Link To Table Of Contents

Chapter 6
Benefits and Costs

Introduction

This chapter provides estimates of the benefits and costs that would be expected due to deployment of a freeway management system and ITS transit technologies. System benefits due to a freeway management system, discussed in the second section, are presented on an annual basis for each of four deployment phases. Costs associated with a freeway management system, discussed in the third section, include both capital and operating expenses and are provided as the summation of the component costs that comprise the system. The benefit cost ratios for each of the four phases of a freeway management system are presented in the fourth section. The fifth section addresses the benefits and costs associated with deployment of ITS transit technologies.

Estimated Benefits - Freeway Management System

The primary benefits expected to result from the deployment of a freeway monitoring system are travel time savings that would result from a decrease in incident response time. A reduction in the time that elapses before an incident is identified and located would be expected due to the deployment of freeway monitoring equipment, including roadway detectors and closed circuit television (CCTV).

Incident response would also be facilitated by the provision of information to emergency responders. Information from the CCTV would help emergency responders decide what kind of equipment is needed; this would decrease vehicle delay by assuring that equipment that is needed arrives quickly, and by minimizing the transport of unnecessary equipment to the scene (unneeded equipment reduces capacity by further obstructing traffic flow). Information from the CCTV could also be used to determine the best method of access for emergency responders. Sometimes accidents are best accessed from surface streets that are close to the freeway or from the freeway lanes in the opposite direction. Finally, information on current travel speeds could be used to help determine the best route for emergency responders. A representational diagram of the freeway management system is shown in Figure 6-1.

Benefits also accrue as a result of informing motorists about traffic conditions. Variable message signs (VMSs), highway advisory radio (HAR), and the provision of current and accurate traffic information through commercial radio and television are all valuable mechanisms for communication with the public. Although it is difficult to predict the magnitude of the impact of this information, it does have an impact. In addition to reducing driver frustration, it can also affect travel behavior. In fact, almost half of respondents using a traveler advisory telephone service reported that the information they received had a direct effect on their travel behavior.[1]

[1] Summary of Findings, Massachusetts Highway Department Independent Evaluation of SmarTraveler Operational Test (conducted for the Massachusetts Highway Department and presented in a paper to ITS America).

The benefits expected to result from the deployment of a freeway monitoring system due to a reduction in incident duration are shown in the Figure 6-2 These are the annual benefits that would result if each incident in the peak hour were reduced by eight minutes. Additional information regarding the calculation of the benefits, including the assumptions used, is included in Appendix B.

The annual benefit varies depending on the number of incidents and the volume of vehicles in the peak hour on each segment. The values are calculated on a per mile basis, so segment length does not impact the expected benefits. The calculation of benefits on a per mile basis is also logical from the standpoint that the cost of loop detectors and other monitoring equipment may easily be calculated on a per mile basis.

A number of assumptions were necessary to estimate the annual benefits. While these assumptions affect the absolute magnitude of the benefits, they do not affect the relative magnitude of the benefits. Thus, they are not critical with respect to identifying which segments would be expected to result in the greatest benefit. However, because these assumptions affect the magnitude of the estimated benefit, they do affect the benefit cost ratios (discussed in Section 4.4), and impact the recommended time frame for deployment and the extent and kinds of technologies that appear to be warranted.

Note that benefits are higher on segments with higher volumes and higher accident rates. This is due to the fact that benefits would accrue to a greater number of vehicles where volumes are higher, and would accrue more frequently on facilities where the accident rate is higher. Benefits are highest on the downtown loop, on I-70 east of downtown, on I-35 immediately north of downtown, on I-35 south of downtown, and on the southern portion of I-435.

Based on the estimated benefits, four phases for deployment were identified and are shown in Figure 6-3. Benefits and costs were estimated for each of these phases. Deployment issues related to project phasing are discussed in Chapter 5. Benefits for each phase are shown in Table 6-1. Detailed benefits by state are shown in Tables 6-2 and 6-3.

Table 6-1. Summary of Benefits per Phase for Freeway Management System

Phase	Mileage			Benefit (in Millions)			Average Benefits per Mile[1]
	Kansas	Missouri	Total	Kansas	Missouri	Total[1]	
1	20	28	48	$4.7	$8.9	$13.5	$285,000
2	14	20	34	$1.3	$3.5	$4.7	$141,000
3	15	60	75	$1.3	$4.4	$5.6	$75,000
4	49	52	101	$0.7	$0.6	$1.3	$13,000
All	98	160	258	$7.9	$17.3	$25.2	$98,000

[1]Values may not be the sum or the factor of the values shown due to rounding

Table 6-2. Benefits by Segment in Kansas

Facility	County	Segment Description Beginning	End	Segment Length (Miles)	Average Daily Volume	Average Accident Rate	Annual Benefit per Mile	Phase
I-35	Johnson	K-7	K-150	2.4	43,000	1.13	$40,055	4
		K-150	119th	2.3	67,000	0.93	$79,948	3
		119th	I-435	2.3	86,000	0.93	$131,721	3
		I-435	US 69 cut-off	3.2	80,000	1.44	$176,678	1
		US 69 cut-off	63rd Street	3.0	139,000	1.12	$414,848	1
		63rd Street	US 69/18th St Exp	3.0	106,000	1.10	$236,944	1
		US 69/18th St Exp	MO state line	3.0	78,000	0.93	$108,354	1
I-70	Wyandotte	K-7	I-435	3.6	20,000	1.57	$12,039	4
		I-435	K-32	3.9	35,000	1.25	$29,449	4
		K-32	I-635	3.3	55,000	1.34	$77,709	3
		I-635	I-670	3.1	51,000	1.60	$79,781	2
		I-670	MO state line	2.1	27,000	1.64	$22,920	2
I-435	Johnson	State Line	US 169	3.3	116,000	1.15	$296,657	1
		US 169	US 69	2.0	104,000	1.05	$218,341	1
		US 69	I-35	2.4	85,000	1.20	$166,211	1
		I-35	K-10	1.1	60,000	1.05	$72,673	4
		K-10	Renner Rd	4.3	35,000	1.08	$25,363	4
		Renner Rd	Holliday Dr	4.2	32,000	1.05	$20,671	4
I-435	Wyandotte	Holliday Dr	K-32 (Kaw Dr)	1.3	33,000	0.69	$14,489	4
		K-32	I-70	3.3	29,000	0.83	$13,382	4
		I-70	Leavenworth Rd	2.6	25,000	0.69	$8,315	4
		Leavenworth Rd	MO state line	4.8	13,000	0.69	$2,248	4
I-635	Johnson	I-35	Wyandotte Co. line	0.4	60,000	2.66	$183,580	2
I-635	Wyandotte	Johnson Co. line	K-32	2.8	60,000	1.52	$105,179	2
		K-32	I-70	1.0	74,000	1.60	$167,967	2
		I-70	K-5 (south jcn)	3.0	52,000	1.76	$91,235	3
		K-5 (south jcn)	MO state line	1.3	38,000	1.52	$42,188	3
I-670	Wyandotte	MO state line	I-70	1.6	42,000	0.58	$19,580	2
K-7	Wyandotte	Johnson Co. line	I-70	4.3	11,000	2.20	$5,103	4
K-7	Johnson	K-10	Wyandotte Co. line	7.2	10,000	0.65	$1,242	4
K-10	Johnson	I-435	K-7	4.6	27,000	0.70	$9,783	4
US 69	Johnson	K-150	US 169/US 69 merge	1.0	39,000	1.36	$39,569	4
		US 169/US 69 merge	I-435	3.2	44,000	1.56	$57,899	3
		I-435	I-35	3.0	67,000	1.53	$131,669	2

