

Cost Analysis of ITS Technologies

ATMS/ATIS Integration

Phase IIB Deliverable

#9. Cost Analysis Research Approach

EECS · ITS LAB · FT96 · Q24

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Introduction

Deployed since 1991¹, FAST-TRAC (Faster and Safer Travel - Traffic Routing and Advanced Control) in Oakland County, Michigan, is one of the largest field tests of ITS technologies nationwide. This project, initiated by the Road Commission for Oakland County (RCOC), integrates Advanced Traffic Management Systems (ATMS) with Advanced Traveler information Systems (ATIS) and involves public-private participation among various government agencies, enterprises, and citizen groups. On the ATMS side, FAST-TRAC uses a real time computerized traffic signal control system (SCATS, Sydney Coordinated Adaptive Traffic System) developed by the Roads and Traffic Authority, NSW, Australia. This project also utilizes Autoscope developed by Image Sensing System Inc. (ISS), and some traditional underground loop detectors to detect real time traffic demand at each equipped intersection. On the ATIS side, FAST-TRAC deploys a dynamic route guidance system (ALI-SCOUT) developed by the Siemens Corporation, Germany, to provide equipped travelers with real time route guidance services. In order to serve the systems' needs for centralized control, a traffic operation center (TOC) was established in 1992.

This study organizes all FAST-TRAC related cost items based on functional categories. It is hoped that this study will serve as a source of information useful both to the project evaluation task, and as a reference for cities and regions that may seek to develop similar ITS applications. This document aims to facilitate communication among all relevant parties in order to ensure adequate coverage and classification of all cost items.

1. In 1991, the idea of deploying and integrating several ITS technologies in Oakland County, Michigan, was initiated and soon got positive responses from a variety of public and private agencies. An incremental technology deployment process was adopted which proposed to start this effort with the contribution of private and public agencies.

Methodology

Interview

In order to categorize all related cost items and expenditures, several interviews were conducted with RCOC personnel, including FAST-TRAC project administrators, ATMS/ATIS system vendors, and participating city government officials.

Analysis framework for cost incurred

A complete cost study of an ITS implementation such as FAST-TRAC will need to include an analysis both of direct expenditures - i.e., cost incurred -- as well as other costs systemwide that might change because of the presence of the project. Since this change may be in either direction, these costs are referred to here as indirect cost impacts, i.e., cost induced/avoided.

Costs incurred and costs induced/avoided are analyzed in this study independently. For costs incurred, this study categorizes all expenditure items 1) by sub-system, 2) by task type, such as system design, and program management, and 3) by major project participants.

1) Sub-system: Five sub-systems in this cost analysis are defined as:

ATMS (S1) - SCATS/AUTOSCOPE¹ Traffic management system

ATIS (S2) - ALI-SCOUT Traveler route guidance system

TOC (S3)- Centralized traffic operation center

RCOC (S4) - Project administration

Evaluation (S5)- Overall project evaluation.

1. SCATS and AUTOSCOPE are currently grouped as one subsystem, but all costs incurred and analyzed later in this report are broken down as SCATS(AWA) and AUTOSCOPE(TCC) respectively.

2) Task type: Based on the characteristics of each sub-system, two to seven task types are assigned for related cost items. Table 1 shows the applicability of each task type to each sub-system. Expenditures pertaining to each sub-system are classified according to up to seven task types, including system design, program management, etc.

3) Major project participant: There are several major project participants (fund receivers) in each sub-system development. Table 2 shows the applicability of each major participant to each sub-system. All costs are recorded under the heading of the organization receiving the funds, rather than spending. Thus if the RCOC purchases Ali-Scout related services from Siemens, these cost are recorded as being associated with Siemens; internal expenditures would come under RCOC itself.

In addition to above three study-defined cost categories, all project expenditures in the database also contain information about their program-defined cost classifications, e.g., project phase, work order, and fiscal year, etc. Please refer to Appendix A for definitions of all RCOC-defined categories. Through the FAST-TRAC cost information system, which is a co-product of this study, cost summary and information query can be obtained according to multi-dimensional table structures interactively defined by the war

Table 1: Applicability of Task Types to Sub-System

	ATMS (S1)	ATIS (S2)	TOC (S3)	RCOC (S4)
System Design (T1)	applicable	applicable	applicable	non-applicable
Equipment (T2)	applicable	applicable	applicable	non-applicable
Program Management (T3)	applicable	applicable	non-applicable	applicable
Engineering (Installation) (T4)	applicable	applicable	non-applicable	non-applicable
System Management (T5)	non-applicable	non-applicable	applicable	non-applicable
System Communication (T6)	applicable	applicable	non-applicable	non-applicable
Technical Support (T7)	applicable	applicable	applicable	non-applicable
Public Information (T8)	non-applicable	non-applicable	non-applicable	applicable
ATMS/ATIS Data Sharing (T9)	non-applicable	non-applicable	applicable	non-applicable
System Maintenance (T10)	applicable	applicable	non-applicable	non-applicable

Table 2: Applicability of Project Participants to Sub-System

	ATMS (S1)	ATIS (S2)	TOC (S3)	RCOC (S4)	Evaluation (S6)
AWA (M1)	applicable	non-applicable	applicable	non-applicable	non-applicable
ISS (M2)	applicable	non-applicable	non-applicable	non-applicable	non-applicable
Siemens (M3)	non-applicable	applicable	applicable	non-applicable	non-applicable
Rockwell (M4)	non-applicable	non-applicable	applicable	non-applicable	non-applicable
Other Contractors (M5)	applicable	applicable	non-applicable	applicable	non-applicable
RCOC (M6)	applicable	applicable	applicable	applicable	applicable
Miscellaneous ^a (M7)	applicable	applicable	applicable	applicable	non-applicable
Ameritech (M8)	applicable	applicable	applicable	applicable	non-applicable
RTA (M9)	applicable	non-applicable	non-applicable	non-applicable	non-applicable
Sequoia ^b (M10)	non-applicable	non-applicable	applicable	applicable	non-applicable
U of M (M11)	non-applicable	non-applicable	non-applicable	non-applicable	applicable
TCC (M12)	applicable	non-applicable	non-applicable	non-applicable	non-applicable

a. This miscellaneous vendor group contains all organizations with each of which provides relatively small amount of equipment and/or services to the project.

b. Sequoia is a computer equipment vendor from which this project purchased computers and many other equipment.

