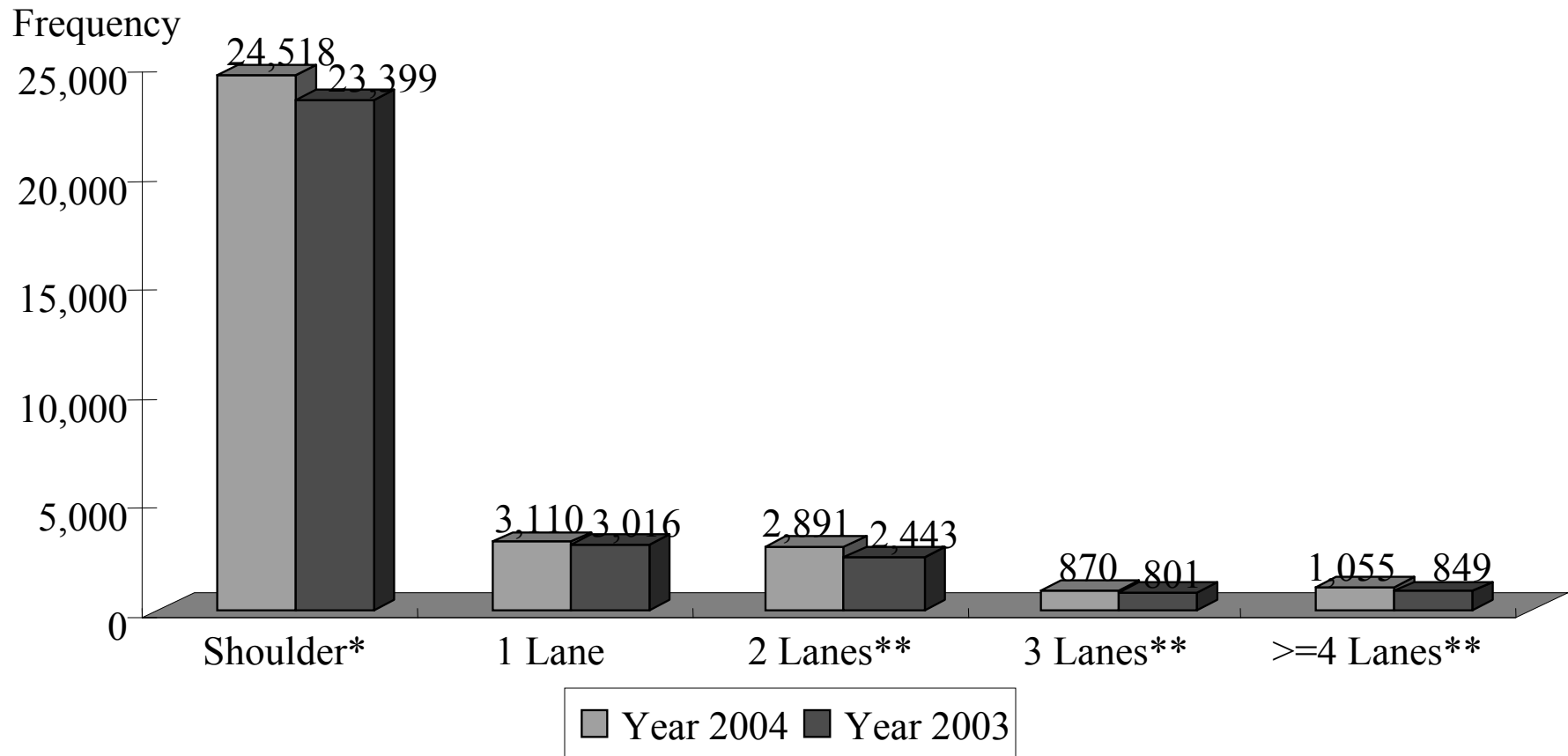
Distribution of Incidents and Disabled Vehicles

- by Weekday and Weekend -

	TOC 3		TOC 4		TOC 5	
	2004	2003	2004	2003	2004	2003
Weekdays	99%	98%	99%	98%	29%	30%
Weekends	1%	2%	1%	2%	71%	70%
	SOC		Other		Total	
	2004	2003	2004	2003	2004	2003
Weekdays	66%	70%	74%	70%	91%	92%
Weekends	34%	30%	26%	30%	9%	8%