Table 6-3. Benefits by Segment in Missouri

Facility	County	Segment Description Beginning	End	Segment Length	Average Daily Volume	Average Accident Rate	Annual Benefit per Mile	Phase
I-29	Platte	N UL KC	I-435	0 7	29,500	1 12	$18,668	4
		I-435 jcn	Rt D	3 6	35,100	1 20	$28,267	3
		Rd D	Rt 152	4 3	43,667	1 44	$52,539	3
		Rt 152	Rt 45	3 3	58,400	2 04	$133,524	3
		Rt 45	Clay Co. line	2.7	73,833	0.91	$95,253	3
I-29	Clay	Platte Co line	Rt 283	1 5	72,750	2 18	$221,357	2
		Rte 283	I-35/I-29	1.0	59,600	0.85	$57,801	2
I-29	Jackson	I-70	end of I-29	1.1	55,400	0.13	$7,936	1
I-35	Clay	Rt 69	I-435	6 5	44,625	1 91	$72,884	3
		I-435	Rt 269	3 4	44,250	1 46	$54,718	3
		Rt 269	I-29	1 4	51,150	2 38	$119,146	3
		I-29	Jackson Co line	3.2	75,500	2.27	$248,466	1
I-35	Jackson	Clay Co line	I-670	2 3	75,600	2 47	$270,964	1
		I-670	KS state line	2.3	118,150	1.60	$427,495	1
I-70	Jackson	KS state line	I-35 s jcn	2 5	64,940	4 19	$338,365	1
		I-35 s jcn	23rd St	2 4	101,310	1 77	$347,318	1
		23rd St	I-435	3 4	98,555	1.92	$358,249	1
		I-435	Rt 40 E jcn	2 8	105,650	1 55	$332,542	1
		Rt 40 E jcn	I-470	4 4	82,600	1 50	$196,119	2
		I-470	Rt 7	5.0	60,550	1.25	$87,842	3
I-435	Platte	KS State line	Rt 45	2 6	12,300	0 52	$1,508	4
		Rt 45	Rt 152	1 4	15,300	0 12	$558	4
		Rt 152	Rt D	4 7	11,600	0 40	$1,044	4
		Rt D	I-29	2 7	8,000	0 13	$156	4
		I-29	Rt C	3 4	12,500	0 39	$1,166	4
		Rt C	Clay Co line	2.5	21,800	0.64	$5,842	4
I-435	Clay	Platte Co line	I-35	12 0	17,875	0 73	$4,462	4
		I-35	Jackson Co line	3.9	52,400	1.15	$60,752	3
I-435	Jackson	Clay Co Line	US 24	3 2	76,000	1 13	$125,212	3
		US 24	Truman Rd	1 0	76,000	1.13	$125,212	2
		Truman Rd	I-70	2 4	88,100	0 99	$146,625	2
		I-70	Rt 350	2 8	98,500	1 45	$268,801	2
		Rt 350	Gregory Blvd	1 9	81,450	1 43	$181,699	2
		Gregory Blvd	Bannister Rd	3 4	81,350	1 37	$173,699	2
		Bannister Rd	Holmes Rd	3 5	88,167	2 09	$311,840	1
		Holmes Rd	KS state line	1.4	102,350	2.38	$478,280	1
I-470	Jackson	I-435	Raytown Rd	4.0	54,450	1 01	$57,339	3
		Raytown Rd	Rt 50	3 5	40,600	0 56	$17,623	4
		Rt 50	Colborn Rd	2 5	25,450	0 74	$9,200	4
		Colborn Rd	Woods Chapel Rd	2 6	37,250	0 66	$17,578	4
		Woods Chapel Rd	I-70	4.1	42,700	0.51	$17,920	4
I-635	Platte	I-29 to Rt 9	Rt 9	1 5	235,900	0 08	$81,514	3
		Rt 9	Rt 69	0 5	43,800	0 47	$17,395	3
		Rt 69	Van De Populier	1.0	37,600	0 30	$8,152	3
		Van De Populier	KS state line	0.8	44,500	0.95	$36,004	3
I-670	Jackson	KS State line	I-35	1.2	45,500	1.18	$46,979	2
US 71	Jackson	I-70	63rd St	5 9	28,040	5 39	$81,279	3
		63rd St	I-435	5 0	30,135	4.31	$75,055	3
		I-435	I-470	0 6	95,600	0.29	$50,296	1
		I-470	Blue Ridge Ext	2 1	82,793	3 11	$408,392	1
		Blue Ridge Ext	Main St	1 3	69,800	0 47	$44,137	3
		Main St.	Rt 150	2.2	64,500	0 69	$54,945	3
US 169	Clay	I-435	I-29	8 9	27,200	2 41	$34,186	4

Estimated Costs - Freeway Management System

The cost estimate for the freeway monitoring system includes both capital and annual operating and maintenance costs. Capital costs reflect the need for freeway monitoring equipment, both CCTV and vehicle detection equipment; VMSs; HAR, both transmitters and advisory signs with flashing lights; power distribution and communications to system components; field data processing equipment, a traffic operations center (TOC), and centralized hardware and software. Additional information regarding costs is provided in Appendix B.

Tables 6-4 through 6-7 show the costs associated with each phase of deployment. Table 6-8 shows the cost for deployment of all phases. All costs indicated are in 1996 dollars. Capital costs were converted to equivalent annual costs, assuming a 15 year life and an interest rate of 6 percent. In general, the quantities shown in Tables 6-4 through 6-8 correspond to the quantities indicated in the deployment plan and shown in the figures in Chapter 7. The exception to this is for closed circuit television cameras, which for cost purposes are estimated for placement every half mile. Only selected (priority) locations for each phase are indicated in the deployment plan.

Also note that Tables 6-4 through 6-8 indicate that shared costs, including the TOC, central hardware, software and systems integration, and personnel costs, are divided between the states based on the proportion of freeway miles included from each state.

The costs shown in Tables 6-4 through 6-8 are based on full deployment of each phase. It is likely that rather than implementing the equipment for an entire phase at one time, key interchanges or freeway segments would be deployed, and additional equipment would incrementally be added to complete the system. Although the cost for equipping a given interchange varies depending on the geometrics, accident and operating characteristics, a range of costs can be estimated.

At the low end, 2 to 3 CCTV cameras could be installed. This would provide substantial benefit, and a minimal investment of approximately $60,000 to $90,000. If automated detection is desired, as many as 8 to 12 detector stations could be added, adding $80,000 to $120,000 to the price tag. Provisions for motorist information would require as many as 4 HAR signs, costing $12,000, and perhaps a HAR transmitter (depending on the location), which would cost $17,000. The greatest cost would be for VMSs. Two to 4 VMSs would incur a cost of $240,000 to $480,000. To summarize, the cost for installing cameras at an interchange, which would provide some monitoring capabilities, would be less than $100,000. The cost for installing full equipment at an interchange could range from just under $400,000 ($392,000) to more than $700,000 ($719,000).