Analysis Framework for Indirect Costs

The FAST-TRAC experience has suggested that some traffic operation expenditures are increased after the installation of ITS equipment. For example, the monthly bills, invoiced by RCOC, of City of Troy for traffic signal maintenance tasks averaged around \$8,500 before the deployment of SCATS/Autoscope systems. Since June 1992 when 28 intersections were equipped with SCATS/Autoscope systems, the monthly bill averaged \$10,100. After another 67 intersections joined the test-bed in December 1993, the average monthly charge for signal maintenance was further up to around \$12,000¹. A more detailed analysis on this issue will be provided later in this paper.

1. All three numbers (\$8,500, \$10,100, \$12,000) are derived based on the monthly maintenance cost data from August, 1990 through September, 1994.

FAST-TRAC Cost Information System

Unlike the analysis of costs incurred which can be relatively consistently covered with a uniform framework with little modification between different sub-systems, costs induced are much more irregular in terms of their sources. Therefore, the framework for the analysis of cost induced in this paper will be on a case-by-case basis.

The research team has developed a FAST-TRAC cost information system which supports various functions, including different formats of summarization and query. Microsoft FoxPro 2.6 for Windows' PAL feature has been used to design the system in such a way that users are able to maintain and query the data base interactively. Currently, Quick Step, Phase I, Phase IIA, and Phase IIB cost information as of fiscal year 1995 has been incorporated in the system.

Funding (Budget) Source

Starting from Quick Step through Phase III of the project, most FAST-TRAC project funding (budget), \$71.2 million¹, was from federal grants (Federal Highway Administration, FHWA), which equals \$55.5 million (77.9%). Local matching funds committed were about \$15.7 million, (22.1%) of the total budget cost. Table 3 summarizes the FAST-TRAC project budget by funding source by phase.

Table 3: FAST-TRAC budget by funding source by incremental stage

	Quick Step (FY 91 - 93)	Phase I (FY 92 - 94)	Phase IIA (FY 93 - 95)	Phase IIB (FY 95 - 97)	Phase III (FY 96 - 98)	Total
Federal Grant		\$10 million (85.5%)	\$10.5 million (78.4%)	\$20 million (79.4%)	\$15 million (79.2%)	\$55.5 million (77.9%)
Local Match^a	\$2 million (100%)	\$1.7 million (14.5%)	\$2.9 million (21.6%)	\$5.2 million (23.4%)	\$3.9 million (20.8%)	\$15.7 million (22.1%)
Total	\$2 million	\$11.7 million	\$13.4 million	\$25.2 million	18.93 million	\$71.2 million

a. Local match includes private contributions as well as local authorities' matching funds.

Source: RCOC

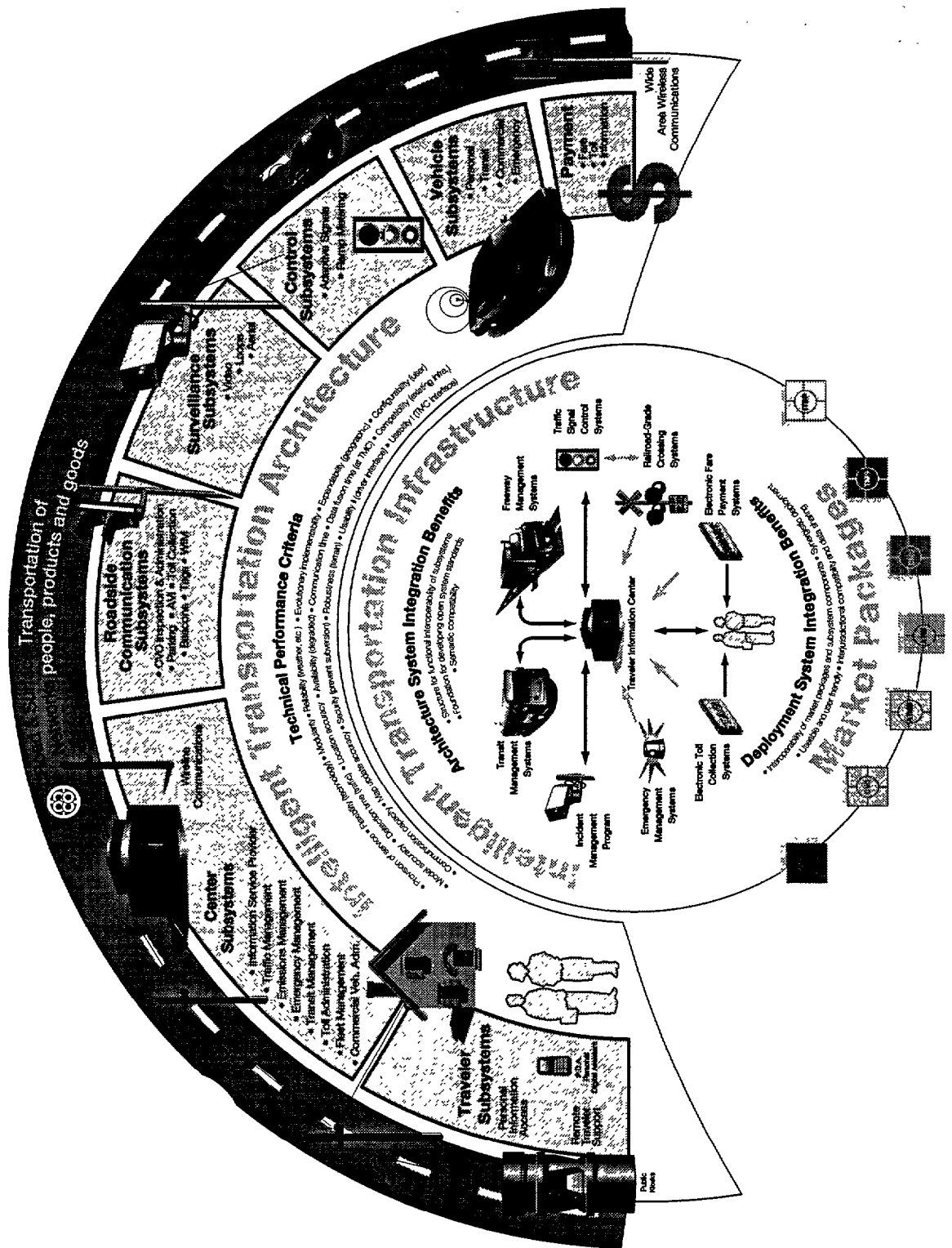
Note: Numbers in the parenthesis show the column percentages.