Distribution of Incidents and Disabled Vehicles*

- by Lane Blockage -

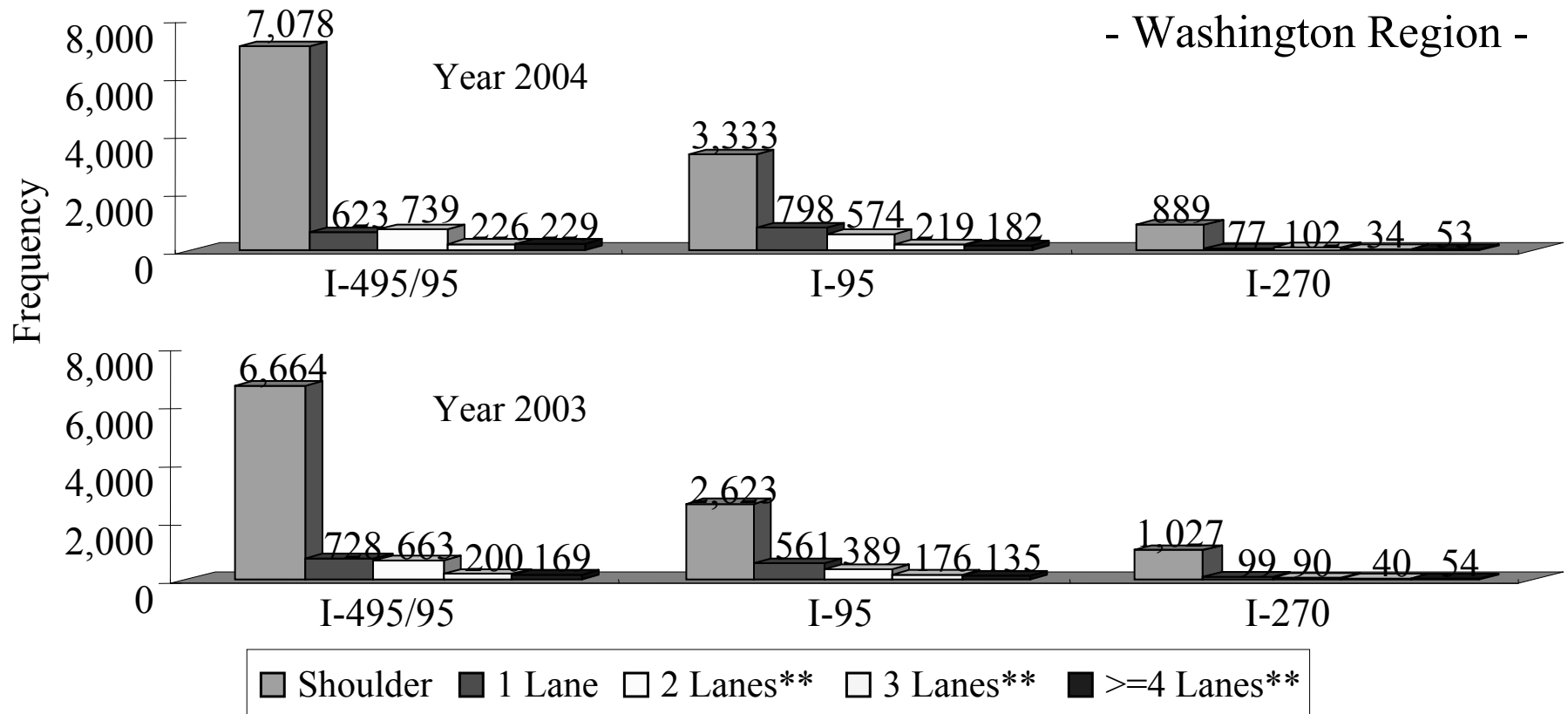


Note: * “Disabled Vehicles” are all classified as “Shoulder” lane blockage

** Also includes shoulder lane blockages

Distribution of Incidents and Disabled Vehicles*

- by Lane Blockage and Road -

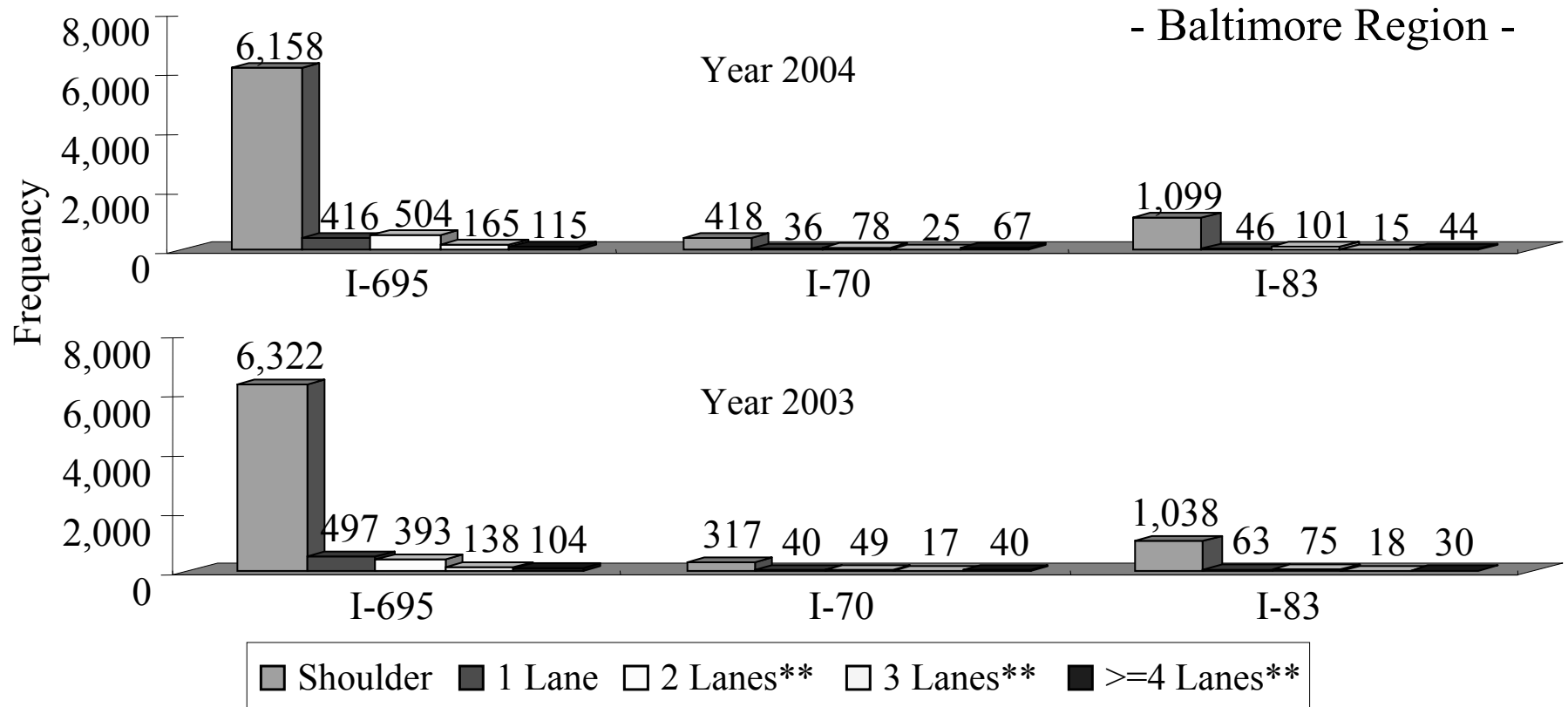


Note: * “Disabled Vehicles” are all classified as “Shoulder” lane blockage

** Also includes shoulder lane blockages

Distribution of Incidents and Disabled Vehicles*

- by Lane Blockage and Road -

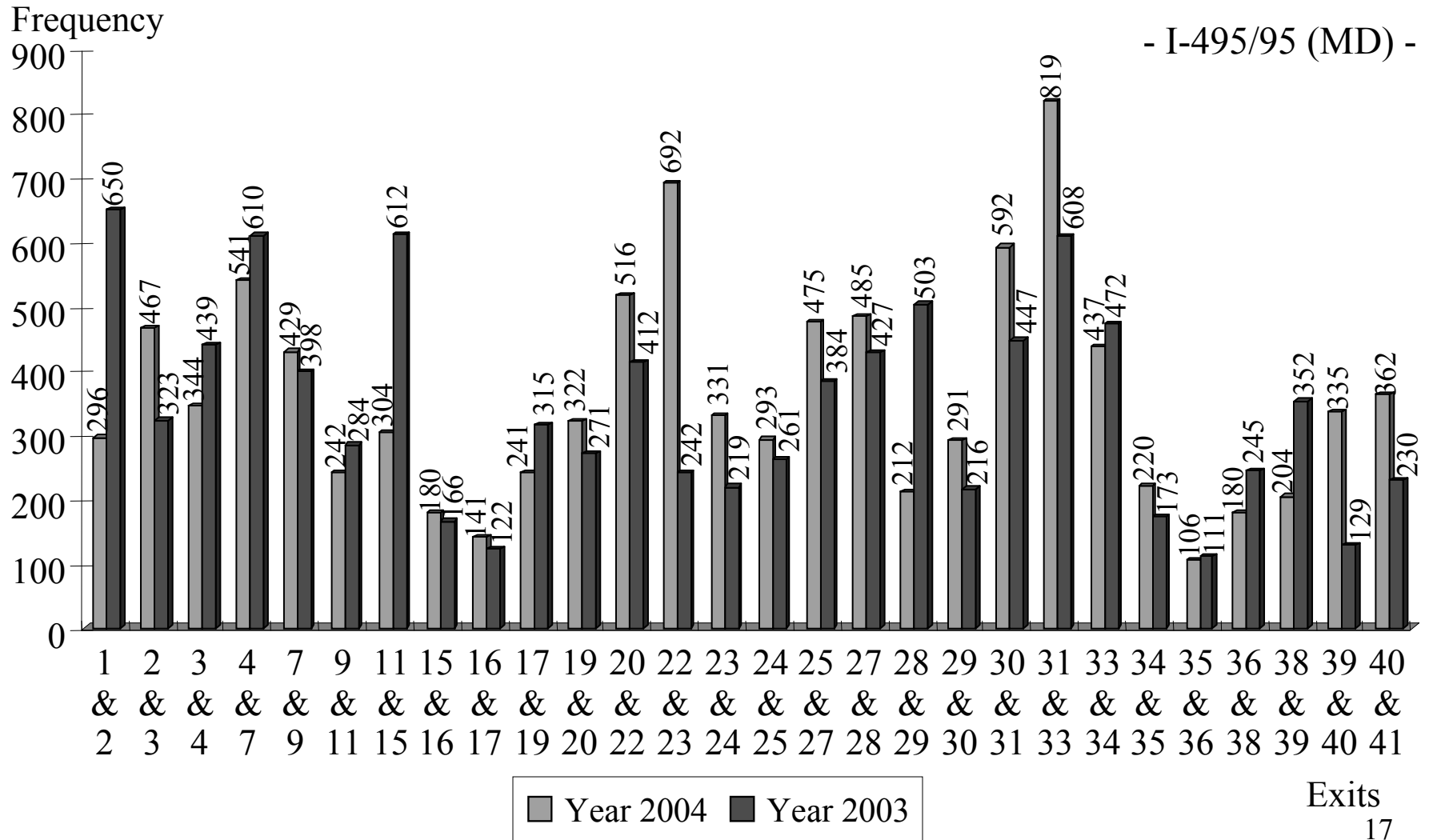


Note: * “Disabled Vehicles” are all classified as “Shoulder” lane blockage

** Also includes shoulder lane blockages

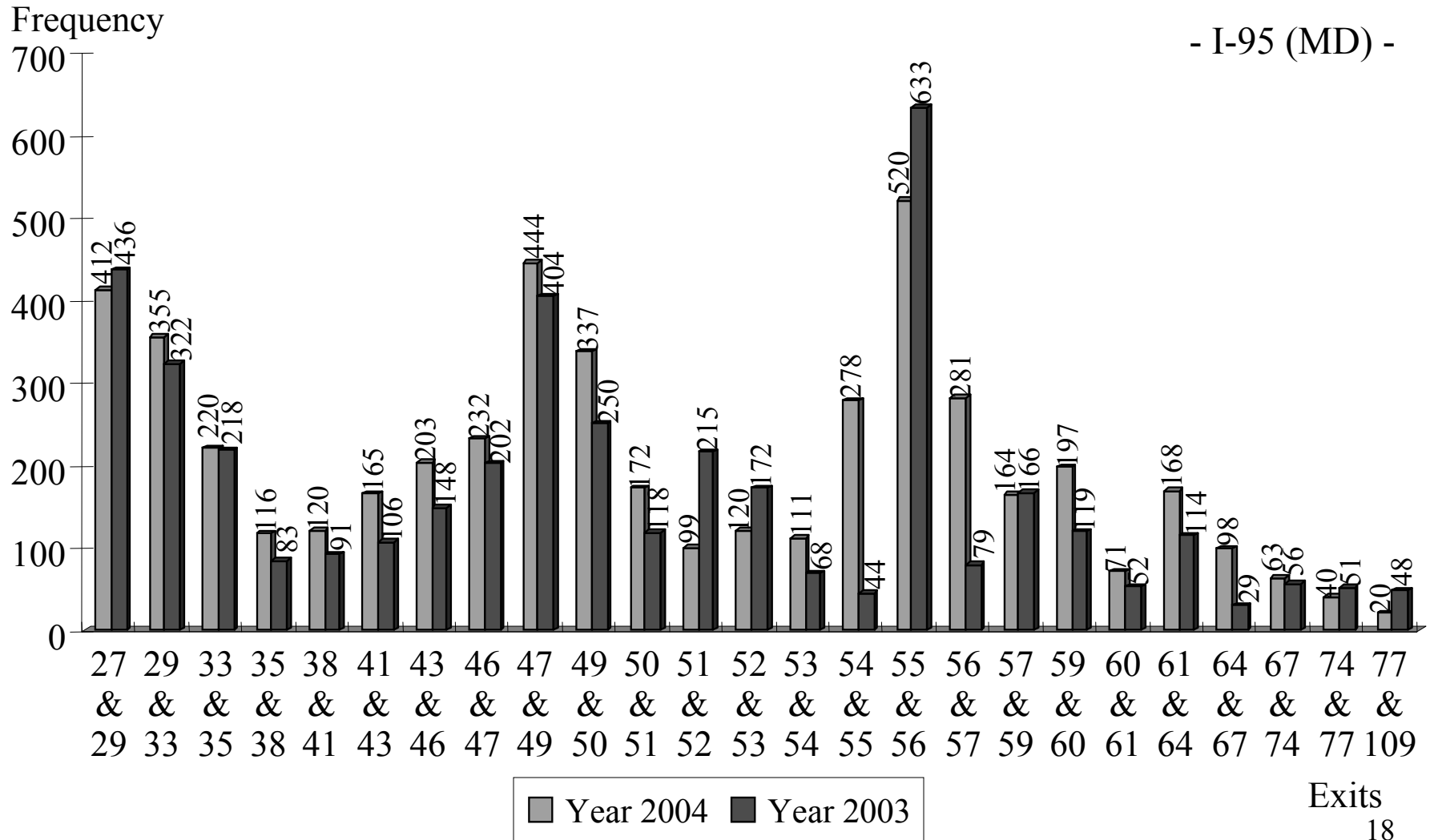
Distribution of Incidents and Disabled Vehicles

- by Location -



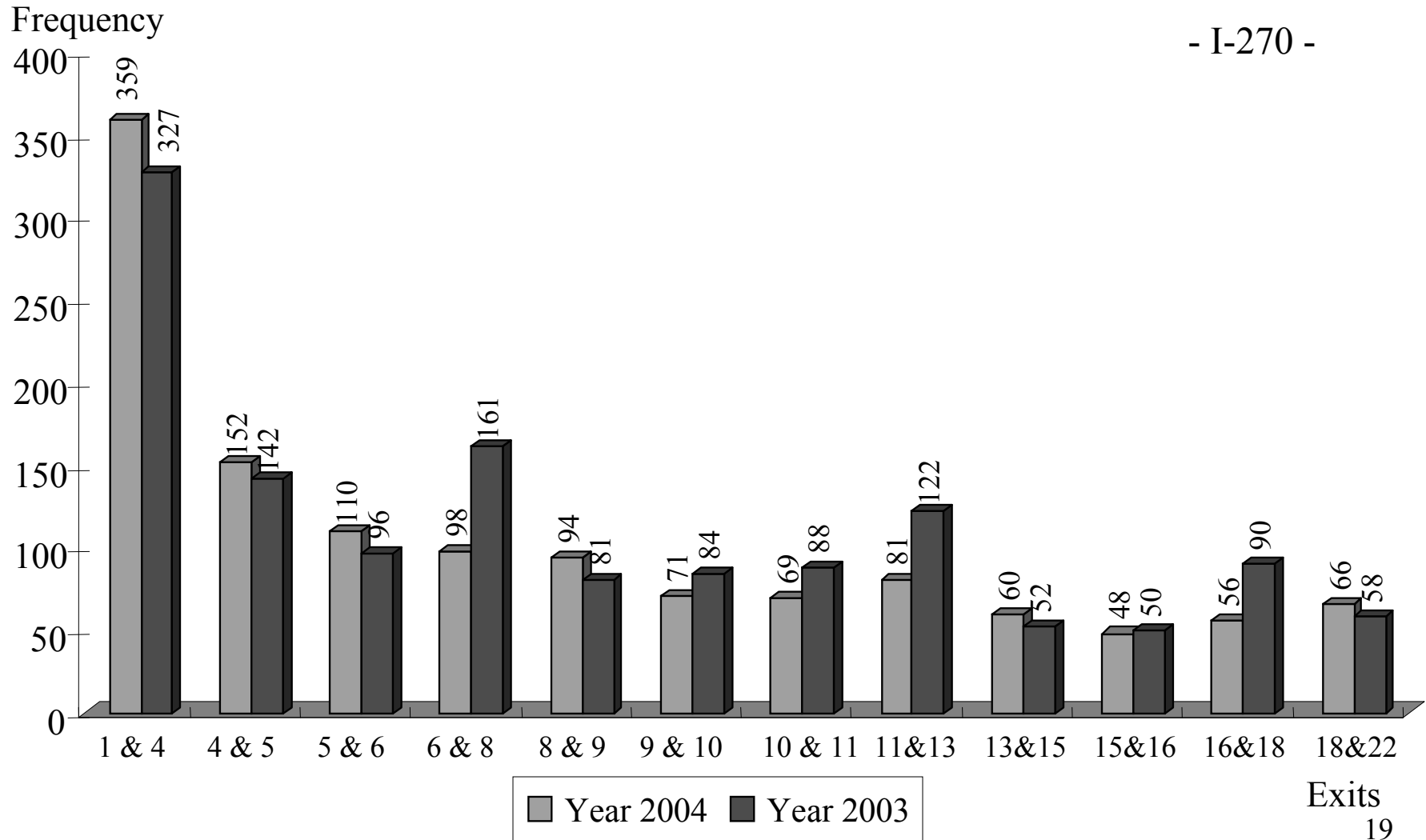
Distribution of Incidents and Disabled Vehicles