Benefit Cost Ratios - Freeway Management System

Benefit cost ratios were calculated for each phase of the project, as shown in Table 6-9. The benefit cost ratio for Phase 1 is greatest, with annual benefits almost three times the annual costs. The benefit cost ratio decreases for each phase thereafter. Benefit cost ratios must be greater than one in order for the project to be currently justified. Based on this analysis,

Table 6-4. Phase 1 Costs

			Kansas	Missouri	Total
		Number of miles	20	28	48
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	cost per site	$30,000	$30,000	$30,000
		number	40	56	96
		total cost	$1,200,000	$1,680,000	$2,880,000
	Detection	cost per site	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		number	40	56	96
		total cost	$400,000	$560,000	$960,000
	Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
		number	12	23	35
		total cost	$1,440,000	$2,760,000	$4,200,000
	Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
		number	3	3	6
		cost per sign	$3,000	$3,000	$3,000
		number	10	12	22
		total cost	$81,000	$87,000	$168,000
	Power Distribution to System Components				
		cost per mile	$30,000	$30,000	$30,000
		total cost	$600,000	$840,000	$1,440,000
	Communications to ITS Elements				
		cost per mile	$10,000	$10,000	$10,000
		total cost	$200,000	$280,000	$480,000
	Conduit Installation	cost per foot	$40	$40	$40
		total cost	$4,224,000	$5,913,600	$10,137,600
	Field Data Processing Equipment				
		cost per processor	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		total cost	$400,000	$560,000	$960,000
	Traffic Operations Center	number of centers[1]	0.38	0.62	1
		square feet per center	10,000	10,000	10,000
		cost per square foot	$110	$110	$110
		total cost	$418,000	$682,000	$1,100,000
	Central Hardware	base cost[1]	$304,000	$496,000	$800,000
		cost per mile	$3,333	$3,333	$3,333
		total cost	$370,660	$589,324	$959,984
	Software and Systems Integration[1]		$380,000	$620,000	$1,000,000
	Subtotal for 15 Year Life		$9,713,660	$14,571,924	$24,285,584
	Construction and Contingency (20%)		$1,942,732	$2,914,385	$4,857,117
	Subtotal		$11,656,392	$17,486,309	$29,142,701
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$1,200,142	$1,800,390	$3,000,532
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel[2]		$147,000	$203,000	$350,000
	Maintenance Personnel[2]		$105,000	$145,000	$250,000
	Replacement Parts and Spare Equipment		$445,783	$663,496	$1,109,279
	Subtotal		$697,783	$1,011,496	$1,709,279
Total Cost per Year			$1,897,925	$2,811,887	$4,709,812

1 Allocation between states based on mileage for all phases.

2 Allocation between states based on Phase 1 mileage

Table 6-5. Phase 2 Costs (Incremental Costs)

			Kansas	Missouri	Total
		Number of miles	14	20	34
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	cost per site	$30,000	$30,000	$30,000
		number	28	40	68
		total cost	$840,000	$1,200,000	$2,040,000
	Detection	cost per site	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		number	28	40	68
		total cost	$280,000	$400,000	$680,000
	Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
		number	4	6	10
		total cost	$480,000	$720,000	$1,200,000
	Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
		number	1	1	2
		cost per sign	$3,000	$3,000	$3,000
		number	4	3	7
		total cost	$29,000	$26,000	$55,000
	Power Distribution to System Components				
		cost per mile	$30,000	$30,000	$30,000
		total cost	$420,000	$600,000	$1,020,000
	Communications to ITS Elements				
		cost per mile	$10,000	$10,000	$10,000
		total cost	$140,000	$200,000	$340,000
	Conduit Installation	cost per foot	$30	$30	$30
		total cost	$2,217,600	$3,168,000	$5,385,600
	Field Data Processing Equipment				
		cost per processor	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		total cost	$280,000	$400,000	$680,000
	Traffic Operations Center	number of centers	0	0	0
		total cost	$0	$0	$0
	Central Hardware	base cost			
		cost per mile	$3,333	$3,333	$3,333
		total cost	$46,662	$66,660	$113,322
	Software and Systems Integration		$102,500	$147,500	$250,000
	Subtotal for 15 Year Life		$4,835,762	$6,928,160	$11,763,922
	Construction and Contingency (20%)		$967,152	$1,385,632	$2,352,784
	Subtotal		$5,802,914	$8,313,792	$14,116,706
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$597,468	$855,988	$1,453,456
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel		$143,500	$206,500	$350,000
	Maintenance Personnel		$61,500	$88,500	$150,000
	Replacement Parts and Spare Equipment		$236,663	$339,033	$575,696
	Subtotal		$441,663	$634,033	$1,075,696
Total Cost per Year			$1,039,131	$1,490,021	$2,529,152

Table 6-6. Phase 3 Costs (Incremental Costs)

			Kansas	Missouri	Total
		Number of miles	15	60	75
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	cost per site	$30,000	$30,000	$30,000
		number	30	120	150
		total cost	$900,000	$3,600,000	$4,500,000
	Detection	cost per site	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		number	30	120	150
		total cost	$300,000	$1,200,000	$1,500,000
	Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
		number	2	12	14
		total cost	$240,000	$1,440,000	$1,680,000
	Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
		number	0	2	2
		cost per sign	$3,000	$3,000	$3,000
		number	0	7	7
		total cost	$0	$55,000	$55,000
	Power Distribution to System Components				
		cost per mile	$30,000	$30,000	$30,000
		total cost	$450,000	$1,800,000	$2,250,000
	Communications to ITS Elements				
		cost per mile	$10,000	$10,000	$10,000
		total cost	$150,000	$600,000	$750,000
	Conduit Installation	cost per foot	$20	$20	$20
		total cost	$1,584,000	$6,336,000	$7,920,000
	Field Data Processing Equipment				
		cost per processor	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		total cost	$300,000	$1,200,000	$1,500,000
	Traffic Operations Center	number of centers	0	0	0
		total cost	$0	$0	$0
	Central Hardware	base cost			
		cost per mile	$3,333	$3,333	$3,333
		total cost	$49,995	$199,980	$249,975
	Software and Systems Integration		$25,000	$100,000	$125,000
	Subtotal for 15 Year Life		$3,998,995	$16,530,980	$20,529,975
	Construction and Contingency (20%)		$799,799	$3,306,196	$4,105,995
	Subtotal		$4,798,794	$19,837,176	$24,635,970
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$494,084	$2,042,436	$2,536,519
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel		$105,000	$420,000	$525,000
	Maintenance Personnel		$70,000	$280,000	$350,000
	Replacement Parts and Spare Equipment		$198,700	$821,549	$1,020,249
	Subtotal		$373,700	$1,521,549	$1,895,249
Total Cost per Year			$867,784	$3,563,985	$4,431,768

Table 6-7. Phase 4 Costs (Incremental Costs)

