

# **Applications for Improved Inventory Management for Public Transit Systems**

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### **DISCLAIMER**

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**This report has not been edited by TRB.**

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## ABSTRACT

This report documents and presents the results of a Testing and Demonstration (T&D) Project on applications for improved inventory management for public transit systems. This project is a follow-up to an earlier study on inventory management for bus and rail public transit systems. The conclusions reached in the initial research project (E-3) on organization and inventory performance indicators were developed into criteria for further study. Five case studies were conducted at selected transit properties on how to apply and measure the benefits of improved inventory performance indicators, including the use of technology. The results of the case studies were then analyzed to determine the relationships between inventory control factors and management performance, the conditions under which inventory management techniques are best applied, and implementation issues and solutions to potential problems when applying the inventory control techniques. The characteristics of public transit properties (such as demographics, organization, etc.) that affect the application of the inventory control techniques were also identified. The case study results are used in the revised *Inventory Management Desk Guide* to illustrate the application of inventory management techniques.

## **SUMMARY OF FINDINGS**

In FY 1993, TCRP sponsored research project statement E-3, “Inventory Management for Bus and Rail Public Transit Systems”. The research project described in this report (Testing and Demonstration (T&D) activities for TCRP project E-3A, “Applications for Improved Inventory Management for Public Transit Systems”), is a follow-up to the original study.

The objectives of the original research project were to identify and describe those inventory control techniques appropriate to the public transit industry, to establish benchmarks, and to create a decision-modeling guide for transit professionals to use to achieve better inventory management. The research concluded that, in general, no inventory organization factor, decision factor, agency or fleet characteristic had a comprehensive and consistent effect on inventory performance. In addition, none of the factors were shown to affect more than one service level performance indicator (e.g., inventory fill rates, days to fill back orders). Those that affected the efficiency of managing inventory were seldom shown to have more than minimal effects on performance factors relating to inventory investment or service level.

As a follow-up to the initial research, this testing and demonstration project more fully investigates the application of inventory performance measures in reducing transit system costs, reducing the incidence of vehicle downtime and maintenance overtime, and in increasing service delivery.

### **Purpose and Objectives of the Testing and Demonstration Project**

Public transit systems have been under increased pressure to provide the same or a higher level of service with fewer operating dollars and reduced staff. Moreover, transit system managers are being urged to demonstrate to state and local officials, governing boards, and the public that initiatives are in place to reduce operating costs. As a result, inventory managers have been under increased pressure to justify inventory size and value and provide information on inventory performance.

The objectives of this Testing and Demonstration (T&D) project, “Applications for Improved Inventory Management for Public Transit Systems” were

- (1) to further isolate and review the test results in a “real” environment considering demographics, fleet size and composition, organization, inventory management practices, performance, and technology and information systems; and
- (2) using case studies, test and demonstrate that the conclusions reached from the research phase are valid or identify adjustments required to implement the conclusions in “real world” conditions.

## **Approach**

The approach followed in conducting this project included developing the conclusions reached in the initial research project (E-3) on organization and inventory performance indicators into criteria for further study. Case studies were conducted at five transit properties on how to apply and measure the benefits of improved inventory performance indicators, including the use of technology. The results of the case studies were then analyzed to determine the impacts on the application of improved inventory management techniques in the public transit industry.

During this testing and demonstration project, thirteen performance indicators were used, based on the initial project findings and the practicality of gathering information during the case studies. Inventory management and organizational factors were also examined and analyzed. The six areas covered in the case studies included agency characteristics including service area, fleet size and age; inventory management organization characteristics; inventory management practices including storekeeping and replenishment; inventory management performance; and the use of technology and information systems.

## **Findings and Conclusions**

Comparing and contrasting the five case studies, as well as interpreting inventory management results within each transit property, yielded the following items as key inventory performance factors.