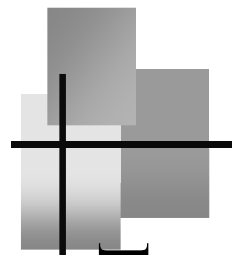
- by Location -



Distribution of Incidents and Disabled Vehicles

- by Location -

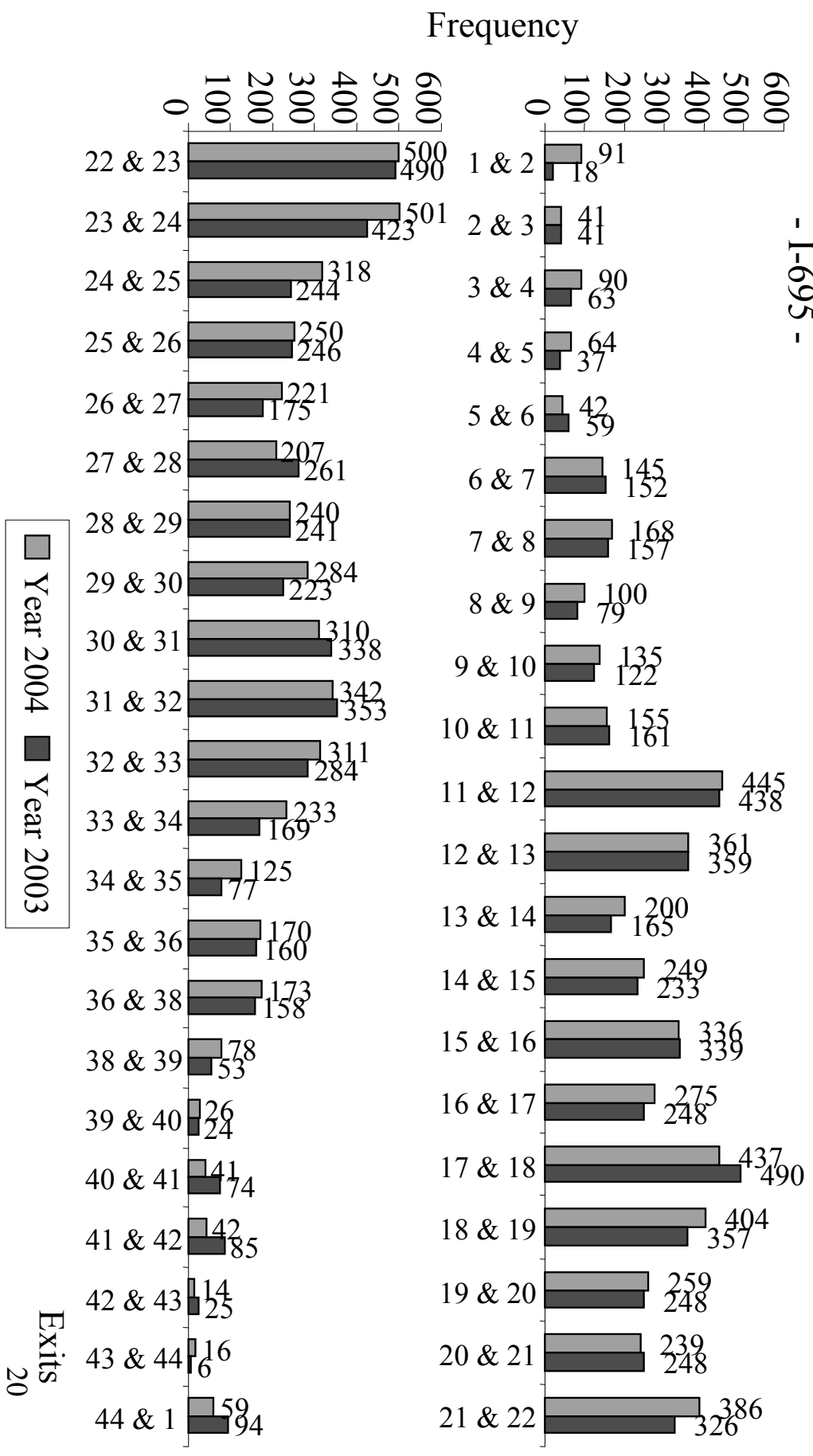




Distribution of Incidents and Disabled Vehicles

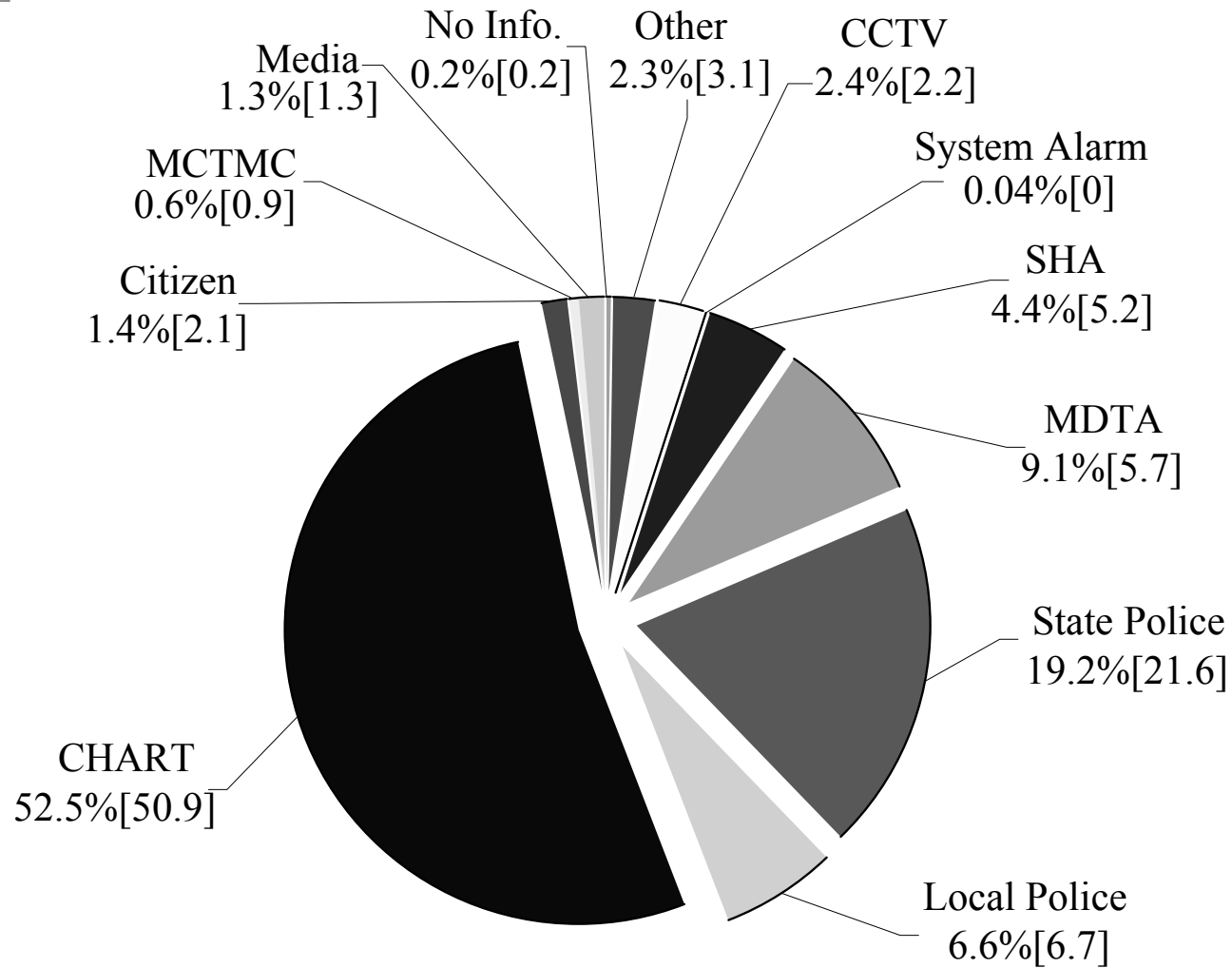
- by Location -

- I-695 -



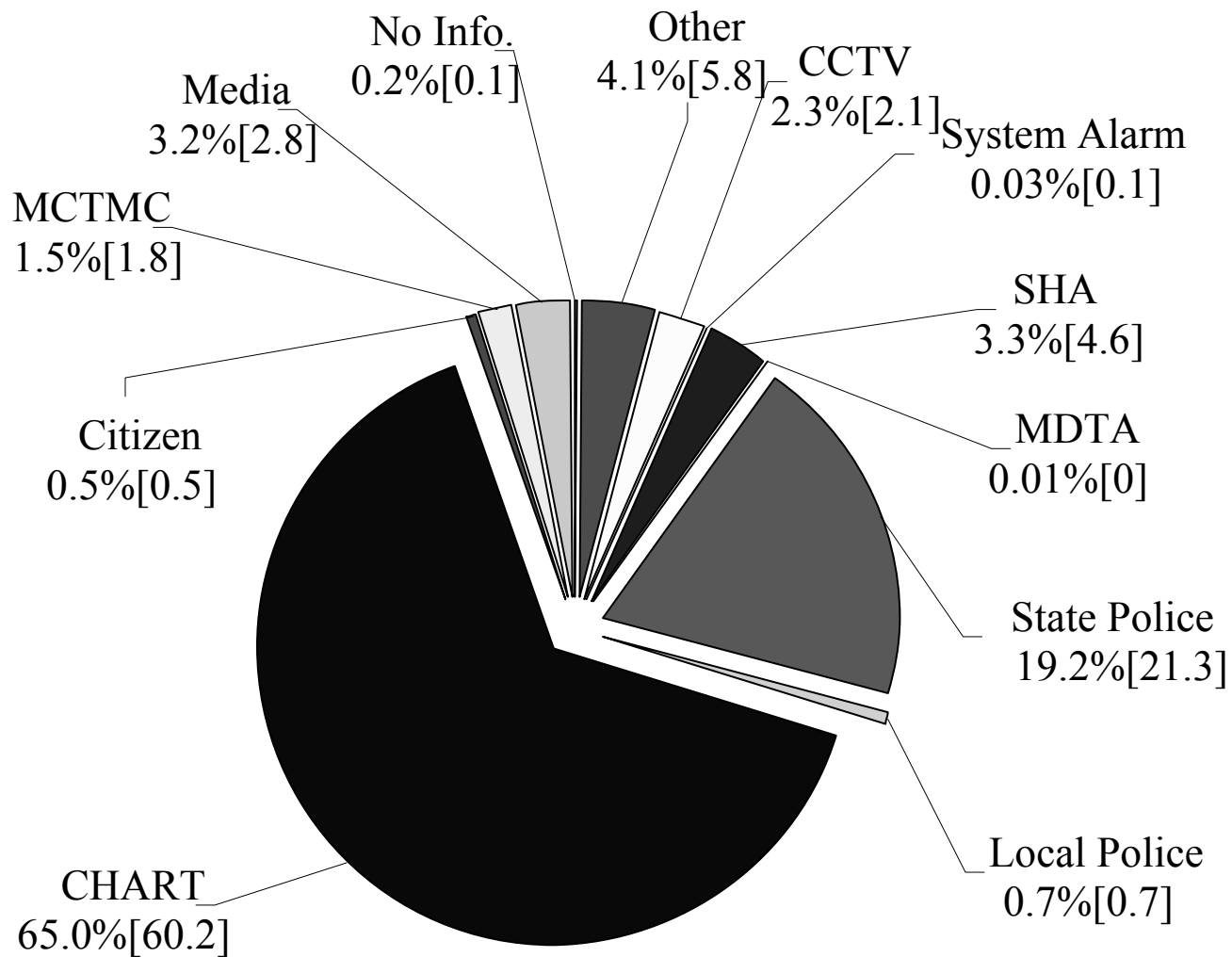
Exits
20

Sources of Detection



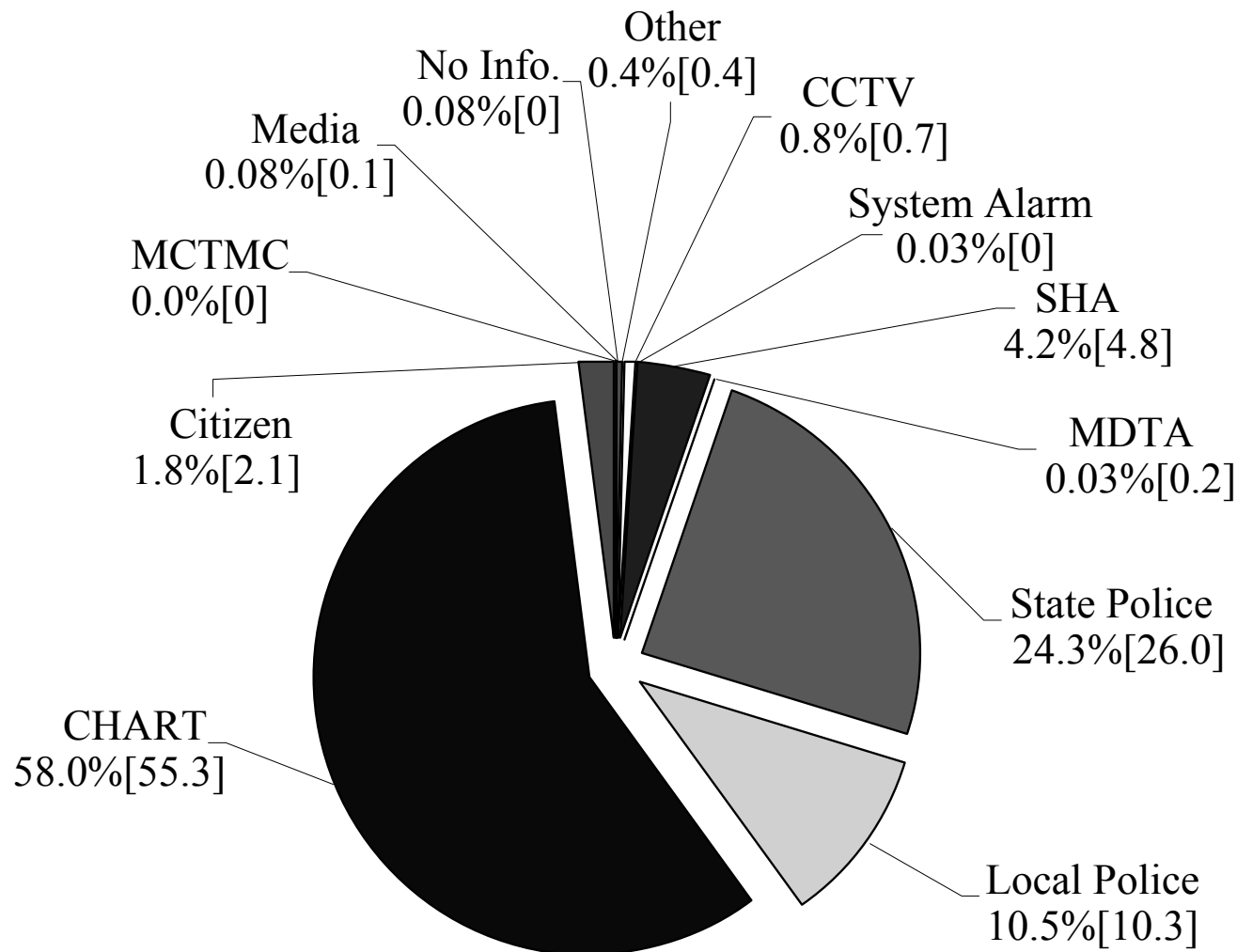
Note: Numbers in [] show the percentages from Year 2003

Sources of Detection for TOC 3



Note: Numbers in [] show the percentages from Year 2003

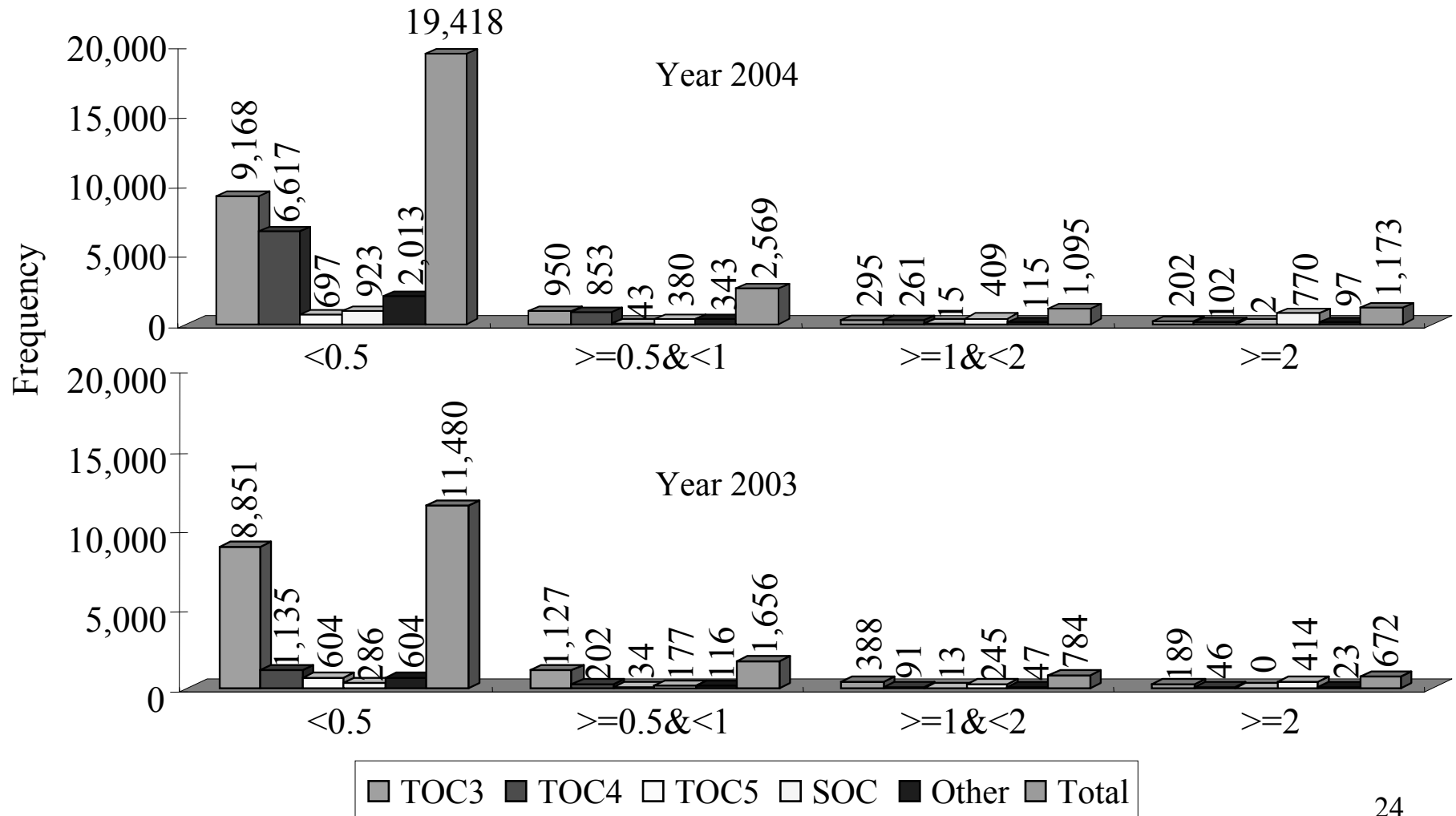
Sources of Detection for TOC 4



Note: Numbers in [] show the percentages from Year 2003

Distribution of Incidents and Disabled Vehicles

- by Duration and Operations Center -



Average Duration of Incidents

- by Lane Blockage and Road -

Duration (min) (Data Avail.)	I-495/I-95		I-95		I-270		I-695	
	2004	2003	2004	2003	2004	2003	2004	2003
