NATIONAL COOPERATIVE TRANSIT RESEARCH & DEVELOPMENT PROGRAM

15 Synthesis of Transit Practice

Supervision Strategies for Improved Reliability of Bus Routes

TRANSPORTATION RESEARCH BOARD
National Research Council

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Supervision Strategies for Improved Reliability of Bus Routes

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Administrators, engineers, and many others in the transit industry are faced with a multitude of complex problems that range between local, regional, and national in their prevalence. How they might be solved is open to a variety of approaches; however, it is an established fact that a highly effective approach to problems of widespread commonality is one in which operating agencies join cooperatively to support, both in financial and other participatory respects, systematic research that is well designed, practically oriented, and carried out by highly competent researchers. As problems grow rapidly in number and escalate in complexity, the value of an orderly, high-quality cooperative endeavor likewise escalates.

Recognizing this in light of the many needs of the transit industry at large, the Urban Mass Transportation Administration, U.S. Department of Transportation, got under way in 1980 the National Cooperative Transit Research & Development Program (NCTRP). This is an objective national program that provides a mechanism by which UMTA's principal client groups across the nation can join cooperatively in an attempt to solve near-term public transportation problems through applied research, development, test, and evaluation. The client groups thereby have a channel through which they can directly influence a portion of UMTA's annual activities in transit technology development and deployment. Although present funding of the NCTRP is entirely from UMTA's Section 6 funds, the planning leading to inception of the Program envisioned that UMTA's client groups would join ultimately in providing additional support, thereby enabling the Program to address a large number of problems each year.

The NCTRP operates by means of agreements between UMTA as the sponsor and (1) the National Research Council as the Primary Technical Contractor (PTC) responsible for administrative and technical services, (2) the American Public Transit Association, responsible for operation of a Technical Steering Group (TSG) comprised of representatives of transit operators, local government officials, State DOT officials, and officials from UMTA's Office of Technical Assistance, and (3) the Urban Consortium for Technology Initiatives/Public Technology, Inc., responsible for providing the local government officials for the Technical Steering Group.

Research Programs for the NCTRP are developed annually by the Technical Steering Group, which identifies key problems, ranks them in order of priority, and establishes programs of projects for UMTA approval. Once approved, they are referred to the National Research Council for acceptance and administration through the Transportation Research Board.

Research projects addressing the problems referred from UMTA are defined by panels of experts established by the Board to provide technical guidance and counsel in the problem areas. The projects are advertised widely for proposals, and qualified agencies are selected on the basis of research plans offering the greatest probabilities of success. The research is carried out by these agencies under contract to the National Research Council, and administration and surveillance of the contract work are the responsibilities of the National Research Council and Board.

The needs for transit research are many, and the National Cooperative Transit Research & Development Program is a mechanism for deriving timely solutions for transportation problems of mutual concern to many responsible groups. In doing so, the Program operates complementary to, rather than as a substitute for or duplicate of, other transit research programs.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to the transit industry. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire transit community, the Urban Mass Transportation Administration of the U.S. Department of Transportation has, through the mechanism of the National Cooperative Transit Research & Development Program, authorized the Transportation Research Board to undertake a series of studies to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on measures found to be successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to transit agency managers and supervisors, as well as to operating and planning personnel who are concerned with the reliability and scheduling of buses. Information is provided on service monitoring, service supervision and control, and supervision strategies.

Administrators, engineers, and researchers are continually faced with problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to the available methods of solving or alleviating the problem. In an effort to correct this situation, NCTRP Project 60-1, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common transit problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCTRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific problems or sets of closely related problems.

Reliability of transit service is critical to bus transit ridership. The extent of service supervision has an important bearing on reliability. This report of the Transportation Research Board describes the various procedures that are used by transit agencies to monitor and maintain bus service reliability. Most transit systems conduct checks of the number of riders at maximum load points and monitor schedule adherence at these locations. Other supervisory actions include service restoration techniques, and strategies such as schedule control, headway control, load control, extraboard management, and personnel selection and training. More sophisticated technologies, such as automatic passenger counting (APC) systems and automatic vehicle location and control (AVLC), have been employed by some transit agencies and are described in this synthesis.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of public transportation agencies. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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W. Campbell Graeub, Engineer of Public Transportation, Transportation Research Board, assisted the Project 60-1 Staff and the Topic Panel.

Information on current practice was provided by many transit agencies. Their cooperation and assistance were most helpful.

SUPERVISION STRATEGIES FOR IMPROVED RELIABILITY OF BUS ROUTES

SUMMARY

A reliable bus service involves running buses on time, maintaining uniform intervals between successive buses, and keeping schedule variations to a minimum. Transit managers have monitored on-time performance and passenger loads for many decades to achieve more reliable bus service. However, the emergence of automatic vehicle location and control and automatic passenger vehicle technology affords new opportunities for monitoring and supervising bus service.

Achieving reliable bus service requires realistic routes and schedules, well maintained equipment, effective supervision, and a sound personnel policy. This synthesis brings together current practices and needs in a format that is useful to transit management. The following summary highlights the salient findings from the state-of-the-art review and sets forth suggested procedures.

The specific methods of supervising service vary among properties, but there are many commonalities. Most transit agencies make checks of riders at maximum load points and monitor schedule adherence at these locations. Two-way radios are widely used and are helpful in relaying problems to drivers. Automatic passenger counting (APC) and automatic vehicle location and control (AVLC) systems are used by a few transit properties and have proven useful in improving service supervision and reliability:

- Automatic passenger counting (APC) systems as used in North America are essentially planning tools. They provide basic information on vehicle location, number of passengers boarding and alighting, and travel times, but not on a real-time basis. They are useful in identifying recurrent schedule adherence problems and taking corrective actions.
- Automatic vehicle location and control (AVLC) systems provide real-time data on bus performance. They permit instantaneous response to service problems and reduce (but not eliminate) the need for street supervision. One console supervisor can handle up to 125 buses at a cost of approximately $15,000 per bus.

An important goal is to merge the two systems to allow real-time decisions that are based on full information.

Supervisory strategies to improve the reliability of bus service include service restoration/recovery techniques; control of schedules, headways, and passenger loads; and extraboard management. Improved technology can play an important role in re-enforcing these strategies. Applications are specific to each problem, route, and system; there are no simple mathematical formulas.

- Service restoration strategies should be used when there is a major disruption in service.
- Schedule control strategies should be used when buses run early or late.
- Headway control strategies apply along selected sections of outbound routes during the evening peak hour.
- Load control strategies address problems of delays and overloads at major passenger boarding points.
- Extraboard management strategies address the problems of absenteeism and missed runs.

Personnel management practices must be fair from a labor standpoint, maintain operator morale, and be keyed to "team building" among supervisors, drivers, and field staff. A close communication should be maintained among drivers, supervisors, and planners. On-time performance incentives can be built into labor contracts.

Effective driver hiring and training, and supervision policies are essential. Drivers should be monitored on buses for factors such as driving skill, appearance, passenger relations, and vehicle cleanliness as well as schedule adherence. This is necessary even when service reliability is monitored through automatic vehicle location and control systems.

Supervisors, too, should be trained and supervised, and the criteria for selection should include assertiveness and public relations capabilities. Supervisors should be part of management and act as such. They should be free to supervise and should not be diverted to other activities. When they are visible to drivers, there is a tendency for schedule adherence to improve.

The deployment of supervisors depends upon route structure and density. Area supervisors may be necessary for large systems; line supervisors are needed for heavily used bus routes; and foot supervisors are desirable in the city center and other areas of high bus service density.

Sound supervisory practices represent good resource management because the costs of poor supervision result in the need for extra buses. It is essential, therefore, that adequate resources be directed to bus service supervision, with a desirable target of at least five supervisors per 100 drivers.

Several research directions emerged from the state-of-the-art review. Among these are the need to:

- Improve the data base to better determine the relationship between traffic conditions and bus service reliability.
- Assess and verify the concept of dynamic scheduling, where schedule adherence policies vary throughout the day.
- Field test the applications of APC and AVLC and determine techniques for modifying supervisory practices in various settings.
- Develop workable technologies that integrate APC and AVLC system capabilities.
- Identify the cost-effectiveness of alternative supervisory strategies and the extent that investments to achieve on-time performance should take precedence over other operating improvements.

CHAPTER ONE

INTRODUCTION

A reliable bus service is one where buses run on time along a route, where the spacing between successive buses is uniform, and where variations in schedule adherence are kept to a minimum. Reliability is an important asset to both transit managers and transit passengers, and it is particularly important in the design of innovative services.

Transit managers perceive reliable bus service as a means of making the best use of equipment and personnel. Poor reliability requires building unnecessary slack into schedules. This results in less effective utilization of equipment and personnel; it reduces productivity and increases costs in the system's operations.

Passengers prefer consistent and predictable service; they want buses that run on time and are not overcrowded. Poor adherence to schedules increases waiting times, makes transferring more difficult, causes uncertain arrival times at destinations, and erodes ridership over the long run.

The following observations illustrate the difficulties of maintaining headways and underscore the need for more reliable service. A survey was conducted in a major city along a major bus corridor with four long routes. Headways were checked over a 1-hr time period during the morning peak on three consecutive days. Despite the scheduled 3- to 5-min headways, there were gaps ranging from 10 to 21 min each day. The gaps were followed by bunching of two to four buses (headways of 1 min or less).

CONTEXT

Transit agencies have monitored passenger loads and on-time performance for many decades by means of traffic checkers and street supervisors. However, several factors have brought about a renewed interest in improving service reliability: (a) Longer bus routes and growing traffic congestion in some cities have made on-time performance more difficult. (b) Concerns over containing operating costs and deficits have forced many agencies to improve service monitoring and reliability. (c) The growing availability of automatic vehicle location and control (AVLC) systems affords new opportunities to systematize and improve service monitoring activities.

Monitoring and supervising service, therefore, have become increasingly important concerns to many transit agencies, because the extent of service supervision has an important bearing on the costs, reliability, and attractiveness of the service.

- A 1985 survey of 146 transit agencies in the United States conducted for the Transportation Research Board indicated that 65 percent of all operators reported on-time performance as essential, critical, highly important, or very important (Table 1). Another 35 percent viewed it as important or moderately important (*1*).
- In 1984, 71 percent of the transit agencies in the U.S. monitored vehicle loads, 84 percent schedule adherence, 70 percent vehicle headways, 47 percent missed trips, and 55 percent public complaints (Table 2) (*2*).

TABLE 1
IMPORTANCE OF ON-TIME PERFORMANCE AS PERCEIVED BY TRANSIT OPERATORS (1986) (*1*)

Response	Number	Total (%)	Adj. (%)	Cum. (%)
Not important	1	0.7	0.7	0.7
Important	37	25.3	25.9	34.6
Moderately important	1	0.7	0.7	35.3
Very important	50	34.2	34.9	70.2
Highly important[a]	8	5.5	5.6	75.8
Extremely important	12	8.2	8.4	84.2
Critical	7	4.8	4.9	89.1
Essential[b]	27	18.5	18.9	100.0
Subtotal	143	97.9	100.0	
No response	3	2.1		
Total	146	100.0		
Median	Very important			
Q_1	Important			
Q_4	Extremely important			
Mode	Very important			

[a]Also: great importance, very high importance

[b]Also: most importance, absolutely nothing more important, imperative, fundamental, vital, paramount, key, absolute importance, ultimate importance, primary importance

The goals of reliable service are to keep buses on schedule along a route, achieve uniform headways and minimize the variance of the maximum passenger loads. These translate into shorter waiting times and more comfortable rides for passengers, and lower operating costs for the transit agency. They call for effective service monitoring and supervision.

The methods of monitoring and supervising service largely have evolved from street railway practices. Despite the importance of supervision strategies, there has been relatively little change over the years in the techniques used in supervising bus routes. Buses are checked at key points (often the maximum-load points) for schedule adherence and passenger counts. Supervisors at critical locations, or roving along the line, make on-the-spot decisions regarding service or schedule changes, as in emergencies.

An early overview of transit service reliability was prepared for the Transportation Systems Center in 1978 (*3*). This report, drawing upon U.S. and British experience, including a 10-agency

TABLE 2
TRANSIT INDUSTRY PERFORMANCE CRITERIA AND SERVICE STANDARDS (*2*)[a]

Performance Criteria	Percentage of Transit Agencies Reporting				
	Formal Standard	Informal Standard	Proposed Standard	Monitoring Only	Total Monitoring
Route Design Criteria					
1. Bus stop spacing	27%[b]	19%	3%	14%	62%
2. Route coverage	26%	16%	8%	13%[b]	60%
3. Route deviation	17%[b]	6%	5%	16%	43%
4. Route duplication	8%	6%[b]	3%	19%	30%
5. Route length	6%	8%	3%	16%[b]	33%
6. Route structure	6%	2%	2%	23%[b]	32%
Service Quality Criteria					
1. Vehicle loads	41%[b]	17%	6%	7%	71%
2. Schedule adherance	39%[b]	12%	5%	29%	84%
3. Vehicle headways	36%[b]	17%	4%	14%	70%
4. Passenger safety	23%	7%	2%	26%[b]	58%
5. Bus shelter placement	18%[b]	9%	5%	19%	51%
6. Missed trips	17%[b]	8%	1%	21%	47%
7. Passenger transfers	16%	10%	2%	26%[b]	53%
8. Span of service	13%	1%[b]	3%	17%	40%
9. Public complaints	6%	5%	0%	45%[b]	55%
10. Handicapped accessibility	NA[b]	NA	NA	NA	NA
Economic and Productivity Criteria					
1. Passengers per vehicle-hour	28%[b]	12%	6%	26%	71%
2. Cost recovery	25%[b]	10%	6%	20%	61%
3. Passengers per vehicle-mile	16%	10%	6%	31%	62%
4. Passengers per trip	15%	5%	1%	18%	39%
5. Cost per passenger	6%	1%	2%	30%[b]	39%
6. Operator recovery time	NA[b]	NA	NA	NA	NA

[a]Taken from Metropolitan Transit Authority of Harris County, "Bus Service Evaluation Methods: A Review," Report No. DOT-I-84-49, U.S. Department of Transportation, Washington, D.C. (1984).

[b]OCTD service evaluation standard, as of 6/1/88.
NA = OCTD performance criterion not included in national review.

bus survey, showed how reliability influences passenger and operator behavior, defined various measures of reliability, identified causes of unreliable service, suggested strategies to improve reliability, and proposed demonstrations and future studies. The report contained empirical analyses of certain aspects of service reliability and a thorough discussion of theoretical considerations.

The issue of service reliability also has been approached from a theoretical and research perspective. Much of the research, however, is mathematical and does not provide easily understood results for transit managers. Thus, it has borne little fruit in improving service reliability.

In the past few years, several transit agencies have experimented with new management methods or technologies. The application of proven AVLC technology adds a new dimension to service supervision. These emerging methods and technologies are not fully understood by the transit industry.

SYNTHESIS OBJECTIVES

There is need to bring together the state of the art of current practices and research activities in a format that is useful to transit system supervisory and management people. This synthesis on Supervision Strategies for Improved Reliability of Bus Routes was prepared in response to this need. It presents current practices and needs in a format that is clear and useful to transit system supervisory and management people. It translates journal articles into practical strategies for dealing with service reliability. It explores both manual and automated methods, and it contains guidelines for transit agency use.

The synthesis:

- Surveys existing supervisory strategies by sampling a range of transit agencies in North America.
- Identifies impediments to transit service reliability and suggests ways to overcome these impediments for various operating conditions.
- Describes the role of emerging technologies in service supervision and control.
- Reviews literature for relevant research efforts and their applicability to practice.
- Identifies areas that need further experimentation and study.

It was developed as follows: (a) Available literature was assembled and reviewed, (b) a questionnaire was distributed to some 20 U.S. and Canadian transit systems, and (c) meetings were held with representatives of selected transit systems to obtain their insights and suggestions. The survey was conducted in 1989, and the information shown reflects the responses at that time, with some updates included.

KEY FACTORS

Achieving reliable bus service requires realistic routes and schedules, adequate maintenance, effective supervision, and sound personnel policy (Figure 1).

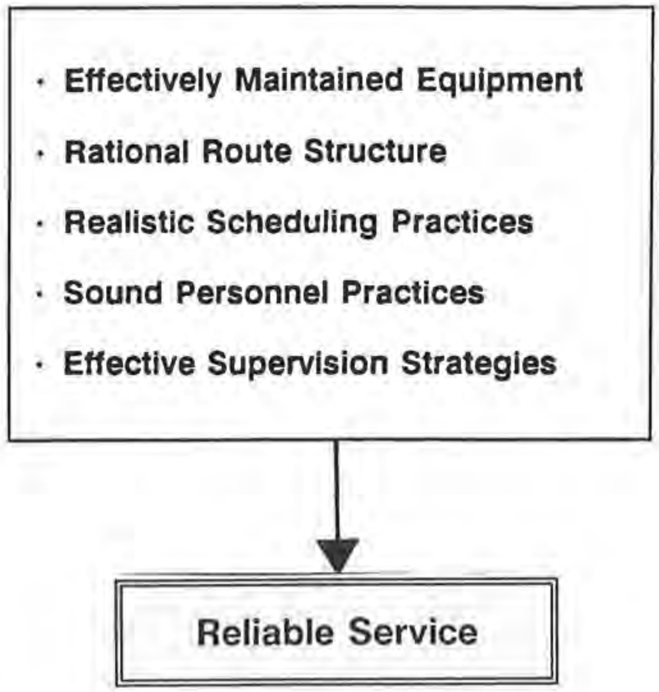


FIGURE 1 Components of reliable bus service.

- Equipment must be well maintained. This is essential to maximize the mean distance between road failures, and to minimize the number of buses that are inoperable.
- Schedules must be realistic. Schedules that are too fast or too slow will result in poor schedule adherence, and "bunching" of vehicles in some cases. This leads to some buses being overcrowded and others lightly used. There is a corresponding need for a route structure that permits reliable service.
- Personnel policies must be sound. Drivers, supervisors, and other transit personnel should be carefully selected, trained, and motivated. Team building must be encouraged, with the concept of "people serving people" as the underlying theme.
- Supervision strategies must be effective. Driver performance must be monitored. Prompt and informed decisions must be made when emergencies or service problems occur. A fast exchange of information is essential to reduce response times. Communication and information technology provide the means for this rapid communication.

Each of these elements is needed to assure reliable bus service. A poorly maintained fleet, unrealistic schedule or excessively long route, and/or a high rate of driver absenteeism will *not* provide reliable service, even with the most effective supervision strategy or control technology. Each is assumed in the discussions and analyses that follow. Within this context, the report focuses on supervision methods and strategies. However, it also indicates the types of planning information that are useful for service monitoring.

OVERVIEW OF PROCEDURES

Bus routes and service frequencies reflect the geography, market, and street system within a service area. Bus schedules consider (a) ridership variations by time of day, direction of travel, and section of route and (b) travel times taking into account passenger boarding and alighting times, street traffic conditions, and schedule recovery/driver layover requirements.

Service monitoring and supervision play important roles in assuring that the service responds to needs and is delivered as planned. Service monitoring provides the basic information for translating broad service policies into transit service on the street. Service supervision (or control) ensures that service on the street reflects, as closely as possible, the intent of the published schedule.

Service Monitoring

Service monitoring provides input for changes in routes and schedules. The data obtained also help in assessing driver performance. The service monitoring process involves the collection of service data, the development of performance indicators, the identification of problems, and the reporting of monitored information to management.

Surveys normally include passenger loading checks, generally at the peak load point, ride checks of boarding and alighting passengers by stop (or total boarding passengers), counts of transferring passengers, and running time checks. Running time checks are sometimes done in conjunction with on and off counts.

Most transit agencies rely on manual techniques for the collection of service data; however, a growing number of agencies use hand-held computers or automatic passenger counting (APC) equipment. Traffic checkers normally undertake the required passenger and travel time counts on a periodic basis. They check running times, boardings, loadings, and transfers when problems have been identified or when service changes are considered. They also can be used to identify problems and to help deploy supervisors. Supervisors may make running time and loading checks when service changes are needed.

Table 3 gives guidelines for the desired sampling frame, survey period, tolerance level, and frequency of monitoring. The desired tolerance may vary substantially, depending upon a transit agency's needs and resources. Where an agency operates service at or near capacity, more precise information is required.

Service Supervision and Control

The objectives of bus service supervision are to ensure that management policies are enforced, service quality and reliability are maintained, and service disruptions are minimized. Service control commonly includes dispatching, occurrence handling, and field supervision, although some agencies combine these functions.

- The dispatching function involves the daily deployment of vehicles and drivers to the field in accordance with the schedules provided through the service planning process. This function is normally carried out at the bus garage, where drivers report for work. The dispatcher ensures that all drivers have reported for work, arranges for other drivers to fill in when a shift comes open or additional vehicles are required, and assigns vehicles to the drivers. Sufficient resources should be available to permit an adequate response to disruptive occurrences in the field, such as vehicle breakdown in service, excessive delays, and special events.
- The occurrence-handling function involves processing information received from drivers, supervisors, and other sources in the field and coordinating activities in response to major service disruptions. This function is usually carried out at the transit headquarters or operating division and can range in scope from utilizing regular telephones and two-way radio facilities to sophisticated control rooms staffed by numerous personnel using specialized communication equipment and computers.
- Field control and supervision activities include checking schedule adherence, adjusting service during disruptions, restoring scheduled service following delays, and monitoring the actual effectiveness of the operating service. These activities are normally performed by route or point supervisors that are on foot

TABLE 3
SAMPLING PLAN FOR MONITORING BUS SERVICE OPERATIONS (*4,5*)

Data Item	Items Sampled	Period	Desired Tolerance (at 90% confidence)	Desired Frequency
Load point check	All runs	Peak Off peak Weekend	±10 - 15% ±15 - 20% ±30 - 50%	Seasonally
Schedule adherence/bus running time checks	All runs	Peak Off peak Weekend	±10 - 15% ±15 - 20% ±30 - 50%	As required
Bus running time/schedule development	All runs	Peak Off peak Weekend	±10 - 15% ±15 - 20% ±30 - 50%	Each pick or board
Riding counts (on and off by stop, line profile)	All weekday runs	Peak Off peak	±15 - 20% ±30 - 50%	Seasonally
Transfer rates between routes	All runs	Specific time period	±30%	As required

and usually equipped with a portable radio and sometimes in radio-equipped vehicles, in radio contact with service vehicles, or a combination of these. The route area or point supervisors continually monitor the routes assigned to them, making changes to the service as conditions warrant. These changes can include measures such as short-turning vehicles, spacing service, ordering additional service, and rerouting of service. Foot supervisors normally function in the central business district while mobile supervisors normally cover outlying areas. Table 4 gives the advantages and disadvantages of foot versus mobile supervision.

The types of service supervision and control vary by type and size of transit system. The number of buses, the geography of the routes, the levels of passenger activity, and the amount of street congestion influence the methods used.

Service control may be centralized or decentralized or a combination of both. Centralized control, which is normally used by smaller agencies, requires all supervision from a common base, including response to occurrences. A few large agencies also use centralized route control in conjunction with AVLC systems. Under decentralized control, various field supervisors report directly to a district manager. This approach works best where there are several operating garages, and/or where the system covers a large service area. It enables supervisors to concentrate on the problems associated with a specific area. Table 5 gives the advantages and disadvantages of the two types of control.

Supervision Strategies

Transit agencies use a number of corrective methods to improve reliability and to restore bus routes to regular service once deviations and disruptions occur (i.e., headways become irregular, buses run late, etc.). These include modifying the speed of buses, holding "early" buses to maintain more uniform intervals, adding a reserve vehicle from the garage or another route, turning back buses before the end of the line, skipping stops, and passing delayed buses.

TABLE 4

COMPARISON OF FOOT (LINE) SUPERVISION AND MOBILE SUPERVISION (*4*)

Foot Supervision	Mobile Supervision
Advantages	**Advantages**
There is personal contact with drivers	Greater mobility
There is visual contact with vehicles	There is emergency response capability
Periodic loading checks are carried out	There is visual contact with service
There is direct responsibility for a route or routes	Periodic loading checks are carried out
Disadvantages	**Disadvantages**
Limited mobility	Supervision is of a general nature
Limited emergency response capability	An emergency response may interfere with supervision of routes
	Reduced personal contact with drivers
	Reduced knowledge of route characteristics
	Only an indirect responsibility for individual routes

TABLE 5

COMPARISON OF CENTRALIZED AND DECENTRALIZED SERVICE CONTROL (*4*)

Centralized Control	Decentralized Control
Advantages	**Advantages**
Staff obtain an overall view of system operation	There is more familiarity with area personnel and problems
The capital cost of a single facility is lower	Specialized skills can be developed
Supervision is more consistent	There is greater information-handling capability
It provides a central facility for major emergencies	This approach is less vulnerable to disruption
Disadvantages	**Disadvantages**
There is less familiarity with localized conditions	The application of management policies is less consistent
The information flow may be too great to handle	It is more difficult to obtain an overall view of system operations
It may be perceived by drivers and other staff as being overly intrusive in its surveillance of operations, the so-called "big brother" syndrome	The ability to amalgamate resources in an emergency may be compromised
If the center is out of service for any reason, service control is difficult	Specialization may reduce the scope of supervisors

Technologies for Monitoring and Supervising Service

Many transit agencies use a broad range of techniques for the monitoring and supervision of their operations. The specific technologies used, in order of complexity are (a) direct control with driver, (b) radio control, (c) hand-held data collection computers, (d) on-board data collection computers, and (e) automatic vehicle location and control systems.

On-board data collection systems (automatic passenger counting) perform the tasks done by traffic checkers for service schedule purposes. However, data are not usually available on a real-time basis. Vehicle status and location monitoring systems provide real-time monitoring of vehicle operations by a control facility, and allow for centralized supervision of bus drivers. Table 6 gives the merits of each.

Two-way radio communication is widely used; almost every transit system with more than 100 buses has some sort of radio communication. Automatic passenger counting systems are less common. Relatively few agencies in North America have AVLC systems because of their newness and cost, although the number is growing.

ISSUES AND ORGANIZATION

The synthesis focuses on bus transit supervision strategies. It summarizes the state of the art and sets forth emergent guidelines for practice. It addresses questions such as these:

- Should service supervision and control be centralized on a system basis or decentralized by garage?
- What methods of service control are most effective? Adjusting schedule speeds to improve spacing? Using "gap" buses? "Relaying" drivers? Turning buses back? When can vans best be used?
- How do these methods apply to specific types of bus routes and operating environments?
- What types of technologies are available to monitor driver performance and respond to emergencies or service problems?
- How effective have the various research efforts been? What additional research is needed to improve service reliability?

The remaining chapters summarize the state of the art, based largely on a 20-agency survey (Chapter 2), present specific examples of technology in bus service supervision and planning (Chapter 3), review and interpret relevant research efforts (Chapter 4), and suggest directions to achieve more effective supervision (Chapter 5).

TABLE 6

COMPARISON OF RADIO CONTROL AND AVLC SYSTEMS (*4*)

Radio Communications	AVLC
Advantages	**Advantages**
There is immediate contact with vehicles over a large area	It provides an overview of all service vehicles
Service disruptions are minimized	An immediate response to service disruptions is possible
It provides emergency reporting capability	It provides emergency-response capability
It provides increased security for drivers and passengers	There is extensive management-reporting capability Dynamic scheduling is possible
Disadvantages	**Disadvantages**
It is limited to small or moderate-sized fleets	There is no visual contact with the driver
There is no visual contact with drivers	There is less personal contact with drivers
It relies on the driver for schedule adherence	
There is no loading or schedule adherence information	

CHAPTER TWO

CURRENT PRACTICE—SERVICE SUPERVISION

This chapter sets forth the state of the art of bus service supervision. It compares and analyzes factors such as resources allocated, organization of activities, surveys conducted, supervision methods used, technologies applied, impediments to effective supervision, and ways to improve supervision activities.

The findings are largely based on a 1989 survey of 20 transit agencies throughout the United States and Canada, and follow-up interviews with several of these agencies (Appendix A). The agencies surveyed have a broad geographic distribution and vary widely in the size of bus fleet. These systems, shown in Table 7, operate peak buses in service that range from almost 130 (Tidewater Transportation District Commission, Norfolk) to more than 1,500 (Los Angeles, Chicago, Toronto). Fleets of less than 100 buses were not included since their supervisory requirements are much simpler.

RESOURCES ALLOCATED

The personnel allocated to supervising and monitoring bus service are set forth in Tables 8 and 9. The number of supervisors per 100 bus drivers ranges from about 2 to 8, averaging 4.6. This number shows no consistent relationship to size of bus fleet.

The number of traffic checkers per 100 drivers ranged from 0 to 2.7, averaging 1.1. There was no systematic variation according to fleet size.

TABLE 7

AGENCIES RESPONDING TO SURVEY

	Agency
1	Capital District Transportation Authority (Albany)
2	Chicago Transit Authority
3	Connecticut Transit (Hartford Division)
4	Dallas Area Rapid Transit
5	Greater Cleveland Regional Transit Authority
6	Massachusetts Bay Transportation Authority
7	Metropolitan Atlanta Rapid Transit Authority
8	Metropolitan Transit Authority (Houston)
9	Metro Transit (Seattle)
10	Regional Transit Authority (New Orleans)
11	Rhode Island Public Transit Authority
12	Sacramento Regional Transit District
13	San Diego Transit
14	Santa Clara County Transportation Agency
15	Southeast Pennsylvania Transportation Authority
16	Southern California Rapid Transit District
17	Tidewater Transportation District Commission
18	Toronto Transit Commission
19	Tri-County Metropolitan Transportation District (Portland)
20	Washington Metropolitan Area Transportation Authority

The number of supervisors "on the street" throughout the day relates closely to the number of buses in service at any given time (Figure 2). However, there is somewhat more supervision per bus during base, evening, and overnight periods than during the rush hours.