Table 3.1: FAST-TRAC Calendar

Quickstep	91 → 93
Phase I	92 → 94
Phase II	93 → 95

1. \$71.2 million is the total federal aid appropriated, including \$3 million redistributed to MDOT. Thus, the total budget is \$37.5 million for RCOC (FAST-TRAC), as appeared in Table 3.

Figure 0.1. System Architecture



Cost Incurred Analysis - Summarized Results

According to financial reports provided by RCOC, a total amount of \$25,855,700¹ was spent on the project as of fiscal year 1995 (as of September 1995). A summary table (Table 4) of FAST-TRAC expenditures by sub-system is developed to give readers a preliminary overview. Numbers in each cell represent dollar value and/or percentage of total FAST-TRAC expenditures.

In a more detailed fashion, Table 5 shows all ATMS related expenditures while Table 6, Table 7, Table 8, and Table 9 reveal costs incurred for ATIS, RCOC, TOC, and Evaluation, respectively². Meanwhile, Figure 1 illustrates the percentage of the total ATMS related expenditures by task type. Similarly, Figure 2 shows the same information for the ATIS sub-system.

Table 4: Overview of FAST-TRAC Cost Incurred as of FY 1995

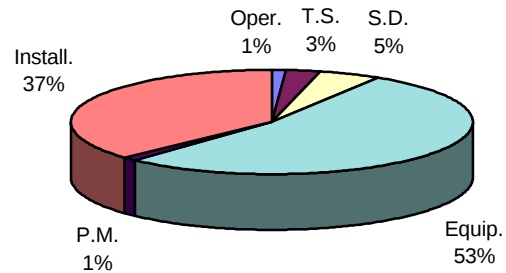
Sub-System	Phase I	%	Phase IIA	%	Phase IIB	%	Total	%
ATMS (S1)	\$6,834,400	63.1%	\$8,433,700	74.8%	\$354,700	9.5%	\$15,622,700	69.0%
ATIS (S2)	\$2,292,600	21.2%	\$1,377,600	12.2%	\$2,695,000	72.1%	\$6,365,100	16.6%
TOC (S3)	\$886,600	8.2%	\$795,700	7.1%	\$327,900	8.8%	\$2,010,200	7.6%
RCOC (S4)	\$238,300	2.2%	\$225,300	2.0%	\$359,800	9.6%	\$823,400	2.1%
Evaluation (S5)	\$587,000	5.3%	\$447,100	3.9%	-	0%	\$1,034,100	4.7%
Total	\$10,838,900	100%	\$11,279,400	100%	\$3,737,400	100%	\$25,855,700	100%

1. This number is derived based on the FAST-TRAC financial reports for Phase I, Phase IIA, and Phase IIB issued in December 1995. It does not include any Quick Step expenditures.

2. For simplicity, in this report, costs are not broken on an annual basis. The database developed does, however, contain this information.

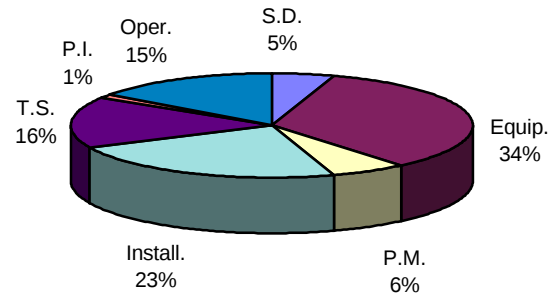
Tables 5 through Table 9, (cost tables by sub-system by task type by major project participant), follow similar frameworks to allow further query and investigation. These queries may take simple forms, such as total expenditures on ATMS system design (Table 5). Alternatively, they may be more complex queries such as the total amount billed by RCOC; this is answered by a vertical summation of the RCOC columns from Table 5 through Table 8. In addition, readers are encouraged to use the FAST-TRAC cost information system to define conditions and develop their own table structures based on individual need.

Figure 1. Percentage of ATMS Expenditures by Task Type



Note: T.S. = Technical Support, S.D. = System Design, Oper. = Communication system operation and installation cost, P.M. = Program Management, Equip. = Equipment.

Figure 2. Percentage of ATIS Expenditures by Task Type



Note: PI. = Public information, S.D. = System Design, P.M. = Program Management, T.S. = Technical Support,

Table 5: ATMS Sub-System Expenditures by Task Type by Major Participant

	AWA	ISS	Contractors	RCOC	TCC	RTA	Amer-itech	Misc.	TO BE IDENTI-
System Design		\$45,000	\$768,300	\$14,900					
Equipment	\$612,200			\$800	\$73,000	\$422,000		\$48,800	\$7,172,100
Program Management	\$86,900								
Installation			\$4,407,900	\$937,500				\$426,100	
Operation Cost				\$200			\$212,300		

Table 6: ATIS Sub-System Expenditures by Task Type and Major Participant

	Siemens	Contractors	RCOC	Misc.	Total
System Design	\$92,400	\$219,300			\$311,700
Equipment	\$2,137,800			\$59,200	\$2,197,000
Program Management	\$400,600				\$400,600
Installation	\$227,400	\$1,113,900	\$76,900	\$34,600	\$1,452,800
Technical Support	\$998,800				\$998,800
Public Information	\$50,000				\$50,000
TO BE IDENTIFIED	\$954,200				\$954,200
Total	\$4,861,200	\$1,333,200	\$76,900	\$93,800	\$6,365,100