Shoulder	14.0 (71%)	15.0 (73%)	23.3 (68%)	22.3 (40%)	15.6 (85%)	15.9 (73%)	20.2 (49%)	15.6 (9%)
1 Lane	23.5 (67%)	17.6 (75%)	27.9 (50%)	28.9 (30%)	37.9 (75%)	17.8 (65%)	52.0 (55%)	55.8 (16%)
2 Lanes*	26.5 (76%)	57.7 (71%)	54.1 (53%)	40.6 (29%)	34.8 (86%)	31.3 (74%)	48.1 (52%)	77.5 (15%)
3 Lanes*	39.6 (82%)	49.4 (65%)	67.6 (52%)	56.0 (31%)	43.2 (83%)	37.8 (76%)	63.4 (54%)	59.3 (21%)
≥ 4 Lanes*	77.6 (83%)	84.5 (64%)	95.7 (55%)	90.4 (31%)	81.3 (82%)	65.5 (84%)	88.7 (63%)	97.2 (27%)

Note: * Also includes “Shoulder” lane blockages

** The number in each parenthesis shows the percentage of data available



Module 3

Evaluation of Incident Management Performance

- Response Time, Clearance Time and Duration -



Contents

- Comparison of performance classified by operations center
 - Response Time
 - Duration
- Comparison of performance classified by lane blockage
 - Response Time
 - Clearance Time
 - Duration