- The degree of focus of executive management on inventory performance goals
- The capability to accurately measure inventory performance indicators
- The staff time actually spent performing inventory management functions
- The reasons and strategy behind configuring a storehouse network.
- The extent to which multiple replenishment methods are fully utilized
- The types of items included in or excluded from inventory and how inventory is valued
- The classifications used for managing inventory items
- The level of joint planning between inventory and maintenance personnel
- The extent to which multiple procurement methods are used
- The level of discipline associated with record keeping during non-covered storehouse hours
- The focus of the cycle counting program
- The level of inventory responsibility assigned to non-inventory personnel and inventory tasks omitted.

The case study assessments provide a basis for extrapolating conclusions that are generally applicable to inventory management in transit properties regardless of size, mode, geographic location and other demographic and operating factors. This section presents these

conclusions and suggests additional follow-up research to further examine and isolate the effect of these factors on inventory management performance.

Based on an assessment of case study results, it can be concluded that the following general actions can have a positive effect on inventory management performance in most transit properties:

- Elevate the focus of inventory management personnel from an inventory transaction orientation to an inventory management orientation.
- Define specific performance indicators for inventory, set goals and track actual performance versus goal.
- Use “ABC” stratification as a tool for focusing inventory management effort.
- Increase interaction and joint material planning with Maintenance and other “customers”.
- Use multiple replenishment methods based on actual statistics and maintenance projections.
- Utilize a full range of purchasing methods depending on the specific characteristics of the purchase.
- Initiate a cycle counting program with emphasis on resolving the root cause of discrepancies.
- Upgrade automated systems and technology for inventory management support.

The case studies provided affirmative evidence that “real world” analysis of inventory management at public transit properties can yield valuable insight into the relationship between inventory management decisions and performance. The results of the case study analysis have advanced the work began with the survey in project E-3 and have contributed significantly to understanding the conclusions reached during the survey project. In addition, the case study analysis has presented several conclusions that can be examined further through longer-term on-site studies with public transit properties. The logical next step in examining the effects of inventory decisions on inventory performance is to develop empirical evidence to test the conclusions reached in this study.

## **CHAPTER 1 INTRODUCTION AND RESEARCH APPROACH**

In FY 1993, TCRP sponsored research project statement E-3, “Inventory Management for Bus and Rail Public Transit Systems”. The research project described in this report (Testing and Demonstration activities for TCRP project E-3A, “Applications for Improved Inventory Management for Public Transit Systems”), is a follow-up to the original study. This chapter includes a description of the original study, the purpose and objectives of this Testing and Demonstration (T&D) project, project scope, research approach, and the organization of the remainder of the report.

### **1.1 SUMMARY OF THE PRECEDING RESEARCH PROJECT**

The objectives of the original research project were to identify and describe those inventory control techniques appropriate to the public transit industry, to establish benchmarks, and to create a decision-modeling guide for transit professionals to use to achieve better inventory management.

Project activities included

- (1) identifying the inventory management practices and techniques that best assist transit agencies in meeting inventory management objectives;
- (2) determining the effects of different organizational structures policies, and practices used for inventory management on satisfying inventory management goals and inventory service objectives; and
- (3) defining the conditions and developing the strategies necessary to ensure the most effective and efficient implementation of inventory control techniques, decision-making techniques and performance indices appropriate to the transit industry.

The approach followed in conducting this earlier research project consisted of a national mail survey of transit properties followed by data analysis. The survey and data collection and analysis tasks consisted of the following:

- (1) a national survey of transit agencies;
- (2) analyses of the relative merits of the full range of organizational structures, policies, and practices used for inventory management;
- (3) the development and definition of indices useful for inventory management including but not limited to stockouts, turnover ratios, inventory cost per vehicle, demand satisfaction, stock-keeping units (SKU’s), shrinkage and carrying costs based on such qualifying factors as scale, fleet size and standardization, fleet composition, mileage, etc.; and

- (4) identification of significant relationships between performance indices and organizational profiles.