			Kansas	Missouri	Total
		Number of miles	49	52	101
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	cost per site	$30,000	$30,000	$30,000
		number	98	104	202
		total cost	$2,940,000	$3,120,000	$6,060,000
	Detection	cost per site	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		number	98	104	202
		total cost	$980,000	$1,040,000	$2,020,000
	Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
		number	9	11	20
		total cost	$1,080,000	$1,320,000	$2,400,000
	Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
		number	2	4	6
		cost per sign	$3,000	$3,000	$3,000
		number	6	12	18
		total cost	$52,000	$104,000	$156,000
	Power Distribution to System Components				
		cost per mile	$30,000	$30,000	$30,000
		total cost	$1,470,000	$1,560,000	$3,030,000
	Communications to ITS Elements				
		cost per mile	$10,000	$10,000	$10,000
		total cost	$490,000	$520,000	$1,010,000
	Conduit Installation	cost per foot	$20	$20	$20
		total cost	$5,174,400	$5,491,200	$10,665,600
	Field Data Processing Equipment				
		cost per processor	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		total cost	$980,000	$1,040,000	$2,020,000
	Traffic Operations Center	number of centers	0	0	0
		total cost	$0	$0	$0
	Central Hardware	cost per mile	$3,333	$3,333	$3,333
		total cost	$163,317	$173,316	$336,633
	Software and Systems Integration		$61,250	$63,750	$125,000
	Subtotal for 15 Year Life		$13,390,967	$14,432,266	$27,823,233
	Construction and Contingency (20%)		$2,678,193	$2,886,453	$5,564,647
	Subtotal		$16,069,160	$17,318,719	$33,387,880
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$1,654,481	$1,783,135	$3,437,616
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel		$257,250	$267,750	$525,000
	Maintenance Personnel		$171,500	$178,500	$350,000
	Replacement Parts and Spare Equipment		$666,486	$718,426	$1,384,912
	Subtotal		$1,095,236	$1,164,676	$2,259,912
Total Cost per Year			$2,749,717	$2,947,811	$5,697,528

Table 6-8. Cost for All Phases

			Kansas	Missouri	Total
		Number of miles	98	160	258
Capital Costs					
	Freeway Surveillance Equipment				
	CCTV	cost per site	$30,000	$30,000	$30,000
		number	196	320	516
		total cost	$5,880,000	$9,600,000	$15,480,000
	Detection	cost per site	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		number	196	320	516
		total cost	$1,960,000	$3,200,000	$5,160,000
	Variable Message Signs	cost per sign	$120,000	$120,000	$120,000
		number	27	52	79
		total cost	$3,240,000	$6,240,000	$9,480,000
	Highway Advisory Radio	cost per transmitter	$17,000	$17,000	$17,000
		number	6	10	16
		cost per sign	$3,000	$3,000	$3,000
		number	20	34	54
		total cost	$162,000	$272,000	$434,000
	Power Distribution to System Components				
		cost per mile	$30,000	$30,000	$30,000
		total cost	$2,940,000	$4,800,000	$7,740,000
	Communications to ITS Elements				
		cost per element	$10,000	$10,000	$10,000
		total cost	$980,000	$1,600,000	$2,580,000
	Conduit Installation	cost per foot	$25	$25	$25
		total cost	$13,018,133	$21,254,095	$34,272,229
	Field Data Processing Equipment				
		cost per processor	$10,000	$10,000	$10,000
		frequency per mile	2.0	2.0	2.0
		total cost	$1,960,000	$3,200,000	$5,160,000
	Traffic Operations Center	number of centers	0.38	0.62	1
		square feet per center	10,000	10,000	10,000
		cost per square foot	$110	$110	$110
		total cost	$418,000	$682,000	$1,100,000
	Central Hardware	base cost	$304,000	$496,000	$800,000
		cost per mile	$3,333	$3,333	$3,333
		total cost	$630,634	$1,029,280	$1,659,914
	Software and Systems Integration		$568,750	$931,250	$1,500,000
	Subtotal for 15 Year Life		$31,757,517	$52,808,625	$84,566,143
	Construction and Contingency (20%)		$6,351,503	$10,561,725	$16,913,229
	Subtotal		$38,109,021	$63,370,350	$101,479,371
	Capital Recovery Factor (15 years, 6%)		0.10296	0.10296	0.10296
	Subtotal for Annual Cost		$3,923,705	$6,524,611	$10,448,316
Annual Operating and Maintenance (O-M) Costs					
	Traffic Operations Center Personnel		$665,000	$1,085,000	$1,750,000
	Maintenance Personnel		$418,000	$682,000	$1,100,000
	Replacement Parts and Spare Equipment		$1,538,538	$2,559,769	$4,098,307
	Subtotal		$2,621,538	$4,326,769	$6,948,307
Total Cost per Year			$6,545,243	$10,851,380	$17,396,623

Table 6-9. Benefit Cost Ratio for Each Phase

Phase		1	2	3	4	All
Annual Benefits (in Millions)[1]		$13.5	$4.7	$5.6	$1 3	$25.2
Kansas		$4.7	$1.3	$1.3	$0.7	$7.9
Missouri		$8.9	$3 5	$4 4	$0.6	$17 3
Annualized Cost (in Millions)		$4.7	$2.5	$4.4	$5 7	$17 4
Kansas	Capital	$1.2	$0.6	$0.5	$1.7	$3 9
	Operating and Maintenance	$0.7	$0.4	$0.4	$1.1	$2.6
	Total	$1.9	$1.0	$0.9	$2.7	$6 5
Missouri	Capital	$1 8	$0 9	$2.0	$1.8	$6 5
	Operating and Maintenance	$1.0	$0.6	$1.5	$1.2	$4.3
	Total	$2.8	$1.5	$3.5	$2.9	$10.9
Cumulative Capital Investment (in Millions)		$29	$43	$68	$101	$101
Benefit Cost Ratio		2.9	1.9	1.3	0.2	1.4

[1] Total values may not be the sum of the values shown for Kansas and Missouri due to rounding

Phases 1 and 2 are currently justified, Phase 3 is marginally justified, and Phase 4 is not justified for deployment based on existing conditions.

PROVISION OF FIBER OPTICS CABLE IN KANSAS

The costs shown in Tables 6-4 through 6-9 do not include the cost for the installation of fiber optics cable, which is recommended to serve as the communications backbone for the metropolitan Kansas City ITS system. The cost of fiber is omitted based on the assumption that it will be provided through a public/private partnership at no cost to the Kansas Department of Transportation (KDOT). A similar agreement was reached in Missouri, where fiber is being installed on all interstates and on selected freeways. This agreement, which allows a private firm to use the Missouri Highway and Transportation Department's (MHTD) right-of-way, provides MHTD with a fiber optics backbone at no cost. It is recommended that KDOT pursue a similar agreement, and the costs shown in Tables 6-4 through 6-9 reflect an assumption that such an agreement can be obtained.

The value of such an agreement is substantial, as demonstrated by the costs shown in Table 6-10. The top half of Table 6-10 documents the costs associated with the installation of fiber, including conduit, fiber, and associated equipment (manholes, splice enclosure, pull boxes and fiber hub equipment). If an agreement similar to MHTD's is reached, benefits would be realized due to the value of annual maintenance, as well as due to the capital cost.

The second portion of Table 6-10 shows the total cost for an ITS freeway management system, including the cost of a fiber optics backbone, and all field, communications and data processing equipment. As can be seen in the table, the capital cost of the fiber optics backbone is almost half of capital cost for the entire freeway management system.