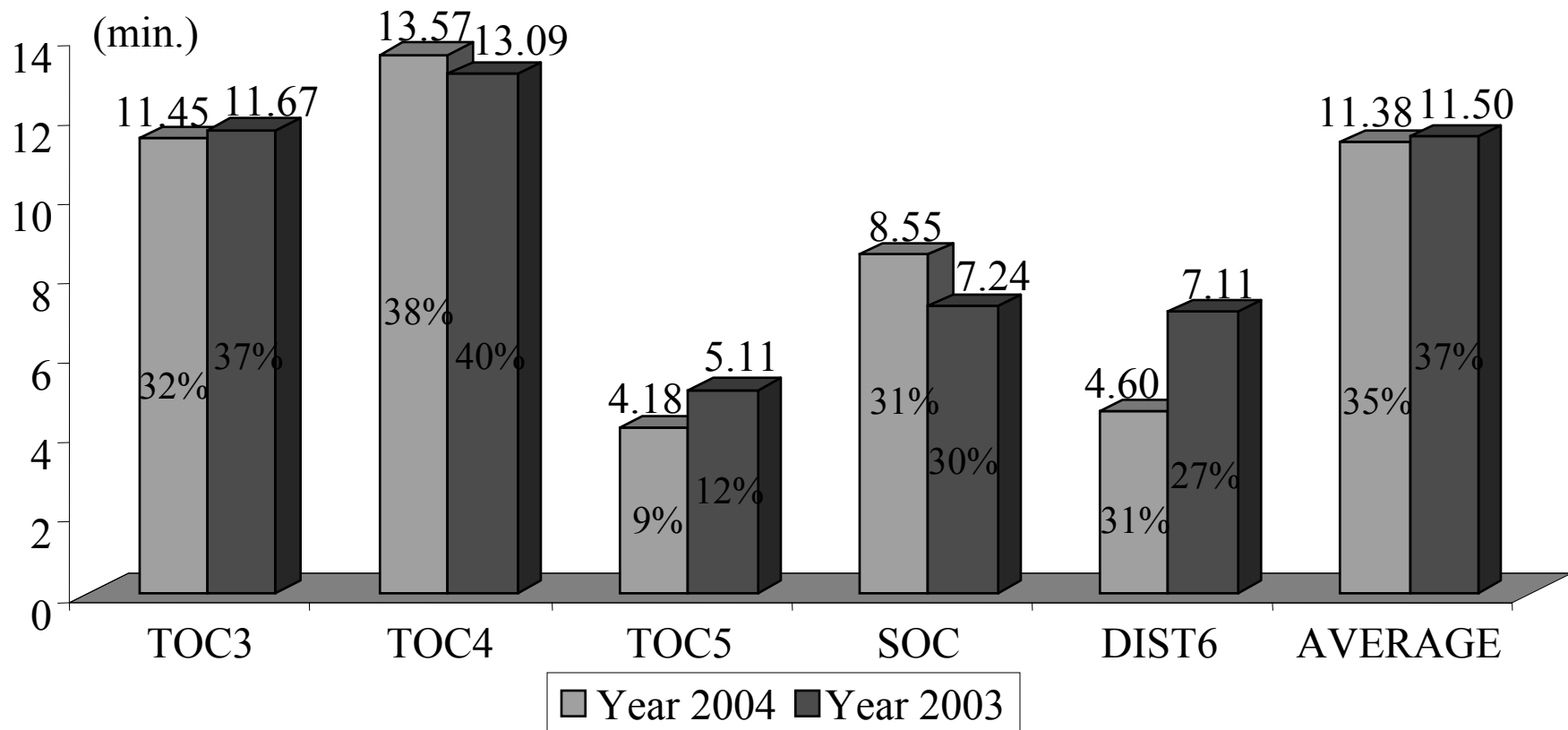


Response Time by Operations Center

Year 2004 v.s. Year 2003

Response Time = Arrival Time – Received Time

Response Time
(min.)

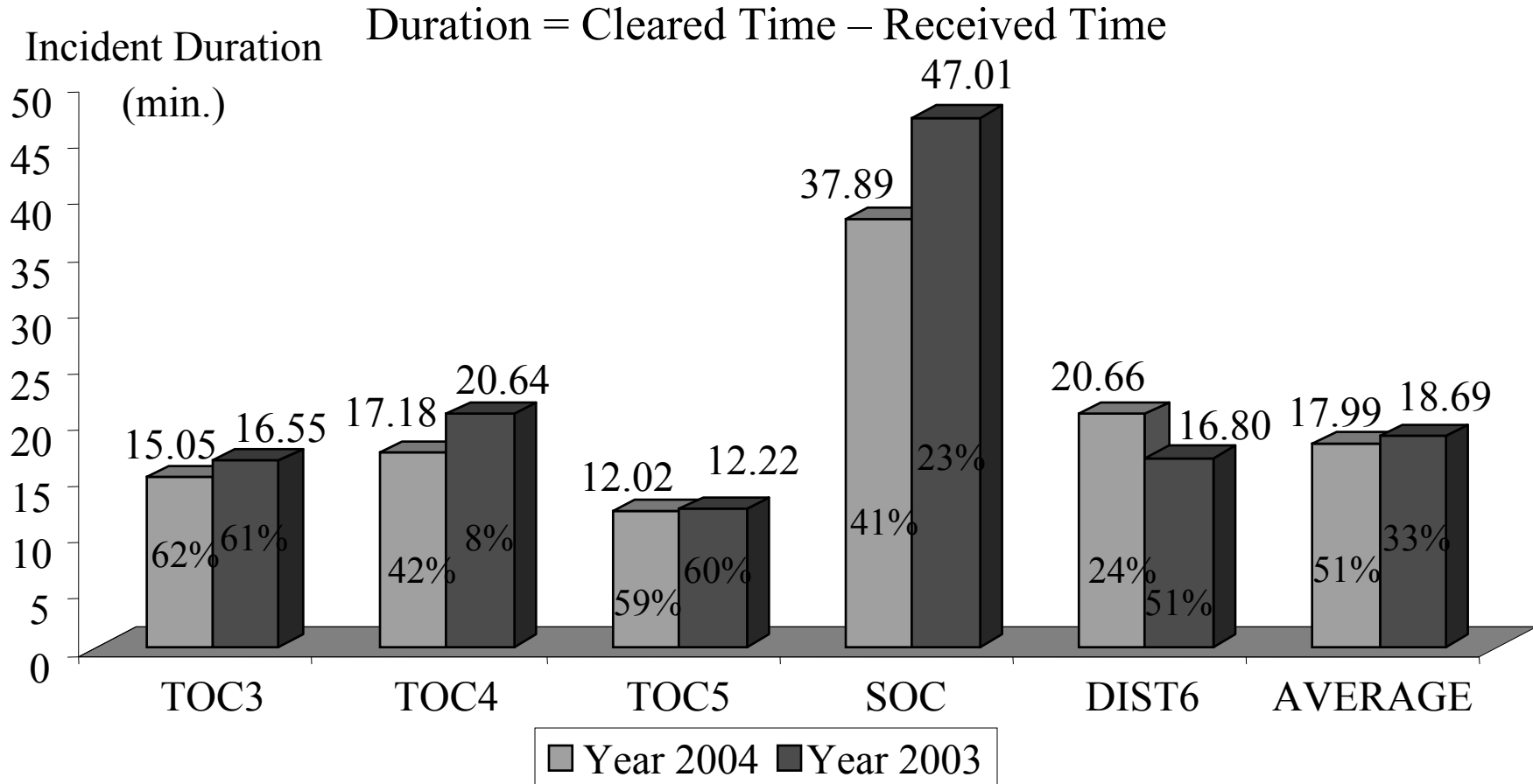


Note: 1. Only use data with Response time \geq 60 seconds and \leq 1 hours.

2. The percentage shows the amount of data available for computing the Response Time.

Duration by Operations Center

Year 2004 v.s. Year 2003



Note: 1. Only use data with Response time \geq 60 seconds and \leq 1 hours.

2. The percentage shows the amount of data available for computing the Duration.

Incident Response Time by Lane Blockage

Response Time = Arrival Time – Received Time

Blockage	With SHA Patrol		Without SHA Patrol	
	Response Time (min)	Frequency	Response Time (min)	Frequency
shoulder	3.96	2,798	2.21	307
1 lane	5.63	1,648	2.51	1,462
2 lanes	4.22	2,159	2.53	732
3 lanes	5.03	653	1.93	217
>=4 lanes	5.14	847	1.83	208
Unknown	9.30	6,777	4.55	1,319
Total	6.73 (7.27)	14,882 (14,591)	3.06 (3.03)	4,245 (3,477)

Note: 1. “Response Time” is computed by the qualified samples with their durations within mean \pm 2*deviation and less than 2 hours.

2. The number in each parenthesis shows the result of year 2003.

Incident Clearance Time by Lane Blockage

Clearance Time = Cleared Time – Arrival Time

Blockage	With SHA Patrol		Without SHA Patrol	
	Clearance Time (min)	Frequency	Clearance Time (min)	Frequency
shoulder	10.16	2,798	21.71	307
1 lane	19.03	1,648	15.78	1,462
2 lanes	23.20	2,159	28.86	732
3 lanes	31.72	653	40.12	217
>=4 lanes	49.59	847	41.44	208
Unknown	10.11	6,777	16.23	1,319
Total	16.20 (17.00)	14882 (14,591)	21.10 (23.74)	4245 (3,477)

Note: 1. “Clearance Time” is computed by the qualified samples with their durations within mean \pm 2*deviation and less than 2 hours.

2. The number in each parenthesis shows the result of year 2003.

Incident Duration by Lane Blockage (1/2)

Incident Duration = Cleared Time - Received Time

Blockage	With SHA Patrol		Without SHA Patrol	
	Duration (min)	Frequency	Duration (min)	Frequency
shoulder	14.93	2,798	24.64	307
1 lane	43.99	1,648	22.86	1,462
2 lanes	49.86	2,159	54.41	732
3 lanes	52.47	653	76.69	217
>=4 lanes	106.61	847	77.04	208
Unknown	41.84	6,777	62.77	1,319
Total	42.34 (39.5)	14,882 (14,591)	46.24 (49.1)	4,245 (3,477)

Note: 1. "Duration" is computed by the qualified samples with durations within mean ± 2 *deviation.

2. The number in each parenthesis shows the result of year 2003.

Incident Duration by Lane Blockage (2/2)

Incident Duration = Cleared Time - Received Time

Blockage	With SHA Patrol		Without SHA Patrol	
	Duration (min)	Frequency	Duration (min)	Frequency
shoulder	14.93	2,798	24.64	307
1 lane	23.40	1,648	19.15	1,462
2 lanes	27.50	2,159	32.76	732
3 lanes	35.41	653	43.39	217
>=4 lanes	53.47	847	43.90	208
Unknown	19.40	6,777	20.14	1,319
Total	22.82 (24.13)	14,882 (14,591)	24.65 (26.77)	4,245 (3,477)

Note: 1. "Duration" is computed by the qualified samples with durations within mean ± 2 *deviation and less than 2 hours.