### **1.1.1 Organizational Profiles**

As a result of the survey, five distinct organizational structures were identified. All 75 survey respondents, regardless of the size and complexity of the functional units responsible for the management of inventory, could easily be classified into one of these five structures:

- (1) No formal inventory management function -- inventory responsibility is located in the Maintenance Department;
- (2) Formal inventory management function -- inventory management responsibility located in a department other than maintenance at the sub-department level;
- (3) Formal inventory management function -- inventory responsibility is located in the Maintenance Department;
- (4) Formal inventory management function -- inventory management responsibility located in a department other than maintenance, and;
- (5) Formal inventory management function -- a single dedicated inventory management group at the department level.

Each of these organizational structures was profiled in the context of the organization, inventory management practices and performance measures utilized by the transit systems examined. The relative merits of the different organizational structures were also evaluated relative to their ability to meet inventory management goals and service objectives.

### **1.1.2 Performance Indices**

The survey showed that most public transit properties use a small number of indicators to monitor inventory performance. Moreover, many properties, particularly those with less than 50 vehicles, do not formally monitor inventory performance. These properties merely set minimum and maximum levels for inventory items to control replenishment and address parts shortages as they occur.

Although many of the survey respondents did not regularly track performance indicators, most were able to provide values in response to the survey questions. The respondents also provided information to calculate and examine additional indicators, such as the percent of obsolete inventory and the number of inventory personnel per vehicle. As a result, benchmark values were identified for fifteen inventory performance indicators including turnover, stockouts as a percentage of stockkeeping units, inventory dollars per vehicle, fill rates, percentage of obsolete

items, days to fill backorders, inventory dollars per person and transactions per person. These performance indicators are shown in Table 1, following page 6. (An additional performance measure designated as “new” was added during the T&D project.)

### **1.1.3 Findings and Conclusions**

The research concluded that transit agency and fleet characteristics alone have no significant effect on inventory performance indicators, except for some differences between bus and rail inventory.

In general, no inventory organization factor, decision factor, agency or fleet characteristic had a comprehensive and consistent effect on inventory performance. In addition, none of the factors were shown to affect more than one service level performance indicator (e.g., inventory fill rates, days to fill back orders). Those that affected the efficiency of managing inventory were seldom shown to have more than minimal effects on performance factors relating to inventory investment or service level.

The survey process used in conducting the research yielded valuable information regarding the inter-relationships between inventory management and organizational decision factors. However, the conclusions based on this information were preliminary at best. Most of the statistical tests applied during this study tested a pair or group of factors and assumed that “other things are equal”. In addition, there was no way to verify the accuracy of survey responses beyond the application of common sense tests to the range of response values, comparing related responses in different sections of the survey and comparing an individual response to the normal range of responses.

The research highlighted relationships between inventory organization/policy and inventory performance, many of which represented new concepts in the application of inventory management to public transit. The research showed that a majority of the smaller transit systems and many of the larger systems could not provide sufficient information on inventory performance. Due to the limitations inherent in any survey, information regarding the competence and attitude of the individuals actually involved with inventory management at transit agencies could not be captured.

As a follow-up to the initial research, this testing and demonstration project more fully investigates the application of inventory performance measures in reducing transit system costs, reducing the incidence of vehicle downtime and maintenance overtime, and in increasing service delivery.

## **1.2 PURPOSE AND OBJECTIVES OF THE TESTING AND DEMONSTRATION PROJECT**

“Doing more with less” has been the motto for the 1990’s. Public transit systems have been under increased pressure to provide the same or a higher level of service with fewer operating dollars and reduced staff. Moreover, transit system managers are being urged to demonstrate to state and local officials, governing boards, and the public that initiatives are in place to reduce operating costs. As a result, inventory managers have been under increased pressure to justify inventory size and value and provide information on inventory performance.

The objectives of this Testing and Demonstration (T&D) project, “Applications for Improved Inventory Management for Public Transit Systems” were:

- (3) to further isolate and review the test results in a “real” environment considering demographics, fleet size and composition, organization, inventory management practices, performance, and technology and information systems; and
- (4) using case studies, test and demonstrate that the conclusions reached from the research phase are valid or identify adjustments required to implement the conclusions in “real world” conditions.