MANAGEMENT AND ORGANIZATION

Most transit systems conduct their service supervisor and monitoring activities as part of their transportation and operations planning departments. The supervisors normally report to the transportation department, while the traffic checkers typically report to the scheduling or operations planning departments (Figures 3, 4). However, the specific arrangements vary from system to system. The Southeast Pennsylvania Transit Authority (SEPTA), which serves the Philadelphia area, for example, reports a four-step approach to service supervision: (1) use of service quality teams, (2) increased line observation by supervisory personnel, (3) special checks of customer complaints, and (4) enhanced sensitivity to passengers by supervisory personnel. Service quality teams check the bus before it leaves the garage for cleanliness and safety. If a problem is found, the bus does not leave the garage. Small touring teams of two to three supervisors ride buses as though they were passengers. Planning personnel also check each line for an 8-hr period.

The Southern California Rapid Transit District (SCRTD) in Los Angeles has monthly coordination meetings between transportation and operations planning scheduling groups to review problems and work toward reflecting supervisors' concerns in preparing schedules.

MONITORING RIDERSHIP AND TRAVEL TIMES

The methods of monitoring bus ridership and travel times reported by the transit agencies are shown in Table 10. Most properties make three basic types of checks; these checks are usually made by traffic checkers.

Maximum Load Point Checks

Maximum load point checks of riders are made at least once per year per route, or location; although some agencies make them as often as every other week. Figure 5 shows the maximum load points in the Portland, Oregon central business district (CBD) and in its environs.

Point Checks of Travel Time

Point checks of schedule adherence are made at specified time points (sometimes the maximum load point). A few properties,

TABLE 8

RESOURCES ALLOCATED TO SUPERVISING AND MONITORING SERVICE

Agency	Bus Fleet (No.)	Bus Fleet Max. Service	Bus Drivers (No.)	Bus Drivers (per max. bus)	Supervisors (No.)	Supervisors (per 100 drivers)	Checkers (No.)	Checkers (per 100 drivers)
1	225	200	275	1.38	20	7.27	5	1.81
2	2238	1870	4885	2.61	227	4.64	22	0.45
3	239	200	320	1.60	14	4.38	4	1.25
4	730	610	788 (729)	1.29 (1.20)	26	3.30	11	1.40
5	686	600	1009	1.68	69[a]	6.83	10	0.99
6	981[b]	770	1700	2.21	134	7.88	14	0.82
7	681	500	1407 (1057)	2.81 (2.11)	25	1.78	15	1.07
8	890	710	1478 (1364)	2.08 (1.92)	43	2.91	13	0.88
9	1095	850	1990 (1141)	2.34 (1.34)	115	5.78	15	0.75
10	490[c]	410	669	1.63	29	4.33	4	0.60
11	254	200	356 (318)	1.78 (1.59)	9	2.53	4	1.12
12	200	170	300	1.76	18	6.00	7	2.33
13	283	210	557 (497)	2.65 (2.37)	11	1.97	0	0.00
14	518	440	1006	2.29	25	2.48	5	0.50
15	1615	1180	2129	1.80	125[d]	5.87	31[e]	1.46
16	2462	1910	5679 (4942)	2.97 (2.59)	114	2.01	52	0.92
17	176	130	260	2.00	18	6.92	7	2.69
18	2094[f]	1600	3647[g]	2.28	226[h]	6.20	44	1.21
19	587	460	937 (708)	2.04 (1.54)	25	2.67	0	0.00
20	1559	1380	2615	1.89	63	2.41	32	1.22

( ) = Full time
[a]Includes 20 dispatchers
[b]Includes 50 trackless trolleys
[c]Includes 39 streetcars
[d]Also supervise rail operations
[e]6 full time
[f]Includes 280 streetcars
[g]3151 bus, 496 streetcar
[h]214 inspectors, 12 supervisors

TABLE 9

RESOURCES ALLOCATED TO SUPERVISING AND MONITORING SERVICE BY SIZE OF FLEET

Peak Buses	No. of Agencies	Ave. Size (peak buses)	Ave. Drivers per Peak Bus	Ave. Superv. per 100 Drivers	Ave. Checkers per 100 Drivers
0-400	6	185	1.86	4.84	1.54
401-800	8	565	2.00	4.02	0.78
801-1200	2	1015	2.07	5.82[a]	1.10
>1200	4	1690	2.44	3.82	0.95
Total	20	720	2.05	4.36	1.07
0-800	14	400	1.95	4.38	1.11
>800	6	1470	2.31	4.31	1.00

[a]Result is weighted upward because of one observation.

however, select locations on a random basis. The frequency of these checks varies from 1 per location per year up to 36.

On-Vehicle Ride Checks

The frequency of on-vehicle checks of riders and travel times varies widely depending upon specific agency needs, precedents, and resources.

TECHNOLOGY USED

The technologies used in monitoring bus service are shown in Table 11. Most systems have (or are implementing) two-way radios. Seattle has an automatic passenger counting system. Toronto was the only system surveyed that had a fully operational AVLC system. The Toronto Transit Commission's Communications and Information System (CIS) was initially installed on buses based at its Wilson Garage, and is now installed on the entire surface fleet.

The Rhode Island Public Transit Authority reports that it has a form of AVLC. Dallas indicates that it is making its AVLC system operational, and the Tidewater Transit District Commission is installing a system.

Chicago is proposing a demonstration of signal preemption equipment on buses that would be actuated only if buses are late. The same equipment could provide schedule adherence data, passenger counts, and event recording.

SUPERVISION METHODS

The methods of supervising bus service reflect the size and complexity of the system, the kinds of problems encountered, management and operating philosophies, and resources available.

The basic types of bus service reliability problems that most systems encounter include: (a) major service disruptions as a result of vehicle breakdowns, accidents, or emergencies, (b) buses not adhering to schedule on a given day, either because of abnor-

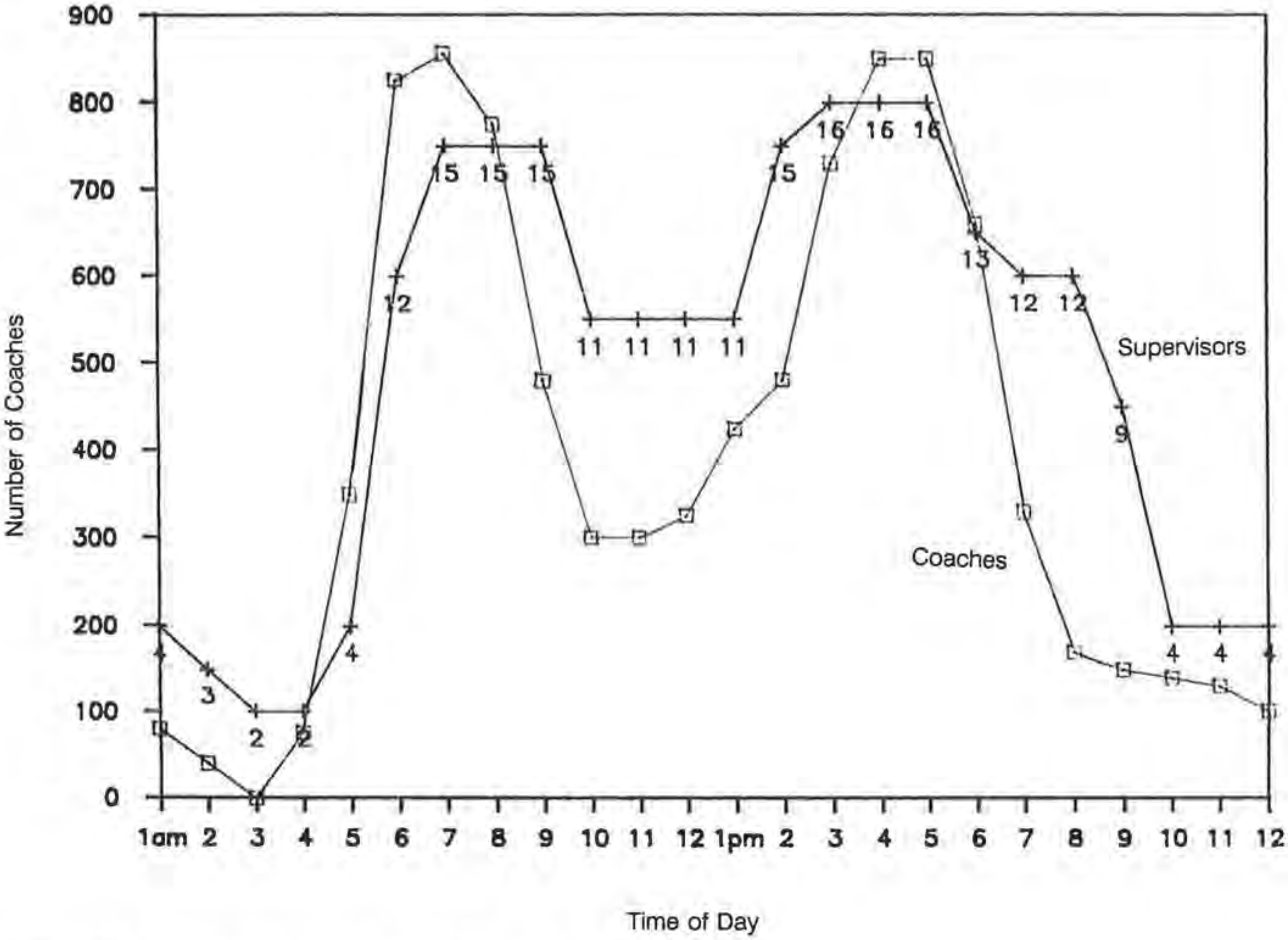


FIGURE 2 Supervisory coverage compared to buses in service (Seattle).

mal conditions or driver problems, and (c) vehicles not adhering to schedule on a "recurrent" basis. There are also problems of missed runs due to driver absenteeism. Problems are identified in various ways: supervisor's reports, driver's reports, service monitoring attitudes, and passenger and driver complaints.

Service disruption problems are normally corrected by service restoration or schedule recovery techniques. These techniques include replacing a defective bus; diverting a bus from another route; providing a standby or gap bus; using a supervisor's van as a bus; rerouting a bus around a problem area, or providing shuttle service; turning back buses; running late buses express, or letting following buses pass leaders; and providing relief drivers or introducing bus relays.

Schedule adherence problems are normally corrected by schedule control, headway control, or load control techniques. They involve holding early buses, changing bus speeds to meet the schedule or adjusting layover times at terminals, maintaining uniform intervals between buses without concern for schedules, providing empty buses at terminals or major boarding points, or encouraging street fare collection.

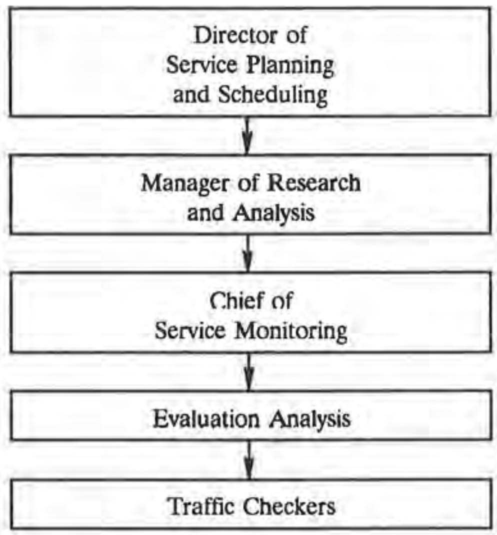
Recurrent service reliability (schedule adherence) problems are addressed by changing routes or schedules and by improving bus movement through congested areas through better traffic engineering, bus priority lanes, or traffic signal preemption.

The various methods used by the 20 transit systems surveyed in supervising bus service are shown in Table 12. This table also identifies the types of supervision treatment of long and short bus lines, constraints posed by labor agreements, and measures taken to correct schedule adherence problems.

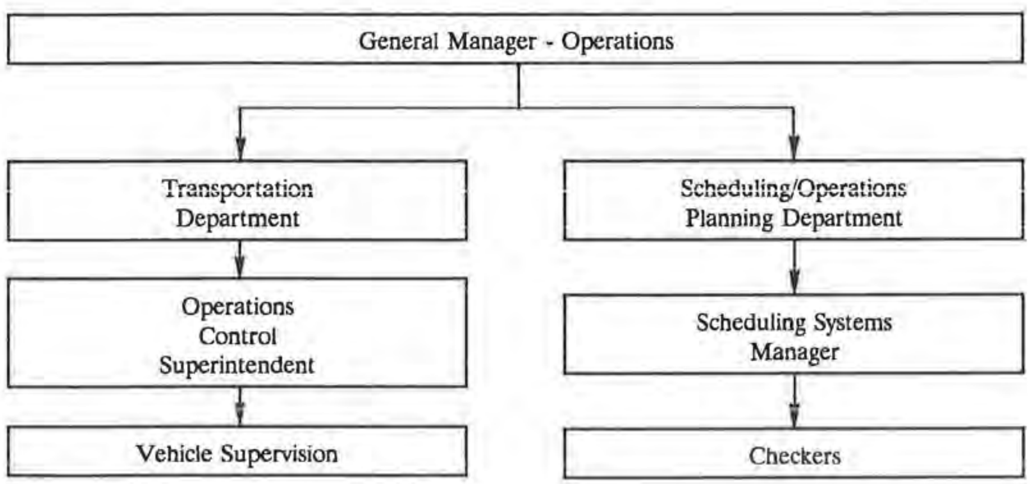
Types of Supervision

Supervisors may be assigned to cover a given geographic area (i.e., area supervision), specific bus routes or line (i.e., line supervision), or a given location (i.e., point supervision). Mobile supervision in cars or vans is common; foot supervisors are typically limited to the city center or other congested areas.

Most transit systems use some form of area supervision that monitors bus routes that operate within a specific area. Large systems such as Chicago, Toronto, and Los Angeles provide both district and area supervision. As shown in Figure 6 and Appendix B, Chicago has five district superintendents, and approximately 40 areas. Toronto has three districts that monitor



Metropolitan Atlanta Rapid Transit Authority



Southern California Rapid Transit District

FIGURE 3 Examples of management of service monitoring and supervision.

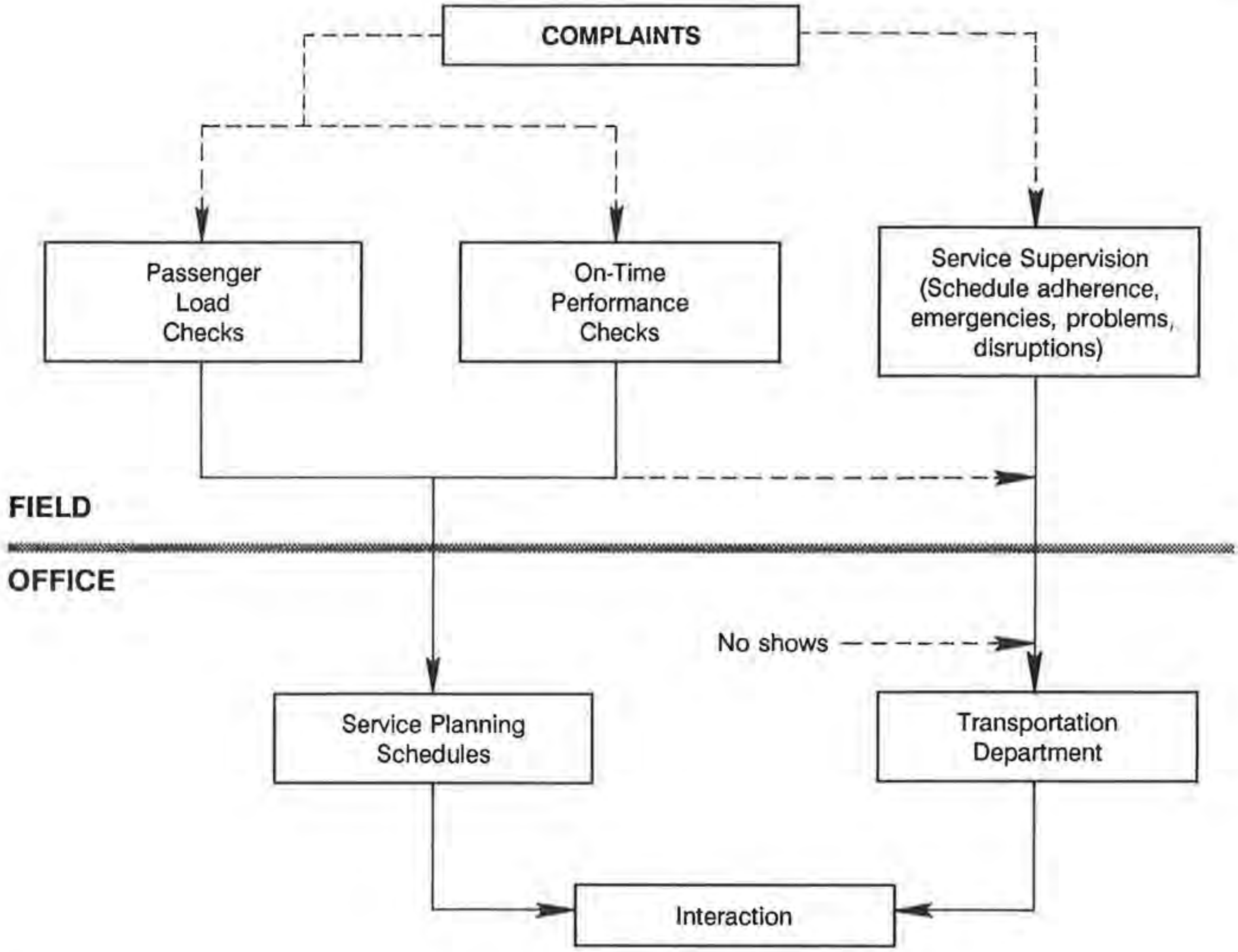


FIGURE 4 Typical management of service monitoring activities and supervision.

11 divisions. Philadelphia has eight city districts; each is keyed to a specific garage. Houston divides its service areas into eight daytime supervision districts (Figure 7). Portland has six districts with mobile inspection, plus two CBD districts with foot patrols (Figure 8).

A few systems use line supervision. Toronto uses line supervisors ("inspectors") on its heavily traveled surface routes. SEPTA uses line supervisors selectively throughout the system; New Orleans uses it on a few lines, and Rhode Island Public Transit Authority reports some use. Chicago uses foot supervisors for heavily used bus lines and mobile supervisors for other lines.

End-of-Line Dispatching

End-of-line dispatchers are not widely used. A few properties use them at downtown staging areas (Albany, Atlanta, Boston, Los Angeles, Rhode Island) or at major terminals or at park and ride lots (Houston). Chicago requires drivers to telephone supervisors before leaving the end of the line in a few locations.

Treatment of Long Lines

Several transit systems reported that long lines pose problems of schedule reliability and that they experience the poorest on-time performance. This is compensated in part by providing more schedule recovery time or more intensive supervision. The SCRTD indicates that heavily traveled routes with less than 4-min peak hour headways are the main problem.

The SCRTD's on-time performance by type of service provided is shown in Table 13. The local bus lines are reported to be on time 70 to 79 percent, while limited stop and express lines are on time 62 to 67 percent of the time. The peak period express service has the poorest reliability, being 2 or more min early 4 percent of the time and 5 or more min late 30 percent of the time; freeway congestion is undoubtedly a factor, suggesting the need for bus priority treatments.

The Chicago Transit Authority's (CTA's) service planning policy is to replace long radial routes by converting them into rapid transit feeders to minimize the impact of service irregularity.

TABLE 10
METHODS OF MONITORING RIDERSHIP AND TRAVEL TIMES

		Maximum Load Point Checks (Ridership)				Point Checks of Travel Times (Schedule Adherence)		On-Vehicle Ride Checks (Riders/Travel Times)
			Frequency					
Agency	Buses	No. of Points	per route/yr	per loc./year	per supr./day	Locations	Frequency	Frequency
1	225	9		2		Vary	2/year/route	300/year
2	2238	80-supervisors 1-8 checkers	Most 8 minor 4		Min. 8 (20 minutes)			8/day min. (about 2100/year)
3	239	1/route	2			Time points	2500 trips/month	1/3 of all trips each year
4	730	150	2	24-36		Random	24-36/year	4/day random (1100/year)
5	686	1/route 45 locations		26		Vary	1/year/route	255/year/route
6	981	1/route 50 locations		4		Ends of routes & key time points	As needed	As needed
7	681	62[a]		12		Max. load point	12/year/location	As needed
8	890	70		9-13		None		Previously 1/yr/route; now as needed
9	1095	See point check			90 locations	9-20/yr/location	Only for complaint	
10	490	1/route	12 weekday 1-2 night			Daily; random		
11	254	5		2		Maximum load point[b]		4 trips/week
12	200	10		2				1/year/trip
13[c]	283							4/year/route
14	518	[d]				12 locations	1/year/location or as needed	1/year/trip
15	1615		1		2 min.	Vary		Vary[e]
16	2462	See point check				100 time points; usually max. load pts.	As needed	1/yr daily lines 1/4 years weekend lines
17	176		1			CBD cordon Trail check	1300 hr/yr - riders 285 hr/yr - times	7200 hr/yr
18	2094	140	8[f]			20/route	1-2/loc./year	200/year
19	587	12		3			Not conducted	As needed
20	1559							As needed

[a]Also at branch deviation points.

[b]Elsewhere by roving supervisors.

[c]Conducted by San Diego Association of Governments.

[d]No longer done.

[e]Frequency depends on availability of people and extent of service-related problems that need supervisory coverage.

[f]1100 counts/year.

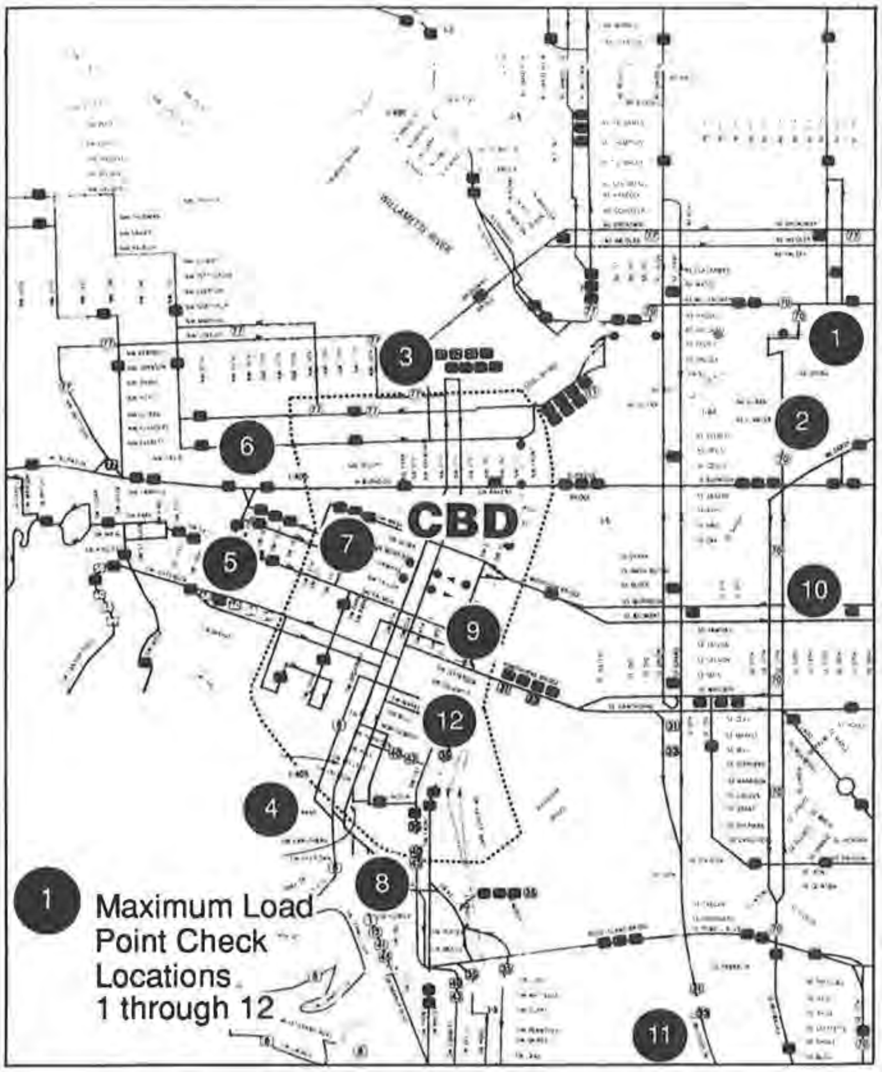


FIGURE 5 Maximum load point check locations (Portland, Oregon).

Constraints Posed by Labor Agreements

Labor agreements, for the most part, do not constrain supervision activities. Supervisors are able to make needed changes on the spot. A few properties, however, indicated that work rules must be taken into account, especially when runs are substantially altered. In Chicago "driver relays" (or exchanges) are prohibited by the labor rules. Supervisors are normally considered part of management although they belong to the transport union in some cities (e.g., Boston and Chicago).

Corrective Actions to Improve Service Reliability

Problems in schedule adherence and service reliability result from several factors. Unforeseen traffic and weather conditions, emergencies such as fires and utility breaks, and bus breakdowns adversely impact reliability. The factors also include poorly maintained buses, unrealistic schedules, traffic congestion, variable driver performance, drivers not reporting for work or reporting late with inadequate extraboard personnel available, inadequate supervisor or driver training, and poor employee motivation.

Service and schedule adherence problems are usually corrected by changing service, changing drivers, changing schedules, or taking administrative actions. The measures taken by the systems surveyed are summarized in Table 14. Important in most of the corrective actions is the need to "space service" by turn backs, adding buses, or other means. Uniform spacing is essential to maintain schedules and to avoid overcrowded or under-used buses.

- Service change actions are the most common. Reported changes include adding an extra bus (a "gap" bus), or short turning a bus, spacing the service (or adjusting the speed), filling runs from other routes, and carrying people in supervisors' vans. Houston, Seattle, and Toronto use gap buses at key points along the route.

TABLE 11

TECHNOLOGY USED IN MONITORING SERVICE

Agency	Buses	Driver Telephones[a]	2-Way Radio	AVLC	APC[b]	Remarks
1	225		X			Drivers phone supervisors before leaving end of line
2	2238	X	X			
3	239		X			54 buses have radios. Supervisor paging system integrated with radios. More radios planned.
4	730		X			AVL system is being made operational.
5	686		X			
6	981	X	X			
7	681		X			Automated passenger counters, electronic fare box system, and hand-held data collectors are being implemented.
8	890		X			Surveillance, communications, and control on transitways.
9	1095				X	System has computerized ridership and performance system.
10	490		X			
11	254		X	X		
12	200		X			
13	283		X			
14	518	X	X			
15	1615	X	X			
16	2462	X	X			Direct line to SCRTD bus dispatch center. Road supervisor vehicles are equipped with two-way radios and AVLC will be installed by 1993.
17	176	X				AVLC is being installed.
18	2094	X[c]	Mobile suprv.[c]		X[d]	Communications and Information System installed systemwide 1991.
19	587	X	X			Automatic passenger counters installed on 50 buses.
20	1559		X			

[a]Roadside call boxes or two-way radios reported as telephones.

[b]Includes passenger counts and travel times check by location.

[c]TRUMP unit has two-way radio and cellular telephone (as fallback) on all vehicles.

[d]Selected vehicles for off-peak monitoring.