2. The number in each parenthesis shows the result of year 2003.



Module 4

Benefits due to Incident Management by CHART

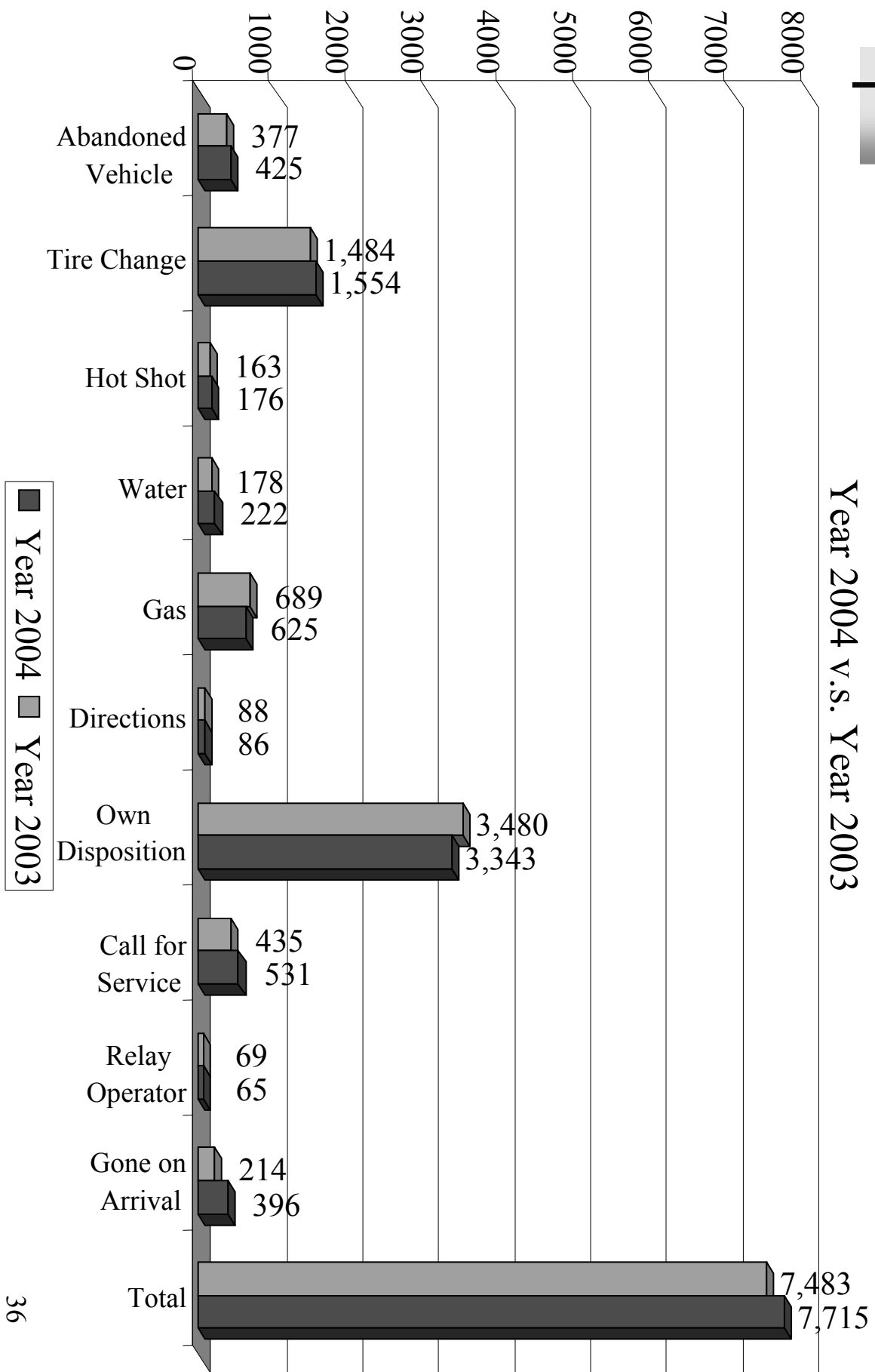


Contents

- Benefits due to Incident Management by CHART
 - Assistance to Drivers
 - Direct Benefits to Highway Users
 - Benefits due to efficient removals of stationary vehicles