The last two rows of Table 6-10 show the benefit cost ratio first, if KDOT must bear the cost of the installation of fiber, and finally, if the fiber is provided by a private entity. Table 6-10 demonstrates the fact that substantial savings can be realized if KDOT can work out an agreement with a private entity for the provision of fiber optic cable.

Table 6-10. Estimated Value of Fiber Optic Cable on KDOT Freeways in Kansas City Metropolitan Area

	Phase 1	Phase 2	Phase 3	Phase 4	All Phases
Number of miles	20	14	15	49	98
Cost of Fiber Optics Cable					
Conduit[1]					
Cost per foot	$40	$30	$20	$20	
Total cost	$4,224,000	$2,217,600	$1,584,000	$5,174,400	$13,200,000
Fiber optic cable					
Cost per mile (12 fiber cable)	$7,920	$7,920	$7,920	$7,920	
Total cost	$158,400	$110,880	$118,800	$388,080	$776,160
Manholes					
$3,000 each, 1 per 4 miles					
Cost per mile	$750	$750	$750	$750	
Total cost	$15,000	$10,500	$11,250	$36,750	$73,500
Splice enclosure					
$850 each, 1 per 4 miles					
Cost per mile	$213	$213	$213	$213	
Total cost	$4,250	$2,975	$3,188	$10,413	$20,825
Pull boxes					
$1,000 each, 1 per 500 feet					
Cost per mile	$10,560	$10,560	$10,560	$10,560	
Total cost	$211,200	$147,840	$158,400	$517,440	$1,034,880
Fiber hub equipment[2]					
$25,000 every 5 miles					
Cost per mile	$5,000	$5,000	$5,000	$5,000	
Total cost	$100,000	$70,000	$75,000	$245,000	$490,000
Total Cost of Fiber and Equipment	$4,712,850	$2,559,795	$1,950,638	$6,372,083	$15,595,365
Expected Annual Maintenance Cost	$235,643	$127,990	$97,532	$318,604	$779,768
Total Cost for ITS Freeway Management System					
Total Cost of Fiber and Equipment	$4,712,850	$2,559,795	$1,950,638	$6,372,083	$15,595,365
Fiber Annual Maintenance Cost	$235,643	$127,990	$97,532	$318,604	$779,768
Other Capital Costs[3]	$5,489,660	$2,618,162	$2,414,995	$8,216,567	$18,557,517
Other Annual Maintenance Costs[3]	$486,583	$330,783	$294,500	$836,516	$1,961,538
Total Capital Cost	$10,202,510	$5,177,957	$4,365,633	$14,588,650	$34,152,882
Capital Recovery Factor	10296	10296	10296	10296	.10296
Annualized Capital Cost	$1,050,450	$533,122	$449,486	$1,502,047	$3,516,381
Total Maintenance Cost	$722,226	$458,773	$392,032	$1,155,120	$2,741,306
Total Annualized Cost for Kansas	$1,772,676	$991,895	$841,517	$2,657,167	$6,257,687
Total Annual Benefits (in Millions)	$4.7	$1.3	$1.3	$.7	$7 9
Benefit Cost Ratio for Freeway Management System					
B/C if KDOT Funds Fiber Installation	2.65	1 31	1 54	0 26	1 26
B/C if Fiber Provided by Private Entity[4]	4 47	2.17	2 39	0 42	2.04

[1] Cost for conduit also included in ITS infrastructure estimates shown in Tables 6-4 through 6-9

[2] Includes SONET hub, air conditioned cabinet, transformer, and back up power

[3] "Other" costs include the costs estimated in Tables 6-4 through 6-8 (except the cost for conduit installation which is subtracted because it is included in this table) Capital cost does not include construction and contingency

Future Prioritization for Freeway Management System

The deployment phases shown in Figure 6-3 reflect current priorities, which are based on current operating characteristics. In the future, these priorities may change due to changes in operating characteristics. The purpose of this section is to review the methodology that could be used to prioritize freeway segments in the future.

Since the benefits of a freeway management system are calculated as a function of the freeway volume and the accident rate, a change in either of these factors would affect the expected benefits and the resulting priorities. Changes in operating characteristics would be expected to result from a variety of factors, as demonstrated by the following examples.

- Construction and reconstruction activities may result in increased volumes due to latent demand that can be served by an increase in capacity.

- Additional capacity that results from construction and reconstruction activities may reduce demand on parallel facilities. For example, congestion may be relieved on the southeast leg of I-435 due to the completion of Bruce Watkins Drive.

- Geometric improvements may reduce accidents at the affected locations or on the affected segments.

- Increased development or changing demographics may affect travel volumes on facilities that serve the affected areas.

Prioritization of facilities for deployment was based on two factors. The first factor was the benefit cost ratio that would be expected to result from deployment of a freeway management system. If the system were designed based only on benefit cost ratios, a seamless, integrated system may be slow to evolve. Thus, the second factor considered was system continuity. Although system continuity is an important factor that should be considered, it cannot be easily quantified. For this reason, this section will primarily address the calculation of the benefit cost ratio.

CALCULATION OF BENEFITS

The benefits of a freeway management system are calculated based on the time savings that accrue to drivers as a result of the elimination or reduction of incident related delay. For this analysis, time savings are initially calculated separately for the peak and off-peak directions

Equation 6-1 can be used to calculate the time saved in the peak direction in the peak hour for each minute of incident related delay eliminated.

(Eqn 6-1) $$T_P = V_P * [I_P * (1 \text{ minute}) + I_O * (0.25 \text{ minutes})]$$

where: T_P = Time saved in peak hour in peak direction for each minute of incident related delay eliminated (in minutes)
V_P = Peak direction peak hour volume
I_P = Number of incidents in peak hour in peak direction

I_O = Number of incidents in peak hour in off-peak direction

Similarly, the time saved in the off-peak direction in the peak hour for each minute of incident related delay eliminated can be estimated as follows.

(Eqn 6-2) $$T_O = V_O * [I_O * (1\ minute) + I_P * (0.25\ minutes]$$

where: T_O = Time saved in peak hour in off-peak direction for each minute of incident related delay eliminated (in minutes)
V_O = Off-peak direction peak hour volume
I_P = Number of incidents in peak hour in peak direction
I_O = Number of incidents in peak hour in off-peak direction

Equations 6-1 and 6-2 reflect the assumption that an accident in one direction affects flow in the other direction due to rubbernecking. It is assumed that for every minute of delay in the direction of the accident, 0.25 minutes of delay result in the opposite direction. This value can be verified or revised, using data collected through the freeway management system In both cases, the number of incidents in the peak hour (I_P and I_O) can be estimated based on the accident rate and peak hour volume for the segment as follows.

(Eqn 6-3) $$I_P = k * V_P * (accident\ rate)$$

(Eqn 6-4) $$I_O = k * V_O * (accident\ rate)$$

where: I_P = Number of incidents in peak hour in peak direction
V_P = Peak direction peak hour volume
I_O = Number of incidents in peak hour in off-peak direction
V_O = Off-peak direction peak hour volume
k = Constant, representing the incident to accident ratio

Equations 6-3 and 6-4 utilize a constant to represent the incident to accident ratio. This multiplier is used to account for the fact that not every incident that disrupts traffic and results in delay is represented in an accident log. A value of 5 was used to represent the incident to accident ratio in the analysis of current conditions. This means that for every accident recorded in the state accident statistics, there are 5 incidents (such as flat tires, stalled cars) that are not recorded. This value can be verified or modified based on data collected using the freeway management system.