TABLE 12
METHODS OF SUPERVISING SERVICE

Agency	Buses	Types of Supervision: Area Supervision	Line Supervision	Point Supervision	End-of-Line Dispatcher/ Supervisor	Measures Taken for Schedule Adherence Problems	Treatment of Long vs. Short Lines	Constraints Posed by Labor Agreements	Special Methods	Other
1	225			Yes	Downtown staging areas	a. Drop trips b. Short turn bus c. Use stub bus		None		
2	2238	5 districts, each further subdivided	None; point supervisors heavier lines, mobile supervisors lighter lines	Yes	None	a. Fill runs from other routes b. Turn back runs c. Space service when delays occur	A planning policy is to replace long radial routes by feeders to minimize impact of breakdowns	None	Driver phones supervisor at a central location before leaving end of line	
3	239	5 areas; two road supervisors remain stationary in CBD	None	Yes	None	a. Reduce layover b. Combine with another trip or route c. Turn back bus d. Change destination		None; supervisors can make on-the-spot rules		
4	730	Yes	None	Yes	None	Supervisors may add extra bus		None		
5	686	Yes; 7 zones	None	Yes; fixed point inspectors monitor one or more lines	3 locations (2 at rapid transit stations)			None; supervisors can take needed steps		
6	981	Yes	Yes, on line failing to meet headways	Yes	Only where several routes terminate	a. Use cover list b. Hire on overtime c. Divert from other routes d. Combine routes e. Require operators to do extra trips		None		

NA = Not applicable

TABLE 12 (continued)

Agency	Buses	Types of Supervision: Area Supervision	Line Supervision	Point Supervision	End-of-Line Dispatcher/ Supervisor	Measures Taken for Schedule Adherence Problems	Treatment of Long vs. Short Lines	Constraints Posed by Labor Agreements	Special Methods	Other
7	681		None	Yes, partial (Keyed to time check points and rapid transit stations)		a. Use another bus b. Adjust schedule	Provide more recovery time for long lines	Some union requirements when runs are substantially altered		
8	890	Zones - mobile supervision	No	Yes	8 park-and-ride lots	Corrections by roving street supervisors alerted by dispatchers		None		
9	1095	Yes	NA	Yes	NA			None; district supervisors can make immediate changes	Use automatic passenger collection system	
10	490	No	1 or 2 lines per supervisor	Yes	NA	a. Short turn or detour buses to re-establish proper spacing b. Change schedule where schedule adherence is a consistent problem (but cannot affect driver relief or total hours)		None	Radio used to coordinate with dispatcher	Coordinate schedule changes with planning and scheduling
11	254	Roving supervisors	Yes	NA	City terminus (peak hours)	a. Adjust schedules and running times b. Supervisors can use standby operators to set back operators running late (i.e., insert bus)	Longer lines more apt to run late	None		

NA = Not applicable

TABLE 12 (continued)

Agency	Buses	Types of Supervision: Area Supervision	Line Supervision	Point Supervision	End-of-Line Dispatcher/ Supervisor	Measures Taken for Schedule Adherence Problems	Treatment of Long vs. Short Lines	Constraints Posed by Labor Agreements	Special Methods	Other
12	200	Yes	None	Yes	None	a. Short-term problem - fill-in service or run late b. Long-term - adjust schedule and/or routes		None		
13	283	3 geographic areas - 1 supervisor/area	None	Yes	None	a. Evaluate schedules b. Interview drivers c. Adjust schedules d. Request relay (relief) to get schedule back on time		None		
14	518	Yes	None	Yes	None	a. Initiate extra service b. Adjust schedules c. Put in another bus where mechanical problems exist		None		
15	1615	8 service districts (city); none in suburban operations	Yes	Yes	NA	a. Initiate immediate reinstruction and submission of observation report b. Control centers and/or street supervisors adjust service (pull out extra buses as needed)	Long lines require routine monitoring, short lines need periodic monitoring. Long routes with long headways cause more problems than long routes with short headways	None		Service quality teams; on-time route performance audits; certification programs; independent performance audits

NA = Not applicable

TABLE 12 (continued)

		Types of Supervision								
Agency	**Buses**	**Area Supervision**	**Line Supervision**	**Point Supervision**	**End-of-Line Dispatcher/ Supervisor**	**Measures Taken for Schedule Adherence Problems**	**Treatment of Long vs. Short Lines**	**Constraints Posed by Labor Agreements**	**Special Methods**	**Other**
16	2462	Transit operations supervisors in radio-equipped vehicles; "post shift" supervisors in CBD 5 sectors, 13 senior supervisors, 26 dispatchers	No, except for "Service Reliability Program" (SRP)	Yes	Service directors at major terminals	a. Provide another bus on schedule from terminal; exchange operators when schedules meet (i.e., relay) b. "Bumping" the line, i.e., fall back or cascading of drivers c. Let a bus work additional trip d. Add buses		None, but work rules must be taken into account		
17	176	Specific areas by time of day	None	Yes	None	a. Supervisors' vans can transport people when vehicles break down b. Supervisors can operate unscheduled extras		None	Supervisors use 13-passenger vans with radio units	
18	2094	Mobile inspectors - 3 districts, 11 divisions	AVLC	Foot inspectors (routes)	None	a. Supervisors are notified and adjust service b. Turn schedules c. Adjust vehicle speed		None		Quality service task force; service reports by route inspectors
19	587	Yes, both foot and mobile supervisors	None	Yes	None	Road supervisors must clear schedule changes with lead supervisor	More turnback opportunities on long lines			
20	1559	Patrol area in radio dispatched vehicle	None	Yes	Subway stations					

NA = Not applicable

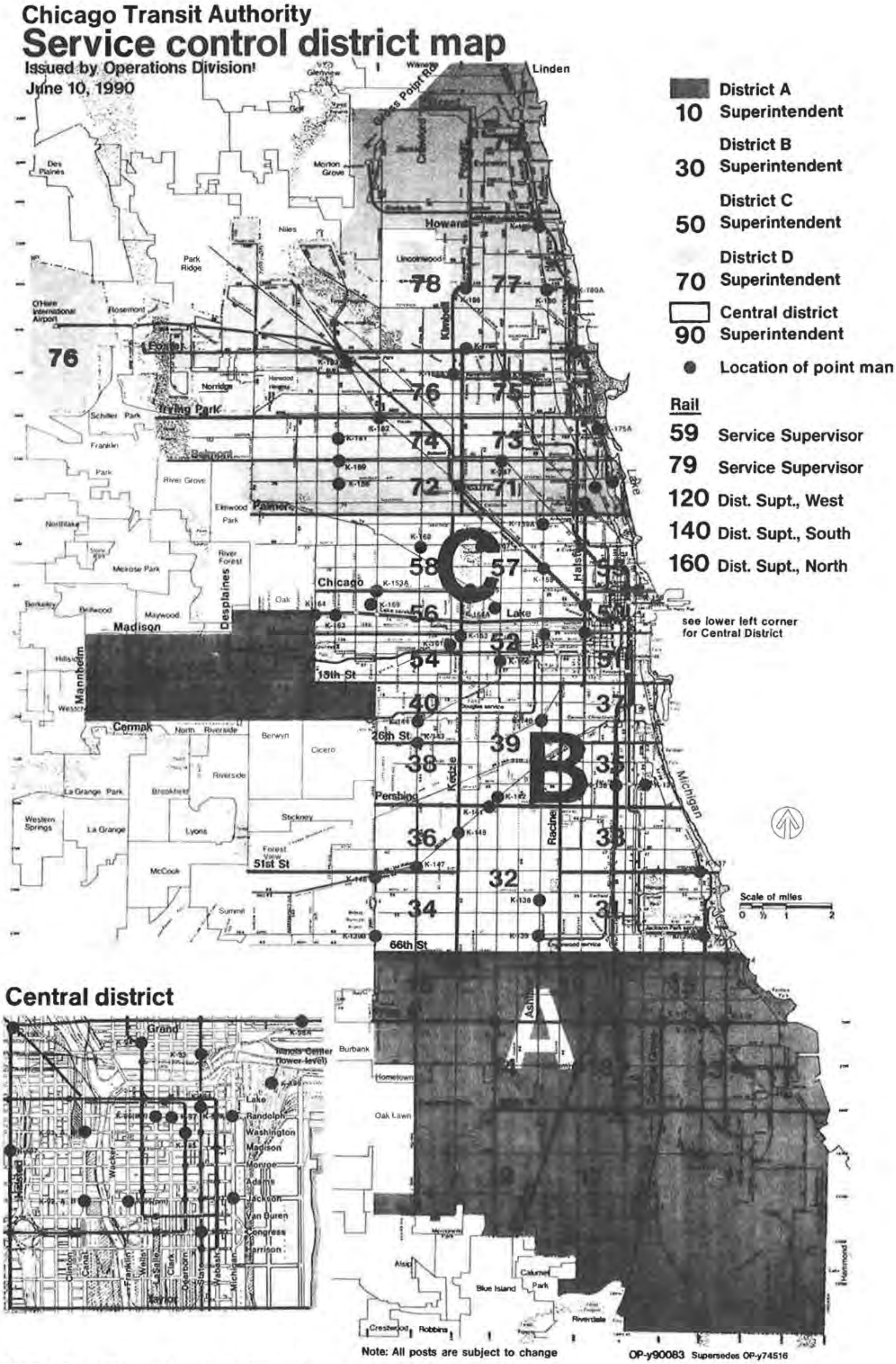


FIGURE 6 Chicago Transit Authority Service Control Districts.

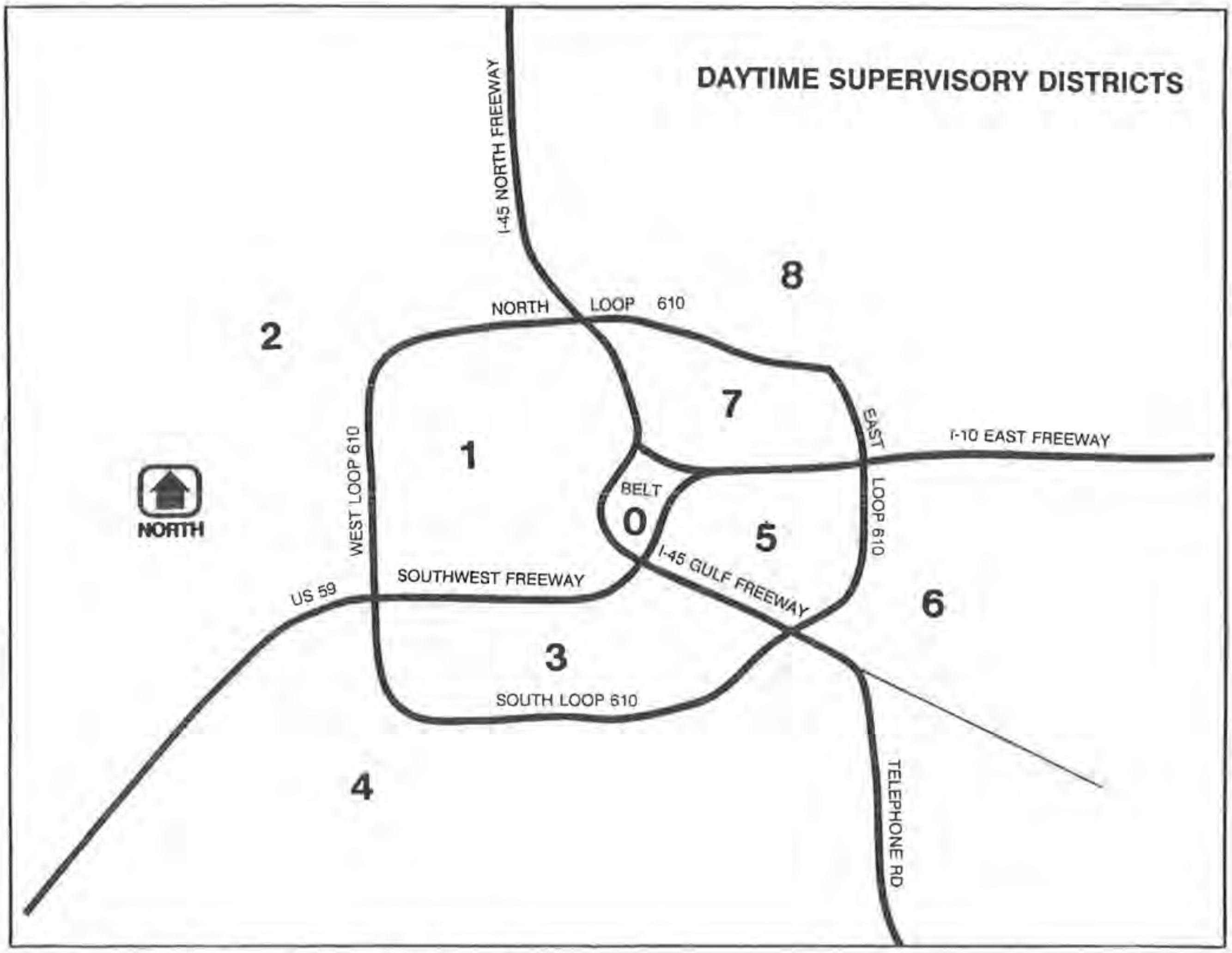


FIGURE 7 Daytime supervisory districts (Houston).

TABLE 13

AVERAGE ON-TIME PERFORMANCE BY LINE GROUPING (SCRTD, FY 1987)

Line Number/ Grouping	Type of Service	2 Minutes or More Early (%)	5 Minutes or More Late (%)	On Time (%)
1-99	LA/CBD local line	1.7	23.3	75.0
100-149	East/west local lines (south of LA CBD)	1.5	22.6	76.2
150-199	East/west local lines (west of LA CBD)	1.2	20.0	78.7
200-249	North/south local lines (west of LA CBD)	1.8	22.0	76.2
250-299	North/south local lines (east of LA CBD)	1.7	28.2	70.1
300-349	Limited-stop services	1.3	33.1	65.6
400s, 560	All day express service	2.2	31.1	66.8
400s, 576, 600s	Peak period express service	7.4	30.9	61.7
System	All district lines	2.2	24.5	

Notes: 1. Unweighted averages based on riding check data. Data extracted from annual reports prepared by the Operations Planning Section of the Scheduling/Operations Department.

2. Percentage early and late are based on observations taken at all time points along the route for all trips.

3. Some peak period express lines have "free running time" to far terminal.

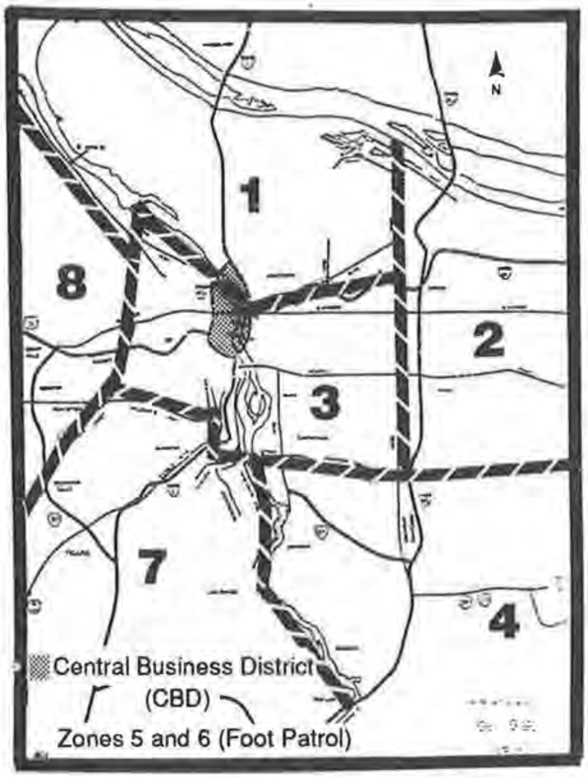


FIGURE 8 Road supervisor geographic deployment areas (Portland, Oregon).

TABLE 14
TYPES OF CORRECTIVE ACTION

Category	Item	No.	System
Service Changes	Add extra bus	6	1, 4, 7, 14, 15, 16
	Short turn bus	6	1, 2, 3, 10, 12, 16, 18
	Space service; adjust speed	3	2, 10, 18
	Fill runs from other routes (or combine with another trip or route)	3	2, 3, 6, 16
	Carry people in supervisors' vans	1	3
	Change destination	1	20
	Detour bus, drop trips	1	1
Driver Change	Require operators to do extra trips	2	6, 16
	Use standby drivers	2	6, 11
	Request driver relay	2	3, 16
	"Cascade" drivers	1	16
	Reduce layover	1	3
Schedule Change (usually over longer run)	Adjust schedules	6	7, 10, 11, 12, 13, 14, 16
	Evaluate schedules	1	13, 16
	Adjust schedules	1	12, 16
Administrative Actions	Drivers submit reports	1	15
	Interview drivers	1	13

- Driver changes are less common than service changes. They include use of the extraboard, requiring operators to do an extra trip, "relaying" drivers, or reducing layover times.
- Schedule changes are a common corrective action, especially over the longer run. They include changes in routes and schedules.
- Administrative actions are less common. Only a few systems identified driver reports and interviews as corrective actions.

Chicago

The CTA uses 11 specific techniques to restore bus service or maintain service reliability. These techniques, in order of their frequency of use, are summarized as follows:

1. Spreading or closing the interval between buses by holding back buses, moving up buses, or rescheduling service.
2. Putting the following bus ahead of the delayed bus. This passing procedure usually is done when an inexperienced operator falls behind schedule.
3. Filling-in by adding operators from the same route or from some other route.
4. Rerouting buses around blockades.
5. Turning back a bus (short turn).
6. Special trouble shooting along the line.
7. Replacing a defective bus with a properly functioning bus that is pulling in.
8. Pulling out another bus to relieve a driver at a given point on the line, then trying to get the line back on schedule.
9. Having a driver operate an extra trip. This often occurs when weather conditions make drivers late, or when relief does not show up. In such cases, the rush hour trip continues.
10. Operating a shuttle service (where a blockade cuts off part of a line).
11. Running a delayed bus non-stop or on an express route. This is common practice in the a.m. rush, when late buses can return via a faster route.

Tidewater

Mobile supervisors in the Norfolk area (Tidewater Transportation District Commission) use 13-passenger vans to carry passengers along the bus routes when service is interrupted. This type of transport works best on lightly traveled, short bus lines.

Toronto

The Toronto Transit Commission (TTC) uses a variety of methods to assure reliable service. An AVLC system (entitled Communications and Information System) initially controlled some 300 buses operating from the Wilson Garage, and now covers the rest of the system. A transit control center covers emergency response. The center has direct lines to fire, police, and ambulance services and mobile inspectors.

Line supervisors (inspectors) are concentrated on the heavy lines. They conduct "ad hoc" travel time studies by taking counts that provide inputs for service planning and schedule adjustments. Supervisors participate in annual route reviews with the Planning Department.

The TTC instituted new spare-board (extraboard) procedures in January 1990 to deal with vacation relief and known absences. The procedures, which reduce the reliance on calling drivers to cover missed runs, have been estimated to save $1.0 to $1.5 million annually.

Spare-board drivers previously were required to report at specific times, and therefore were unable to cover work before their report time or situations where the maximum 12½-hr spread was exceeded. This required the use of volunteers, i.e., off-duty drivers for uncovered trips at premium pay. Under the new procedures, which were negotiated with the American Transport Union, all known open work is pre-detailed to spare-board operators in order of finishing time. The spare-board operators sign up for a sequence of work (and off-days) that is keyed to their finishing times. They are advised of the uncovered work on the late afternoon of the previous day. The use of off-duty drivers (on call) is limited to emergencies or uncovered work that occurs after the sign-up time.

The new procedures provide greater flexibility in the use of personnel, reduce costs, and result in fewer cancellations. Previously, a typical TTC garage might use 16 spare-board drivers and 14 "volunteers" to cover 30 trips; with the new procedures, only six would be needed. Experience at TTC's Wilson garage shows that the "no-shows" have reduced from two to three per day to two to three per month.

ON-TIME PERFORMANCE CRITERIA

The on-time performance criteria used by the transit systems surveyed are given in Table 15.

- Buses are considered on time if they are 0 to 3 min ahead of schedule. Almost half of the systems considered a bus early unless it appeared exactly on schedule.
- Buses are considered on time if they are arriving 1 to 5 min behind schedule. Almost half of the systems considered a bus on time if it was not more than 5 min late.

IMPEDIMENTS TO SUPERVISION

The impediments to supervision reported by specific properties are shown in Table 16. Table 17, in turn, summarizes the principal impediments reported. The most pervasive obstacle reported appeared to be budget limitations. Transit systems, caught in a cost-revenue squeeze, are not able to provide sufficient resources. This limits the size of the supervisory staff and results in too broad a span of control.

Several other impediments relate closely to the limited fiscal resources. Supervisors are too often diverted to other activities, taking them away from their supervision. Communication is inadequate, resulting in too long a time period to respond to a route and take appropriate action. Old shop and garage facilities limit effective maintenance.

TABLE 15

ON-TIME PERFORMANCE CRITERIA

Agency	Buses	Early (minutes)	Late (minutes)
1	225	0	5
2	2238	1	5
3	239	0	5
4	730	1	3-5
5	686	0	5
6	931	0	5
7	681	0	4.5
8	890	0	5
9	1095	<2	<6
10	490	0	5
11	254	3	5
12	200	0.5	3
13	283	0	3
14	518	0	5
15	1615	1	5
16	2462	2	5
17	176	1	4
18	2094	1	1
19	587	1	5
20	1559	2	5

Transit agencies also report traffic, weather, fire, and service disruptions as obstacles to reliable service.

The SCRTD (Los Angeles) cites the following problems:

- Some schedules have too little or too much running time.
- Supervisors have many tasks (e.g., fixing bus mirrors, investigating accidents, and repairing malfunctioning fare boxes).
- The lack of workable equipment often results in the cancellation of scheduled bus runs. This makes it difficult to maintain schedules.
- There are periodic "no shows."

IMPROVING SUPERVISION

From the survey, the various methods identified to improve supervision of bus service are set forth in Table 18 and summarized in Table 19. Implicit, of course, is a need for greater resources in terms of both personnel and equipment.

The greatest perceived need (or way to improve supervision) is for better technology. Almost half of the properties surveyed indicated that the installation of APC or AVLC systems would improve supervision. In fact, several of the systems are proceeding in this direction.

Next in importance was the need to improve and/or increase training of supervisors and drivers, and to increase the supervisory staff.

The SCRTD suggests the following approaches to improving service supervision:

- Schedule fast travel times and give drivers more recovery time at terminals.

TABLE 16

REPORTED IMPEDIMENTS TO SUPERVISION

Agency	Buses	Impediments
1	225	Need more supervisors than budget can afford.
2	2238	Disruptions to service.
3	239	Working out of an old facility, operating old buses, inability to communicate via two-way radio to entire bus fleet.
4	730	No response
5	686	Supervisors are called away to do other duties when need arises.
6	981	Weather, fires, inadequate communication.
7	681	None
8	890	None
9	1095	None
10	490	Supervisors are often hampered by having to deliver inter-office mail, run errands, or perform school break up duty.
11	254	No response
12	200	No response
13	283	Limited staff has other duties that take priority over on-time performance.
14	518	None
15	1615	Traffic conditions, street conditions, weather,special events; too broad a span of controls; special assignments.
16	2462	Length of bus lines - many are 10-20 miles or more long; complexity of bus lines and need to interline buses extensively; daily fluctuations in traffic; inadequate number of supervisors to adjust service in a timely fashion.
17	176	None
18	2094	Time required (without CIS) to receive information from operators and inspectors, and inability of inspectors to see the routes as a whole.
19	587	Budgetary constraints limit supervisory personnel for a highly integrated route system that needs a high level of schedule reliability (timed transfer, bus/rail interface, grid system, through routing).
20	1559	No response

- Target problem lines with poor reliability. Talk to the operators and review schedules.
- Break long lines into segments to avoid accumulating headway problems.
- Minimize diversion of supervisors to other activities. Supervisors should focus on (a) establishing detours, (b) adjusting schedules, and (c) getting trippers to replace breakdowns.
- Supervise the supervisors.
- Improve management and "team building" to reduce absenteeism and excessive overtime due to "no shows."

Techniques for monitoring performance by two transit agencies, SEPTA and Houston MTA, are shown in Appendixes C and D.

What emerges, therefore, is a two-fold approach to effective supervision—better technology and better management. Significant examples of both approaches are contained in subsequent chapters.

TABLE 17

SUMMARY OF PRINCIPAL IMPEDIMENTS TO SUPERVISION

Item	Responses	Agencies
Budget Limitations (Inadequate number of supervisors; span of control too broad)	4	1, 4, 15, 16, 19
Diversion of Supervisors to Other Activities	4	5, 10, 13, 15, 16
Traffic, Weather, Fire, Disruption of Service	4	2, 6, 15, 16
Inadequate Communications (Excessive time required; lack of radio communications; inability to see entire route)	3	3, 6, 18
Old Facilities, Equipment	1	3
Length of Bus Routes	1	16

TABLE 18

WAYS TO IMPROVE SUPERVISION

Agency	Buses	Method
1	225	More training of drivers and supervisory personnel.
2	2238	Provide continuous motivation to supervisors.
3	239	New facility under construction; specifications prepared for buses; two-way radios being installed on buses.
4	730	No response
5	686	Make more checks at more time points.
6	981	Instruct first line supervisors about proper performance duties; require daily reporting of scheduling variations; interview operators to find out why problems occur.
7	681	Hand held data collectors are being implemented; electronic farebox system and automatic passenger counters will be operative.
8	890	Use automatic vehicle location (LORAN-C).
9	1095	Looking for ways to improve what we currently do well.
10	490	No response
11	254	Connection of vehicle location signal through radio system.
12	200	No response
13	283	Increase staff; evaluate AVL/AVM technology.
14	518	No response
15	1615	Use authority's management information service department's services for computerized capturing of supervisory on-time performance, line checks, special checks; use service quality teams for plainclothes monitoring and reporting.
16	2462	Expand intensive road supervision program; implement automated vehicle monitoring system (during 1993).
17	176	Install two-way radio system with AVL (in process); install new farebox system; provide additional training for supervisors.
18	2094	Install city-wide communications information system
19	587	Continue to review and expand APC and AVL
20	1559	No response

TABLE 19

METHODS BEING CONSIDERED TO IMPROVE SERVICE RELIABILITY AND SUPERVISION

Method	Number	Agencies
Improved technology (install AVLC, AVM, APC, or CIS)	10	3, 7, 8, 11, 13, 15, 16, 17, 18, 19
Improve and/or increase training of supervisors and drivers	4	1, 6, 16, 18
Increase staff	2	5, 13
Improve motivation of supervisors	1	2, 16
Require daily reporting of problems	1	6
Interview operators to find out why problems occurred	1	6, 16
Use service quality teams for plainclothes monitoring and reporting	1	15, 16

TECHNOLOGY IN SERVICE SUPERVISION

Technology plays an increasing role in bus supervision strategies, although the use of electronics in bus transit is far more recent than in rail transit. (The application of electronics or electromechanical logic to rail operations was straightforward since the rails and private rights of way provided a guidance system and an electrical pathway for train detectors and train-to-wayside communications.) Electronics came to bus operations through the taxicab industry, which adopted two-way radios for dispatching soon after World War II. Continued improvements in electronic technology, coupled with the need to improve system performance and labor productivity, have increased the use of bus radios and related component systems. Almost every major transit system now has, or is planning, two-way radio systems. About a dozen systems in the United States and Canada have APC systems, a few have operational AVLC systems, and several more are planning to implement these systems.

- Existing APC systems in North American cities are essentially planning tools. They provide basic information on vehicle location, passengers boarding and alighting, and travel times, but not on a real-time basis. They are useful in planning and updating schedules, but they also can be used to pinpoint problem runs. They reduce the role of the field checker.
- AVLC systems provide real-time data on bus performance. They permit instantaneous adjustments of service, and thereby reduce the role of street supervisors. They provide centralized control of schedules, services, and operators by supervisors who are able to see all buses on a route. This enables the street supervisors to deal primarily with accidents and bus inspection. A goal is to merge the two systems to allow real-time decisions based on full information.

These technologies provide important tools for gathering new information and identifying problems. They are important complements to good street supervision, which is still used in conjunction with the electronic systems. They require trained personnel to operate. Costs may be substantial. Toronto's automatic vehicle location and monitoring system took more than 15 years to develop at a cost of nearly Can$16,000 per bus; a system-wide AVLC will cost approximately Can$37,000,000.

AUTOMATIC PASSENGER COUNTING SYSTEMS

APC systems have been developed and implemented to overcome the problems associated with manual data collection techniques. These problems include poor reliability, low accuracy, relatively high costs, and long turnaround times between observations and reporting of events. In response to the need for more effective, reliable, and cost efficient data collection methods, automated data collection techniques were developed in the 1970s, and continue to be refined.

System Concept and Components

APC systems involve the use of electronic devices or "sensors" to detect transit passenger activity. Data on the number of passengers boarding and alighting the bus and the location of that activity are accumulated and stored on tape or in a microprocessor on-board the bus. These data are later transferred (either manually or automatically) to a central, stationary computer for data processing and report generation. Today, many of the agencies using APC systems have limited or discontinued manual data collection activities (*6*).

APC systems provide report-oriented information that can be used for transit planning, scheduling, marketing, and transit management. They are "off-line" rather than real-time systems. Data are analyzed and evaluated after a significant amount of data have been gathered, usually a 1-day to a 2-week sample. (In contrast, AVLC systems do not count passengers boarding and alighting the bus, but provide bus location and schedule adherence information for real-time monitoring by transit operations staff.)—APC system components include hardware, software, and personnel. Figure 9 shows the basic steps that are involved, and identifies some of the innovative system hardware. Data are obtained through counting sensors on the bus that are keyed to mile post and/or odometers and clock. The information is then transferred to a central computer for processing and preparing reports.

The system flow chart, Figure 10, displays one software version of APC data processing and shows how files are created.

- Module A represents the initial editing and labeling of APC ("in-service") data. During this stage, data are edited for inconsistencies in passenger counts, location data, and APC vehicle assignment information. Also the route and run numbers of the APC vehicle assignments are appended to the APC data during this stage. Data are discarded when runs or parts of runs can not be matched or if runs do not conform to known behavior of the transit system (i.e., too many passengers carried or boarded at one stop, speed too high or too low at some point, distance traveled not appropriate).
- Module B edits the information that identifies the bus stop location (bus stop number, distance from previous stop, intersection closest to the stop, route, and any other information needed to identify the bus stop) and for miscellaneous information such as deadhead mileage. (Deadhead mileage is the distance traveled by the bus either before or after it is in revenue service.)
- Module C edits schedule data, rejecting internal contradictions and conflicts with the in-service data on file. This is the

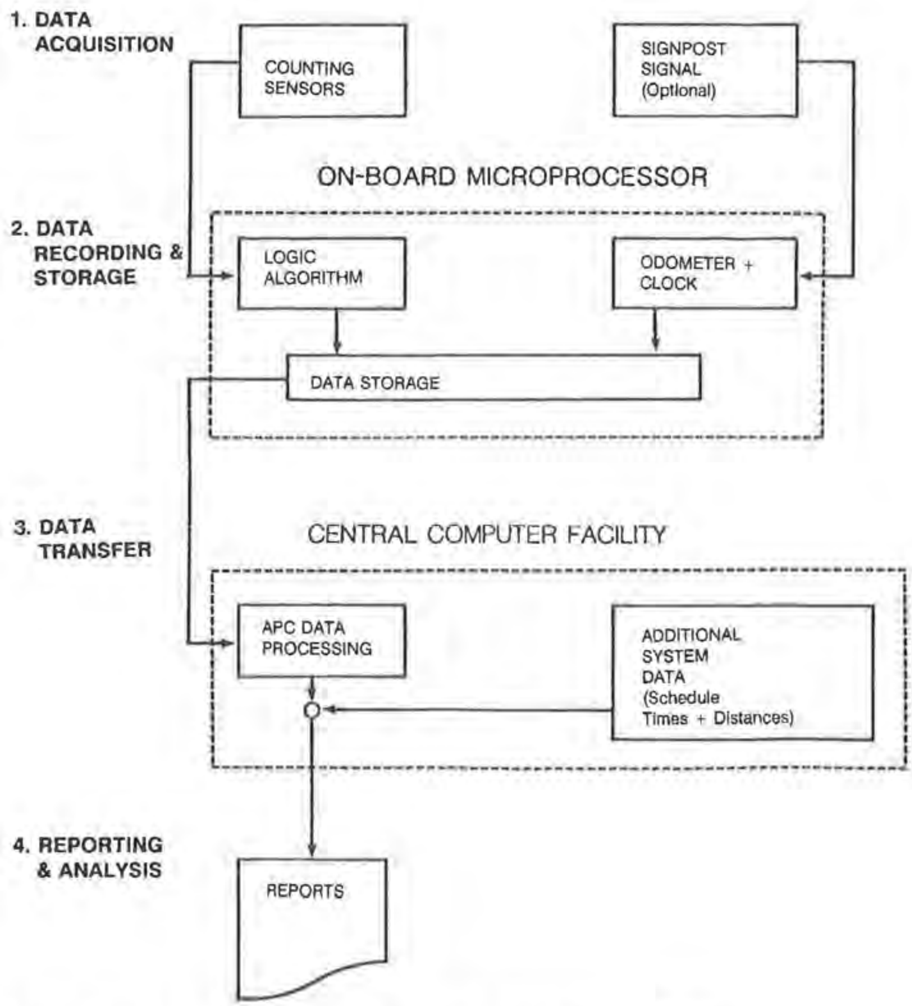


FIGURE 9 Automatic passenger counting steps and procedures (7).

first opportunity to determine automatically which runs did not take place or were truncated because of breakdowns. The module matches actual performance of the buses by route and run with the schedule by integrating the two files. This process is required to obtain schedule adherence data. The module also formats and generates hard copy reports and archives the data for possible future statistical analysis and reports. Proprietary packaged software is frequently used for report generation.