Table 7: TOC Sub-System Expenditures by Task Type and Major Participant

	RCOC	Rockwell	Siemens	Amer-itech	Sequoia	Misc.	Total
System Design		\$278,000					\$278,000
Equipment					\$124,200	\$73,800	\$198,000
System Management	\$434,500			\$55,800		\$318,200	\$808,500
System Communication				\$195,400		\$1,000	\$196,400
Technical Support	\$53,700					\$9,200	\$62,900
ATMS/ATIS Integration		\$208,100	\$108,600				\$316,700
TO BE IDENTIFIED				\$149,700			\$149,700
Total	\$488,200	\$486,100	\$108,600	\$400,900	\$124,200	\$402,200	\$2,010,200

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Table 8: RCOC Sub-System Expenditures by Task Type and Major Participant

	RCOC	Contractors	Misc.	TO BE IDENTIFIED	Total
Program Management	\$220,800		\$8,700	\$1,100	\$230,600
Public Information	\$13,000	\$225,800	\$38,100		\$276,700
System Maintenance	\$311,200		\$5,000		\$316,200
Total	\$545,000	\$225,600	\$51,800	\$1,100	\$823,500

Table 9: Evaluation Sub-System Expenditures by Major Participant

U. of M.	RCOC	Siemens	Misc.	Total
\$1,002,600	\$900	\$30,700		\$1,034,200

System Design Cost (ATMS, ATIS, TOC)

While this section presented an overview of the various sub-system categories, the next section goes into greater detail in the areas of task types and major project participants.

RCOC contracted with the Hampton Engineering & Associates, Inc. to take over most SCATS/Autoscope and ALI-Scout related system preliminary engineering design tasks. The Image Sensing System Inc., designer of the Autoscope system, the Siemens Corporation, and RCOC also committed some efforts at this system design stage. Table 10 summarizes all system design costs by sub-system by billing organization through fiscal year 1995.

Table 10: System Design Cost by System Type by Billing Organization

	Hampton	Rockwell	RCOC	ISS	Siemens
ATMS	\$768,300		\$14,900	\$45,000	
ATIS	\$219,300				\$92,400
TOC		\$278,000 ^a			

a. \$195,000 was for the existing TOC system design while the balance, \$83,000, was for the new TOC site system design.

Source: RCOC

Equipment Cost (ATMS, ATIS)

ATMS (SCATS/Autoscope) Equipment

Table 11 shows the quantities of major system components used for ATMS by participating municipality.

Table 11: Quantity of ATMS Equipment Used in FAST-TRAC by Phase

	Troy	Pontiac	Auburn Hills	Rochester Hills	South Lyon
Date of Completion	6/92 for 28 12/93 for 67	6/94	6/94	11/94	12/95
Project Phase	Quick Step & Phase I	Phase IIA	Phase IIA	Phase IIA	Phase IIB
# of Intersections	95	13	46	51	6
SCATS Controller	95	13	46	51	6
Autoscope Controller	8.5	13	41	49	5
2-channel	20	2	8	2	-
4-channel	64	11	32	47	5
6-channel	1	-	1	-	-
Autoscope Camera	280	46	133	171	19
Push Button	390	88	138	234	34

As shown in Table 5, the total Autoscope equipment purchasing cost (\$5,856,500 under TCC, including both Autoscope cameras and controllers) is the largest expenditure (70%) in this ATMS equipment category. According to the bidding records collected, the unit price of SCATS controller was about \$3,050-\$3,200. The unit price for the Autoscope camera was about \$2,845. Three types of Autoscope controllers, 2-, 4-, and 6-channel, are available for installation depending on the size and geometric layouts of the intersections. In December 1992, the unit price for the 2-channel controller was \$25,200, \$30,200 for a 4-channel, and \$36,200 for a 6-channel controller. In October 1993, the unit price for a 4-channel controller dropped to \$20,175 while the unit price of a 6-channel controller remained virtually unchanged (\$36,175). The considerable reduction in unit prices for 4-channel controller in the second procurement can be attributed to both an increase in the quantity ordered and to a change in the specification which

1. TOC equipment cost will be discussed independently later in this section.

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resulted in a more simplified Autoscope controller design. Table 12 through Table 14 summarize the equipment unit costs by procurement date for Autoscope controllers, Autoscope cameras, and SCATS controllers, respectively.

Table 12: Autoscope Controller Unit Price by Procurement

	Date of Bid	Quantity	Unit Price
2-channel Controller			
First Procurement	August, 1991	12	\$23,390
Second Procurement	December, 1992	20	\$25,200
4-channel Controller			
First Procurement	August, 1991	15	\$33,556
Second Procurement	December, 1992	60	\$30,200
Third Procurement	October, 1993	150	\$20,175
6-channel Controller			
First Procurement	August, 1992	1	\$36,200
Second Procurement	October, 1993	6	\$36,175

Table 13: Autoscope Camera Unit Price by Procurement

	Date of Bid	Quantity	Unit Price
First Procurement	August, 1991	67	\$2,658
Second Procurement	December, 1992	250	\$2,100
Third Procurement	October, 1993	401	\$1,625
Fourth Procurement	October, 1995	120	\$1,600

Table 14: SCATS Controller Unit Price by Procurement

	Date of Bid	Quantity	Unit Price
First Procurement	April, 1992	30	\$3,200
Second Procurement	September, 1992	90	\$3,050
Third Procurement	October, 1993	150	\$3,050
Fourth Procurement	May, 1995	60	\$3,500

Ali-Scout (ATIS) Equipment

A total amount of \$2,454,500 was spent on purchasing Ali-Scout related equipment which included 101 beacons and 800 in-vehicle units (IVU). The unit prices for major beacon's and IVU's components by project phase are summarized in Table 15. All equipment purchasing cost inherently includes system operational software costs.