The total time saved in the peak hour is then calculated using Equation 6-5. The total time saved is the sum of the time saved in each direction per minute of delay eliminated, times the average reduction in incident duration.

(Eqn 6-5) $$T_{TOT} = d * (T_P + T_O)$$

where: T_{TOT} = Time saved in both directions in peak hour (in minutes)
T_P = Time saved in peak hour in peak direction for each minute of incident related delay eliminated (in minutes)
T_O = Time saved in peak hour in off-peak direction for each minute of incident related delay eliminated (in minutes)

d = Constant, representing the average reduction in incident delay

Equation 6-5 utilizes a constant to represent the average reduction in incident duration. A value of 8 minutes was used in the analysis of current conditions. This value can be verified or modified based on data collected using the freeway management system.

The value of time (T_O and T_P) is then converted to an annual dollar value using the following equation:

(Eqn 6-6)

$$\text{Annual benefit} = T_{TOT} * \frac{1\ hour}{60\ min} * [(.95)\frac{\$10}{hour} + (.05)\frac{\$25}{hour}] * \frac{2\ peak\ hours}{day} * \frac{250\ days}{year}$$

This calculation is based on a number of assumptions, as follows.

- Passenger vehicles comprise 95 percent of the traffic and are valued at $10 per hour
- Commercial vehicles comprise 5 percent of the traffic and are valued at $25 per hour
- Daily benefits are based on 2 peak hours per day (a.m. and p.m.)
- Annual benefits are based on 250 days per year (5 days per week, 50 weeks per year)

These assumptions can be verified or modified based on data collected using the freeway management system. The resulting annual benefit is used as the numerator in the benefit cost ratio. It is recommended that all benefits be stated on a per mile basis, to facilitate comparisons between segments.

Note that the benefits calculated above reflect only the benefits that would be expected to accrue as a result of a reduction in incident related congestion. A decrease in recurring congestion may be expected due to the deployment of ramp metering or other demand management strategies. While cities such as Minneapolis and Seattle have documented increases in freeway capacity and average speed as a result of ramp metering, it is recommended that data collected in conjunction with the ramp demonstration project on I-35 be used as a basis for estimating benefits in the Kansas City metropolitan area.

CALCULATION OF COSTS

Annual costs are calculated as the annualized capital cost plus operating and maintenance costs, as shown in Tables 6-4 through 6-8. Although technologies may change, the basic functions of the freeway management system are expected to remain the same and include monitoring, data processing and motorist information. In support of these activities, operating and maintenance costs will be incurred and must be considered. In the future, technologies to facilitate traffic control, such as ramp meters, may be included in the freeway management system, although these technologies were not evaluated as part of the costs shown in Tables 6-4 through 6-9.

As technologies advance, different kinds of technologies may be incorporated into the system, replacing existing technologies or enhancing system capabilities. The costs associated with the various technologies will need to be updated, due to the rapid changes in technology cost and capability. Although costs cannot be accurately forecasted, the following discussion identifies the kind of issues that may be relevant

Monitoring - Roadway monitoring equipment used for incident detection and verification currently includes CCTV and detection equipment such as induction loops or radar Although current technologies are recommended for placement every half mile, this distance may increase as technologies become more advanced.

Data Processing - Data processing requirements due to system expansion will be defined to some extent by the initial system and its capabilities. The current recommendation for field equipment is a Type 170 controller (or comparable equipment) to be placed every half mile. As the components become more sophisticated, additional processing may be needed.

Provision will also need to be made for expansion of central hardware (video monitors and switching equipment, workstation, console, etc.) and software. The costs associated with expansion will vary depending on the configuration and excess capacity built into the central hardware and the adaptability of the software.

Motorist Information - Motorist information may be provided through a variety of means. Current technologies include VMSs, HAR, highway advisory telephone, teletext, personal pager, information kiosk, commercial radio, commercial television and the Internet. The provision of motorist information is often identified as an activity appropriate for cooperative efforts with private entities. Coordination with private entities and the potential for revenue and/or cost sharing should be considered when evaluating costs and mechanisms for providing motorist information.

Operating and Maintenance Costs - Operating and maintenance costs include operators at the TOC, maintenance personnel, and supervision of both activities. These expenses can best be estimated by evaluating the costs associated with operating and maintaining the portions of the freeway management system already deployed. In terms of the cost for replacement parts and spare equipment, five percent of the initial hardware cost is often used as an estimate. This value may be modified based on the experience gained through deployment of the first phase.

Amortization - Capital costs for equipment should be converted to an annualized cost based on the expected life of the equipment and the current interest rate. It is necessary to convert the costs to an annual basis to allow comparison with the benefits which are calculated on an annual basis. The capital recovery factor used in the analysis of current conditions was 0.10296, which represents a capital recovery factor for 15 years at 6 percent interest. The capital recovery factor for other amortization periods and interest rates can be found in an accounting or engineering economics reference book. The total annual cost, to be used as the denominator in the benefit cost ratio, is the annualized capital cost, plus all annual operating and maintenance costs.

BENEFIT COST RATIO

The benefit cost ratio is calculated as the annual benefit divided by the total annualized cost. The benefit cost ratio, which must be calculated for all candidate segments, can then be used in conjunction with a qualitative assessment for the determination of priorities for the system. Qualitative objectives might include system continuity (discussed previously) and coordination with other ITS applications, such as transit and commercial vehicle operations.

Estimated Benefits and Costs - ITS Transit Applications

This section discusses the benefits and costs associated with ITS applications related to transit. The specific technologies were discussed in greater detail in Chapter 5.

BENEFITS

The benefits attributable to ITS transit projects are difficult to estimate, in many cases because the benefits are intangible. For example, video monitoring of bus stops may have a positive effect of the *perception* of security among transit users, but quantifying the benefit is very difficult. Similarly, improvements in the availability of transit service information is obviously beneficial, but estimating the effect on ridership and revenues is very difficult.

Instead of attempting to quantify the benefits of these projects, it is suggested that the value of the applications be assessed by the extent they address specific objectives. These objectives are based on inputs from transit agency representatives. The objectives are as follows.

1. Reduce operating costs. With anticipated reductions in federal operating assistance, and continued competition for local funding, this objective is a clear priority.

2. Employ proven technology to improve methods, increase productivity and enhance service delivery.

3. Improve the timeliness and reliability of transit service.

4. Improve the integration of services provided by different operators. Coordination among the three primary fixed operators has been identified as an important objective. Coordination among the multitude of paratransit operators is perhaps the highest priority with respect to paratransit.

5. Improve the fact and perception of security for transit customers.

6. Improve the availability of transit system information to current and potential transit users.

7. Meet the requirements of the Americans with Disabilities Act (ADA) with respect to complementary paratransit services for disabled persons.

Table 6-11 is an assessment of ITS applications and whether each addresses the stated objectives. All of the applications suggested for consideration employ proven technology that has been applied successfully in other areas. In addition, the projects shown as addressing objective #1 have the potential to reduce operating costs and/or increase productivity. The projects addressing objective #4 have value in helping to achieve a "seamless" regional transit system.