Transit agencies report that at least one full-time person is needed to manage the APC system. Sometimes called an APC technician, this person is responsible for: hardware monitoring and diagnostics; coordinating APC vehicle assignments; devising a sampling plan; running the programs; entering the data defined above (schedule, bus stop, vehicle assignment, etc.); and overseeing general operation of the project. This person is sometimes responsible for data transfer as well.

Implemented Systems

Examples of implemented APC systems are set forth in Table 20. It is evident that APCs have been applied in a variety of transit settings in terms of fleet size and route structure. (In addition to the transit agencies shown, APC systems have been installed in Hamilton, Ontario and Hull, Quebec.)

Most transit properties equipped only a small proportion of their bus fleet, generally 7 to 12 percent. The APC-equipped buses are generally rotated among the various bus lines to obtain system-wide information.

A 1985 U.S. Department of Transportation survey obtained the intended use of APC data for 10 transit properties (6). All 10 systems planned to use the data for scheduling and route planning activities; the U.S. properties also intended to use the data for Section 15 reporting. Half of those interviewed planned to use the data to evaluate marketing strategies, determine fleet needs, and determine the location of bus stop facilities (i.e., shelters). The Canadian systems planned to use APC data to estimate revenue or to monitor driver performance.

Key findings of this survey are as follows:

- Most properties expressed satisfaction with the accuracy of their APC data, although the accuracy of the location data presented general difficulty for some properties. Signposts can

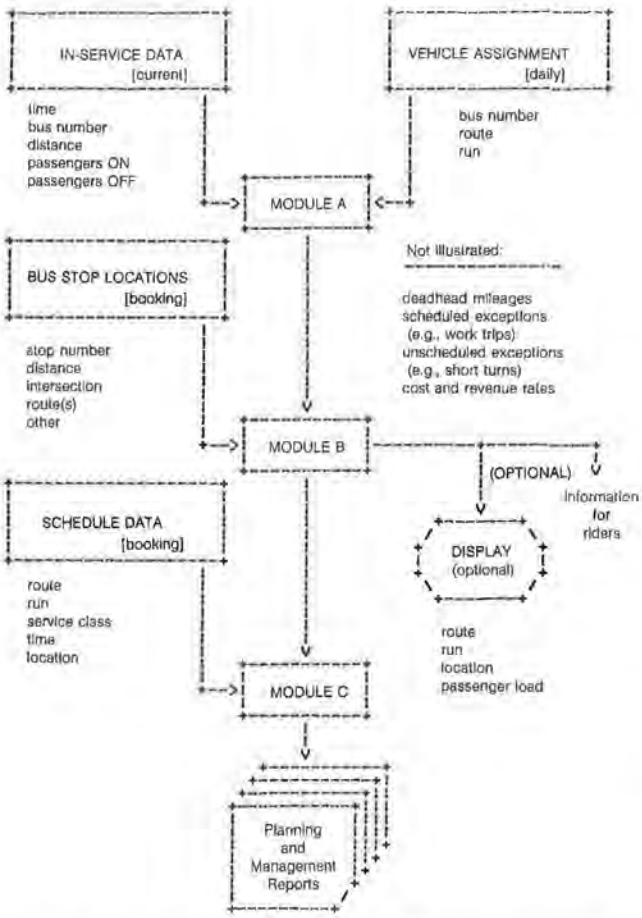


FIGURE 10 System flow chart for APC data processing (*8*).

significantly increase the accuracy of location data, especially when they are provided at major time points and endpoints.

- Most properties predicted that unit reliability would be a problem, but that proper system maintenance, monitoring, and operational procedures significantly improve the reliability of the hardware.
- The most extensive improvements in APC technology have been in report-generating software rather than hardware modifications. With few exceptions, the hardware used is similar to the technology employed in the earliest applications.
- Personnel is a key, but often underestimated, component of an APC system. Minimal personnel requirements reported by APC properties include at least one full-time person to manage and coordinate the APC project and at least one person half time to maintain the hardware.
- The capital cost of an APC system is highly sensitive to software costs, especially for small properties (100 peak buses or less). For small transit agencies, software costs can exceed all other capital costs of the system combined. Depending on the extent and expense of current data collection efforts, APCs can be more cost-effective than manual methods. For large agencies with permanent checker staffs, APCs may approximate the costs of checker salaries alone. For small agencies (less than 100 peak buses), the cost-effectiveness of APCs is less precisely defined. Cost data for three systems is summarized in Table 21.

Ottawa-Carleton Regional Transit Commission

The APC system installed by the Ottawa-Carleton Regional Transit Commission (OC Transpo) is one of the better documented APC efforts. The system, first installed in 1976 and progressively updated in the 1980s, is in place on 80 buses of varying size of the 800-bus fleet system (*9*). These buses are rotated throughout the system to obtain information on passenger loads and schedule adherence. The various reports provide

TABLE 20
EXAMPLES OF AUTOMATIC PASSENGER COUNTING SYSTEMS (1985) (*6*)

System	Year APC Began	Fleet Total	Fleet Peak	Fleet Base	Route Structure	Service Population (millions)	No. of APC Buses	% of Buses with APC
Seattle, WA	1978	1069	915	450	Radial	1.3	116	10.9
Ottawa, Ont.	1978	765	710	300	Radial, F.T.[a]	0.5	66	8.6
Kalamazoo, MI	1980	54	31	23	Radial	0.2	20	37.0
London, Ont.	1981	160	152	90	NA[b]	0.2	18	11.8
Windsor, Ont.	1981	92	78	39	Modified F.T.[a]	0.2	27	29.3
Calgary, Alb.	1982	683	435	155	Mainline, F.T.[a]	0.5	5	0.7[c]
Portland, OR	1982	631	424	228	Radial, grid, F.T.[a]	1.0	43	6.1
Columbus, OH	1982	NA	294	NA	Radial, F.T.[a]	0.9	20	0.9[d]
Chicago, IL	1983	2275	1950	995	Radial, grid	3.7	6	0.3[c]
Kitchener, Ont.	1985	84	70	46	Radial	0.2	20	23.8
Mississauga, Ont.	1985	172	135	70	Radial, grid, F.T.	0.4	30	17.6

[a]F.T. = Feeder trunk route structure.

[b]NA = Information not available.

[c]These small proportions are for demonstration projects.

[d]Percentage of peak buses in service.

TABLE 21

REPORTED COSTS OF SELECTED AUTOMATIC PASSENGER COUNTING SYSTEMS (1985) (*6*)

Item	Seattle	Ottawa	Portland, Oregon
Counting sensors	$1200-1700/bus[a]	$400/passenger stream	$620/bus
Microprocessor	$1500/bus[a]	$3300-3500/bus	$2160/unit
Data retrieval unit	$4000-5000/unit		$7600[b]
Portable transfer device		$5000/unit	$5000/unit
System display unit	$1500/unit		
Signposts	$300/unit		
Signpost transmitter		$1200/unit	
Signpost receiver	$1000/unit	$300/unit	
Signpost receiving antenna	$200/bus		
Other bus wiring unit			$8258/bus
Installation			
Microprocessor	24 person-hr/bus	2 person-days/bus	$290/bus
Signposts	$300/unit		
Software development	2+ person-years	$250,000	2.5 person-years

[a]Including wiring.

[b]Stationary central processing unit ($7000 for extra disk drive in minicomputer and $600 for two modems).

important planning information for schedule development and changes.

Background

Before the APC was first installed in 1975, OC Transpo employed eight traffic checkers on a full-time basis to collect load-point, on-board, and running-time counts and special passenger surveys. Since then, all but one of these checkers have been replaced by APC.

A prototype APC was installed on a test bus in 1977, and by 1978, 13 buses were equipped with APC. Expansion and modernization of the system took place in successive years. An automatic radio transmission system (ARTS) replaced floppy diskette data in 1984, and major upgrading took place in the following two years.

The Upgraded System

The upgraded APC units enable time along a section of bus routes to be broken down into five components. These are:

- Time spent between stops—moving,
- Time spent between stops—in congestion,
- Time spent between stops—idle time,
- Time spent at stops—actively boarding/alighting passengers, and
- Time spent at stops—excess time.

Microcomputers on each bus were retrofitted for three new log records and the extra memory required. The passenger log counts passenger activity by door at a bus stop. It also records the amount of total time at the stop (stopped time, measured from odometer pulse preceding wheel stop to odometer pulse following wheel start), and the amount of time spent actively boarding and alighting passengers (measured by time from first door opening to time of last passenger beam breakage at a stop). The idle log records whenever a bus is idle for at least 45 sec without any passenger activity. The stop-and-go log measures the time spent in traffic congestion (i.e., moving very slowly).

Figure 11 shows the new APC on-bus hardware configuration, which includes a passenger counting module, radio control module, and electronic signpost module. Figure 12 shows the flow of information for the upgraded APC system.

Reports Produced

The new APC system produces four types of reports:

- Management overview reports are produced at the end of each booking period. They are stratified by type of day (weekday, Saturday, and Sunday) and time periods (early morning, a.m. peak, midday, p.m. peak, evening, and all day). They include reports on performance statistics and passenger activity. The types of reports produced are shown in Table 22. A route performance exception report is used to highlight poor performance and identify problems as measured against eight criteria; an example is shown in Table 23.
- Detailed service statistics reports can be stratified by day type (weekday, Saturday, Sunday), date range (from date to date) time period (from time to time, or five major periods), route, route section, and geographic area. They include the various reports shown in Table 24.
- System maintenance reports produced are shown in Table 25.
- On-line statistical summaries include statistics on passenger boardings, passenger kilometers, boardings per revenue hour, and revenue cost ratios.

Service Analysis Systems

Using the APC as a core, OC Transpo has developed a comprehensive service analysis system. This system has input from five basic sources:

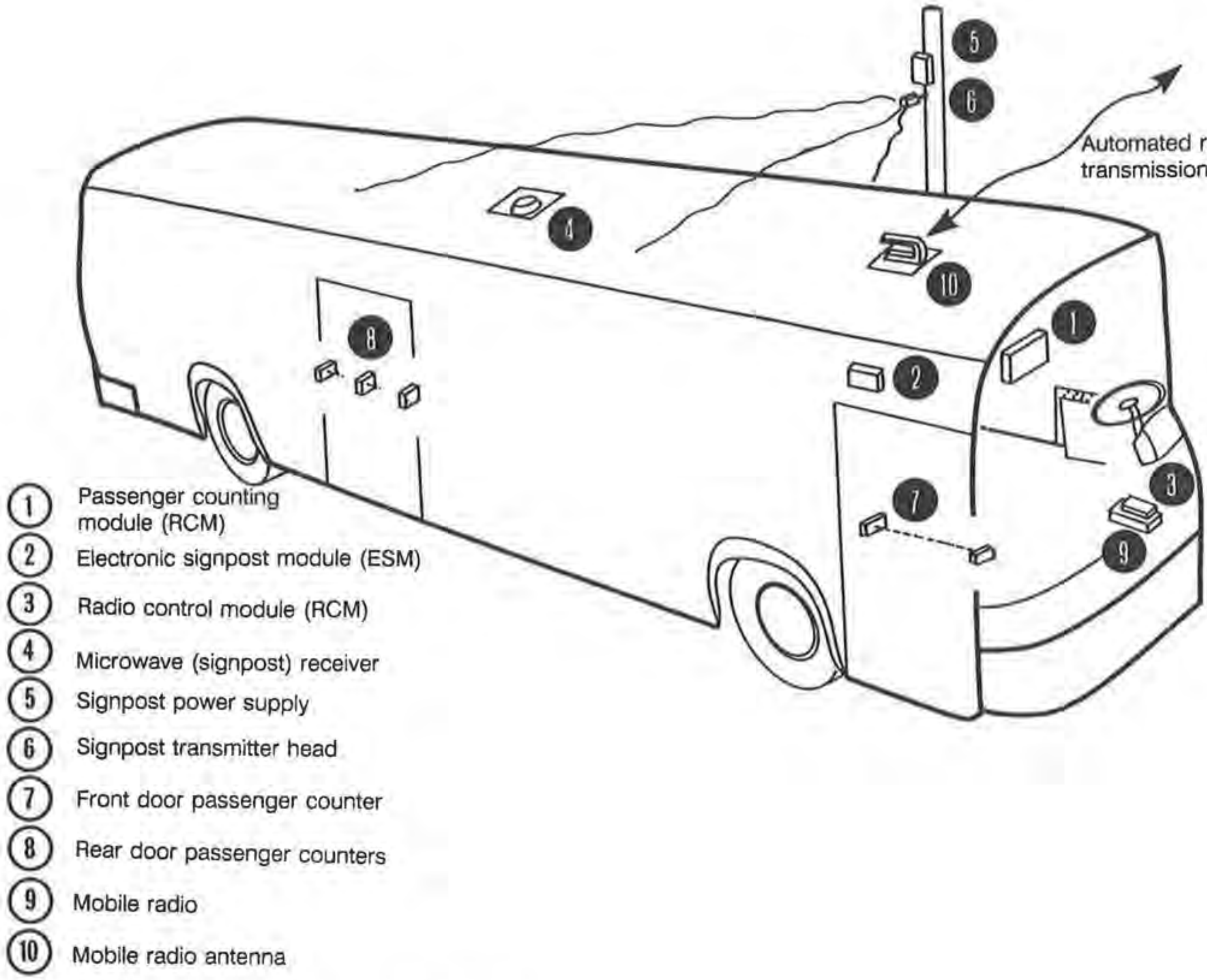


FIGURE 11 APC on-bus configuration (Ottawa).

1. Upgraded APC system provides data on passenger movements, vehicle running times, schedule adherence, and time utilization.
2. Customer relations reports indicate the frequency and nature of customer contact, classified by route and time period.
3. The computerized telephone information system gives patrons the scheduled departure times for each route serving the stop.
4. Communication operators and bus assignment (COBA) log reports give lost and extra kilometers, and provide historical trends relating to on-street corrective action taken by control staff.
5. Information obtained from finance/equipment gives costs of vehicle kms and hours for peak and off-peak services, vehicle types, etc. and information on fares, ticket/cash collected, passes sold, etc.

In addition, any manual counts made by inspectors as a result of specific problems or requests are included.

AUTOMATIC VEHICLE LOCATION AND CONTROL

AVLC systems provide real-time surveillance and control of bus operations. These systems:

- Monitor and track the location of all buses at all times,
- Display to service supervisors the schedule adherence status of a route (often a geographic display),
- Include a silent alarm for operator emergencies,
- Allow for digital two-way communication between the bus operator and central control,
- Contain some form of management reporting system, and
- Sometimes contain provisions relative to a vehicle's mechanical, electrical, and hydraulic conditions.

A goal is to incorporate a real-time passenger counting capability, and to make this information available to the central control.

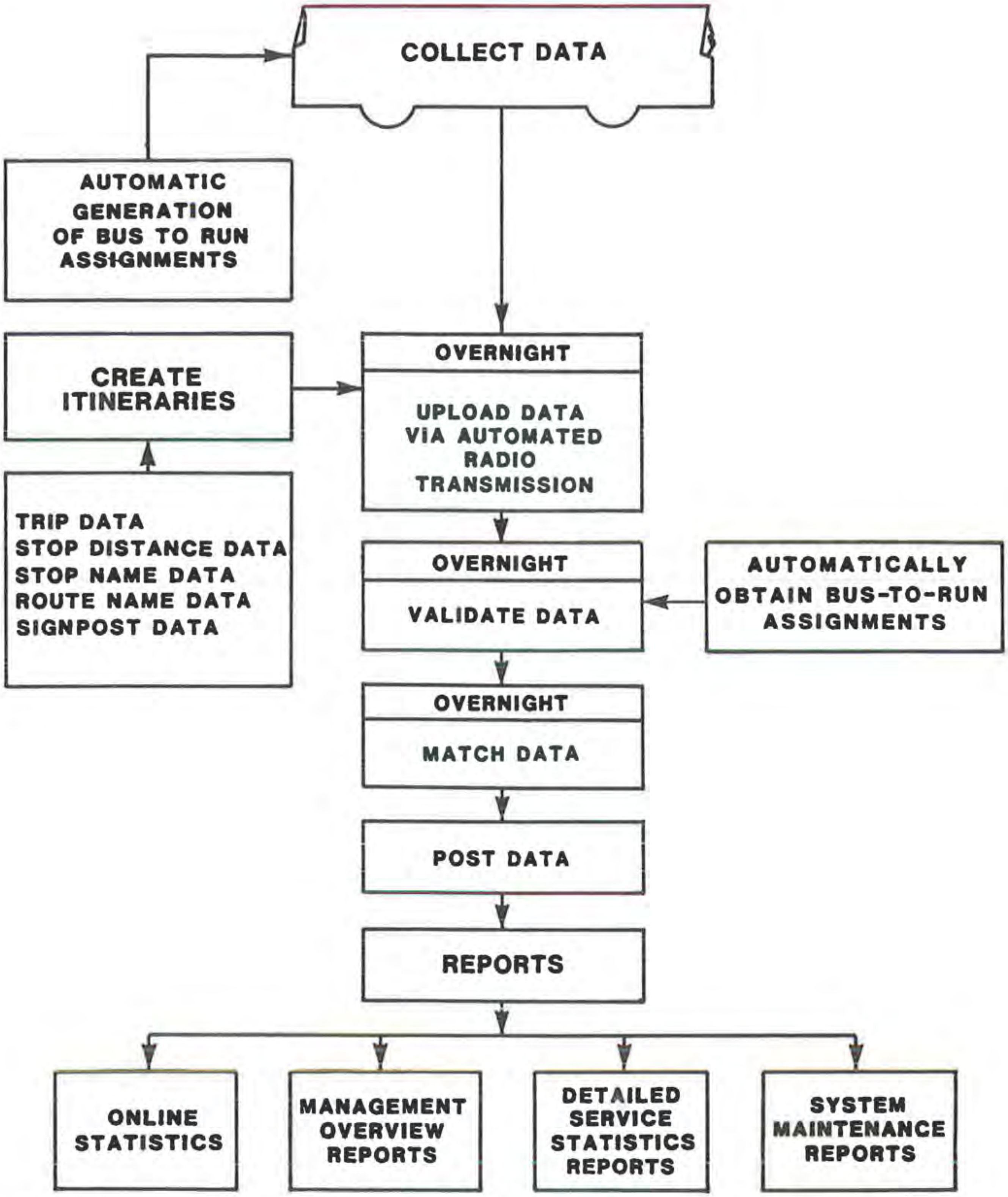


FIGURE 12 Information flow chart for APC system (Ottawa).

TABLE 22
MANAGEMENT REPORTS PRODUCED BY OC TRANSPO APC SYSTEM (*9*)

Performance Statistics
Overall Service Provision
Regular Route Service Provision
Interline Service Provision
Route Performance Exceptions
Passenger Activity
Passenger Volumes at Screenline
Passenger Boardings by Time Period
Passenger Alightings by Time Period
Revenue Time Utilization
Distribution of Schedule Adherence
Distribution of Average Maximum Passenger Loads
Average Maximum Passenger Loads by Time Period

System Concept

The most common form of system equips all buses with a microprocessor, a display/keypad unit, and a device to receive location input from roadway signpost transmitters or transponders. The on-bus microprocessor stores in memory the last roadside location unit passed, along with the distance traveled since this location. A central computer frequently polls all buses to obtain their location, and these data are displayed to the service control staff.

The systems are designed to facilitate communication between bus driver and supervisor, and thereby permit a prompt response to service problems. In addition to improving on-street service control, AVLC systems provide an important method of data collection. Information available in even the simplest systems includes: schedule adherence performance, running times, runs not covered, and trips missed. The technology has advanced rapidly in recent years.

Implemented Systems

AVLC received much attention during the 1970s when demonstration projects were launched in a number of U.S. cities including Chicago and Los Angeles. Many of the early systems, however, did not prove successful largely because of the primitive technologies then available. The results of these experiments together with the costs and complexities involved inhibited their use by North American transit systems. Within the last decade, many of the earlier technology problems appear to have been overcome, and systems have been increasingly implemented both in North America and Europe.

A high percentage of European transit systems have installed AVLC systems, especially in France and Germany. A complete report on the status of the implementation of these systems entitled *Technical and Economic Aspects of Operation Control Systems* was published by the International Union of Public Transport (UITP) in June 1991 (*10*).

Examples of implemented systems are given in Table 26. Systems operate in Kansas City, Norfolk, San Antonio, and Westchester County in the United States, and in Calgary, Halifax, Hamilton, Hull, and Toronto, Canada. Systems also operate in many West European cities in Austria, France, Germany, Ireland, Italy, Spain, and Switzerland. The number of implemented systems continues to grow rapidly.

Examples of North American cities under contract or under advanced study are given in Table 27. If the pace of AVLC interest and development experienced in the last few years continues, it is likely that most major U.S. and Canadian transit systems will have AVLC within the next decade.

A 1988 survey of North American and European AVLC systems conducted by the Ministry of Transportation of Ontario (*11*) indicated that the implemented systems had many common features. Survey respondents included Angouleme (France), Caen (France), Darmstadt (Germany), Dublin (Ireland), Friedrichshafen (Germany), Halifax (Nova Scotia), Hamburg (Germany), Hannover (Germany), Hull (Quebec), Nürnberg (Germany), San Antonio (Texas), Toronto (Ontario), and Zurich (Switzerland) (*11*). The principal findings based on this survey are:

- Most AVLC systems use radio-based two-way data communications. All systems offer voice communication between drivers and the central control facility. All systems provide some form of vehicle location, with the use of wayside beacons and odometer-based distance measurement being the most commonly used configuration. In some systems, passenger stops provide position reference points in place of the wayside beacon—a "dead reckoning" system. Some North American systems are being designed to use Loran C to provide vehicle location.
- The accuracy of the location systems ranges from about 30 to 660 ft. Communication polling rates are between 5 and 45 sec. No system contains a large-scale wall-type map indicating overall city-wide operations. All systems appear to have multiple screens for displaying system status and vehicle messages. As a minimum, central displays show schedule deviation, mechanical and emergency alarms, and requests for voice communication between drivers and supervisors. Multiple terminals at each supervisor station are the norm, with a monochrome terminal used to display alarms and messages, while a second and possibly third color monitor is used to show vehicle position, schedule deviation, and system statistics.
- In-vehicle driver displays provide the driver with schedule deviation, a real-time clock, variable text messages, and the capability to communicate with the central control through a multi-key keypad.
- One supervisor generally monitors and controls from 50 to 150 vehicles. Field supervisory control appeared limited to the management of incidents, emergencies, and transfers, with schedule-related functions being under the control of the automatic control system.

Improved schedule adherence is the primary goal of both European and North American transit systems. European operators tend to hold buses in reserve during the peak period for insertion into the system as required, with Caen, Dublin, Angouleme, Zurich, Friedrichshafen, and Nürnberg following this strategy. Transit properties in Europe also expressed concern about assuring good connections at transfer points.

- The system operating in Friedrichshafen provides demand responsive service and dynamic schedule synchronization in low

TABLE 23

SAMPLE MANAGEMENT REPORT--OC TRANSPO (*9*)

Route	Name	Direction	Percent Off Sched.	Percent Over Loading	Percent Under Supply	Percent Revenue Cost Ratio	Percent Excess. Stopped Time	Percent Excess. Layover Time	Percent Excess. Idle Time	Percent Excess. Congestion
001	Rockliffe	Southbound	19	22						
001	Rockliffe	Northbound	17							
003	Elmvale	Southbound				28				
008	Overbrook	Eastbound						21		
026	Gloucester	Northbound	17							
028	Orleans	Eastbound		24						

TABLE 24

DETAILED SERVICE STATISTICS REPORTS PRODUCED BY OC TRANSPO APC SYSTEM (*9*)

GENERAL

Route Rank
Route Direction Summary
Point Check
Passenger Activity for Major Centres
Route Sampling Statistics

TIME

Distribution of Running Times
Schedule Adherence at Timing Points by Time Period
Schedule Adherence at Timing Points
Deadhead Running Times
Dwell Time Analysis by Route
Revenue Time Utilization by Route by Time Period
Revenue Time Utilization by Route
Schedule Adherence by Route
Schedule Adherence by Time of Day
Running Times by Section

LOADINGS

Load Profiles by Section by Time Period
Load Profiles by Section
Load Profiles by Stop by Time Period
Load Profiles by Stop
Load Profiles by Route

PASSENGER ACTIVITY

Passenger Activity by Section by Time Period
Passenger Activity by Section
Passenger Activity by Stop by Time Period
Passenger Activity by Stop
Passenger Activity by Area by Time Period
Passenger Activity by Area
Passenger Volume at Screenlines by Route
Poor Usage by Route

TABLE 25

SYSTEM MAINTENANCE REPORTS PRODUCED BY OC TRANSPO APC SYSTEM (*9*)

Route Run Sections
Starter Sheet Exceptions
Daily Starter Sheet
Run Summary Report
Garage Summary Report
Validation Parameters
Validation Summary Report
Validation Detail Report
Service Exceptions Report
Matching Parameters
Matching Summary Report
Matching Detail Report
Raw Data Statistical Report
Bus Status Report
Bus Run Assignments Report
Current Master Starter Sheet Exceptions
Current Itinerary Model Exceptions
Current Stop Data Exceptions
Current Itinerary Model Statistics
Current Route Group Assignments
Booking Definitions
Day Type Definitions
Special Data Definitions
Data Selection
Report Status
Geographical Areas Definitions
Screenlines Definitions
Route Groups Definitions
Systems Parameters
Report Parameters
Vehicle Information
Signpost Information
Current Stop Data
Current Trip Data

demand areas. This service is complemented by demand responsive stop deviation in intermediate areas and line haul operation in more heavily traveled corridors. The Nürnberg system also offers dynamic schedule synchronization.

- In Zurich, drivers are issued departure commands from the central control point at each stop. This probably accounts for precise schedule adherence achieved by the Zurich system: 92 percent of the time vehicles are within 1.5 min of schedule.

TABLE 26

EXAMPLES OF IMPLEMENTED AVLC SYSTEMS

United States

- Kansas City, Mo.
- Norfolk, Va.
- San Antonio, Tex.
- Westchester County, N.Y.

Canada

- Calgary, Alberta
- Halifax/Dartmouth, Nova Scotia
- Hamilton, Ontario
- Hull, Quebec
- Toronto, Ontario

Europe

- Amsterdam, The Netherlands
- Angoulême, France
- Barcelona, Spain
- Bordeaux, France
- Caen, France
- Cedex, France
- Clermont-Ferrand, France
- Darmstadt, Germany
- Dublin, Ireland
- Friedrichshafen, Germany
- Geneva, Switzerland
- Hamburg, Germany
- Hannover, Germany
- Manheim, Germany
- Milan, Italy
- Nancy, France
- Nürnberg, Germany
- Osnabrück, Germany
- Salzburg, Austria
- Turin, Italy
- Wiesbaden, Germany
- Zurich, Switzerland

Source: References *11, 12,* D. L. Phillips, personal communication, June 3, 1991.

The Zurich system also offers an impressive range of graphical displays of system performance to the supervisory and planning personnel. Several systems, including Angoulême, provide preemption to transit vehicles through an interface to the traffic control system.

Chicago Transit Authority Survey

A 1991 survey conducted by the CTA provided information on existing or planned AVLC systems in North America, Europe, and Australia (*12*). Nearly one-third of the 39 survey respondents reported a functioning AVLC system on their entire network. More than two-thirds did, or are planning, small-scale tests of AVLC technology.

More than half use or plan to use signposts with dead reckoning; overhead detectors and inductive loops are the next most popular. The primary reason that inductive loops, global positioning satellites (GPS), and overhead detectors were not used is the relatively high cost of these systems.

TABLE 27

NORTH AMERICAN AVLC SYSTEMS IN ADVANCED PLANNING (JULY 1991)

Under Contract or in Bidding

- Ann Arbor, Michigan
- Baltimore, Maryland
- Broward County, Florida
- Denver, Colorado
- Houston, Texas
- Los Angeles, California
- Louisville, Kentucky
- Milwaukee, Wisconsin
- New Jersey Transit, New Jersey
- Palm Beach, Florida
- San Francisco, California
- Seattle, Washington
- Springfield, Massachusetts
- Tampa, Florida
- Vancouver, British Columbia

Under Advanced Study

- Chicago, Illinois
- Dallas, Texas
- Montreal, Canada
- New York, New York
- Ottawa, Canada

Source: D. L. Phillips, personal communication, June 3, 1991.

Of the systems reporting, more than half used or are using a single company for implementation of their whole AVLC system. Less than one-third used a single company for small tests.

More than two-thirds report AVLC service control from one central location. Slightly over one-third use two monitors per workstation and almost one-third use three monitors per workstation. The average number of vehicles supervised was 147. The average of the "best" number to supervise was 125.

More than one-third of the systems, almost all in Europe or Canada, provide real-time passenger counts. Nearly three-quarters of AVLC systems are capable of being expanded to provide real-time reports of mechanical alarms, but less than two-thirds are actually using that capability. One-third (nearly half overseas) have computer-aided dispatch with automatic vehicle "turning" capability and one-quarter (one-third overseas) with automatic rescheduling of previous or following vehicles.

Of overseas systems, more than half desire real-time passenger information, nearly half desire traffic signal priority, and more than one-quarter desire remote control destination signs. Only 10 percent of North American systems desire real-time passenger information or remote control of designation signs. However, nearly one-fifth desire traffic signal priority.

If agencies were to select an AVLC technology today, one-third would choose signposts and one-quarter would use GPS.