Table 15: Units Prices for Major Ali-Scout Components by Project Phase

	Phase I		Phase IIA		Phase IIB	
	QTY	Unit Price	QTY	Unit Price	QTY	Unit Price
Cost of IVU' s						
Display Control Unit (DCU)	60	\$653.47	--	--	740	\$364.53
Navigation Control Unit (NAC)	60	\$893.54	--	--	740	\$504.73
IR Transceiver (IRT)	60	\$248.20	--	--	740	\$140.20
Cost of Beacons						
Beacon Controller	30	\$5,022.22	10	\$5,462.26	61	\$5,843.71
IRBD Beacon Inset	240	\$698.49	84	\$698.49	532	\$707.18

Engineering (installation) Cost (ATMS, ATIS)

ATMS Equipment Installation

Over 76 percent (\$4,407,900) of total ATMS installation expense (\$5,771,500) was actually billed by contractors for installing 205 intersections plus 125 overhead signs at 12 locations. The RCOC engineering team itself installed SCATS/Autoscope at 26 intersections. The costs of installing SCATS/Autoscope by contractors were \$71,000 per intersection while the costs were \$67,200 for RCOC installation.

ATIS Installation

For Ali-Scout installation, \$1,452,800 was spent on installing beacons and in-vehicle units. About \$1,113,900 (76.7%) was actually billed by contractors.

Communication Installation

In addition to transportation engineering tasks, the communication system installation cost is another significant expenditure item for ATMS/ATIS deployment. Currently, the transmission of real time information between site controllers, regional controllers, and

System Communication Cost (ATMS, ATIS)

Program Management Cost (ATMS, ATIS, RCOC)

the central management center mainly relies on wired networks.¹ A fixed cost of \$700 per intersection for communication system installation is paid to Ameritech (or Michigan Bell). The \$700 includes \$500 for channel termination, \$150 for circuit design, and \$50 for order processing.

Overall, a total of \$557,400² was paid to Ameritech, including communication system installation and operations for both ATM5 and ATIS sub-systems. To simplify the management task, currently, RCOC and Ameritech have reached an agreement on a flat rate per intersection per sub-system for FAST-TRAC data transmission.

Program management focuses on administrative activities, work plan development, procurement control, and contract management. RCOC is the major player in this category in conjunction with two major system vendors, AWA Traffic Systems America (AWATSA) Inc. and the Siemens Corporation. AWATSA charged \$86,900 for its program management services while Siemens billed \$400,600. The reason for the much higher Siemens' program management charges is attributed to the fact that RCOC has undertaken most of program management work for SCATS/Autoscope and thus less for AWATSA to contribute. Meanwhile, RCOC has less expertise in the management of the Ah-Scout system than in SCATS/Autoscope. Therefore, Siemens is currently in charge of most of the program management tasks for the Ali-Scout system. In Phase IIB, Siemens and AWATSA are conducting a data exchange test to determine whether the data generated by both subsystems can be shared and integrated to improve the system's overall performance.

There are many other efforts devoted to program management. Other than the above mentioned charges which have specifically indicated purposes, it is virtually impossible to categorize most program management efforts to either ATMS or ATIS. Thus there exists a program management account located under RCOC to accommodate these program management expenses. For example, salary and benefits for RCOC employees who are in charge of coordinating all FAST-TRAC related administrative and accounting

1. RCOC is investigating the feasibility of adopting wireless and multiplexing options in Phase IIB.
2. Most Ameritech bills actually mixed all charges into a single bill per month. RCOC and the research team are jointly examining this issue for further clarification.

Technical Support (ATMS, ATIS)

activities are assigned to this category. As of fiscal year 1995, \$230,600 was spent on this RCOC program management task force account, including \$220,800 direct RCOC cost, as shown in Table 8. Nevertheless, this RCOC program management cost is likely underestimated due to the fact that FAST-TRAC activities are so widely spread within RCOC that not all program management effort committed by RCOC staff members are included.

Every major equipment vendor is requested to provide technical support and service on their equipment. For example, after the installation of Ali-Scout beacons, the Siemens Corporation conducts tests and makes all necessary calibrations before the beacons can properly function as expected. Thus, all adjustment expenses are assigned to this category. As of fiscal year 1995, SCATS/Auto-scope system expenditures in this category is \$394,500, including \$306,200 to AWA, \$70,000 to ISS (Image Sensing System, Auto-scope designer), \$1,000 for RCOC, and \$18,200 to others. For the Ali-Scout system, only Siemens is capable of providing technical support. Consequently, \$998,800 was paid for Ali-Scout technical support.

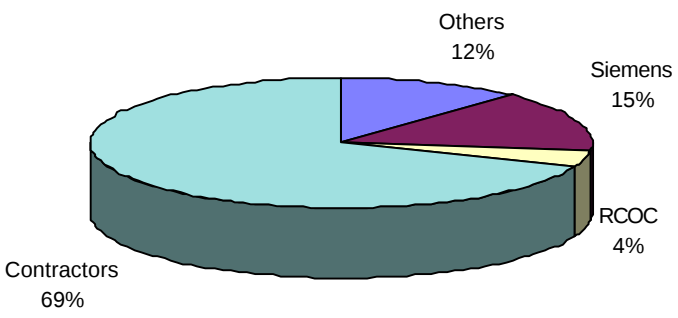
Public Information (ATIS, RCOC)

Based on competitive proposals, RCOC hired Hermanoff, a public information consultant company, to produce, distribute, and collect relevant public information for the FAST-TRAC operational field test. The Siemens Corporation, under the contract to RCOC, provides guidance to the consultants regarding information on Ali-Scout. As of fiscal year 1995, a total of \$326,700 was billed for public information. As shown in figure 3, \$225,600 (69%) was paid to the contractor (Hermanoff), another \$50,000 (15%) to the Siemens Corp., \$13,000 for RCOC (4%), the balance, \$38,100 (12%), was spent on other related activities, such as materials, and travel, etc.