Table 6-11. Benefit Assessment of Transit Applications

Project	Objectives						
	#1	#2	#3	#4	#5	#6	#7
Telephone Information Center Automation	yes	yes		yes		yes	
On Bus Video Monitoring		yes			yes		
On Bus Audio Monitoring		yes			yes		
Bus Stop Video Monitoring		yes			yes		
Park & Ride Lot Video Monitoring		yes			yes		
AVL Expansion	yes	yes	yes	yes	yes		
Consolidated Paratransit Scheduling	yes	yes	yes	yes		yes	yes
Personalized Public Transit	yes	yes	yes			yes	

COSTS

The costs associated with deploying ITS transit projects depend upon the scope of the project and the specific technology employed. For example, the cost of video monitoring all buses or a large number of bus stops would be prohibitive. However, the strategic deployment of video monitoring hardware at select locations can be achieved at a reasonable cost. New technology tends to be more expensive than applications that have been on the market a longer time and have become production standards. Technology involving software applications have a high initial cost, often due to the need to customize the application, but can be expected to perform and produce for a long period of time.

Table 6-12 shows estimated initial costs for ITS technology applications suggested for consideration in the Kansas City metropolitan area. As previously stated, some of these applications are currently being pursued by the KCATA. Because of the integration among projects and components, the cost estimates are valid only in the context of related systems. For example, the telephone information system automation requires an automated scheduling system. The estimate includes the entire cost of both systems. Conversely, the cost estimates for consolidated paratransit scheduling and personalized public transit assumes that the paratransit scheduling and dispatching system recently acquired by the KCATA is in place. The estimates reflect the cost of expanding the use of this system.

Table 6-12. Estimated Costs for Transit Applications

Project	Priority	Unit Cost	Units	Total Cost
Telephone Information Center Automation	High	$500,000	1	$500,000
On Bus Video Monitoring	High	$3,500	30	$105,000
On Bus Audio Monitoring	High	$400	250	$100,000
Bus Stop Video Monitoring	High	$5,000	10	$50,000
Park & Ride Lot Video Monitoring	High	$5,000	5	$25,000
AVL Expansion	High	$350,000	1	$350,000
Consolidated Paratransit Scheduling	High	$25,000	2	$50,000
Personalized Public Transit	High	$10,000	1	$10,000

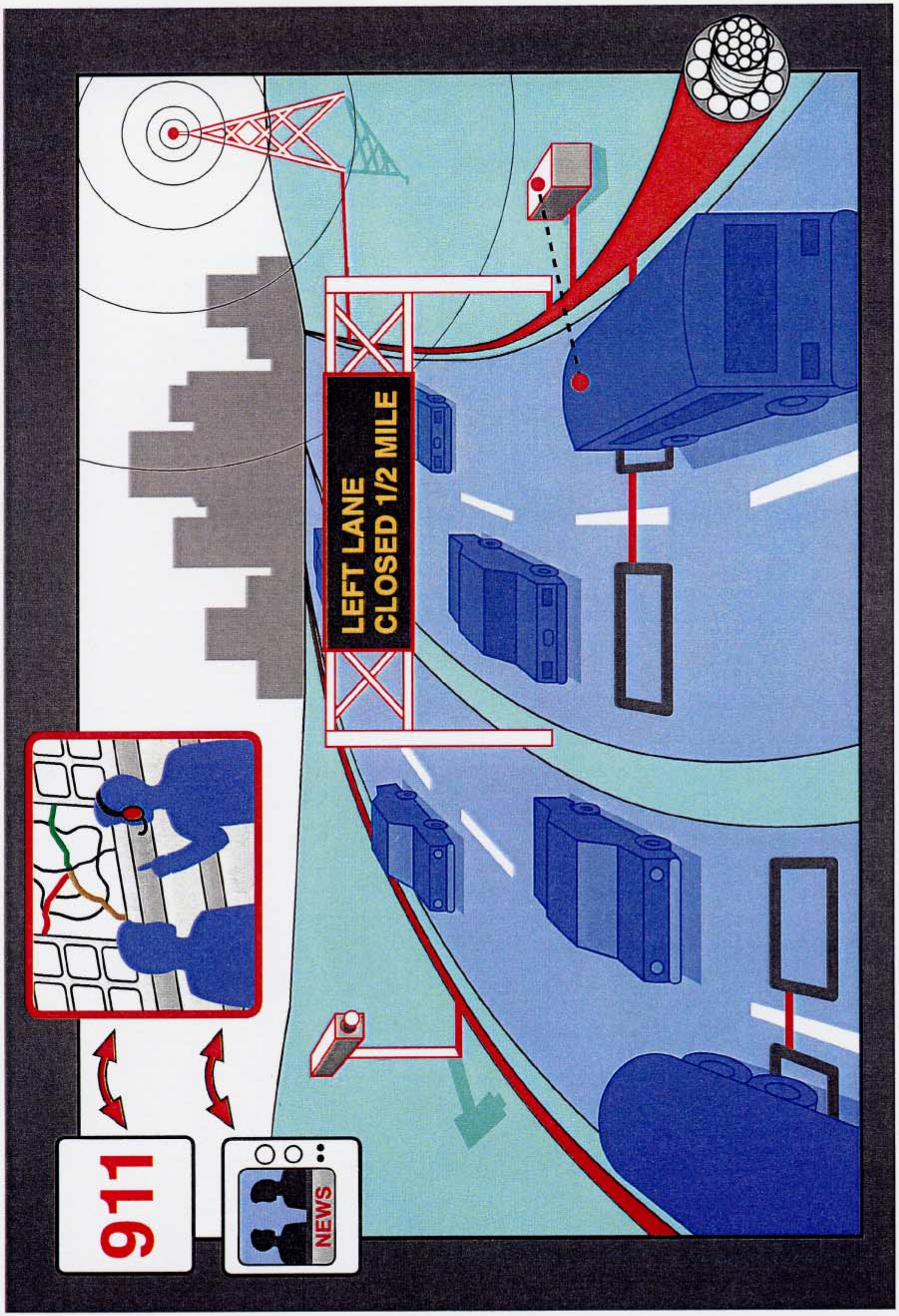
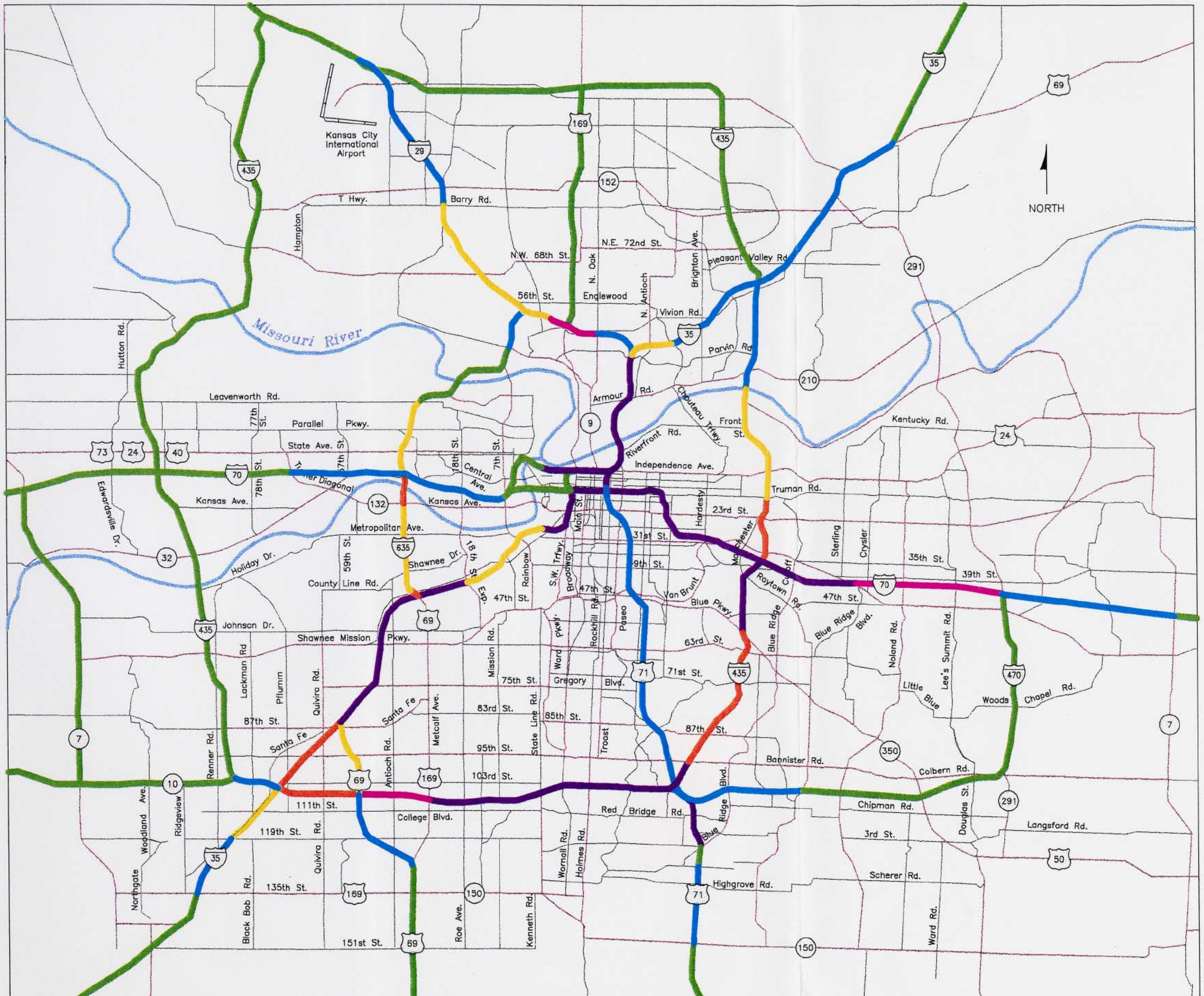