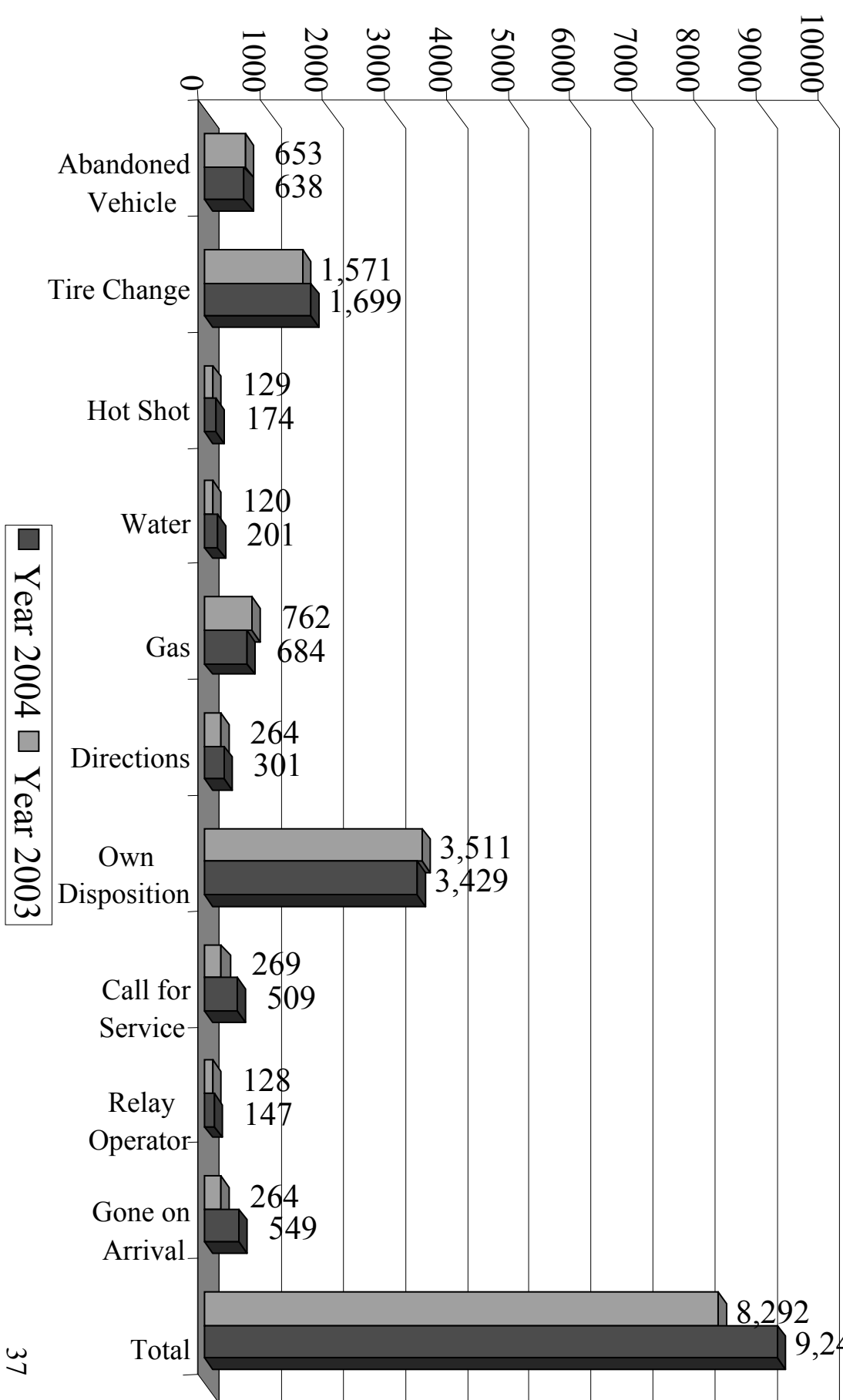
Nature of Driver Assists by TOC-3

Year 2004 v.s. Year 2003



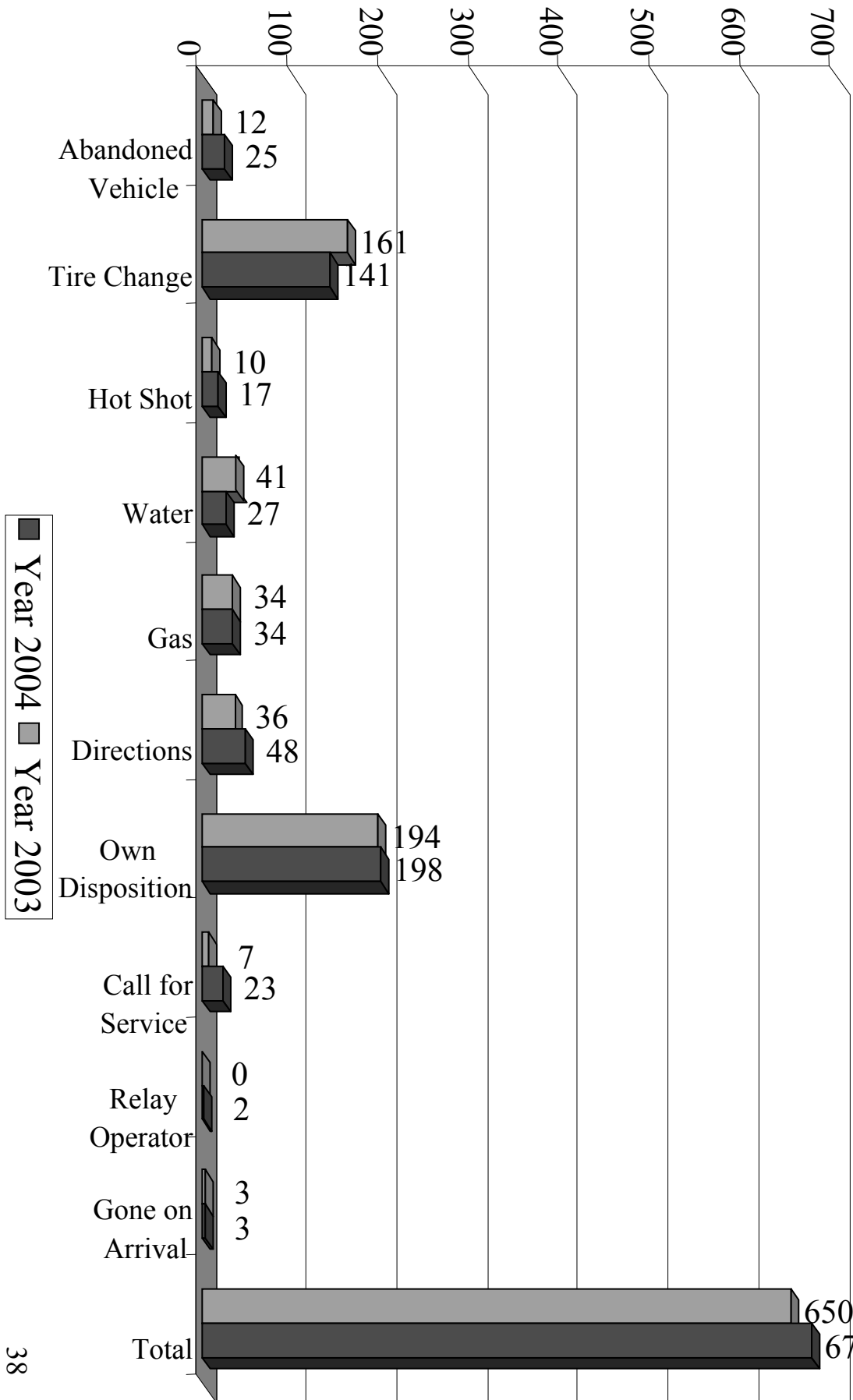
Nature of Driver Assists by TOC-4

Year 2004 v.s. Year 2003



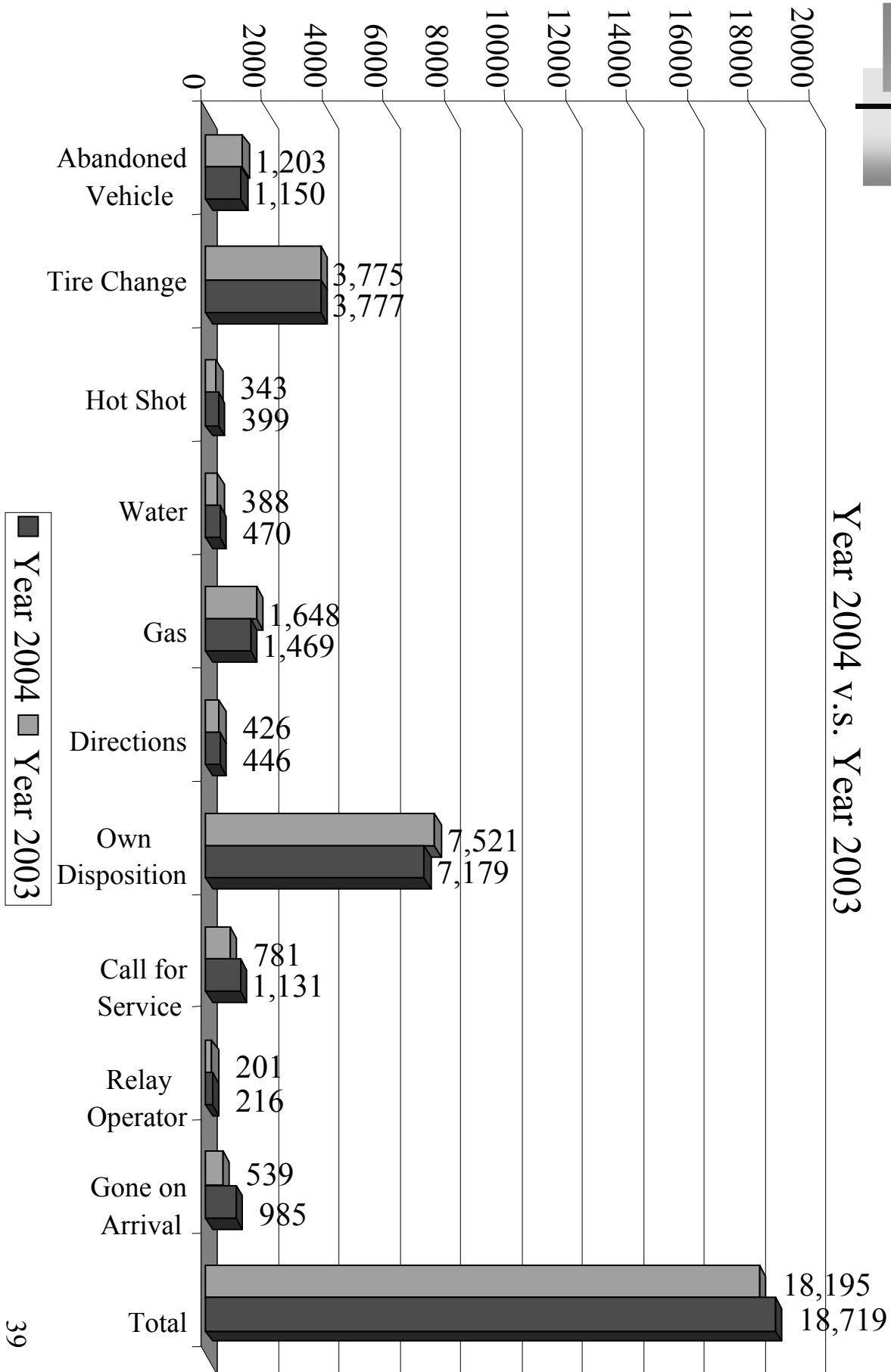
Nature of Driver Assists by TOC-5

Year 2004 v.s. Year 2003



Nature of Driver Assists (Total)

Year 2004 v.s. Year 2003





Direct Benefits to Highway Users (cont.)

- Excessive Delay due to a Non-Recurrent Incident:

$$\Delta Delay = e^{-10.19} * (Traffic Volume)^{2.8} * \left(\frac{No. of Lane Blocked}{Total No. of Lanes} \right)^{1.4} * (Incident Duration)^{1.78}$$

- Additional Fuel Consumptions

$$\Delta Fuel = e^{-10.77} * (Traffic Volume)^{2.27} * \left(\frac{No. of Lane Blocked}{Total No. of Lanes} \right)^{0.9} * (Incident Duration)^{1.69}$$

- *Calibration is based on Actual Incident Scenarios Simulated with CORSIM*



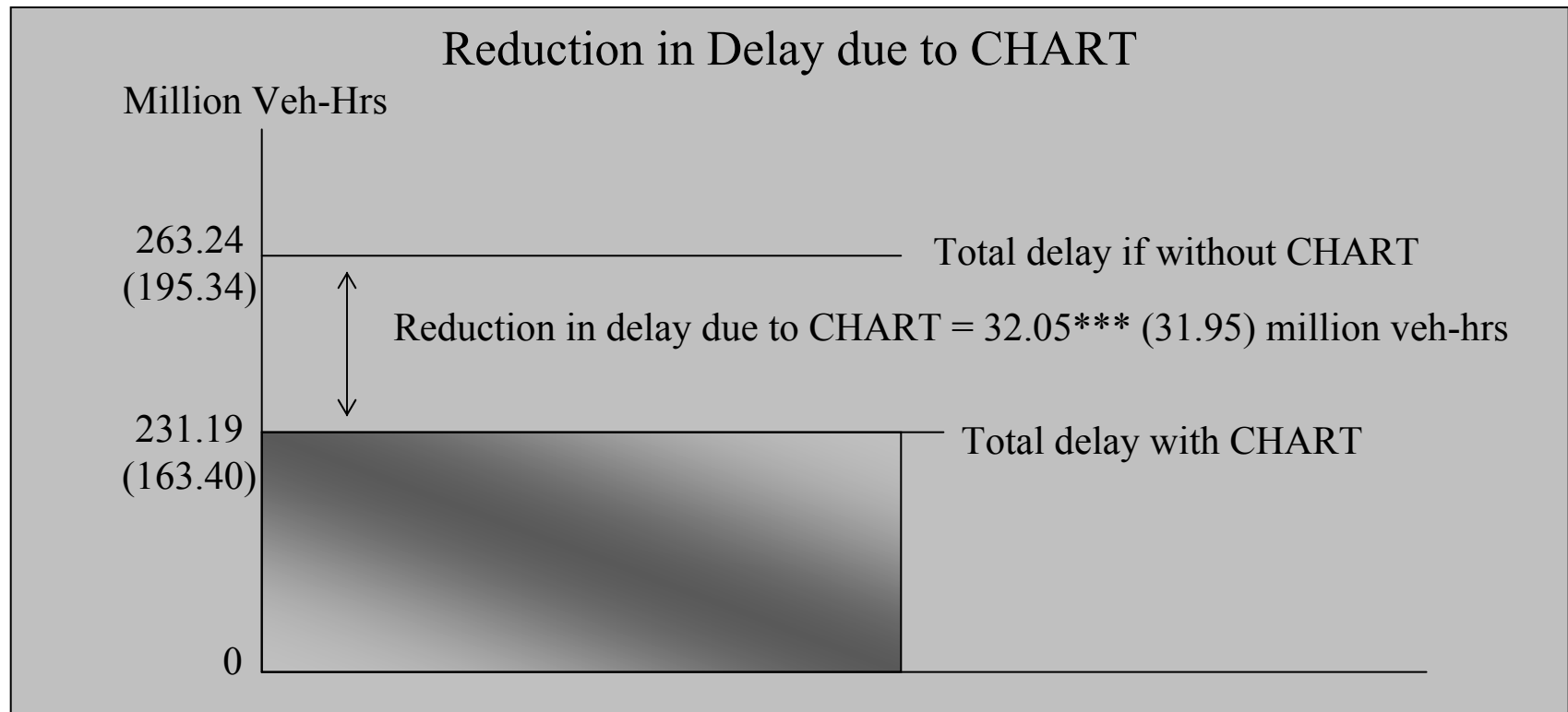
Direct Benefits to Highway Users (cont.)

- Emission Reduction Information
 - The parameters provided by MDOT*
 - HC: 13.073 grams per hour of delay
 - CO: 146.831 grams per hour of delay
 - NO: 6.261 grams per hour of delay
 - The emissions cost data proposed in the literature (Patrick, 1998)
 - \$6,700 per ton for HC
 - \$6,360 per ton for CO
 - \$12,875 per ton for NO

Note: * The parameters are provided by MDOT in Year 2000

Direct Benefits to Highway Users (cont.)

Duration = Cleared Time – Received time



Note: * The analysis has excluded the outlier data (i.e., mean \pm 2 standard deviation)
** Including delays due to rubber-necking effects incurred by shoulder-lane incidents
*** The number in each parenthesis shows the data from Year 2003

Direct Benefits to Highway Users (cont.)

- For Trucks Only -

Reduction due to CHART		I-495/ I-95	I-95	I-270	I-695	I-70	I-83	MD-295	US-50	US-1	Total
Truck (%)		13.83 (10.7)	13.83 (10.7)	8.00 (8.7)	9.94 (10.9)	21.08 (17.9)	13.29 (7.2)	3.58 (1.2)	8.76 (10.9)	6.25 (4.4)	
Delay (million veh-hrs)		0.530 (0.41)	0.430 (0.25)	0.032 (0.03)	0.816 (1.07)	0.110 (0.03)	0.192 (0.09)	0.044 (0.03)	0.076 (0.09)	0.006 (0.003)	2.236 (2.01)
Fuel consumption (million gallons)		0.089 (0.07)	0.073 (0.04)	0.005 (0.01)	0.138 (0.18)	0.019 (0.01)	0.032 (0.02)	0.007 (0.004)	0.013 (0.02)	0.001 (0.001)	0.377 (0.34)
Emissions (tons)	HC	6.93 (5.41)	5.62 (3.21)	0.42 (0.44)	10.67 (13.97)	1.44 (0.45)	2.51 (1.22)	0.57 (0.34)	0.99 (1.18)	0.08 (0.04)	29.23 (26.3)
	CO	77.83 (60.8)	63.11 (36.0)	4.71 (4.99)	119.88 (157)	16.14 (5.04)	28.18 (13.7)	6.43 (3.86)	11.10 (13.2)	0.95 (0.50)	328.32 (295)
	NO	3.32 (2.59)	2.69 (1.54)	0.20 (0.21)	5.11 (6.69)	0.69 (0.21)	1.20 (0.59)	0.27 (0.16)	0.47 (0.56)	0.04 (0.02)	14.00 (12.6)

Note: The number in each parenthesis shows the result in Year 2003

Direct Benefits to Highway Users (cont.)

- For Trucks Only -

Reduction due to CHART		Amount	Unit rate	In dollar (million)
Delay (million veh-hrs)	Truck	2.236	\$19.58/hour (truck driver's cost)	43.78 (39.34)
			\$45.40/hour (cargo's cost)	101.52 (91.21)
Fuel consumption (million gallons)		0.377	\$1/gal.	0.377 (0.339)
Emissions (tons)	HC	29.23	\$6,700/ton	2.464 (2.21)
	CO	328.32	\$6,360/ton	
	NO	14.00	\$12,875/ton	
Total		\$ 148.14 (133.10)		

Note: 1. The truck driver's cost and cargo's cost are computed based on the information shown later in the references

2. The number in each parenthesis shows the result in Year 2003.

Direct Benefits to Highway Users (cont.)