Overseas System Features

The German association of transit operators, the Verband Deutsche Verkehrsbetriebe (VDV, formerly the VöV) has developed standards for an open architecture AVLC system. Several suppliers make equipment which, because of the standards, is interchangeable. This system includes capabilities for computer-aided dispatch, traffic signal preemption, operation of changeable signs at bus stops giving the real-time arrival of buses, and operation of signs and voice synthesis inside buses to announce stops. There has been some integration of APC to give the computer and controller a current passenger count as a further input to service restoration strategy selection. This data is also available to support the schedule-making process.

The location function under the VDV standard is normally based on infrared signposts, which give a much more exact location than radio signposts. This is especially helpful in traffic signal preemption, which should be very specific as to when it is required and no longer required. Many cities in Germany and Switzerland have installed systems based on the VDV standards. CTA is considering adopting these standards for its proposed Service Management System.

Many French facilities have installed AVLC systems, also supplied by several different (French) manufacturers. These incorporate essentially the same capabilities as the German systems. The French have also supplied systems used in Spain and Italy. Several cities in Japan have AVLC systems, supplied by two different vendors. The list of features provided is very similar to the French and German systems.

The Dutch also have developed AVLC systems. This approach has roots in transit traffic signal preemption, which they have developed to a very sophisticated degree. Inductive loops, which communicate with devices on streetcars or buses, are buried in or under the pavement and are wired to a wayside "interrogator." In addition to the normal role of communicating to the adjacent traffic signal controller, some Dutch systems have connected the interrogators to central computers by phone lines to provide AVLC. The on-vehicle units can be used to record data such as passenger counts for uploading to central computers when the vehicle returns to its home base.

Toronto

The TTC's Communications and Information System (CIS) represents the first major AVLC installation in North America. The system, first conceived in the 1970s, represents more than a decade of research, testing, and refinement. The TTC wanted an automatic vehicle and location control system that would automate supervision, scheduling, and emergency procedures, as well as monitor ridership information, produce management reports, and allow for possible integration with such systems as APC.

System Evolution

After consulting with transit systems worldwide, the Commission and the province of Ontario decided to develop their own system once they realized no existing system matched their particular needs. The CIS project concept and its design specifications are the result of a study approved by the TTC in 1973 and carried out by a special study team of TTC staff, consultants, and representatives of the Ministry of Transportation of Ontario and the Municipality of Metropolitan Toronto during 1973 and 1974. The first three phases of CIS dealt with defining the requirements for a communications system for the Commission's surface fleet, researching the available alternatives and recommending a system that would fulfill the requirements. Phase IV of CIS, undertaken during 1974, involved the development and testing of the proposed system on 10 vehicles to prove the capability of the technology.

Phase V of the CIS project began in 1976. Its goals were to test the CIS concept on a larger scale and to verify the benefits of the system. Accordingly, a prototype of the computer-based system was installed late in 1978 when 100 buses from the Wilson Division garage, one of TTC's 11 bus divisions, were equipped with CIS (*13*).

Phase VI, which involved equipping the remaining 150 buses in the Wilson Garage, began in 1980 and became operational in September 1984. Following detailed testing of Phase VI, Phase VII was initiated. This Can$37.0 million phase involves expanding CIS to all surface transit vehicles (buses, streetcars, and trolley coaches) at 11 operating divisions by the end of 1991.

Phase VI Coverage

All bus routes that operate from the Wilson Garage are equipped with CIS modules. The single exception is the Bathurst North route that operates most buses from the Davenport Division. Most Wilson CIS routes operate in the Northern Toronto area.

System Operations

The CIS permits real-time automatic vehicle location and control by allowing instant communications between vehicle operators and the control center. It consists of three basic units: (a) a single and compact unit Transit Universal Micro Processor (TRUMP), which is installed on the vehicle, (b) a central computer, and (c) the divisional control center of which there are 10. General capabilities of the on-vehicle and control center equipment are summarized in Table 28.

The TRUMP unit (shown in Figure 13) is an important key to CIS. This on-board equipment receives information from various sensors, including the doors, engine, odometer, and microwave (reading the roadside transmitter called "signposts"). The TRUMP unit also incorporates a keypad that can be used for inputting identification along with a few standardized messages such as emergencies, talk requests, mechanical problems, and fare disputes.

Each vehicle is also equipped with a two-way radio, power supply, a 32-character alpha/numeric display, a keyboard, a telephone-type handset, and a cellular phone (for a fallback system). Also included are a microphone and an internal public address system, which allow a CIS inspector to speak directly to the passengers, as in the case of a fare dispute. The system also includes an odometer sensor, and signpost receivers for automatic vehicle location information. Distances are calibrated to signposts generally 1.5 miles apart.

Each signpost is a microwave transmitter that relays a unique identification code to each vehicle. The identification code is picked up by the vehicle's TRUMP system and transmitted to the central computer.

The fallback system, which incorporates a cellular phone system, is automatically activated should normal communication

TABLE 28
CAPABILITIES OF CIS VEHICLE AND CONTROL CENTER EQUIPMENT (*14*)

Vehicle Equipment Capabilities

Messages sent to control center include:
- silent alarm
- yellow emergency
- fare dispute
- mechanical problem
- request for voice communication
- identification (route, run, operator's badge)
- congestion due to vehicular traffic
- passengers left at stop

Make P.A. announcements to passengers on the vehicle (both by the operator and the control center)

Continual display of the time of day

Continual display of the number of minutes ahead of or behind schedule

Display messages sent from the inspectors at the control center

Voice communications with the control center using a microphone and speaker (hands-free operation) or a handset when appropriate

Control Center Capabilities

Send messages to the vehicle including short turn instructions; express instructions; controlling of extras

Send free-form text messages, up to 40 characters in length

Provide six detailed route displays on each console

Produce a prioritized listing of all incidents in the system including any buttons pushed by operators and a listing of all vehicles ahead of or behind schedule

Display detailed information on any vehicle

Produce voice communication with any vehicle

Make P.A. announcements to any vehicle

fail, whether on a long-term or short-term basis. If an operator pushes an emergency-type key (only) on the TRUMP unit, the TRUMP unit will detect the failure in the normal communications and will then resort to its built-in cellular phone. The phone numbers it dials under the fallback scenario are pre-encoded within the TRUMP unit. The phone number dialed is dependent upon the type of keypush and the operating division that is responsible for supervision.

At the 10 divisional control centers inspectors man three or four computer consoles that display the information generated by the vehicles and the data base. These consoles consist of three CRT screens. Figure 14 shows the configuration of the control consoles.

Each of two screens graphically displays vehicle location for up to three routes. The third screen displays messages and a detailed viewing of vehicles that are off schedule, experiencing problems, or involved in emergencies.

FIGURE 13 TTC TRUMP unit (Toronto).

The information received is compared to a schedule data base and then is displayed as on time, behind, or ahead of schedule. Also displayed are the operator-initiated messages, i.e., keypunches. If voice communications are required, the console inspector sets it up by inputting the appropriate command on the computer keyboard.

Different colors are used to distinguish the status of each vehicle: a white vehicle signifies on schedule, a green vehicle means it is more than 2 min off schedule, and a red vehicle indicates it is even further off schedule. Other features indicate overcrowded, mechanically malfunctioning buses, or emergencies.

With this monitoring capability, the console inspector can initiate procedures to correct scheduling and vehicle location problems. For example, the inspector can institute a "closed doors" order and instruct the overcrowded or late vehicle to skip the next stop and allow the following vehicle to pick up passengers. In this manner, the bunching of vehicles can be avoided and scheduling problems may be arrested before the entire system becomes backlogged.

Communication between the vehicle and the control center takes place on a regular basis. The entire CIS fleet is polled on the average every 10 sec. Messages from the TRUMP unit are then picked up and processed through the computer network, being directed to divisional control centers. By far, the most common form of communication is by data (which includes text messages to the vehicle). The system is also capable of voice communications.

With this type of system, the console inspector initiates the communication with the driver. Drivers can only "request to talk" through the TRUMP's keyboard.

The automatic monitoring of communication between the inspector and driver allows CIS to control situations that arise on the vehicle. A striking example is the manner in which fare disputes are handled. The driver first tries to resolve the problem, and if that is unsuccessful, the driver presses a Fare Dispute button. The inspector then opens the internal public address system and speaks to the passenger, thereby relieving the driver of this responsibility.

FIGURE 14 TTC Control room consoles (Toronto).

Other driver-initiated responses include two safety alarms. A yellow alarm can be activated when the driver is faced with a situation not related to threats of physical assault or danger. More serious situations are reserved for the silent alarm, a red alert alarm. When a red alert alarm is received, within 6 sec the CIS computer opens the vehicle for sound so the inspector can monitor the situation. If emergency personnel are required, they can be sent to the scene within minutes.

Management Reports

Management reports developed to date included:

- Period Summary Report,
- Route Report,
- Running Time Report,
- Point Report,
- Layover Report,
- Schedule Adherence Report,
- Route Operations Report,
- Segment Schedule Adherence Report,
- Lost Mileage Report,
- Change-Off Report, and
- Key Push Report.

Table 29 gives a brief description of the content of each report. The reports are produced on an "as required" basis. All reports use actual data collected via CIS except for the Route Report and the Point Report. These latter reports depend on the use of passenger load data that is not available. Samples of layover reports, schedule adherence reports, route operations reports, segment schedule adherence reports, and lost mileage reports are shown in Tables 30 through 34.

System Benefits

Phase VI evaluated improvements in management reports, of supervision, levels of service, capacity of route supervisors, perceptions of CIS by passengers and operators, vehicles, and manpower. It analyzed use of CIS for emergencies and incidents and assessed changes in service related complaints (*14*). Benefits were found to substantially exceed the Can$3,100,000 Phase VI installation costs. The TTC reported the following financial benefits:

- Tests and analyses indicated that CIS can provide a 5 to 25 percent improvement in the use of the existing surface fleet. Assuming a 2 percent improvement, based upon test results, this would achieve a possible annual operating cost saving of Can$4,800,000 and a possible minimum capital saving of approximately Can$6,600,000.
- The reduction in overtime costs due to CIS could provide an annual additional benefit of approximately Can$110,000.
- The likely increase in ridership, due to the improved security and reliability of service provided by CIS, could provide an additional increase in revenue of at least Can$2,800,000.
- With CIS, the size of the supervisory staff did not expand proportionately with the expansion of the fleet. This would amount to an estimated system-wide annual cost savings of at least Can$470,000.

The additional benefits reported included the following:

- The "real-time" information provided by CIS on the status of vehicles in service, the ability to communicate with the vehicles, and the overview of routes permitted a higher and more constant level of supervision than was previously possible with supervision on the street.
- CIS allowed a better regularity of service with increased traffic and passenger loading.
- CIS provided improved safety and security for operators, passengers, and the community. The Task Force on Public Violence Against Women and Children, established in 1982 by the Metropolitan Toronto Board of Commissioners of Police, recommended "that the installation program of the Communications

TABLE 29
MANAGEMENT REPORTS PRODUCED BY PHASE VI CIS (TORONTO) (*14*)

1. PERIOD SUMMARY

For any week, this report summarizes, for any route:

- number of actual trips
- average running time
- kilometers and miles operated

The information is shown for specific time periods during each day.

When passenger information becomes available, the following can be added to the report:

- number of passengers boarding
- passenger miles
- passengers per mile

2. ROUTE REPORT

For any day, for any route, this report shows:

- number of scheduled trips
- number of actual trips
- the percentage of actual to scheduled trips
- number of scheduled hours of service
- number of actual hours of service
- number of scheduled miles
- number of actual miles operated

This information is available by specific time periods during the day as well as the daily totals.

When passenger information becomes available, the following can be added:

- number of passengers carried
- average number of passengers per trip
- number of passengers per mile

3. RUNNING TIME REPORT

This report is produced for any day and for specified segments (and direction) of any route. It shows:

- scheduled number of trips
- maximum, minimum and average of scheduled running times
- actual number of trips
- the percentage of actual to scheduled number of trips
- maximum, minimum, average, standard deviation and coefficient of variance of actual running times

This is shown by specific time periods during the day as well as totals.

4. POINT REPORT

For any day, at any point and direction on a route, this report shows:

- number of scheduled trips
- number of actual trips
- percentage of actual to scheduled trips
- number of passengers carried
- for the maximum 30 minute loading time
  - time interval
  - average headway
  - standard deviation
  - number of vehicles
  - number of passengers
  - number of passengers per vehicle

This is shown by specific time period during the day as well as daily totals.

5. LAYOVER (DWELL TIME) REPORT

For any day, at the terminals of a route, this report shows:

- number of trips
- minimum dwell time
- maximum dwell time
- average dwell time

This is shown by specific time periods as well as daily totals.

6. SCHEDULE ADHERENCE REPORT

For a specific time period for any day for the major timing points for a route, the following are shown:

- number of trips passing the point
- number and percentage of trips that are
  - on time
  - ahead/behind schedule by - 0-2 minutes, 2-5 minutes, 5-9 minutes, more than 10 minutes

7. ROUTE OPERATIONS REPORT

This report shows for any route and direction, and by specific daily time periods:

- actual and scheduled number of trips
- the number of trips ahead or behind schedule by more than X (specified) minutes
- the segments on the route where more than 50% of the schedule deviations occurred (both ahead and behind)
- number of "overtaxed" incidents reported.

8. SEGMENT SCHEDULE ADHERENCE REPORT

This report can be produced for any segment of a route for specified time period during the day and shows:

- scheduled running time
- actual running time (average)
- scheduled number of trips
- actual number of trips
- average number of minutes ahead of schedule
- average number of minutes behind schedule
- number of "overtax" incidents reported

9. LOST MILEAGE REPORT

This daily report shows all short turns during the day for all routes. For each short-turn the following information is shown:

- time of the turn
- route, run and vehicle number
- location of the turn
- direction of travel prior to the turn
- scheduled destination at time of turn
- mileage lost
- kilometers lost
- a "code" indicating the reason for the short turn

10. CHANGE OFF REPORT

This daily report shows all change-offs for all routes and indicates:

- time of change-off
- route and run number
- badge number of the operator
- vehicle number
- scheduled miles (+ kilometers) for the vehicle
- actual miles (+ kilometers) travelled
- mileage (+ kilometers) lost
- a code indicating the reason for the change-off

11. KEY-PUSH REPORT

This daily report shows the following for all buttons pushed by operators, by route:

- time of the button push
- run number
- vehicle number
- trip direction
- location
- type of button push

TABLE 30
CIS LAYOVER REPORT (TORONTO) (*14*)

LAYOVER REPORT
ROUTE 29 DUFFERIN
DAILY SCHEDULE
86/06/17

LOCATION :- WILSON UPPER

		LAYOVER TIME (MINUTES)		
	NO OF TRIPS	MAXIMUM	MINIMUM	AVERAGE
530: 700	13	10	3	6.7
700: 900	25	9	3	5.7
900:1000	7	9	3	6.6
1000:1500	22	10	3	4.8
1500:1600	6	10	3	5.8
1600:1800	10	7	3	4.0
1800:1900	3	12	6	8.0
1900:2200	16	12	3	7.5
2200:2700	17	20	7	10.4
TOTAL	119	20	3	6.5

LOCATION :- WESTERN ENTRAN

		LAYOVER TIME (MINUTES)		
	NO OF TRIPS	MAXIMUM	MINIMUM	AVERAGE
530: 700	2	3	3	3.0
700: 900	8	3	3	3.0
900:1000	4	6	3	3.8
1500:1600	2	3	3	3.0
1600:1800	2	12	3	7.5
1800:1900	2	3	3	3.0
1900:2200	3	9	3	6.7
TOTAL	23	12	3	4.0

LOCATION :- ONTARIO PLACE

		LAYOVER TIME (MINUTES)		
	NO OF TRIPS	MAXIMUM	MINIMUM	AVERAGE
1000:1500	1	3	3	3.0
1900:2200	15	14	3	9.9
2200:2700	13	14	7	11.3
TOTAL	29	14	3	10.3

END OF REPORT

and Information System capability in all surface transit vehicles be accelerated. This Communications and Information System has proved highly effective and is considered to have high deterrent effect."

- CIS demonstrated that fare disputes can be handled in an improved manner. It has resolved up to 98 percent of the fare disputes reported.
- CIS demonstrated an improved ability to restore service after disruptions.
- CIS can provide information to patrons, thereby improving confidence in the transit system (i.e., voice communication by supervisor).
- CIS allows extending the hours of supervision on routes by 50 percent without an increase in supervisory staff.
- The transfer of vehicles to routes with unusual or emergency situations is more easily accomplished. Vehicles can be dispatched from CIS routes to other problem areas with minimal disruption.
- Toronto is one of the few major transit properties that does not have two-way radio communications with its surface vehicles. The CIS provides the benefit of radios.

INTEGRATING APC AND AVLC CAPABILITIES

APC systems provide a detailed data base for service planning and scheduling. They place a large emphasis on off-line data matching, verification, and editing to produce a sound data base. Because of the processing involved, APC systems do not lend themselves to real-time service supervision.

AVLC systems are designated for prompt real-time response. This makes it difficult to edit the passenger boarding and alighting information for possible errors or inconsistencies in sensors; for example, it may undercount boarding or alighting passengers at busy stops. For this reason, existing North American AVLC systems do not incorporate this passenger interchange information.

Ideally, the AVLC and APC reporting systems should be integrated rather than function as totally separate systems. Figure 15 shows how such an approach might be used to improve bus service efficiency. The goal is to encourage real-time response while simultaneously incorporating the collection of planning information into an AVLC system. This would enable an individual route to be studied on a stop-by-stop basis for a short length of time.

The core of the bus system is the actual operation of the on-street service. Any improvement to this operation does not come directly from the reporting data; it comes from the users (managers, planners, schedulers, and service supervisors) who have access to this information. Thus, the first line of "protection" for the on-street service is the AVLC system.

The ideal AVLC system would have two levels of reporting. First, the real-time activity must be monitored and significant status information (including current passenger counts) quickly displayed (reported) to the service supervisor, who then directs real-time schedule changes to improve and maintain service levels. Second, an AVLC system with on-board data storage can and should be used as an off-line reporting tool. Trend analysis of real-time service conditions and control actions could be studied and undesirable patterns identified. This information would make up the APC historical data base. To make such a combined

TABLE 31
SCHEDULE ADHERENCE REPORT (TORONTO) (*14*)

SCHEDULE ADHERENCE REPORT
ROUTE 29 DUFFERIN
DAILY SCHEDULE
86/06/17

TIME:- 600- 700
DIRECTION:- UP

	# OF TRIPS	ON TIME NO.	%	0-2 MINUTES + NO.	%	0-2 MINUTES - NO.	%	2-5 MINUTES + NO.	%	2-5 MINUTES - NO.	%	5-9 MINUTES + NO.	%	5-9 MINUTES - NO.	%	10 MINUTES + NO.	%	10 MINUTES - NO.	%
WEST-QUEE	14	1	7			2	14			8	57			3	21				
QUEE-DUND	13	12	92	1	8														
DUND-BLOO	12	8	67			4	33												
BLOO-ST.C	12	5	42			7	58												
ST.C-EGL.	11	7	64	3	27	1	9												
EGL.-LAWR	10	3	30	5	50	2	20												
LAWR-WIL.	9			5	56			4	44										

TIME:- 600- 700
DIRECTION:- DOWN

	# OF TRIPS	ON TIME NO.	%	0-2 MINUTES + NO.	%	0-2 MINUTES - NO.	%	2-5 MINUTES + NO.	%	2-5 MINUTES - NO.	%	5-9 MINUTES + NO.	%	5-9 MINUTES - NO.	%	10 MINUTES + NO.	%	10 MINUTES - NO.	%
QUEE-WEST	14	5	36	8	57			1	7										
DUND-QUEE	15	9	60	4	27	2	13												
BLOO-DUND	17	8	47	7	41	1	6	1	6										
ST.C-BLOO	19	9	47	2	11	8	42												
EGL.-ST.C	17	10	59	4	24	2	12			1	6								
LOCK-EGL.	5	5	100																
LAWR-EGL.	13	2	15	9	69	2	15												
WIL.-LAWR	13	3	23	5	38			5	38										

END OF REPORT

system work, the bus would probably have to carry its schedule in memory.

One of the important strengths of the APC system is its ability to bring the user into close contact with the data. There are a number of basic reports, all of which can be varied through parameter inputs, to control the selection of data that is used to generate the report output. The user generally orders a report request to satisfy a data need. It should be noted that no reports are generated automatically but the system is designed around the ad hoc submission of data requests by users. This basic approach should form one of the cornerstones of the reporting system framework of the integrated reporting system that will be part of the future AVLC system.

The goal of integrating APC and AVLC appears to have been accomplished in several European systems. This integration will be required by Chicago's specifications.

TECHNOLOGY IN PERSPECTIVE

The continued development in communications technology will provide increased opportunities for improved information collection and exchange. They will make both the planning and supervision of bus systems more efficient. There will be faster response times to problems, and there will be expanded data bases.

But technology is no panacea. It will require trained people to operate and maintain. It will not achieve the desired objectives unless transit management practices are sound and existing street supervision is good.

Moreover, even with advanced communications technology such as AVLC, some street supervision will be required. It will still be necessary to inspect conditions and cleanliness of vehicles and the appearance and manners of drivers. The need for personal communication between drivers and supervisor will remain. Technology merely supplements these activities by providing quicker, more meaningful, and systematic responses.

TABLE 32
CIS ROUTE OPERATIONS REPORT (TORONTO) (*14*)

CIS ROUTE OPERATIONS REPORT
86/06/17

ROUTE :- 29 DUFFERIN
SCHEDULE :- DAILY
SCHEDULE DEVIATION > +/- 2 MIN.

DIRECTION :- UP

	ACTUAL/SCH TRIPS	TRIPS AHEAD SCHEDULE	PROBLEM AREA*	TRIPS BEHIND SCHEDULE	PROBLEM AREA*	OVERTAXED INCIDENTS
0600:0900	67/ 78	16	LAWR-WIL.	28	WEST-QUEE	1
0900:1500	59/ 60	12	LAWR-WIL.	24	-	4
1500:1800	69/ 74	13	-	26	-	24
1800:2200	43/ 43	24	LAWR-WIL.	7	WEST-QUEE	1
2200:2700	31/ 28	27	LAWR-WIL.	9	ONT.-WEST	

DIRECTION :- DOWN

	ACTUAL/SCH TRIPS	TRIPS AHEAD SCHEDULE	PROBLEM AREA*	TRIPS BEHIND SCHEDULE	PROBLEM AREA*	OVERTAXED INCIDENTS
0600:0900	67/ 72	8	WIL.-LAWR	12	DUND-QUEE	2
0900:1500	66/ 70	10	-	27	DUND-QUEE	4
1500:1800	70/ 70	10	-	59	-	16
1800:2200	44/ 49	3	LAWR-EGL.	32	-	4
2200:2700	25/ 23	9	WIL.-LAWR	16	WEST-ONT.	

*IF MORE THAN 50% OF INCIDENTS OCCUR IN ONE AREA, THAT AREA IS IDENTIFIED.

TABLE 33
SEGMENT SCHEDULE ADHERENCE REPORT (TORONTO) (*14*)

SEGMENT SCHEDULE ADHERENCE REPORT
ROUTE 36 FINCH WEST
DAILY SCHEDULE
86/06/18

TIME	LOCATION	DIR	SCHEDULE RUN TIME (MIN)	ACTUAL RUN TIME (MIN)	SCH # OF TRIPS	ACTUAL # OF TRIPS	AVG SD AHEAD	AVG SD LATE	OVERTAX INCIDENT
700: 800	STN.-BATH	UP	8	8	19	17			
700: 800	BATH-DUFF	UP	6	6	21	18			
700: 800	DUFF-KEEL	UP	6	6	19	20			
700: 800	KEEL-JANE	UP	6	6	21	18			
700: 800	JANE-WEST	UP	6	6	22	18			1
700: 800	WEST-TORY	UP	7	6	6	7	1		
700: 800	WEST-RUMI	UP	2	2	3	3			
700: 800	WEST-WARD	UP	9	7	3	3	2		
700: 800	WEST-ALBN	UP	9	8	7	6	1		
700: 800	ALBN-SILV	UP	8	7	7	6	1		
700: 800	SILV-HUMB	UP	6	5	6	6	1		
700: 800	BATH-STN.	DOWN	8	8	19	18			1
700: 800	DUFF-BATH	DOWN	6	6	19	19			
700: 800	KEEL-DUFF	DOWN	6	6	20	18			
700: 800	JANE-KEEL	DOWN	6	6	20	17			3
700: 800	WEST-JANE	DOWN	6	6	19	20			1
700: 800	TORY-WEST	DOWN	7	8	7	7		1	
700: 800	RUMI-WEST	DOWN	3	3	5	3			
700: 800	WARD-WEST	DOWN	9	8	2	2	1		
700: 800	ALBN-WEST	DOWN	9	9	7	6			1
700: 800	SILV-ISLI	DOWN	8	8	7	6			
700: 800	HUMB-SILV	DOWN	6	6	7	7			

TABLE 34
LOST MILEAGE REPORT (TORONTO) (*14*)

LOST MILEAGE REPORT
DATE:86/06/21
SCHEDULE :- SATURDAY

ROUTE	RUN	TIME	OLD DIR	VEH NO.	SHORT TURN POINT	SCH. DESTINATION	MILES LOST	KM LOST	REASON CODE
29	2	17:30	UP	8448	DUFFERIN-JANE OSL	WIL UPPE-EAST SID	2	3	5
29	6	15:32	DN	8278	DUFFERIN-DUNDAS	DUFFERIN-ONT PL.	4	7	5
29	6	18:44	DN	8278	DUFFERIN-DUNDAS	DUFFERIN-ONT PL.	4	7	5
29	7	17:52	UP	8626	DUFFERIN-JANE OSL	WIL UPPE-EAST SID	2	3	5
29	9	18: 0	UP	7550	DUFFERIN-JANE OSL	WIL UPPE-EAST SID	2	3	5
35	2	15:26	UP	8577	JANE -WILSON	STEELES -JANE	8	12	4
35	6	16:29	DN	8074	JANE -LAWRENCE	JANE -STATION	8	13	5
35	7	14:57	DN	8811	JANE -LAWRENCE	JANE -STATION	8	13	4
35	21	14:55	UP	7533	JANE -YEWTREE	STEELES -JANE	3	5	4
					MILEAGES LOST FOR THE DAY		41	66	
					TOTAL MILEAGES LOST		41	66	

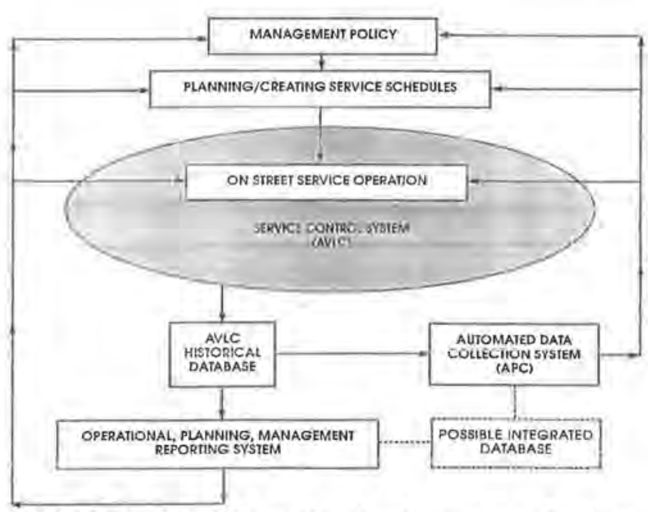


FIGURE 15 Flow of reporting data between user functions (*15*).

CHAPTER FOUR

RESEARCH REVIEW

Several studies have analyzed the various aspects of bus service reliability and their service supervision implications. These studies have included (a) empirical analyses of bus travel times, (b) theoretical analyses of headway-based control strategies, and (c) field investigations of various service control methods. This chapter summarizes some of the more relevant investigations and their implications for improving bus service supervision.

BUS TRAVEL TIMES

Setting realistic schedules requires field observations of actual travel times, taking traffic conditions into account and simulating the time lost in serving passengers. Several research studies have also developed guidelines for bus travel times as a function of stop spacing, dwell times, and traffic signal frequency.

A detailed analysis of bus travel times and speeds was conducted in a cross section of U.S. cities in 1980 (*16, 17*). The study, which was designed to provide inputs for the transportation system modeling process, produced parameters for use in transit planning. Three basic analyses were conducted: (a) bus and car speeds were compared; (b) bus travel times and delays were estimated from various field studies; and (c) bus travel times were derived based upon dwell times, traffic congestion, actual acceleration and deceleration rates, and distance between stops.

The estimated peak-hour service transit travel times based upon observations in Oakland, Minneapolis, New Haven, Santa Ana, St. Louis, and Boston are summarized in Table 35. The data is shown in minutes per mile for CBD, central city, and suburban conditions. The following characteristics were found:

- Peak-hour bus travel times approximate 4.20 min/mile in suburban areas, 6.00 min/mile in the central city, and 11.50 min/mile in the CBD.
- The time in motion approximates 3.00 min/mile in the suburbs, 3.90 min/mile in the central city, and 5.50 min/mile in the CBD. It appears to vary inversely with the frequency of stops.
- Passenger stops account for 0.50 min/mile in the suburbs, 1.20 min/mile in the city, and 3.00 min/mile in the CBD.
- Traffic delay amounts to 0.70 min/mile in the suburbs, 0.90 min/mile in the city, and 3.00 min/mile in the CBD.

TABLE 35
ESTIMATED PEAK-HOUR BUS TRAVEL TIME BY COMPONENT (*17*)

Component	Travel Time (min/mile)[a]		
	CBD	City	Suburbs
Traffic delay	3.00 ± 1.00	0.90 ± 0.30	0.70 ± 0.10
Passenger stops	3.00 ± 1.00	1.20 ± 0.30	0.50 ± 0.10
Moving	5.50 ± 1.00	3.90 ± 0.30	3.00 ± 0.12
Total	11.50 ± 3.00	6.00 ± 0.90	4.20 ± 0.30

Note: Data are from Tables 2 and 3.
[a] Plus-or-minus values represent one standard deviation.