Figure 6-1. Diagram of Freeway Management System



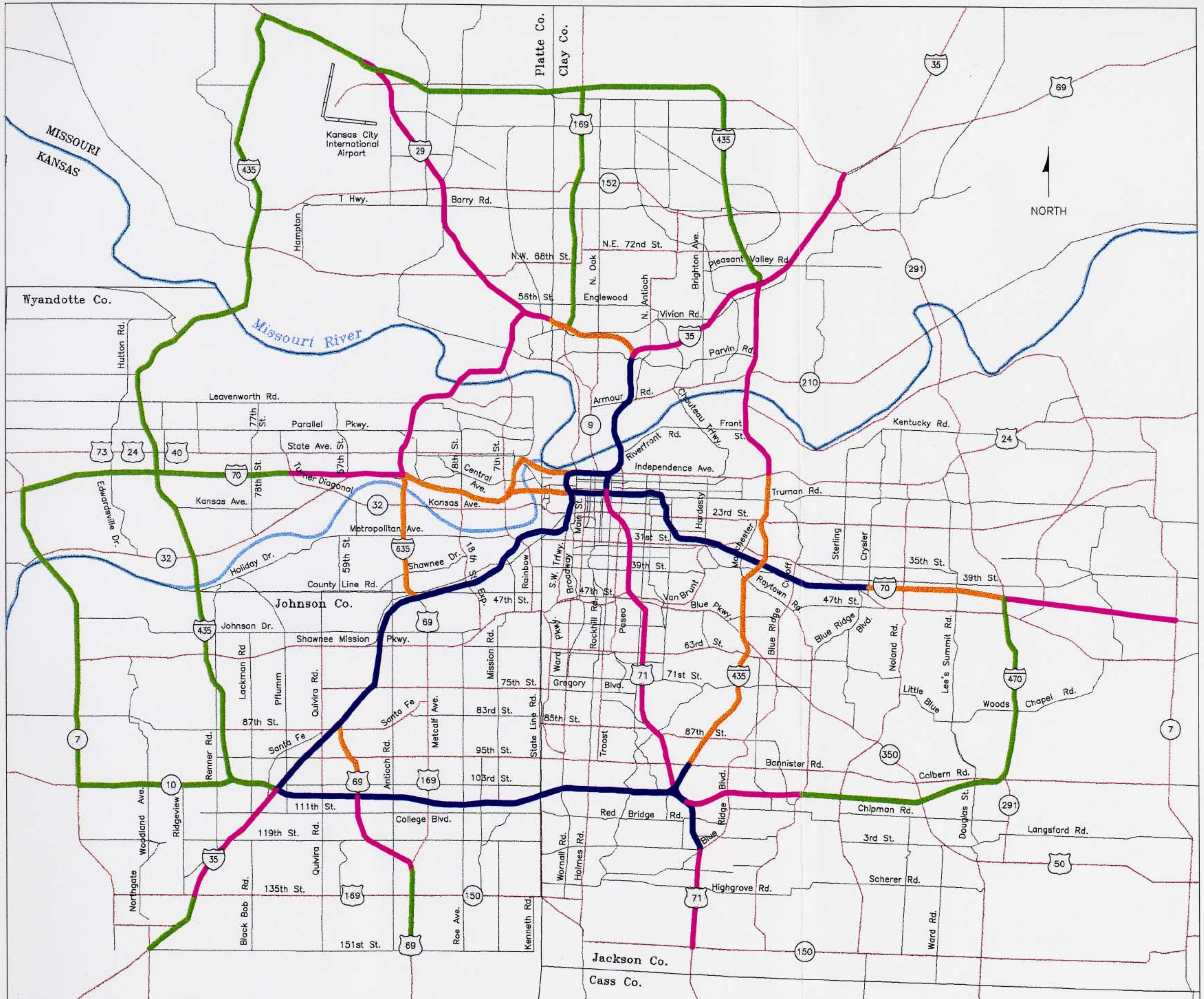
Legend

Green	Less Than $50,000
Blue	$50,000 - $90,000
Yellow	$90,000 - $140,000
Orange	$140,000 - $190,000
Magenta	$190,000 - $230,000
Purple	Greater Than $230,000

ITS Early Deployment Study
Strategic Deployment Plan

FIGURE 6-2
Annual Benefits Expected Due To Freeway Management System

ITS Early Deployment Study
Strategic Deployment Plan



Legend

- Phase 1
- Phase 2
- Phase 3
- Phase 4

FIGURE 6-3
Deployment Phases