**System
Management:
Traffic Operation
Center (TOC)**

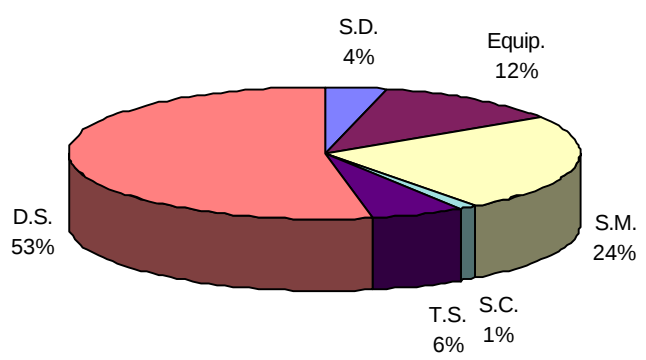
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Figure 3. Percentage of Public Information Expenditures by Participant



A Traffic Operation Center was established to coordinate real time traffic monitoring and the operational activities centrally and to serve as a control and information center for system operations. Due to its uniqueness, the TOC is presented as an independent subsystem. The TOC's direct expenditures, as of fiscal year 1995, are calculated as \$2,010,200 (see Table 7). Figure 4 shows the proportion of TOC spending on each individual task type. System Management cost, e.g., labor costs, office rent, utilities, and so on, is summed to \$808,500 (40%).

Figure 4. Percentage of TOC Expenditures by Task Type



Note: S.D. = System Design, S.M. = System Management, T.S. = Technical Support, D.S. = Data Sharing.

Indirect Cost Analysis

Longitudinal Analysis of Traffic Signal Maintenance Cost

The RCOC maintains traffic signals for 57 of the 61 municipalities in the county, billing them monthly for services performed. In order to examine the extent to which the operations of ATMS-equipped intersections could affect the overall traffic signal maintenance costs, the authors conducted a longitudinal comparison of maintenance costs by spending category (labor cost, equipment cost, material cost, and power cost) for all four participating municipalities¹.

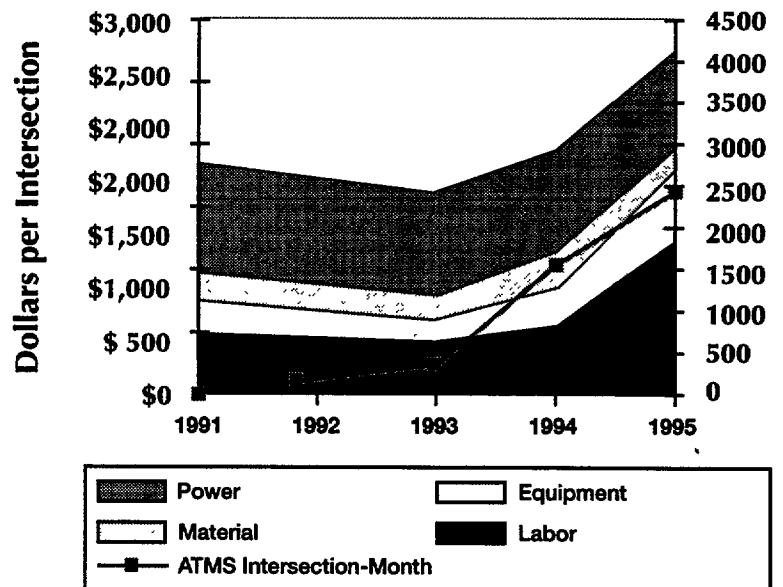
FAST-TRAC equipped a total of 205 intersections with ATMS throughout the region as of FY 1995. Table 16 lists the annual traffic maintenance cost per intersection by category by year. The column "ATMS Intersection-Month" is calculated as the number of ATMS-equipped intersections times the number of months in operation for each corresponding year. For example, ten (10) ATMS-equipped intersections operating for six (6) months will generate sixty (60) ATMS Intersection-months. This information is used as an indicator to detect the existence of any indirect traffic signal maintenance costs associated ATMS deployment. As shown, the average cost for traffic signal maintenance was about \$1,837 per intersection in 1991 before the installation of ATMS equipment. Following slight decreases in 1992 and 1993. Maintenance costs for this group of intersections began to increase in 1994 and 1995. All numbers shown in Table 16 are constant dollar figures which have been adjusted by the corresponding annual Consumer Price Indices (CPI). Figure 5 illustrates annual intersection signal maintenance costs by category.

1. Four participating municipalities include Troy, Pontiac, Auburn Hills, and Rochester Hills. The City of South Lyon didn't install ATMS until December, 1995, beyond the time span of this study, and is thus excluded.

Table 16: Annual Intersection Traffic Signal Maintenance Cost by Year

	Labor	Equip- ment	Material	Power	Total	ATMS Inter- section- Month
1991	\$487	\$258	\$213	\$878	\$1,835	0
1992	\$453	\$242	\$166	\$869	\$1,730	168
1993	\$407	\$193	\$176	\$827	\$1,603	336
1994	\$545	\$324	\$279	\$807	\$1,956	1545
1995	\$1,229	\$565	\$198	\$767	\$2,758	2460

Source: RCOC

Figure 5, Annual Signal Maintenance Cost per Intersection by Category

Based on **Figure 5**, it is shown that the labor cost and equipment cost are two major sources accounting for most of the increased signal maintenance cost in the past three years. According to the RCOC electrical superintendent, the most often performed ATMS related system maintenance tasks include:

1. Autoscope equipment repairs: The reliability of Autoscope cameras and controllers are not yet satisfactory. The breakdown frequency of Autoscope equipment is actually higher than people had expected;

Multivariate Regression Modeling

2. Push button maintenance: In order to preserve the minimum pedestrian clearance time/space for safety considerations, SCATS regional controllers have to know the presence of pedestrians when dynamically calculating the optimal phase sequences and phase timings. In FAST-TRAC, the pedestrian push button device is used to function as an detector of pedestrian appearance and almost every ATMS-equipped intersection is equipped with pedestrian push buttons. The breakdown frequency of pedestrian push buttons has also been higher than expected.

Apart for the labor and equipment costs, Figure 5 also reveals that the other two categories, material cost and power cost, remain virtually unchanged. However, it should be noted that this result does not indicate a stabilized status for both material and power costs due to the following two reasons.