Bus travel times and speeds as a function of stop spacing, passenger dwell times, and street traffic congestion are shown in Table 36 (*18*). This table produces a guide for setting schedules and assessing impacts of changes in traffic controls and operating policy.

These findings are confirmed by a study of transit service regularity conducted by Abkowitz and Engelstein in 1984 (*19*). Their analysis of bus running times based upon bus operations data from Queen City Metro, Cincinnati, found that "mean running time is strongly influenced by trip distance, passengers boarding and alighting, and signalized intersections; other route characteristics have a lesser effect on this measure."

BUS ARRIVAL TIMES

Several researchers have studied the distributions of bus arrival times, and showed how these patterns fit various mathematical distributions. Turnquist (*20*) suggested that the distribution of bus arrivals at a point follows a lognormal distribution. A subsequent study by Talley and Becker (*21*) suggested that the exponential probability distribution should be used to compute the probability that buses on a particular route arriving at a given bus stop will be more than a specified number of minutes early or late. They proposed a formula similar to that for estimating the distribution of headways on a highway.

A further study of on-time performance was conducted by Guenthner and Hamat (*22*) on four bus lines of the Milwaukee County Transit System. The bus system operates 27 local and nine express routes; routes follow a grid system, and a free 1-hr unlimited use transfer is available. The four routes studied—Routes 10, 23, 30, and 31—passed through downtown Milwaukee and through a common point (12th Street and Wisconsin Avenue). Data was collected for a.m. peak, midday, and p.m. peak conditions. Analyses were made of the adjusted arrival times—the difference between scheduled and actual arrival times. The study found that the differences between scheduled and actual arrival times follow a gamma distribution. This distribution has a shorter left tail than right tail. Thus, it reflects actual schedule deviations quite well; the long right tail denotes the buses that arrive quite late. The shorter left tail reflects earliness of buses, which can be controlled. When the drivers feel that they are early, they may slow down or wait some time at bus stops. But if they are late, the only thing they can do is

TABLE 36
BUS TRAVEL TIMES AND SPEEDS AS A FUNCTION OF STOP SPACING AND TRAFFIC CONGESTION (*18*)

				With Traffic Delays (peak conditions)					
		Without Traffic Delays		Central Business District: 3.0 min/mi delay		Central City: 0.9 min/mi delay		Suburban: 0.7 min/mi delay	
Time per Stop (sec)	Stops per Mile	Travel Time (min/mi)	Speed (mph)	Travel Time (min/mi)	Speed (mph)	Travel Time (min/mi)	Speed (mph)	Travel Time (min/mi)	Speed (mph)
10	2	2.40	25.0	5.40	11.1	33.30	18.2	3.10	19.4
	4	3.27	18.3	6.27	9.6	4.17	14.4	3.97	15.1
	6	4.30	14.0	7.30	8.2	5.20	11.5	5.00	12.0
	8	5.33	11.3	8.33	7.2	6.23	9.6	6.03	10.0
	10	7.00	8.6	10.00	6.0	7.90	7.6	7.70	7.8
20	2	2.73	22.0	5.73	10.5	3.63	16.5	3.43	17.5
	4	3.93	15.3	6.93	8.8	4.83	12.4	4.63	13.0
	6	5.30	11.3	8.30	7.2	6.20	9.7	6.00	10.0
	8	6.67	9.0	9.97	6.0	7.57	7.9	7.37	8.1
	10	8.67	6.9	11.67	5.1	9.57	6.3	9.37	6.4
30	2	3.07	19.5	6.07	9.9	3.97	15.1	3.77	15.9
	4	4.60	13.0	7.60	7.9	5.50	10.9	5.30	11.3
	6	6.30	4.5	9.30	6.5	7.20	8.3	7.00	8.6
	8	8.00	7.5	11.00	5.5	8.90	6.7	8.70	6.9
	10	10.33	5.8	13.33	4.5	11.23	5.3	11.03	5.4

to speed up a little or maybe not stop at certain points along the route. Lateness can be caused by many factors that the bus operators cannot control; one of them is traffic congestion. Because of these uncontrolled factors, some buses might arrive extremely late. These extremely late arrivals are represented by the long right tail of this gamma distribution.

HEADWAY CONTROL STRATEGIES

The concept of "spacing" buses to obtain uniform headways between buses has long been applied in the transit industry. In the last 15 years, it also has been the subject of considerable theoretical research that tends to give it credence.

Vehicles are held at control points along a route to regularize headways between successive vehicles. Thus, if a vehicle arrives at a control stop too close to the preceding vehicle, it would be deliberately delayed to make the headway between these vehicles more nearly equal to the scheduled headway.

Range of Applications

Turnquist and Blume (*23*), in a theoretical analysis, identified the range of applications for such control strategies. They indicated that the "major incentive for making headways more regular is to reduce waiting time of passengers who board at or beyond the control point." Making headways more regular reduces the variance of the headways, and, in turn, the average waiting time.

They indicated that the major costs of such a policy are borne by passengers who are already on the vehicle, since they are delayed when the bus is held up. Thus, the implementation of a holding control strategy involves making some passengers better off at the expense of others. At a minimum, if control is to be effective, it must reduce aggregate waiting time by more than it increases aggregate in-vehicle time (possibly allowing for some differential weighing of these two elements of total trip time).

The results of their mathematical analysis for dealing with these trade-offs are developed in Figures 16 and 17. Figure 16 suggests that it is desirable to control a route at a point where relatively few people are on the vehicle and relatively many are waiting to board at subsequent stops.

Generally, this means that the control point should be located as early along the vehicle's route as possible. However, reliability problems worsen as a bus proceeds along a route. If dispatching at the route origin is effective, the headways will be reasonably regular at the early spots along the route, which implies that the variation will be small. At stops further along the route, however, the variation in headways will tend to be larger. Thus, the deci-

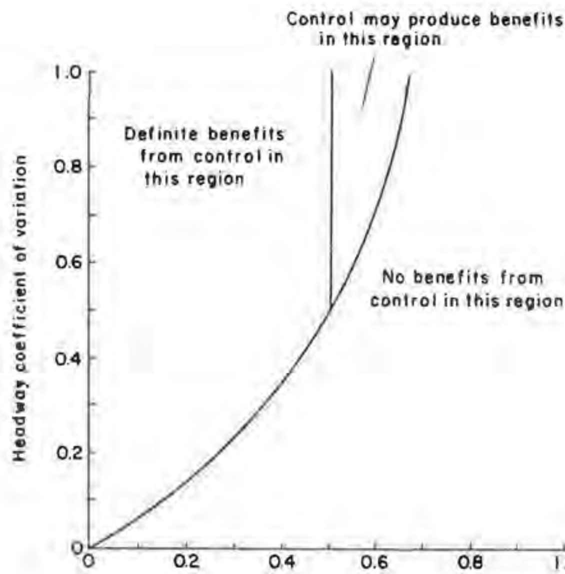


FIGURE 16 Areas of potential usefulness for headway control (*23*).

sion to implement a control strategy is tied to identification of logical control points along the route.

Each stop along a route will have a particular headway distribution. Thus, each stop could be plotted as a point in the space defined by these two variables, as shown in Figure 17. Then, by looking at the trajectory of the route relative to the boundary values, the transit operator can make a decision about whether or not to control the route and, if so, where. For example, for the route illustrated, control at Stop 3 might be worthwhile, but at Stop 8 it is unlikely to be beneficial.

In a further study, Turnquist showed how holding strategies can be one of several techniques that can improve bus service reliability (*24*). Bus bunching was related to frequency of service, variability of link travel times, and level of demand. The research identified several practical implications for transit managers who are attempting to improve the level of service provided to passengers.

The influence of transfers on level of service points calls for giving special attention to the on-time arrival of vehicles at major transfer stations. This is especially true for radially oriented network structures. As a rule, providing excess slack time in the route schedule is to be avoided, since it tends to increase travel time and reduce vehicle productivity. However, when a large number of passenger transfers can be aided by creating enough slack time to assure successful connections, allowing a short delay may be highly beneficial. In such cases, the slack time could be provided at the major connecting point.

The major sources of reliability problems in transit service were identified as bunching of vehicles and poor connections at transfer points. In a broad sense, then, the major objectives of control strategies are to keep bunches from forming (or to break them up after they have formed) and to ensure that scheduled arrival times at transfer points are met. At a more detailed level, deviations from schedule, which lead to bunching and poor transfer connections, can be traced to excessive variability in either link travel times between stops or dwell times at stops.

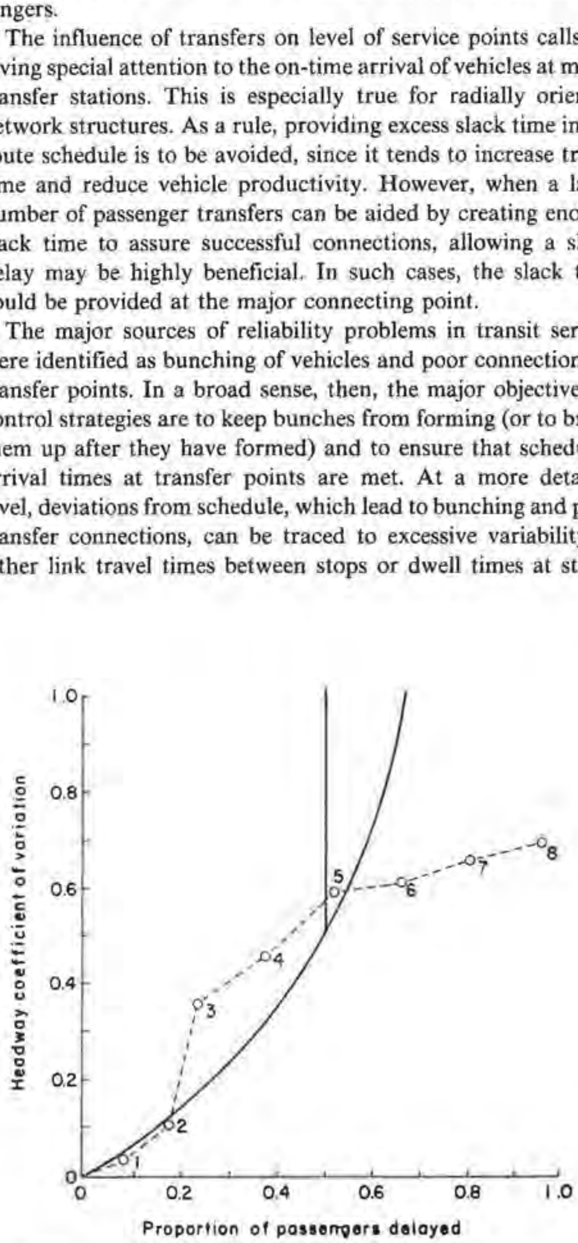


FIGURE 17 Trajectory of stops along a bus route (*23*).

Therefore, potential control strategies should be focused on reducing one or both of these sources of variability.

Accordingly, four classes of strategies for improving the reliability of bus transit service were analyzed: vehicle-holding strategies, reduction of the number of stops made by each bus, signal preemption, and provision of exclusive right of way.

The principal findings were: (a) strategies to improve service reliability can have very substantial impacts on overall service quality, including improvements in average wait and in-vehicle time as well, and (b) the best strategy to use in a particular situation depends on several factors, but service frequency is the most important. For low-frequency services (less than 10 buses per hour), schedule-based holding strategies or zone scheduling is likely to work best. For mid-frequency services (10 to 30 buses per hour), zone scheduling or signal preemption is likely to be most effective, although headway-based holding can also work well if an appropriate control point can be found. In high-frequency situations (more than 30 buses per hour), an exclusive lane combined with signal preemption should be considered.

These guidelines are based more in theory than actual transit operations. In practice, schedule adjustment problems are important for high-frequency services; bus signal preemption has a very selective application; and the feasibility of bus priority lanes depends upon many other factors than bus volume.

Time and Location Variations

Transit running times were examined during various times of the day in different directions of travel, and at different points along a route by Abkowitz and Engelstein (*25*). Their analyses were based on data collected in 1978 by General Motors on two bus routes that extended radially from the central business district along the same corridor. Three running time measures were analyzed: (a) mean running time, (b) running time variations, and (c) cumulative running time variation.

Transit running times were found to be highest and most variable during the afternoon peak period. However, daytime and evening off-peak service also had reliability problems. Regardless of time period, the variation of running time increased with distance from the route origin; thus service deteriorated as buses proceeded downstream. This finding is consistent with results of a similar study conducted in Minneapolis (*26*). It also is consistent with the operating experiences and practices of many transit agencies who find long bus routes unreliable, and, therefore, try to shorten or break routes wherever feasible.

Effects of Route Characteristics

The patterns of passengers boarding and alighting along a route also influence the effectiveness of headway-based reliability control. These effects were modeled by Abkowitz and Tozzi (*27*), drawing upon a modeling methodology validated by data obtained from the SCRTD. Five basic ridership profiles were tested; each varied the locations where people enter and leave the buses along the route. The scenarios and the test results are shown in Table 37. Evaluation of each boarding and alighting profile was conducted by using a 20-stop route with a total of 60 passengers boarding and alighting; all other parameters were held constant.

TABLE 37
PASSENGER BOARDING AND ALIGHTING PROFILES TESTED (*27*)

Profile	Boarding	Alighting	Route Type	Effectiveness of Headway Control
1	Beginning of route	End of route	Begin in suburbs and end in CBD - AM peak period Begin in CBD and end in suburbs - PM peak period	Not effective
2	Beginning of route	Middle and end	Similar to 1 with intermediate passenger alighting	Not effective
3	Beginning of route	Middle of route	Begin in suburbs and pass through CBD	Not effective
4	Uniformly along route	Uniformly along route	Route operating entirely in CBD	Apparently effective
5	Middle of route	End of route	Route begins before CBD and ends in suburbs during PM peak	Apparently effective

Headway-based control proved to be ineffective for those profiles that had passengers boarding at the beginning and alighting at the end, middle, or middle and end of a route, profiles 1, 2, and 3. For these three scenarios, passengers are boarding the bus during the first few stops. Regardless of where these passengers alight, the reduction in total passenger wait time associated with implementing a control strategy is negligible. Control is not effective under these conditions because of the lack of passengers boarding downstream and the relatively large number of people on board the bus at any potential control point. If there are no passengers waiting downstream of the initial boardings, there is no benefit from holding buses. Rather, additional delays are sustained by passengers detained on board the bus at the holding point. The results were consistent across headways ranging from 4 to 10 min.

These results are not surprising; they are similar to what occurs when there are many closely spaced, lightly used stops (or stations). The time lost by passengers on the vehicles vastly exceeds the time saved by passengers using the stop.

Uniform boarding (profile 4) showed marginal reductions in wait time unless the route ridership is large or the importance assigned to passengers detained at the control stop is less than the importance assigned to passengers waiting downstream of the control stop.

The best results occur for profiles in which the number of passengers on board at early stops is low and most passengers board at the middle of the route and alight at the end (profile 5). Increases in the initial headway variation and amount of peaking permitted deteriorate route reliability, which makes headway-based control more effective.

Effects of Holding Buses

The effects of implementing headway-based reliability control on Massachusetts Bay Transportation Authority (MBTA) bus routes were analyzed by Abkowitz and Lepofsky (*28*). Buses were held at control points on two routes until a specified minimum headway was achieved.

The routes and stops studied are shown in Table 38. The two routes, Routes 1 and 57, vary considerably in their operating characteristics. Route 1 is a crosstown route, connecting Cambridge to downtown Boston and then out to the South End and Roxbury. Route 57 is a radial route that connects the inner suburb of Watertown to the Central City (Boston) at Kenmore Square. Although the headway and alighting profiles of most radial routes are not conducive to delaying passengers on board in the middle of the route while proceeding to the CBD, Route 57 was included to test the variability of control strategies under different route conditions. Figure 18 shows the data collection points used in the evaluation.

Results of the experiments are shown in Figures 19 and 20 for Routes 1 and 57 respectively.

- There was a small, but measurable, improvement in running time variation when headway control was improved along Route 1 at Massachusetts Avenue/MIT. This result was consistent along the entire route, not just immediately downstream of the control point. This suggests that either the benefit accrued to the entire route operation, or drivers in general knew they were being held more accountable for consistent performance. Running-time variation propagates along a route, confirming the effects reported by previous research. Similarly, headway variation was reduced, reflecting the usual high correlation between running time variation and headway variation. Mean running time variation between the control point and the succeeding observation point decreased by 35 percent.
- Results for the second Route 1 experiment with control at Harvard Square Terminal Station were less conclusive. There was a slight deterioration in running-time variation following control implementation, and a mixed result for headway variation. However, the location of Harvard Station, at a route terminus with special schedule considerations (slack time) and normally no dispatcher on-site made it far more difficult to isolate the effects due to headway-based control.
- Route 57 received no benefits from headway control.

Taking the case where it appears that a benefit may have been derived from implementing reliability control, namely Route 1

TABLE 38
MBTA ROUTES AND STOPS SELECTED FOR HEADWAY-BASED CONTROL (*28*)

Route number (1)	Route name (2)	Direction/time period (3)	Stop location/threshold (4)
1	Dudley/Harvard	Outbound P.M.	Massachusetts Avenue and MIT, threshold = 1.75 min
57	Kenmore/Watertown	Inbound A.M.	Cambridge and Gordon, threshold = 1.50 min
1	Harvard/Dudley	Inbound P.M.	Massachusetts Avenue and Holyoke (Harvard Station), threshold = 3.50 min

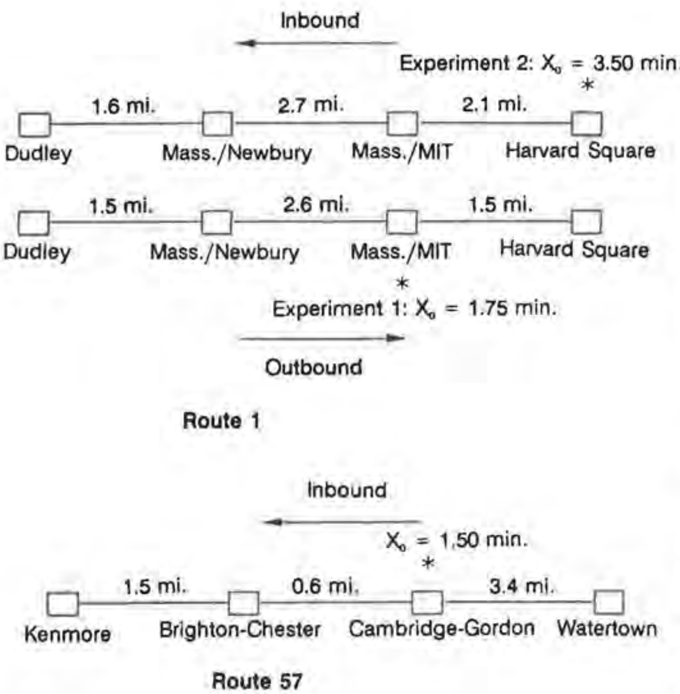


FIGURE 18 MBTA reliability control experiment (*28*).

with control at Massachusetts Avenue/MIT, waiting time savings will accrue because of the decrease in headway variation realized following the use of control. In this instance, for the observation point immediately downstream of the control point, the expected waiting time for a person waiting to board would be 6.22 min without headway control, and 5.75 min with control in effect. While this benefit may seem small on an individual basis, it does represent an 8 percent decrease in waiting time in the aggregate.

The characteristics of transit routes where headway-based holding is likely to be most beneficial are evident on Route 1. This is a crosstown route operating at service frequencies where random passenger arrivals to bus stops are generally expected. The selection of a headway-based control point on such a route depends on the boarding/alighting profile, but in general its viability is established by selecting a point along the route where on-board delays due to holding actions are not too cumbersome, yet are sufficient for passengers waiting downstream to benefit from more uniform headways. Such was the case in the first Route 1 experiment.

Because street supervisors in the demonstration did not appear to have held all vehicles where such action was warranted, the reported effect of control-point holding may have been understated. Even so, the implications of decreased headway variation from headway based holding on reducing vehicle requirements could be significant. Such a decision would necessarily depend on the distribution of passenger load relative to vehicle capacity, and the ability to keep headway variation constant with control at larger scheduled headways. This may preclude a transit operator from taking maximum advantage of service benefits since it works best on close headway routes.

SCRTD SERVICE RELIABILITY PROGRAM

A major objective of SCRTD is to provide reliable, cost-effective service to the public. Meeting this objective includes the resolution of problems of poor on-time performance, overcrowding, and pass-ups that persist on many of the district's lines. Accordingly, in December 1988 SCRTD implemented a pilot program (Service Reliability Improvement Pilot Program or SRIPP) to comprehensively study and deal with the problem of poor service reliability. Based on the promising results of the pilot program, the Board of Directors approved funding for a large-scale "Service Reliability Program" (SRP) beginning Fiscal 1990 (J. Woodhull, personal communication, 1991).

To make the SRP viable, a Transportation Operator Supervisors (TOS) redeployment plan was developed calling for reducing the number of mobile units assigned to outlying areas from 30 to 21. Personnel reassigned from outlying mobile districts, coupled with 10 additional funded positions, allowed for the deployment of 11 supervisory teams on targeted bus lines. Between October 1989 and December 1990, SRP was implemented on a total of 39 lines representing all areas served by SCRTD. The targeted lines account for nearly 60 percent of total daily ridership (Table 39).

Unlike traditional service management strategies that involve relatively low levels of actual road supervision and rely on reactive authority-oriented tactics, SRP incorporates such innovative features as proactive road supervision, integrated field functions (data collection, service monitoring, and supervision) and team-oriented approaches to identifying and resolving problems on a line. Since its inception, SRP has sought to provide empirical assessments of the relative effectiveness of different service man-

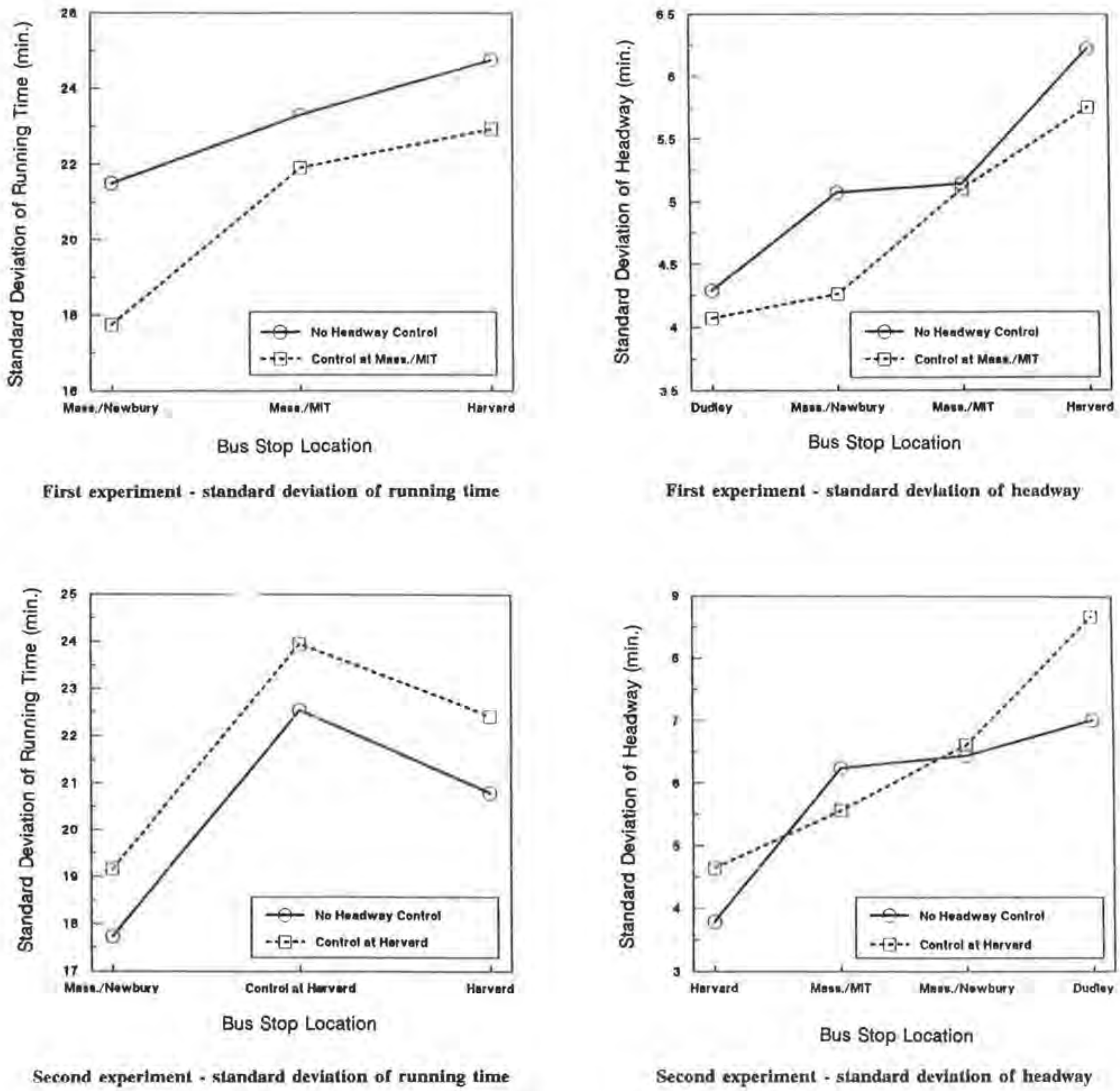


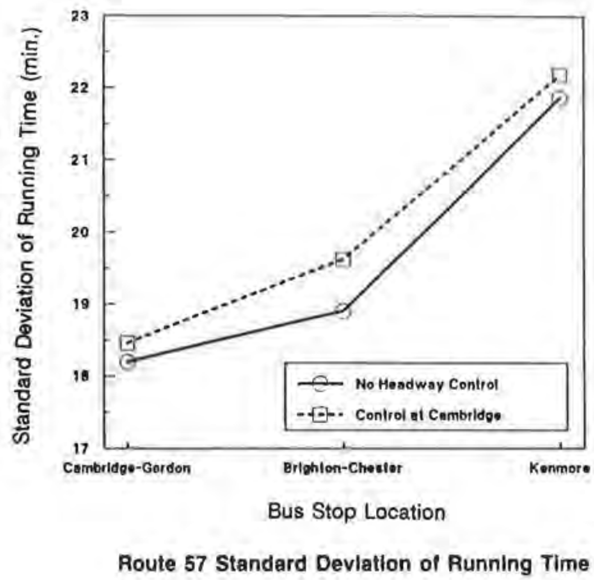
FIGURE 19 Results of MBTA Route 1 experiments (*28*).

agement strategies (e.g., intensive line supervision versus intermittent supervision).

The General SRP Process

Figure 21 depicts the general SRP service management process. Once a line is targeted for strategic management under SRP, the following actions are taken:

- Line operators are notified about the program by TOS assigned to the line. During this process TOS solicit comments and suggestions concerning service quality from the operators. A formal written survey of line operators is often conducted, a priori, to obtain their opinions concerning factors that contribute to poor service quality. Table 40 presents a summary of operators' ranking of factors on a subset of targeted lines.
- On some lines TOS conduct informal interviews with riders to gain insight into a line's operation from the patrons' perspective. Plans are being developed to make formal passenger surveys a routine part of the SRP process.
- TOS establish a highly-visible supervisory presence on the targeted line during which time they observe the line's operation and identify scheduling, safety, and other problems.



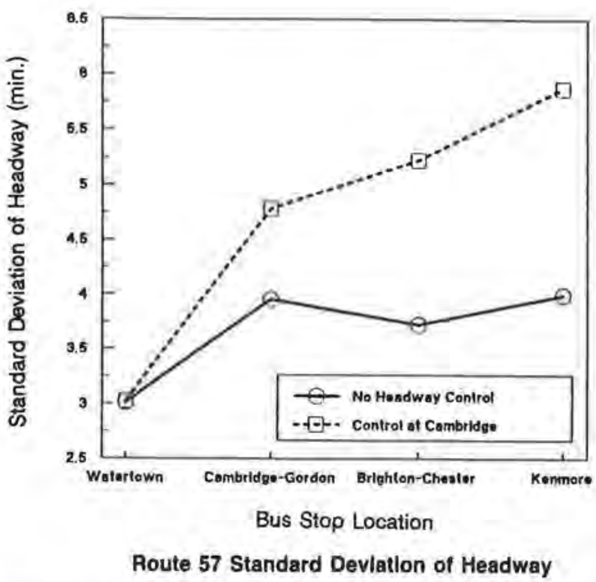


FIGURE 20 Results of Route 57 experiments (*28*).

- TOS devise and test alternative strategies to alleviate problems and submit suggestions and recommendations for review using the "TOS Weekly Problem Report" form (Figure 22).
- Team meetings are held among TOS Operations Control staff, and Scheduling/Operations Planning staff to discuss and further refine recommendations made by the road supervisors. Team meetings typically result in specific actions being taken by Scheduling/Operations Planning staff such as adjusting running times and modifying routes. If schedule, route, or other types of changes are implemented, TOS monitor the line to ensure the changes are working as planned.
- TOS maintain a presence on the line as needed. Supervisors assigned to the SRP generally do not respond to routine calls on nontargeted lines.

Alternative Line Supervision Strategies Attempted

To determine which service management strategy (or combination of strategies) is most cost-effective given very limited supervisory resources, four alternative TOS deployment strategies were implemented and evaluated in conjunction with SRP:

- Short-Term Intensive Supervision—Individual target lines are intensively supervised for a period of 1 to 3 weeks in accordance with the "general SRP process" previously described.
- Long-Term Intensive Supervision—Individual targeted lines are intensively supervised for a period of 4 to 12 weeks.
- Intermittent (Random-Based) Supervision—Multiple lines (two to five) are supervised on a random basis over time. The duration of supervision typically varies between 1 to 3 days per line, per episode.
- Preliminary "Corridor Concept"—Multiple lines (three to five) operating within a well-defined corridor are systematically managed in such a manner that all targeted lines receive highly-visible supervision on a regular basis.