- For Total Vehicles -

Reduction due to CHART		Amount	Unit rate	In dollar (million)
Delay (million veh-hrs)	Truck	2.236	\$19.58/hour (truck driver's cost)	43.78 (39.34)
			\$45.40/hour (cargo's cost)	101.52 (91.21)
	Car *	23.709	\$14.34/hour (car driver's cost)	339.99 (355.79)
Fuel consumption (million gallons)		5.410	\$1/gal.	5.410 (5.39)
Emissions (tons)	HC	418.99	\$6,700/ton	35.32 (35.21)
	CO	4,706	\$6,360/ton	
	NO	200.67	\$12,875/ton	
Total		\$ 526.02 (526.94)		

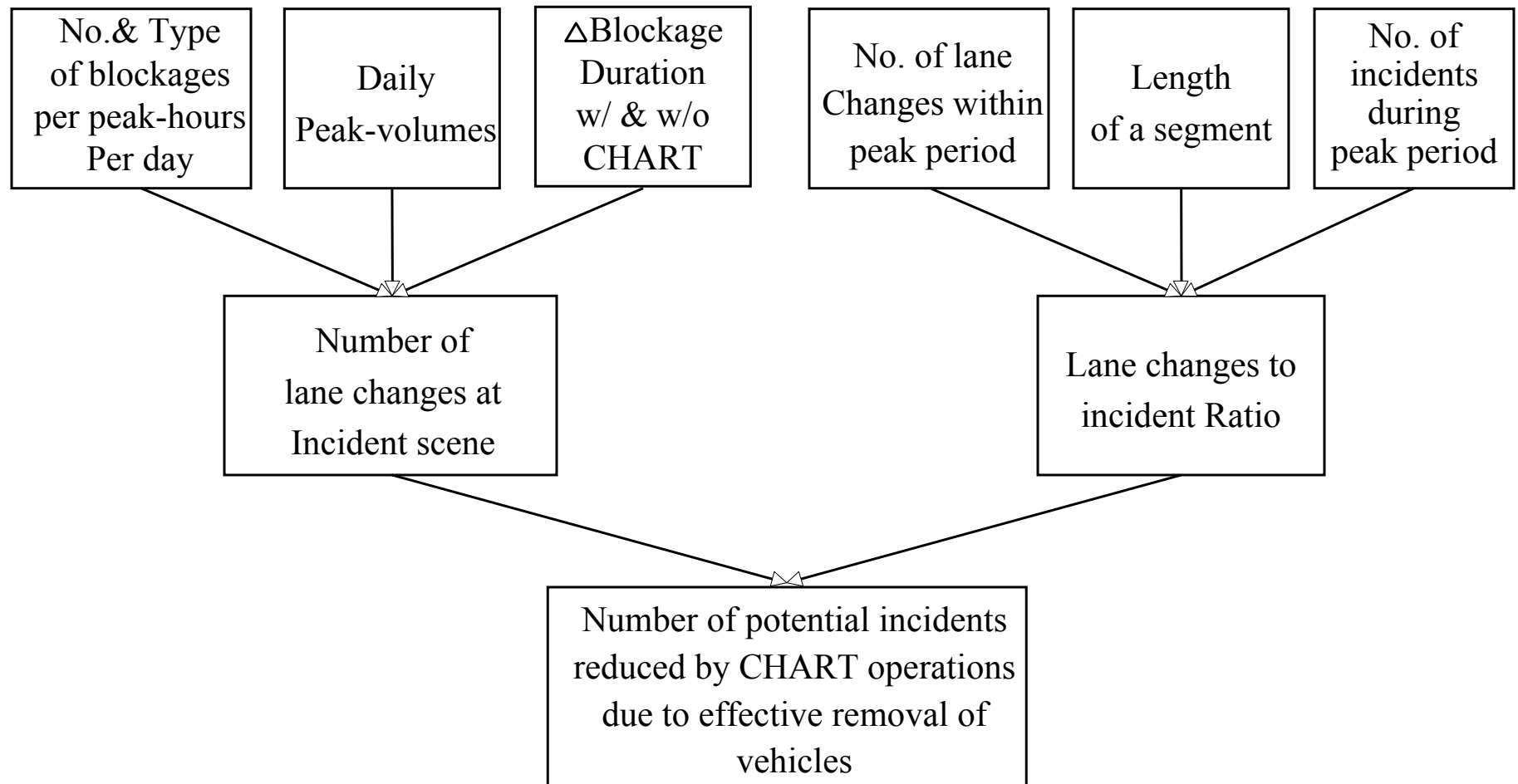
Note: 1. The number in each parenthesis shows the result in Year 2003.

2. Delay Reduction for Cars is computed without using adjusted PCE for trucks.

Direct Benefits to Highway Users (cont.)

		Total by Chart		Washington Region		Baltimore Region	
		Year 2004	Year 2003	Year 2004	Year 2003	Year 2004	Year 2003
Annual Delay Reduction	hours	32,050,143	31,945,820	14,368,130	14,761,838	17,682,012	17,183,983
Daily Delay Reduction	hours	123,270	122,869	55,262	56,776	68,008	66,092
Emission Reduction							
HC Reduction	ton/day	1.612	1.606	0.722	0.742	0.889	0.864
	\$/day	10,797	10,762	4,840	4,973	5,957	5,789
CO Reduction	ton/day	18.100	18.041	8.114	8.337	9.986	9.704
	\$/day	115,115	114,740	51,606	53,020	63,509	61,720
NO Reduction	ton/day	0.772	0.769	0.346	0.355	0.426	0.414
	\$/day	9,937	9,904	4,455	4,577	5,482	5,328
Total	\$/day	135,849	135,407	60,901	62,570	74,948	72,837

Benefits due to Efficient Removals of Stationary Vehicles



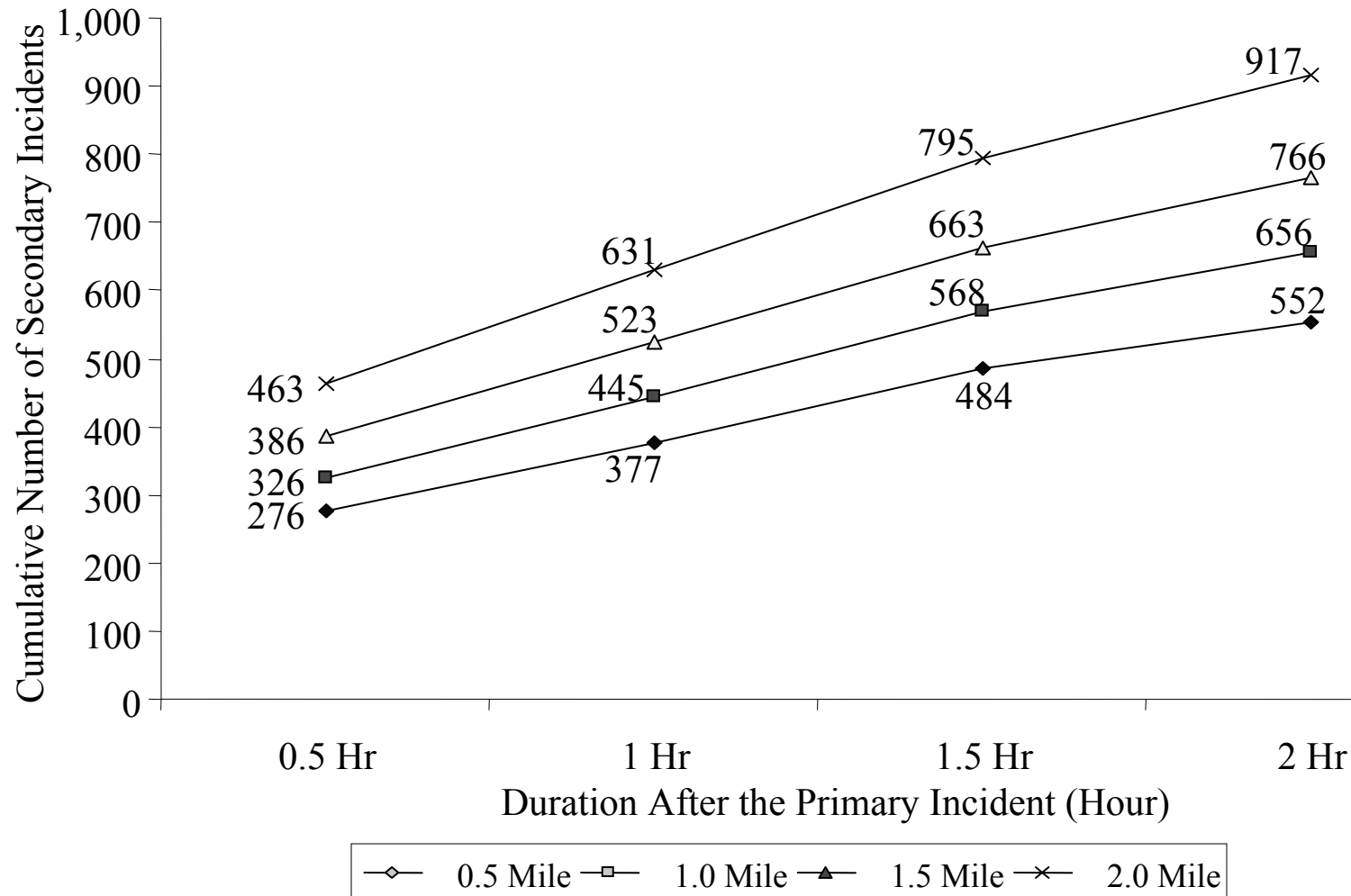
Benefits due to Efficient Removals of Stationary Vehicles (cont.)

- Number of potential incidents reduced by CHART operations due to efficient removals of disabled vehicles

Road Name		I-495/ I-95	I-95	I-270	I-695	I-70	I-83	MD-295	US-50	Total
Mileage		41	63	32	44	13	34	30	42	
Number of Potential Incident Reduction	Year 2004	112	81	16	104	20	20	14	17	384
	Year 2003	171	92	20	147	9	39	7	25	510
	Year 2002	107	105	10	71	12	10	5	23	343
	Year 2001	174	79	13	65	2	10	7	20	370
	Year 2000	297	12	14	47	8	7	N/A	N/A	385

*The analysis has excluded the outlier data (i.e., mean \pm 2 standard deviations)

Distribution of Reported Secondary Incidents





Potential Reduction in Secondary Incidents

Duration = Cleared Time – Received time

- Secondary Incidents – the number of incidents occurred within two hours after a major incident within the range of
 - 2 miles downstream (2 hrs)
 - 0.5 mile upstream (0.5 hr)
 - 0.5 mile downstream opposite direction (0.5hr)
- Reported number of secondary incidents: **917** (760)
- The number of potentially reduced secondary incidents due to CHART operations is **84**** (185)

Note: * The number in each parenthesis shows the result in Year 2003

** The incident durations used excluding the outlier data with duration outside the range of (mean \pm 2 standard deviation) and (less than 2 hours)