1. Product warranty: Most ATMS equipment is still under product warranty granted by the equipment vendors. Therefore the material costs charged, as shown in Table 16 might be significantly lower than the actual costs.

2. Signal system expansions: In order to take full advantage of SCATS's functionality, the number of traffic signal sets has gone up at most SCATS intersections. For example, dedicated left-turn signals are set up at almost all SCATS intersections. Consequently, the power and other maintenance costs should both go up and directly appear on the signal maintenance bills. Nevertheless, there also exist quite a few ATMS-equipped intersections, especially small intersections, which were not even signalized in the early years and thus not included in the calculations of average costs in the early years. Therefore, even though the total power costs actually went up, the average costs went down instead.

In order to determine which of the ATMS components account for the increased maintenance costs, the authors developed a multivariate regression model by using the year 1994 data. All 205 ATMS-equipped intersections by the end of year 1994 are included with each intersection being an unique observation. The model defines the labor cost for signal maintenance in 1994 as the dependent variable, with the following four independent variables:

- 1) Number of Push Buttons
- 2) Channels in Autoscope Controller
- 3) Number of Months Operating ATMS in 1994

4) Power Cost in 1994: Power costs are used here as an indicator of the size of the intersection.

The modeling results are summarized in Table 17. The results suggest that each extra Autoscope channel is associated with \$55.17 in labor costs per year per intersection. The number of Autoscope cameras in the intersection is not included in this analysis because of its high correlation ($r = 0.95$) with number of channels. Therefore, it should be noted that the \$55.17 annual cost per channel, may be associated both with cameras and with controllers. The expected increase in labor cost corresponding to an increase of one month of ATMS operation is \$13.66. As expected, larger intersections (higher power cost) tend to have higher signal maintenance labor costs. Finally, the number of push buttons also shows a positive relationship with the labor cost, but the relationship is not statistically significant.

Table 17: Multivariate Regression Modeling Results

Dependent Variable: Labor Cost for Signal Maintenance in 1994			
independent Variable	Coefficient	T Statistic	Sig. T
Number of Autoscope Cameras	62.56	2.56	0.01
Number of Months Operating ATMS	13.64	2.41	0.02
Power Cost in 1994	0.26	5.06	0.00
Number of Push Buttons	4.19	0.44	0.66
Constant	74.40	1.05	0.29
F Statistic: 21.45			
R-Square: 0.29			

In addition to this regression analysis, the authors have also conducted a maintenance cost analysis of ATMS-equipped intersections by component (Autoscope controllers, Autoscope cameras, SCATS controllers, and push buttons) for the year of 1995. The results are discussed in Appendix B.

Appendix A. RCOC Cost Classification

According to the project proposals and the FAST-TRAC cost data bases maintained by RCOC, all FAST-TRAC expenditures are classified by the following three dimensions:

1. By Project Phase

As of fiscal year 1995, RCOC has completed the FAST-TRAC deployment for both Phase I (FY92 - 94) and Phase IIA (FY93 - 95). Phase IIB (FY95 - 97) is currently proceeding while Phase III (FY96 - 98) is under preparation.

2. By Work Order

Table A-1 explains the work order definitions by phase.

3. By Month by fiscal Year

All expenditures are also grouped by month by fiscal year. Instead of citing the month by which expenditures actually incurred, the "month" data indicates the month by which RCOC submitted the reimbursement requests to MDOT. Therefore, some time lags from costs incurred to cost filed should be expected. This paper examines expenditures within the time period from FY92 through FY95.

Table A-1 shows the work order classification by project stage

	Phase I	Phase IIA	Phase IIB
WO#1	Local Match	Local Match	Local Match
WO#2	Preliminary Engineering	Preliminary Engineering	Preliminary Engineering (RCOC force)
WO#3	Project Management	Program Management	Program Management
WO#4	Command Center, Computer Hardware & Software	SCATS Computer Hardware	Traffic Engineering and Operations
WO#5	System Evaluation	Software Acquisition	Traffic Operations Center
WO#6	Public Information	System Management	Systems Communications

Table A-1 shows the work order classification by project stage

WO#7	Training	Traffic Operations Center	Public Information
WO#8	Michigan Sell Installation & Lease	Systems Communications	Software Acquisition
WO#9	Install SCATS & Autoscope	Public Information	Preliminary Engineering (South Lyon)
WO#10	ATI/ATM System Integration	SCATS & Autoscope Installation	Computer Hardware Acquisition
WO#11		Program Evaluation	SCATS/Autoscope Installation
WO#12		System Integration	Systems Evaluation
WO#13		Siemens Ali-Scout	
WO#14		Public Information (contractors)	SCATS Integration
WO#15			Systems integration Management
WO#16			Siemens

Note: The “Work Order” classification is used by the RCOC to define expenditures; the subject of each work order in each phase is presented here for reference purposes. Work order definitions are largely independent between phases.

Appendix B. ATMS System Maintenance Cost Analysis by Component

Following the indirect cost analysis earlier in the paper, a more detailed ATMS system maintenance cost analysis is conducted here to explore the evolution of patterns of ATMS system maintenance costs throughout 1995. The year 1995 is selected for analysis because this is the first time since the operation of the field test that the FAST-TRAC related signal maintenance costs by system component are available.

As noted before, in general, the deployment of FAST-TRAC is associated with an overall increase of the traffic management system's maintenance cost. The preliminary analysis results also suggest that the increased maintenance cost can be largely attributed to the maintenance needs for ATMS. In phase IIB, all ATMS-related maintenance costs are assigned into an independent work order (WO#4, Traffic Engineering and Operations), and are grouped by participating municipality by ATMS component.