Preliminary Findings and Results

Preliminary findings and results from SCRTD's Service Reliability Program are as follows:

- Load distribution on the targeted lines improved during the a.m. peak rush. The data show that the percentage of trips having more than 20 standees is substantially reduced during the a.m. peak rush when SRP is in place. Reducing overloads in this manner may help to minimize the number of scheduled trips required to operate service within established loading standards.
- Short-term, intensive supervision is an effective strategy for achieving an immediate positive impact on a line's operation. Typically, there are fewer operational problems (e.g., bunched buses and buses out of order). On nearly all lines tested, there was a measurable reduction in the number of pass-up complaints during the first two weeks of intensive supervision. Unfortunately, apart from possible long-term benefits resulting from permanent schedule adjustments, much of the initial effect dissipates within weeks of the supervisors leaving the line.
- Long-term, intensive supervision appears to have a more sustained effect on a line's supervision than short-term supervision. On most lines, it appears that an ongoing supervisory presence is required to maintain the positive effects realized during the first few weeks of implementation. However, given very limited resources for road supervision, long-term intensive supervision of individual lines usually is not feasible.
- Intermittent (random) supervision is not as effective as other service management strategies. The absence of regularly occurring supervision on some lines tends to result in "business as usual" when supervisors are not present. Intermittent (or random) supervision also limits the opportunities road supervisors have to identify and resolve the full range of scheduling and operation problems that can occur on a line.
- The preliminary "corridor concept" appeared to be an effective long-term service management strategy. Unlike intermittent (random) supervision, strategically managing the service within well-defined corridors promotes the perception that a line is being monitored on a regular basis.

TABLE 39
SCRTD--SERVICE RELIABILITY PROGRAM TARGET LINES (OCTOBER 1989-DECEMBER 1990)

Line	Estimated Daily Boardings	Percent of Total Boardings
1	29,811	2.26
4	41,957	3.19
10	24,057	1.83
20	59,866	4.55
28	43,913	3.34
30	46,035	3.50
33	25,454	1.93
40	33,744	2.56
45	29,860	2.27
53	16,073	1.22
55	13,250	1.01
60	30,823	2.34
66	25,327	1.92
68	20,611	1.57
70	17,428	1.32
78	13,156	1.00
81	20,358	1.55
90	6,372	0.48
92	12,462	0.95
94	16,664	1.27
105	19,276	1.46
117	10,306	0.78
152	9,785	0.74
165	13,801	1.05
180	18,667	1.42
202	2,663	0.20
204	52,513	3.99
205	3,471	0.26
212	14,167	1.08
251	22,431	1.70
260	13,951	1.06
420	20,951	1.59
424	19,302	1.47
460	3,234	0.25
480	6,480	0.49
484	9,017	0.69
487	3,984	0.30
497	1,914	0.15
590	14,914	1.13
Total SRP Lines:	788,048	59.87%
Total All Lines:	1,316,313	100.00%

Source: SCRTD

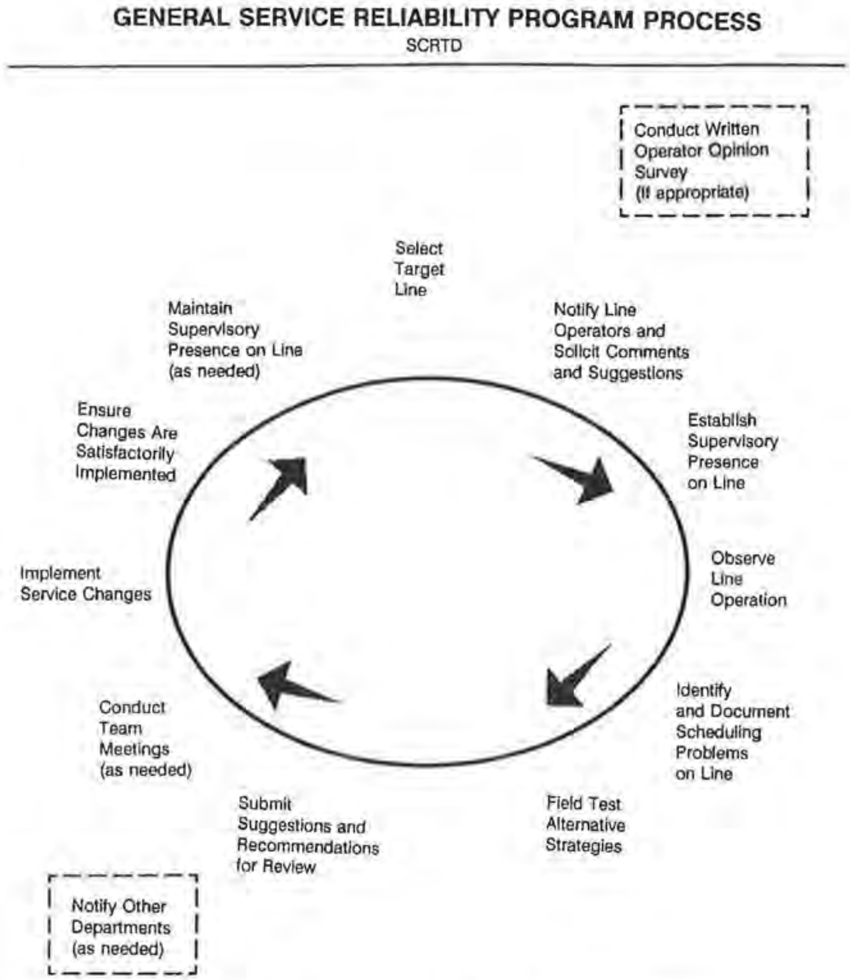


FIGURE 21 General Service Reliability Program Process (SCRTD).

- SRP significantly improved communication between operators and supervisors on targeted lines. Approximately 90 percent of a sample of operators indicated they felt comfortable making suggestions and providing comments to SRP supervisors regarding service reliability on their respective lines.
- Inter-operator cooperation improved on the targeted lines. Operators generally felt that there was more cooperation among themselves when the line was intensively supervised than when it was not. Moreover, there appeared to be less operator apathy on the targeted lines, as evidenced by the fact that operators report pass-ups and overcrowded conditions at a much higher rate when the program is in place.
- According to operators on the five initial target lines, overall line operation appears to have improved. Nearly 70 percent of the operators surveyed felt their line ran somewhat more smoothly once special attention was paid to the line.
- Operators tend to respond very favorably and show a greater willingness to participate in improving service when the program is well publicized.
- There is a need to regularly rotate SRP road supervisors among target lines. During periods of long-term intensive supervision, several SRP road supervisors expressed concern about being assigned to the same line for more than 4 to 5 consecutive weeks. It appears that regularly rotating TOS among lines is very important to maintaining a high degree of motivation.
- Intensive road supervision is requisite to discerning whether problems of poor service reliability are "scheduling" or "operational" in nature (or a result of other factors).

Current TOS Deployment Strategy

Based on the program's preliminary findings and the need to maximize limited field supervisory resources, SRP staff implemented an expanded and refined corridor-based TOS deployment plan in January 1991. The capability to apply short-term intensive supervision on certain targeted lines was, however, retained as part of the current deployment strategy.

To make the expanded corridor-based deployment plan operational, eight "Strategic Management Corridors" throughout the SCRTD service area were identified:

TABLE 40
SRP OPERATOR OPINION SURVEY—RANK ORDER OF FACTORS THAT CONTRIBUTE TO POOR SERVICE

-- Regular Operators Only --

LINES	Not Enough Running Time (Pks)	Poor Dist. of Running Time (Pks)	Not Enough RT (Off-Peak)	Poor Dist. of RT (Off-Peak)	Bus Breakdown	Lack of Cooperation Among Operators	Not Enough Scheduled Service	Uncooperative/Unruly Passengers	Unpredictable Traffic	Passups Due to Overloads
001	7	2	10	6	8	9	5	3	1	4
010	1	4	9	6	10	3	7	8	2	5
014	2	5	10	9	8	3	7	6	4	1
020	5	3.5	7	9	8	1	2	10	3.5	6
030	4	5	10	3	9	6.5	6.5	8	1	2
081	7.5	6	3.5	2	10	5	1	7.5	9	3.5
164	1	3	5	6.5	10	9	2	8	4	6.5
204	6	8	10	3.5	5	2	9	7	1	3.5
260	2	3	6	8	7	10	4	9	1	5
420	7	3	6	4	9.5	5	9.5	2	1	8
497*	4	2	9	8	3	10	5	7	1	6
Mean (Rank):	4.2 (3)	4.1 (2)	7.8 (9)	5.9 (7)	8.0 (10)	5.8 (6)	5.3 (5)	6.9 (8)	2.9 (1)	4.6 (4)

1 = Most important 10 = Least Important *Regular and Extra Operators

Source: SCRTD

Corridor	*Bus Lines*
Hollywood	1, 4, 10, 16, 180
Wilshire	18, 20, 28, 66
Venice	30, 33, 68
South	45, 53, 204, 207
Blue Line	55, 56, 60, 117, 202, 205
San Gabriel	70, 76, 78, 480, 497
San Fernando Valley	165, 420, 424, 560
East San Fernando Valley	90, 92, 94

Taken together, the 34 bus lines operating within the eight strategic corridors represent over half (56.5 percent) of the district's total daily ridership (see Table 41).

The expanded corridor deployment plan is a team-oriented strategy designed to further coordinate and integrate supervisory and scheduling functions while actively encouraging input from operating personnel. Field supervisors are systematically deployed to observe and report on the effectiveness of service and submit recommendations for improvement before problems develop. The corridor-based deployment plan also allows supervisors to respond immediately to complaints and input received from other sources. Unlike traditional supervisory methods, it incorporates a "bottom-up" approach to assuring real-time service reliability.

SRP Summary

SRP, which is being administered by SCRTD, is a nontraditional, highly innovative approach to strategic service management. SRP has resulted in, among other things, greater participation of line operators in identifying problems and suggesting solutions to those problems. Moreover, SRP has greatly enhanced the district's capability to provide timely and effective responses to scheduling problems by increasing communications between road supervisors and Scheduling and Operations Planning personnel. To date, SRP has been restricted to daily service between the hours of 5 a.m. and 9 p.m. Consideration is being given to expanding SRP to include weekend service.

PROPOSED CTA DEMONSTRATION PROGRAM

Research conducted by an interagency working group under the auspices of the Chicago Area Transportation Study (CATS)

SERVICE RELIABILITY PROGRAM
WEEKLY PROBLEM REPORT

(SCRTD)

Report ___ of ___

INSTRUCTIONS:
Describe operational problems detected on the line(s) targeted for the Service Reliability Program. This form shall be submitted on a weekly basis. Attach all pertinent documentation. Note only those problems that occur repeatedly; exclude conditions which are temporary in nature. Use a separate form for each problem.

TOS: ______________________ BADGE:__________ WEEK OF: Sun.___/___/___

I. DETAILS ABOUT PROBLEM (Important!! Fill this section out *completely*)

Problem:
[ ] Overloads
[ ] Running Time
[ ] Canceled Trip(s)
[ ] Pass-ups
[ ] Safety Hazard
[ ] Other (specify)______________

Line: __________ Location: ______________________ Bus Run(s): __________

Time Period: ________ Dates Observed: ______________________ Dir: __________

Documentation: [ ] Trans 1 [ ] OCPM-10 [ ] Supervisor's Time/Load Check [ ] Not Documented
[ ] Other (specify) ______________________

Comments: ____

NOTE: The Scheduling/Operations Planning Department must have data documenting the problem before corrective action can be taken.

II. PROPOSED CORRECTIVE ACTION

In the space below, please provide specific information regarding the proposed schedule/service adjustment. Include bus run numbers, times, direction, etc. (attach additional sheets, if necessary)

SEE REVERSE SIDE

II. PROPOSED CORRECTIVE ACTION (CONTINUED)

III. ADDITIONAL INFORMATION

a. Is the proposed action? [ ] Temporary [ ] Permanent

b. If temporary, what dates should the change be in effect? ______________________

The space below is for Office Use Only

ACTION REQUIRED (Check as many as appropriate)

[ ] Investigate feasibility of proposed action
[ ] Additional information/documentation required (specify below)
[ ] Implement proposed action (date______________________)
[ ] No action required at this time
[ ] Other (specify) ______________________

Remarks:

V. ACTION TAKEN

ROUTING LIST NAME	INITIALS

If proposed action cannot be taken, reasons: ______________________

Final disposition of proposal: ______________________

FIGURE 22 Service Reliability Program Weekly Problem Report (SCRTD).

TABLE 41
SERVICE RELIABILITY PROGRAM STRATEGIC SERVICE MANAGEMENT CORRIDORS

Corridor	No. Line Groups	No. AM Peak Buses Assigned	Estimated Daily Boardings	Percent of Total Boardings
Hollywood	5	145	138,166	10.5
Wilshire	4	183	156,502	11.9
Venice	3	93	92,100	7.0
South	4	115	135,327	10.3
Blue Line	6	100	65,832	5.0
San Gabriel	5	97	51,411	3.9
San Fernando	4	112	68,968	5.2
East San Fernando	3	59	35,498	2.7
Total (Corridors):	34	904[a]	743,804	56.5%
Total (System):	129	867	1,316,313	100.0%

[a]48.4% of total AM Peak Buses
Source: SCRTD

has identified traffic signal preemption as a very promising technique for improving both the speed and reliability of bus service. A body of previous research has identified these factors as keys to building transit ridership which, in turn, can help reduce traffic congestion. A particularly attractive feature found to be available from at least one vendor was the ability to limit signal preemption to late buses.

The CATS study suggested a demonstration in the city of Chicago in a corridor identified as South Michigan/119th Street, which is primarily served by CTA Routes 34 and 119, as well as Pace (the Chicago suburban bus operator) Route 353. An operating plan was developed that identifies intersections to be equipped, garages to be equipped (including likely component locations), an on-bus equipment installation plan, and a tentative division of responsibilities between the contractor, CTA, and the city of Chicago. The vendor identified by the CATS study submitted a fairly detailed proposal for the demonstration study installation. This included active passenger information signs at key stops based on "real-time" information.

A study conducted for CTA indicated that automatic vehicle location (AVL) also would be very effective in permitting supervisory forces to take timely action to restore scheduled service after a disruption. The same equipment can support both functions by adding phone lines back to a control center. This control center would need computer hardware and software capable of graphically displaying location and schedule adherence information. CTA considers the South Michigan/119th corridor to be an excellent place to test AVL as well.

The proposed demonstration project will include technology research, site visits to other cities, traffic signal preemption impact analysis, an interagency agreement relative to responsibilities, and preparation of a bid package.

The site visits would concentrate on communities with fixed-time traffic signals. They would serve to (a) identify actual traffic impacts, (b) observe models for traffic operator-round operator network coordination, (c) identify the most effective service restoration techniques found on AVL, and (d) identify on-board and wayside installation approaches (such as optional location of bus stops and inductive loops).

IMPLICATIONS

A growing body of research has identified the factors contributing to transit service reliability and the various ways to improve it. The research findings largely reinforce the intuition and experience of transit operators. Transit speeds depend upon stop and signal frequency, passenger dwell times, and traffic congestion. Headway variation, the primary characteristic of unreliable service, also correlates with traffic conditions and dwell times; it tends to propagate at stops downstream along a route.

Uniform spacing of vehicles is viewed as a desirable objective. However, holding strategies to improve reliability must be judiciously implemented to avoid unnecessary delays to passengers on vehicles. Reducing the effects of traffic congestion, by eliminating curb parking, signal pre-emption, or bus lanes, will improve reliability, but such techniques are usually limited to a few areas in each city.

Research appears to have shifted from analytical to empirical approaches and simulation methods. Still, much of the research remains focused on probability distribution patterns, rather than supervisory strategies. Assuring real-time service reliability through better supervision is far more than a mathematical exercise. Research results must be tempered with the results of transit operations. The SCRTD service reliability program is an important step in this direction.

CHAPTER FIVE

IMPLICATIONS AND DIRECTIONS

Unreliable bus service results from failures of the vehicles, drivers, and operating environment. Each must be addressed in improving service reliability. Effective supervision strategies are an important element, but they must be complemented by better traffic engineering, sound maintenance practices, realistic schedules, effective driver selection, and continuing training.

This chapter describes the problems and causes of unreliable bus service and shows how each can be addressed. Guidelines for improved supervision strategies are suggested, drawing upon the transit agency surveys, technology assessment, and research review.

PROBLEMS OF POOR PERFORMANCE

The problems resulting from unreliable or erratic bus service differ according to when, where, and how often the buses run. These differences must be recognized in developing specific supervision strategies.

On bus lines with long headways, unreliable service makes transfers undependable, and requires riders to take earlier trips to assure a connection. This tends to discourage riding where transfers are necessary.

The problem is somewhat different on high-volume, short-headway lines. The time lost due to poor on-time performance may be acceptable. However, late buses are likely to be overcrowded, and the delays can propagate along the line so that bus bunching may occur. Moreover, if a bus becomes overcrowded, the chance of a passenger being passed up is high.

Only the larger transit properties generally have reliability problems associated with short headway lines. However, both large and small properties have reliability problems associated with infrequent service. Although the problems of long-headway service appear to be more widespread, short-headway services may affect more people, and may be more difficult to rectify.

In identifying and assessing service reliability problems and appropriate supervision strategies, the on-time performance of each bus route should be quantified. This calls for field observations of on-time performance, or real-time automatic vehicle monitoring. Information obtained from APC systems will provide good service planning data for recurrent problems and driver behavior, but cannot respond to incidents or day-to-day problems. Analyses of APC and AVLC information will indicate the locations, extent, and nature of the schedule adherence problems.

After the routes with poor on-time performance have been identified, the underlying causes should be analyzed, and appropriate actions should be taken to correct the condition.

CAUSES OF POOR RELIABILITY

There are many reasons why buses run early or late, including those related to the traffic stream and surrounding environment (exogenous causes) and those related to the transit system (endogenous causes). Most can be controlled in part, few can be controlled in total (*29*). Some occur each day; others occur infrequently (e.g., emergencies, bus breakdowns).

Traffic Factors

The traffic-related factors that affect schedule adherence include (a) traffic signals, (b) curb parking/loading frictions, (c) variable traffic conditions, (d) unexpected occurrences, (e) weather, and (f) emergencies:

- *Traffic Signals.* Bus drivers become accustomed to traffic signal timing systems and try to adapt to them. However, the interplay between boarding and alighting passengers and frequent signal spacing along the route can cause irregularity in travel times and schedule adherence. This can be a serious problem on high-frequency bus routes that operate through intersections with long traffic signal cycle lengths.
- *Curb Parking.* Cars and commercial vehicles that park and unload along the curb often block moving travel lanes and impede bus flow. Such conditions are most acute along business streets in densely developed urban areas where off-street parking space is not adequate and there are high demands for curb access.
- *Variable Traffic Conditions.* Schedules can adapt to consistent or recurrent traffic conditions. However, when conditions are variable, the exact arrival times of buses will be difficult to achieve. These conditions are especially critical along heavily traveled freeways in large cities where automobile breakdowns, accidents, or ramp turbulence can create major peak hour congestion.
- *Unexpected Occurrences.* Examples include drawbridge openings or railroad grade crossings. A long or slow freight train is not only unpredictable, but it can cause extremely long delays.
- *Weather.* Rain or snow can affect bus and street traffic flow. Under severe weather conditions, schedules cannot be met, and, in extreme cases, service must be stopped.
- *Emergencies.* Fires, accidents, and other unexpected street closures will disrupt normal transit service. Special events may also require changes in routes or services.

These conditions can be ameliorated by both traffic engineering and transit actions. Traffic engineering treatments should be concentrated along bus routes; signal timing should favor these arterials, and complex multiple-phase timing plans should be simplified where possible. Curb parking should be prohibited during peak hours wherever land use conditions permit.

Bus priority lanes and ramp by-passes should be provided at points of recurrent congestion where bus volumes warrant. Bus (or HOV) lanes along congested freeways in large cities will help maintain reliable bus travel times. Selective traffic signal preemption (i.e., advancing or extending the given time when buses arrive) has potential applicability especially when limited to buses that run late. The signal preemption generally should be done within the existing signal cycle by extending or advancing the green time for buses.

The recurrent delays resulting from traffic congestion should be built into the bus schedules. Normal street supervision can respond to schedule adherence problems, i.e., slowing early buses or speeding late buses to maintain uniform intervals.

Emergency conditions require prompt response by bus supervisors. Where buses are late due to unusual circumstances, it may be necessary to turn back buses, run buses express, reroute buses, or when part of a street is impassable, to operate shuttle services on each side of the barrier.

Transit Factors

The "endogenous" transit-related factors that contribute to poor schedule adherence include: (a) fleet maintenance practices, (b) route structure, (c) stop pattern, (d) passenger arrival rates, (e) ridership variations and trends, (f) scheduling practices, and (g) driver selection, behavior, training, and supervision:

- *Maintenance Practices.* A well-maintained bus fleet minimizes the chances of a bus breaking down in service and the need for a replacement vehicle. Careful checking and quality control of buses before leaving a garage is also desirable to minimize the likelihood of a breakdown en route.
- *Route Structure.* Complex routes and schedules have a causal relationship to schedule variance. Long routes are more likely to present major schedule problems since schedule deviations propagate along the line. Complex routes, especially those with branches or short lines, require that management emphasize on-time performance to keep loads balanced on each branch.
- *Stop Spacing.* Stops that create lengthy boarding lines may be too widely spaced. Stops (on a busy line) with too few boarding passengers are too closely spaced.
- *Passenger Arrival Rate.* Variations in passenger arrival rates at major stops (e.g., schools, office buildings, industrial plants) may influence schedule adherence.
- *Variable Ridership.* If ridership on a bus route has large day-to-day changes, the bus might be early on days of low ridership and late on peak-ridership days. These variations can be built into the schedule where they are predictable, but they affect on-time performance when they occur randomly.
- *Ridership Changes.* If ridership has increased since the last schedule, a bus may be constantly late. Conversely, if ridership has declined, the bus may arrive ahead of schedule.
- *Scheduling Practices.* The schedule is the reference point for on-time performance. How well it represents actual operating conditions determines how closely it can be followed. An impossible schedule is hard to follow; where all buses operate ahead or behind schedule, adjustments may be needed. A realistic schedule is essential for effective supervision and on-time performance.
- *Driver Behavior.* Driver behavior is, perhaps, the greatest single cause of schedule variation. Drivers can leave terminals early or late. They can drive too fast or too slow for conditions, or to avoid heavy loads. Great skill is required to drive a bus over a busy line, collect fares, and answer questions under today's traffic conditions. However, driver behavior is largely influenced by selection, training, communication, motivation, and supervision. This is an area where transit management traditionally has been weak and improvements are needed.
- *Inadequate Supervision.* Supervision strategies may not be adequate for a given system. Resources may be inadequate; supervisors may be excessively diverted to other tasks; two-way radio or other communication system technology may not be available; and deployment may be improper.

These causes of schedule variation must be addressed individually and collectively. Supervision strategies can be effective only where they are reinforced by a well-maintained fleet, a reasonable route structure, a realistic schedule, and sound driver training and monitoring.

ROUTES AND SCHEDULES

Rational bus routes and realistic schedules contribute to reliable service. Routes should be clear and simple; complex routes with many branches should be avoided. A general guide is to set a limit of no more than two branches per route.

Similarly, long routes should be avoided, because they usually pose schedule adherence problems. Shorter lines are usually easier to keep on time because opportunities for recovery (i.e., layovers) occur more frequently and because delays propagate along a bus line. Accordingly, where practical, one long route should be broken into several shorter ones. This is easily accomplished where bus lines can be restructured to feed major rail transit stations or transit centers, possibly as part of a timed-transfer system. But it is not practical in every case.

Guidelines for route length vary. Routes generally should be as short as possible. Ideally, routes should not exceed 25 miles per round trip or a 2-hr travel time. The maximum round trip should never exceed 35 miles or 3 hr.

Looping routes in the CBD reduces route length relative to through routes. But this must be balanced against the additional traffic conflicts created, time and distance added, and possible inconvenience to passengers. Where this is not practical, service design should provide turnbacks at strategic points to reduce route length (see Figure 23).

Running Time Policies

Schedules must be realistic and kept up to date with traffic and operating conditions. A good schedule allows just enough time for the service to be operated. It should provide enough running time to account for normal delays due to traffic congestion, traffic signals, and passenger loads. The schedule should provide enough time at the terminal so that a driver who arrives late at the terminal can begin the next trip on time, where erratic travel times along a bus route mandate extra schedule recovery times.

Drivers *must* leave terminal points on time. If a driver leaves a terminal late, it is unlikely that the lost time will be recovered en route. If the driver leaves early, fewer passengers might be picked up en route, resulting in heavier passenger loads and

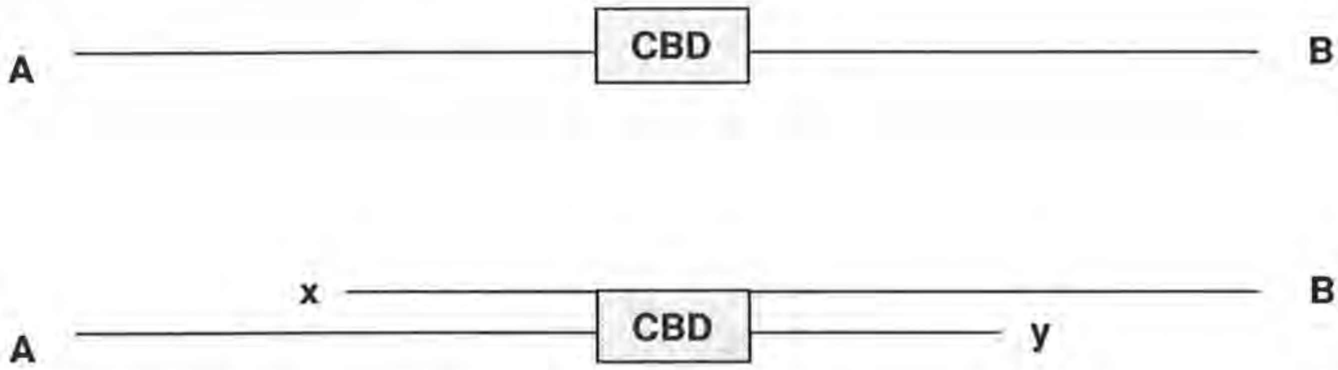


FIGURE 23 Route turnback concept to reduce route length.

likely lost running time on the following bus. Therefore, some means of communication (e.g., telephone, radio, or at-terminal supervision) is necessary to assure on-time departures, but this is not always possible.

Scheduled running time should, as closely as possible, reflect the variations in time required at different times of day on different days of the week. For example, the general practice at CTA includes the following elements:

- Routes are broken up into segments generally ranging from 5 to 10 min long (about 1 to 2 miles).
- To avoid a large number of operators having to "kill time," running time is set slightly shorter than the observed average, ignoring extreme observations.
- The percentage of observations achieving the scheduled time is lower for segments near the beginning of the line and is increased for segments toward the end of the line. This reduces the probability of operators having to "kill time" at the beginning of a trip only to fall behind further down the line.
- Manual observations of 30 to 60 percent of trips are made to form the basis of setting running time (with the arrival of APC units, it is anticipated that this will be significantly increased).
- Scheduled recovery time at the end of the route should be adequate to permit over 95 percent of trips to begin in the return direction on time. On a round trip basis, all trips should be able to get back on schedule under normal conditions.

Schedule-Related Strategies

Two basic schedule-related strategies can be used to improve on-time performance: (a) adjusting the schedule to reflect the service and (b) adjusting the service to meet the schedule:

- Adjusting the schedule might include added or reduced running time, longer or shorter layover periods, or occasionally changed time points.
- Adjusting the service might include increased monitoring, longer or shorter routes, fewer stops, express service, or bus priority treatments such as exclusive lanes or traffic signal pre-emption.

SUPERVISION STRATEGIES

Many supervisory strategies can be adopted to improve the reliability of bus service, and to achieve uniform spacing. These include service restoration/recovery techniques; control of schedules, headways, and passenger loads; and extraboard management. Improved technology can play an important role in reenforcing these strategies.

Table 42 shows how each of the supervision strategies relates to specific reliability problems and identifies the individual techniques that can be used. Applications are specific to each problem, route, and system; there are no simple mathematical formulas.

- Service restoration strategies should be used when there is a major disruption in service.
- Schedule control strategies should be used when buses run early or late.
- Headway control strategies apply along selected sections of outbound routes during the evening peak hour.
- Load control strategies address problems of delays and overloads at major passenger boarding points.
- Extraboard management strategies address the problems of absenteeism and missed runs.

Service Restoration Strategies

Several techniques can be used to bring bus service back to normal after it has been disrupted. The disruptions may result from an accident, fire, traffic blockage, or a bus breakdown.

- *Replace Defective Bus.* A spare bus from a garage replaces the defective bus; this works best when a bus is about to pull into a garage. If the replacement is made en route, passengers will be required to change buses.
- *Divert Bus From Another Route.* The bus may be taken from an intersecting bus line or from a bus in the opposite direction on the same route. This fills the gap in service and reduces loads on the delayed run, thereby avoiding further delays due to overloading. The impact of the diversion on the service from which it was taken must be considered.

TABLE 42

GUIDELINES FOR SUPERVISION STRATEGIES TO IMPROVE BUS SERVICE AND RELIABILITY

Problem	Strategy	Method
Service Disruption (Accidents, vehicle breakdowns, emergencies, weather)	Service Restoration	•Replace defective bus •Divert bus from another route •Provide standby or gap bus •Use supervisors' vans •Reroute bus •Run shuttle bus •Turn back (shortline) bus •Let following bus pass leader •Provide relief driver •Introduce bus delay
Late or Early Buses	Schedule Control	•Hold early bus •Change bus speed (slow early bus, speed late bus) •Reduce layover time
Heavily Traveled Bus Routes - Delays or Overcrowding	Headway Control	•Maintain headways (schedule adherence not required) •Let express buses run "free" on outbound trip from CBD
Delays and Overload at Major Boarding Points	Load Control	•Provide empty buses at terminal or major generator •Provide starter at terminal •Change fare collection practices
Absenteeism or No Show	Extraboard Management	•Require drivers to make extra trips •Hire overtime drivers •Modify extraboard procedures

• *Provide Standby or Gap Buses.* These buses are located on-street near points of major passenger activity. They are assigned as needed to fill "gaps" and pick up loads. (Note that this is an anticipatory technique to avoid service deterioration on heavy lines during peak periods.)

• *Use Supervisors' Vans.* Supervisors' vans can be used to carry passengers when a bus has broken down. Norfolk uses 13-passenger vans to carry passengers, especially along lightly-traveled bus lines. CTA uses vans to carry handicapped people when service is disrupted.

• *Reroute Bus.* When a bus route is blocked (e.g., by fire), buses can be rerouted around the blockade. This makes it possible to continue service without appreciable delay. It requires rerouting the buses on streets that are wide enough, have suitable vertical clearances at underpasses, and adequate turning radii.

• *Run Shuttle Bus.* Where a blockade cuts into a bus line, it may be desirable to have bus shuttles between the blockade and each terminal, although passengers would be delayed. Suitable bus turnarounds should be available on each side of the blockade.

• *Turnback Bus.* Turning around a late bus before it reaches the end of the route enables the bus to get back on schedule by sacrificing a part of the service. Often the loss in service will be on a portion of the line that is not heavily patronized.

• *Let Following Bus Pass Leader.* Sometimes a run is delayed because of a defective bus, an inexperienced operator, or other unusual circumstances. When this occurs, it may be desirable to put the following bus ahead, enabling it to fill the gap and to achieve a better distribution of passengers on each vehicle.

• *Provide Driver Relief.* Sometimes a run to be relieved is late coming into the relief point and the relieving operator is unable to make the other terminal on time. In such a case, the relief operator pulls a bus out of the garage and reaches the relief point at the regularly scheduled time. The late bus then proceeds directly to the garage. Passengers on the delayed bus will be further inconvenienced.

• *Introduce Bus Relay.* The "relay" sends an extra bus to meet a delayed bus. The extra bus operates on the prescribed schedule until it meets the delayed bus where the drivers exchange places. The delayed driver is now back on time going in the reverse direction in a new bus, and the extra driver finishes the delayed trip with the original bus and then returns to the starting point. Many transit agencies do not use relays, however, because this procedure offers too much discretion to the drivers by giving them an incentive for late running.

Schedule Control Strategies

Controlling to schedule is a management procedure that attempts to return buses to their original schedule. There are three basic techniques:

• *Change Bus Speeds.* This technique involves delaying or slowing buses that are ahead of schedule and speeding up buses that are behind schedule. It is one of the most commonly applied techniques.

• *Hold Early Bus.* While it is difficult to get an already delayed bus to move faster through heavy traffic, a bus ahead of schedule can be held until scheduled to depart. This "holding strategy" achieves uniform spacing with the following bus, and it reduces the passengers accumulated on the second bus.

• *Reduce Layover Time.* A bus arriving at a terminal behind schedule should leave the terminal on schedule. This may require reducing the layover and schedule recovery time at the terminal point.

Headway Control Strategies

Controlling headways is important, especially in peak periods on heavily traveled bus routes with short headways. Uniform headways are important to minimize overcrowding and to maximize passenger capacity of the scheduled vehicles. A difficulty sometimes arises in trying to maximize travel speeds while avoiding vehicle bunching and the associated overcrowding. There are two basic techniques:

• *Maintain Headways.* The objective of this technique is to maintain uniform headways whether or not individual buses are behind schedule; this is a "dynamic" scheduling concept. This concept applies to outbound p.m. peak-hour trips from the CBD on radial routes, where the maximum load point is at or near the CBD.

A variation of this technique involves the following two-fold approach: (a) During peak periods, especially when headways are less than 10 min, buses travel at maximum speed, provided that maximum headways are not violated and no passengers are left at stops; (b) in off-peak periods, or when headways are greater than 10 min, schedules are strictly maintained and synchronized at major transfer points. This concept, however, has yet to be fully applied in practice.

• *Let Express Buses Run "Free."* This technique lets express buses run "free" on the outbound trip from the CBD. The basic time-check points would not apply during these trips, thereby giving drivers more latitude. Drivers are required to leave for their return inbound trip (if any) according to schedule.

Load Control Strategies

Controlling loads on high-frequency bus service is usually done by a starter at a terminal, but it also can be done by supervisors along a route. This technique is especially applicable at stadiums, large schools, or other points of major passenger handling where standby buses can be provided. The objectives are (a) to control passenger boardings, thereby keeping buses from getting overcrowded and (b) to reduce dwell times at busy stops. There are three load-control techniques:

• *Provide Empty Buses at Terminal.* Standby buses can be provided at the CBD terminal or other major activity centers and scheduled to depart when the peak crowds arrive.

• *Provide Starter at Terminal.* A starter can be provided at the CBD terminal or major activity center to control passenger loads and to ensure that buses leave according to schedule.

• *Change Fare Collection Practices.* Service reliability can be improved by reducing dwell times at key boarding points during peak periods. This can be done in several ways. Methods used include (a) rear-door passenger loading with street collectors and (b) pay-on-exit outbound, or proof of payment. Ottawa, for example, allows pass patrons to board articulated buses through the rear doors; this contributes to the ability to operate 200 buses and 10,000 passengers per hour in a single bus lane.

Extraboard Management Strategies

The problem of "no-shows" for specific trips can be addressed in several ways:

• *Require Drivers to Make an Extra Trip.* Drivers can be asked to make an additional trip when a relief fails to show, subject to spread-time constraints.

• *Hire Overtime Drivers.* Drivers can be hired on an overtime basis to operate extra trips when necessary. However, this technique (like the one above) can be costly.

• *Modify Extraboard Procedures.* Flexibility in arrival times for the extraboard (spare-board) personnel can minimize reliance on off-duty drivers and reduce the number of missed runs.

Improved Technology

Direct communication between driver and supervisor is essential. Radios should be provided on all bus systems, and incorporated into more advanced technologies. Radios work well when drivers have problems; however, they have not been found effective for ensuring schedule adherence. (Drivers do not report that they are early or late.)

Two advanced technologies have proven successful in improving service reliability and supervision: APC and AVLC systems. The use of these proven technologies by transit systems, coupled with continued improvements in computers and communication systems, should make both APC and AVLC more widespread in the future. The control systems should be centered in the garages from which the buses operate. The choice depends upon the specific assignment of buses to routes from each garage.

• APC systems provide a good planning base for preparing schedules and monitoring system performance. They are useful in identifying recurrent schedule adherence problems and taking corrective actions to alleviate them.

• AVLC systems provide real-time service supervision and monitoring. However, they require a long period of time to perfect, are expensive (about $15,000 per bus), and may not reduce overall supervision staff. The Toronto experience suggests that one console supervisor can handle about 60 to 80 buses; the CTA survey found 125 was the best number of buses to monitor. This suggests that the greatest applicability will be for larger bus systems.

Introduction of the more advanced European technology is under consideration in Chicago. This technology is able to perform both APC and AVLC functions, including preemption of traffic signals by late buses.

PERSONNEL MANAGEMENT

Personnel management practices must be fair to maintain good labor relations and maintain operator morale; they should be keyed to "team building" among supervisors, drivers, and field staff. Close communications should be maintained among drivers, supervisors, and planners, and suggestions should flow from the bottom up. Communications and motivation are keys to effective supervision. Houston, for example, has excellent on-time performance because driver incentives are built into the labor contract.

Effective driver hiring, training, and supervision policies are essential. Drivers should be monitored on buses for factors such as driving skill, appearance, passenger relations, and vehicle

Form 803750/Dec. 85 (800409, 800416)
Toronto Transit Commission
Transportation Department

Inspector's Report
Surface Operation
For Use by Division Supervisory Personnel

________ DAY ____________ 19 ____

NAME __________ BADGE NO. ________

DIVISION __________ ROUTE ________

RUN NO. __________ VEHICLE NO. ________

☐ BUS ☐ T.C. ☐ L.R.V. ☐ P.C.C.

TIME ON ________ TIME OFF ________

☐ STUDENT ☐ OPERATOR

THE ABOVE MENTIONED VISITED IN SERVICE AND THE FOLLOWING NOTED.

SATISFACTORY		UNSATISFACTORY
☐	OPERATION OF C.I.S. EQUIPMENT	☐
☐	ADHERING TO TRAFFIC REGULATIONS	☐
☐	SWITCH OPERATION	☐
☐	DEFENSIVE DRIVING TECHNIQUES	☐
☐	USE OF DIRECTIONAL SIGNALS	☐
☐	ADHERING TO FARE REGULATIONS & PROCEDURES	☐
☐	ALIGNMENT AT STOPS	☐
☐	CALLING OF STOPS	☐
☐	DOOR OPERATION	☐
☐	ADHERING TO TIMING POINTS	☐
☐	KNOWLEDGE OF SCHEDULES/WAYBILLS	☐
☐	OPERATION AT PEDESTRIAN CROSSOVERS	☐
☐	OPERATION AT INTERSECTIONS	☐
☐	OPERATION AT RAILROAD CROSSINGS	☐
☐	KNOWLEDGE OF EQUIPMENT	☐
☐	TURNING PROCEDURES/CURB CLEARANCES	☐
☐	GENERAL VEHICLE OPERATION/PASS. CARRYING	☐
☐	GENERAL APPEARANCE	☐
☐	ATTITUDE TO THE JOB	☐
☐	ATTITUDE TO PASSENGERS	☐
☐	CLEANLINESS OF VEHICLE	☐

WEARING OF EYE GLASSES ☐ NO ☐ YES
WEARING OF CONTACT LENSES ☐ NO ☐ YES

(Over)

(Reverse Side)

COMMENTS:

Inspector __________ Badge ________

Division __________

FIGURE 24 Sample driver monitoring report (Toronto).

cleanliness, as well as schedule adherence (Figure 24). This field supervision is necessary even when service reliability is monitored through AVLC systems. Supervisors, too, should be trained and supervised, and the criteria for selection of supervisors should include qualifications such as assertiveness and public relations capabilities. Once selected, supervisors should be well trained and carefully directed. They should be part of management, and act as such. A good supervisor should know where the buses are, be able to monitor drivers, identify problems, and implement solutions. In addition, the supervisor should compliment drivers for good performance. When supervisors are visible to drivers, there is a tendency for schedule adherence to improve.

A sufficient number of supervisory personnel should be provided. The agency surveys suggest at least five supervisors per hundred drivers as a desirable target. Area or regional supervisors may be necessary for large systems; line supervisors are desirable for heavily used bus routes, and foot supervisors are essential in the city center and other areas of high bus service density.

Supervisors should be free to supervise, and they should not be diverted to other activities. Their main functions are to ensure proper service delivery by overseeing the day-to-day operation of the bus system and assisting in maintaining smooth operation. They should watch the service and make real-time decisions in response to service problems. This involves adjusting schedules, providing additional buses, establishing detours, and making related delay-recovery actions. They may also be needed for special event dispatching.

OTHER CONSIDERATIONS

A clearly written, well-organized summary of supervisory practices relative to each property's policies would improve daily supervision. Each property should decide what actions to take and adequately communicate these procedures and their application.

Sound supervisory practices represent good resource management, because the costs of poor supervision result in the need for extra buses. It is essential, therefore, that adequate resources be directed to the supervision of bus service.

RESEARCH DIRECTIONS

Several research directions are apparent from the state-of-the-art review. There is a need for an on-going data base that describes how traffic and transit conditions influence bus service delay by type of route and time of day.

Further research is needed to determine where and when the various service supervision strategies best apply. What are the relative roles and merits of real-time control of schedules, headways, and loads? The concept of dynamic scheduling needs further field verification. The application of APC and AVLC and how they best can modify existing supervisory practices needs further exploration and operational tests. Advanced AVLC technologies from Europe and Japan should be tested and considered for use in North American cities. Each of these research efforts needs further stratification by type of operating environment (e.g., CBD city, suburb), type of route (local, express, etc.), frequency of service, and size of bus fleet.

Finally, further study is needed to pinpoint the cost-effectiveness of various supervision strategies and the extent that investment to achieve on-time performance should take precedence over other operating improvements.

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APPENDICES

APPENDIX A

SURVEY OF PRACTICE

1 GENERAL
- a) Agency ____________________
- b) Bus Fleet (Number and Type) ____________________
- c) Bus Drivers #__________
- d) Supervisors #__________
- e) Checkers #__________

2 What techniques and procedures have been used, or are planned to improve service reliability?

3 MANAGEMENT
- a) Organization Plan for Monitoring Service.
- b) Role of operations planning, transportation departments in service monitoring.
- c) Checkers/Supervisor (who do they report to)?

4 SUPERVISION ACTIVITIES (DESCRIBE)
- a) Max Load Point Checks:
  - Number of points __________
  - Locations __________
  - Frequency of Checks __________
- b) On Vehicle Checks __________

  Frequency (Number of times per year) __________
- c) Point Checks of Travel Time
  - Locations __________
  - Frequency of checks __________
- d) End of line dispatchers (where used) __________

5 a) USE OF AREA SUPERVISION: (ie., supervisors for specific geographic areas).

b) USE OF LINE SUPERVISORS: (what types of lines) __________
____________________.

(Differences between lines with long headways (20 min+) and short headways (10 min. or less) if any).

6 USE OF TECHNOLOGY/HARDWARE (Please check)
- a) Driver Telephones ______
- b) 2-Way Radio ______
- c) AVL ______
- d) AVM ______
- e) Other ______
- f) Measures taken when schedule adherence goes bad __________
____
____________________.
- g) Experience with long vs. short lines __________
____
____________________.
- h) Union rules - can supervisor take steps to improve service or is he restricted by labor agreements? __________
____
____________________.

7 ON-TIME CRITERIA
- Early (Minutes)
- Late (Minutes)

8 ON-TIME PERFORMANCE EVALUATIONS (if available)

9 REMARKS/OBSERVATIONS
- a) Impediments to Supervision __________
____
____________________.
- b) Proposed Improvements __________
____
____________________.

10 SYSTEM MAPS (Please provide)
- a) Blank Map
- b) Map with time-check points noted

APPENDIX B

CHICAGO TRANSIT AUTHORITY ORGANIZATION PLAN—BUS SERVICE SUPERVISION

I. DIRECTOR OF SERVICE

A. Responsibilities--The Director

1. Is responsible for the 7-day-a-week, 24-hr-a-day service operation.
2. Must assemble and possess a hierarchy of talent that is inspirational in the smooth flow of service.
3. Monitors and directs their activities to assure needs are being met.
4. Offers guidance and the benefit of expertise that is being constantly upgraded through monitoring of systems operations using management by objectives.
5. Projects the service, monetary, and equipment necessities as determined by current and protracted needs.
6. Directs snow operations and procedures to be used by staff and supervisory personnel.
7. Is responsible to the Manager of Transportation for all vehicles and personnel once they leave their garages or train terminals.
8. Commands a scope encompassing the total city, as well as 35 suburban routes. Mechanical resources under this direction number: 2420 buses, 2162 of which are mobilized during peak service in a schedule that includes 254,000 miles per day; 1100 rapid-transit cars, making 2300 train departures daily and covering 191 route miles; the procedures and operations of the multi-million-dollar Control Center.

B. Key Staff

1. Area Staff

Reporting to the Director are the three Area Superintendents of Rail, Bus, and the Control Center. They are in-house staff, centrally located in the Merchandise Mart, but become mobile as the situation demands. Their responsibilities are to oversee CTA's entire operation for their individual sections; they make daily inspections and hold weekly meetings with their personnel, advising them as to any change in operation or instructing them with regard to special operations. They personally monitor all special events and serious service interferences. They work as a joint unit, coordinating the entire CTA activities.

2. District Staff

The District Staff number 34 and are mobiley located in the field. They are responsible for monitoring the following: supervisors and collectors, the condition of vehicles, physical condition of streets, provision of adequate service, schedule adherence and all administrative duties (payroll, assignments, etc.). They meet with people from industries and schools to coordinate quitting times with quality service. They oversee the supervisor's duties.

II. BUS OPERATIONS

A. Physical Overview

Bus operation is served by five Districts. The Districts are geographically divided and are identified as follows: Far South, Near South, Near North, Far North, and the Central Business District. These Districts are coded as A, B, C, D, and Central, respectively.

Each District has a leader (whose duties were previously described in I.B.2) and the supervisors are responsible to this person for their performance.

B. Manpower--240 Bus Supervisors

1. Duties

a. One of the duties of the supervisors is to observe operations in order to effectively adjust service. This is accomplished through supervisor operations, which number 1 million per year. They report all violations of company rules. During the last year, 60,000 violations were reported and referred to Personnel for appropriate action. The following are violations found in operation: running ahead of time, leaving the terminal early, ignoring cross line standards, failure to stop at railroad crossings, improper destination signs, ignoring traffic signals, not curbing the vehicles, improper run number displayed, failure to arrive at destination, passing up passengers, improper uniform, and smoking on duty.

b. Other equally important duties include coordinating reroutes, conducting bus checks, making service adjustments, minimizing delays, responding to emergencies, and restoring service during natural and man-made interferences or disruptions.

c. They also perform need analysis in service schedule adherence, citing problem areas and recommendations for change.

2. Roles

All supervisors are versatile in the three following roles, and their interaction assures a high level of service. Through the use of automobile or portable radios, they have contact with the Control Center.

a. The radio car supervisors are the mobile troubleshooters. They go to the scene of fires and defective buses and make accident checks to restore service by filling (turning a bus around or taking a bus from another street), rerouting, and adjusting headways.

b. The point supervisors' primary purpose is to assure schedule adherence; if necessary, they switch buses in order to honor the street running time. They organize meal reliefs for the operators if special weather or traffic conditions warrant. They space the street in the event that the schedule is not able to be met.

c. The line or route riding supervisors observe the operator's activities. As well as encouraging good performance, they assist through corrective advice, if necessary. In the event that a customer complaint identifies an unusual circumstance, such as irregular service at a given location, they make observation checks.

III. THE CONTROL CENTER

A. Manpower Staff

The Control Center has three separate sections: They are manned by the Rail, the Bus, and the Power Controllers. All personnel are experienced in supervision and so are familiar with their Service Section's needs. In the event of a major delay, these sections form a cohesive unit, and their combined Task Force efforts minimize passenger inconvenience.

1. Bus controllers are related to bus operations. They have direct contact via bus radio with the operators and are the first persons contacted by them to report any service disruptions or unusual occurrences. They must give guidance and direction in all cases and relay the details to mobile field supervisors whom they direct or, if necessary, to the police, fire, etc. departments for backup assistance. They are also responsible for all orders to the mobile maintenance force trucks.
2. The rail controllers handle all train dispatching, recording of train movements, and communication with vehicles and supervisors. They are the operators' link to assistance in the event of service disruptions or unusual occurrences and are responsible for proper guidance and direction. They must inform the field supervisors of current problems and, in the event of major occurrences, are responsible for proper notification of their supervisors and all necessary personnel. This section is also responsible for passenger communication on various station platforms.
3. The power controllers provide centralized control of DC power for the entire rail system. They monitor and control all substation operations, in addition to the ventilating fans, sump pumps, and AC power in the subways.

B. The Equipment

The technical aspect of the Center involves the Bus Radio System, the Supervisor's Radio System, The Rail Controller's System, The Power Supervisor's office, and other additional features. All of these are described in detail below.

1. The Bus Radio System consists of eight radio channels that link the Control Center with the buses. Six of these channels are for voice communications and two transmit alarm data.

   The bus controller consoles can transmit and receive on any voice channel. When the driver begins transmitting, the console automatically displays the run number, garage, and channel numbers.

   Our buses are equipped with an alarm system that, when activated by the operator, sounds an audible alarm in the Control Center. It simultaneously displays the garage number, run number, channel, bus number, location, and time. This is accomplished through wayside posts.

The wayside posts transmit location codes to a passing bus. When the emergency alarm is sent by a bus, the latest location code is included. The controller can then accurately dispatch police and supervisor assistance. The future projection total is 500. One hundred fifty are now in current operation, and 2420 buses are now radio- and alarm-equipped.

A voice page system provides periodic service announcements, courtesy requests, and appreciation statements to the public. This information is heard by passengers and the operator through a speaker that is located in the front of the bus.

2. The Supervisor Radio System consists of four channels. Two are used for bus, one for rail, and one--not on line as yet--for emergency.

3. The Rail Controller System contains the following: automatic train dispatching; train movement recorders that record train operation at more than 100 points on the rail system; station platform paging, with which the Control Center can make announcements on key station platforms to keep riders informed of train operations; train phone and train radio that allow direct communications between the Control Center and the train crew.

   A complete rail radio system is now under design that will provide all operating personnel with radio communication.

4. The Power Supervisor's Office houses the following controls: a substation control that monitors the operation of CTA substations and provides remote control of substation operation; AC power control in subways that indicates the status and operation of such things as ventilation fans and drainage pumps; subway emergency alarms that indicate operation of an emergency alarm in any of the subways; dispatch maintenance forces that respond when reports of defects or failures to any CTA electrical equipment are received.

5. Other Control Center features include:

   A direct weather teletype line that types all U.S. weather service bulletins. We also have Murray and Trettel Meteorologists under contract for immediate update of weather and condition reports.

   A direct phone line communication between the bus, rail, and supervisor controllers and the Chicago police and fire departments, thus providing immediate assistance in emergency situations.

   A vehicle maintenance system--a computer terminal that is part of an elaborate system that monitors and identifies needed repair work on vehicles. It stores vehicle maintenance information, tabulates the use of spare parts, maintains an overview of fleet status, and records employee activities as related to repair.

   A microfiche system that stores pertinent information relative to routes and schedules and provides for rapid recall of that information.

   A master tape recorder that stores all communication to and from the Control Center via all radio, CTA telephone, police, fire, and Illinois Bell Telephone inside and outside lines.

   A superintendent's desk to coordinate the activities of each of the three divisions so that each area functions at maximum efficiency.

   A public relations staff member who is part of the superintendent's desk team during weekday rush hours. This person's task is to relay current service reports to the public from the Control Center. In addition, the updates are entered into the CTA service phone, the direct number of which is available to the public.

   A Chicago Fire Department direct line connection that receives through intercom and a box station the location information concerning all still and box fires. Whenever the fire is on or near a route, supervisors are directed to the scene.

   A command post--provides for snow command and top management support during severe snow and ice conditions.

APPENDIX C

PERFORMANCE ANALYSIS—ROUTE 7 (SOUTHEASTERN PENNSYLVANIA TRANSPORTATION AUTHORITY)

Description:

Route 7, a Southern District route, operates from Strawberry Mansion and Tioga to South Philadelphia via 29th, 22nd, and 23rd Streets.

Route 7 is moderately patronized with about 6,070 passenger trips each weekday. The route operates with peak hour headways of 15 and 12 minutes. The operating ratio for Route 7 is 54 percent.

Observations

1. On-time performance (one minute early to five minutes late)

Date:	Thursday, August 4, 1988
Time:	7:00 a.m. to 3:00 p.m.
Weather:	Clear
Sample Size:	50 percent of scheduled trips for date (136 observations)
Schedule Adherence:	On-time - 102 observations - 75% Early - 30 observations - 22% Late - 4 observations - 3%

Results are detailed on attached frequency distribution.

2. Quality of Service

Date:	Monday, July 7, 1988
Weather:	Clear
Sample Size:	15 trips selected randomly, 20 criteria used as per "Quality of Service Review" attached. Sixty-five percent of the operators working this route were observed.

Results: Generally drivers operated in a safe manner, were normally courteous and in proper uniform.

Analysis/Conclusions

1. On-time performance for Route 7 has increased 9 percent (66% vs. 75%) since previous check in December, 1987. The increase in on-time performance is attributable to a 6 percent decrease in early operation (28% vs. 22%) and a 3 percent decrease in late operation (6% vs. 3%).

2. Twelve percent of the blocks checked (2 blocks) account for 40 percent of the early operation. On-time performance of 84 percent could have been achieved had these operators maintained scheduled times.

3. Operators are arriving early at 20th Street and Oregon Avenue, southbound and 33rd & Dauphin Streets, northbound.

4. Sixty-seven percent of the early operation was for 2 or 3 minutes.

5. Twenty percent of the operators observed called stops and 67 percent provided public timetables. Previous check shows 24 percent called stops and 52 percent provided public timetables.

Action/Recommendations

1. Monitor and address operators consistently running ahead of schedule.

2. Monitor 20th Street & Oregon Avenue , southbound, and 33rd & Dauphin Streets, northbound, for early arrivals.

3. Conduct district campaign to encourage the calling of stops and provision of public timetables.

APPENDIX D

PROCEDURE FOR ESTABLISHING AND MONITORING ON-TIME PERFORMANCE (METROPOLITAN TRANSIT AUTHORITY—HOUSTON)

INTRODUCTION

The quality of METRO service is determined by the punctuality of the bus service on the street. Operations' goals and objectives are designed to measure the efficiency and effectiveness of independent service components; a number of these culminate in a unified effort to support the on-time performance of the transit system.

Definition

- o An Express or Local bus is "on-time" if it departs a time point no earlier than the scheduled time and arrives no later than five minutes after the scheduled time.
- o A Park & Ride bus is "on-time" at the beginning of a trip (at the lot in the morning and downtown in the afternoon) if it is within the same five minute window described for local buses. A Park & Ride bus is "on-time" at all other time points if it departs no earlier than ten minutes before the scheduled time and arrives no later than five minutes after the scheduled time. This is summarized as follows:

	Acceptable Deviation
Local, Express	0-5 Minutes
Park & Ride (start of trip)	0-5 Minutes*
(other time points)	-10-5 Minutes

* Bus is on-time when leaving early if Street Supervisor orders leaving due to passenger loading.

PURPOSE

This procedure establishes the method METRO uses to monitor and report "on-time performance".

SOURCE OF DATA

The Schedule Division

(a) Develops the operating schedule for all scheduled bus trips.

(b) Prepares and distributes to Transportation personnel a Supervisors' Guide that lists the departure time for all scheduled bus trips, by route, from every time point listed on the bus operators' assigned schedule.

(c) Prepares and distributes Corner Guides for individual time points with bus routes and trips listed in order of time due. Street Supervisors use these to check and report on-time performance at designated points.

The bus operator is assigned a printed schedule for each trip with departure time from the route's origin, periodic departure times from intermediate time points along the route, and the departure time from the downtown terminus of the route.

DATA COLLECTION ASSIGNMENTS

(a) Street Supervisors are assigned to the following Downtown locations to monitor the bus service, assist patrons in making transfers, provide patron information, and record daily on-time performance of the bus routes passing these locations:

- o Preston and Main
- o San Jacinto and Preston
- o Capital and Fannin
- o Travis and Lamar
- o Louisiana and Jefferson
- o Texas and Milam
- o Main and Elgin

(b) Other Street Supervisors check schedules regularly, but not daily, at locations outside the central business district. These reports are also used in determining on-time performance:

- o Park & Ride lots are monitored during the a.m. peak, on a rotating basis averaging two complete schedule checks per week.
- o Park & Ride service is monitored in the p.m. peak at Smith and Jefferson on a daily basis, documenting on-time performance of buses beginning the outbound routes.
- o Street Supervisors assigned to five mobile units are responsible for monitoring and reporting on-time performance of Local and Express buses from the end of the line and at intermediary points enroute to downtown. The work of each Street Supervisor is checked at least twice per year.

(c) Street Supervisors will take special care to note buses arriving early and late, as defined above.

DATA QUALITY CONTROL

(a) The accuracy of on-time performance data is verified by the Assistant Superintendent of Road Operation by duplicating a minimum of one hour of each Street Supervisor's checks each quarter. The Assistant Superintendent of Road Operation maintains a file of his or her verification checks for 18 months.

(b) Each Street Supervisor, Superintendent, and Assistant Superintendent will receive data collection training from the Safety and Training Division before November 30, 1987. This training will be incorporated into the training for new full time and relief Street Supervisors." "Refresher training" will be provided on an "as needed" basis, as determined by the Assistant Superintendent of Road Supervisions. This training will include definitions, data collection procedures, data processing, and importance of the data to METRO.

(c) Operations and Maintenance Support staff randomly check the accuracy and completeness of summary sheets submitted by a facility. This staff notifies a facility Superintendent of problems, and sends a copy to the Director of Transportation. The Superintendent is responsible for corrective action. During the month of August, 1987, Operations and Maintenance Support (OMS) will check 40% of all Street Supervisors' sheets. This ratio will decline to 20% in September and 10% thereafter. The OMS staff will maintain a file of these checks for a period of 18 months.

DATA PROCESSING AND SAMPLING PLAN

Operations and Maintenance Support staff have already implemented a new sampling plan, based on the McKinsey II study observations. Sampled data is not randomly taken, but is weighted by facility and location along a route. These weights are:

Downtown locations	26%
Middle of the line points	61%
Facility Pullout/Beginning of line	13%

This procedure is computerized and is identical for weekly and monthly calculations.

LOCATION 1 IS DESIGNATED FOR DOWNTOWN CORNER CHECKS.

1-A = MAIN & PRESTON

1-B = FANNIN & CAPITAL

1-C = TRAVIS & LAMAR

1-D = MAIN & ELGIN

1-E = SAN JACINTO & PRESTON

1-F = LOUISIANA & PEASE

1-G = TEXAS & MILAM

LOCATION 2 IS DESIGNATED FOR THE MIDDLE OF THE LINE

LOCATION 3 IS DESIGNATED FOR THE PARK & RIDES.

CIRCLE THE LOCATION YOU ARE DOING YOUR CHECKS.

A.M. CHECKS SHOULD BE BETWEEN THE TIMES OF 3:00 am to 9:00 am.

MID CHECKS SHOULD BE BETWEEN THE TIMES OF 9:00 am to 2:00 pm.

P.M. CHECKS SHOULD BE BETWEEN THE TIMES OF 2:00 pm to 3:00 am.

IF YOU SHOULD GO FROM MIDDLE OF THE LINE TO A PARK & RIDE, USE ANOTHER CHECK SHEET.

IF YOU SHOULD GO FROM DOWNTOWN TO A PARK & RIDE LOT, USE ANOTHER CHECK SHEET.

REMEMBER: ANY CHECK OUTSIDE THE BELT IS MIDDLE OF THE LINE.
MOBILE SUPERVISORS ARE MIDDLE OF THE LINE.