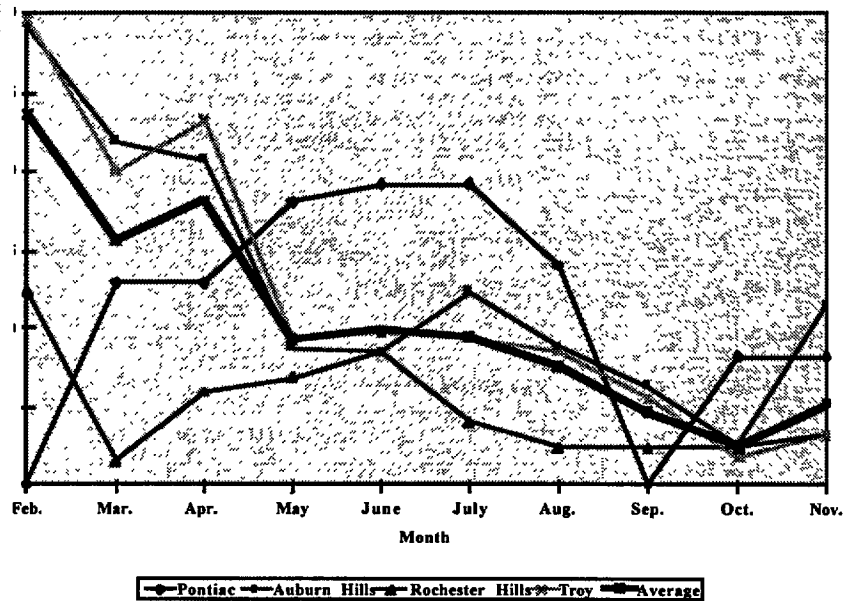
Figure B-1 through Figure B-4 show the ATMS average monthly maintenance cost per unit by participating municipality for SCATS controller, Autoscope controller, Autoscope camera, and push button, respectively. Instead of treating each individual month as a unique observation, the authors use three month moving average ($1/3 * (\text{last month} + \text{this month} + \text{next month})$) in order to smooth the fluctuations.

As shown in Figure B-1, the maintenance cost for SCATS controllers generally followed downward trend throughout the year. This might be an indication that the RCOC engineering department is getting more familiar with the SCATS system and is capable to maintain the system with a lower cost. Unlike SCATS controllers, all three other components are not indicating any declining or growing trends in terms of their maintenance costs (Figure B-2, Figure B-3, and Figure

Appendix B. ATMS System Maintenance Cost Analysis by Component— Cost Analysis of ITS Technologies

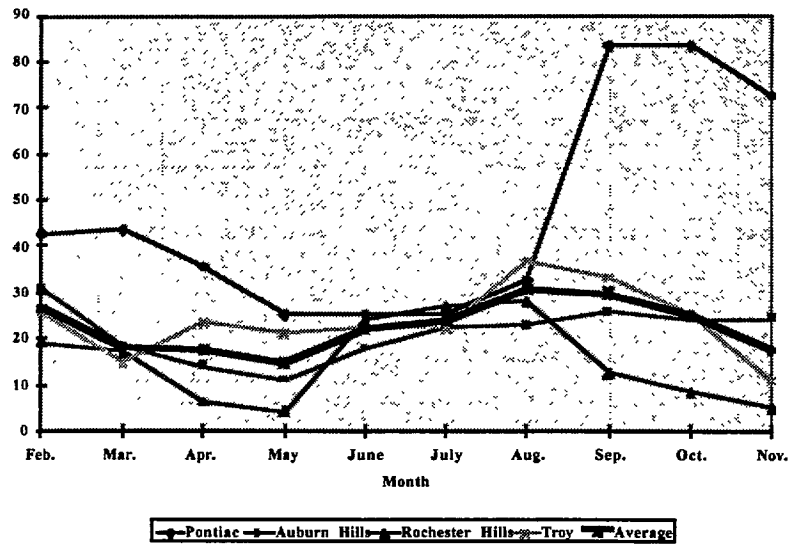
B-4). As shown, the overall Autoscope controller's maintenance costs seem lower over the winter months (**Figure B-2**). In contrast, the maintenance costs for Autoscope cameras appear favorable during the warmer seasons (**Figure B-3**). In **Figure B-4**, the maintenance costs for push buttons are relatively stable over time with a moderate declining tendency.

**Figure B-1, SCATS Controller Maintenance Cost, 1995
(Three-Month Moving Average)**



Appendix B. ATMS System Maintenance Cost Analysis by Component — Cost Analysis of ITS Technologies

**Table B-2, Autoscope Controller Maintenance Cost, 1995
(Three-Month Moving Average)**



**Figure B-3, Autoscope Camera Maintenance Cost, 1995
(Three-Month Moving Average)**

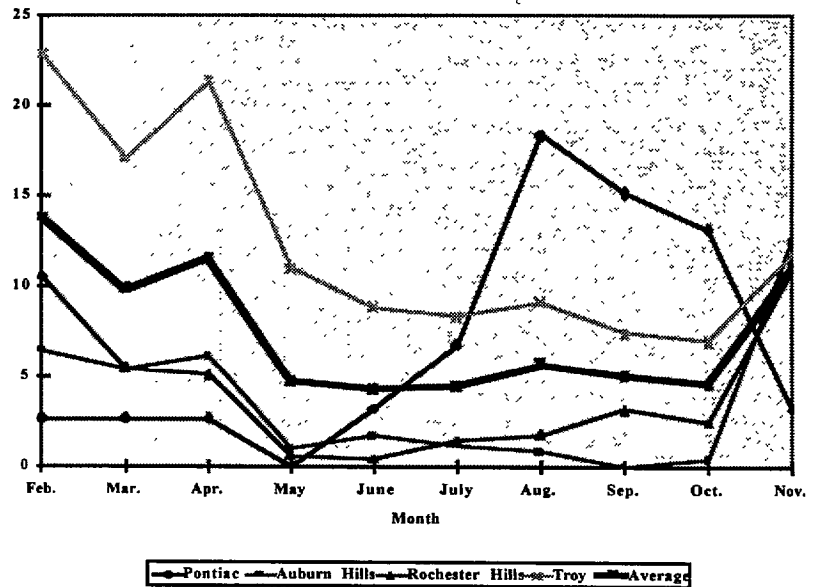


Table B-4, Push Button Maintenance Cost, 1995

Appendix B. ATMS System Maintenance Cost Analysis by Component— Cost Analysis of ITS Technologies

(Three-Month Moving Average)