## **1.3 PROJECT SCOPE**

This testing and demonstration project provides transit executives and inventory managers with information to make informed decisions regarding inventory performance and demonstrates the techniques and processes required. The methodology and guidelines used to conduct the study are the critical elements in ensuring that transit managers have the resources and tools to effectively measure inventory performance. The methodology allows transit agencies to identify the mix of inventory performance indicators that most effectively defines service quality for their agency. The updated *Inventory Management Desk Guide* provides specific examples of application and information on applying the inventory techniques and performance measures. The *Guide* will assist transit agencies in avoiding potential pitfalls and resolving common implementation issues. The methodology and guidelines included in the *Desk Guide* also contain recommendations for the periodic re-evaluation of inventory performance measures.

## **1.4 RESEARCH APPROACH**

The approach followed in conducting this project included developing the conclusions reached in the initial research project (E-3) on organization and inventory performance indicators into criteria for further study. Case studies were conducted at selected transit properties on how

to apply and measure the benefits of improved inventory performance indicators, including the use of technology. The results of the case studies were then analyzed to determine the impacts on the application of improved inventory management techniques in the public transit industry.

The approach was designed to highlight the relationships between inventory control factors and management performance, the conditions under which inventory management techniques are best applied, and implementation issues and solutions to potential problems when applying the inventory control techniques. The approach was also designed to identify those characteristics of public transit properties (such as demographics, organization, etc.) that affect the application of the inventory control techniques.

The earlier project (TCRP Project E-3, “Inventory Management for Bus and Rail Public Transit Systems”), presented several conclusions regarding the critical factors affecting inventory control in the public transit industry and the indicators used to measure inventory management performance. In this study, these conclusions were further refined and developed into a case study methodology. The methodology described protocols for conducting the case studies, visit itineraries, data collection methods and bi-weekly reporting requirements. A copy of the case study methodology is included in the Appendix A.

The inventory performance indicators to be assessed were identified as were the demographic and other transit property characteristics best suited for examination through the case studies (e.g., multi-modal versus single mode, rural versus urban, large versus small, etc.). The table on the following page shows the performance indicators identified in Project E-3. Definitions for each of the performance measures are included in the glossary in Appendix B.

**Table 1 Case Study Performance Measures**

	Performance Indicators from E-3	Use in T&D	Notes
1.	Bus Inventory Dollars per Vehicle	Yes	Primary dollar investment measure
2.	Rail Inventory Dollars per Vehicle	Yes	Primary dollar investment measure
3.	Annual Bus Inventory Turnover	Yes	Data readily available
4.	Annual Rail Inventory Turnover	Yes	Data readily available
5.	Bus Percent Demand Filled (Fill Rate)	Yes	Primary service measure
6.	Rail Percent Demand Filled (Fill Rate)	Yes	Primary service measure
7.	Percent of Items Stocked Out per Week	Maybe	If data is available
8.	Average Days to Fill Bus Inventory Backorder	Maybe	If data is available
9.	Average Days to Fill Rail Inventory Backorder	Maybe	If data is available
10.	Percent of Items Out of Balance	Yes	Primary accuracy measure
11.	Percent of Obsolete Bus Inventory	No	Case study scope insufficient
12.	Percent of Obsolete Rail Inventory	No	Case study scope insufficient
13.	Total Inventory Dollars per Person	Maybe	If not constrained by policy
14.	Inventory Personnel \$/Inventory \$	No	Too dependent on salaries
15.	Total Inventory Transactions per Person	Yes	Primary efficiency measure
New	Absolute % Dollar Variance	Maybe	Secondary accuracy measure

Table prepared by Thomas and Kilpatrick

During this testing and demonstration project, a selected subset of performance indicators were used, based on the initial project findings and the practicality of gathering information during the case studies. Inventory management and organizational factors were also examined and analyzed. A final list of factors for analysis was then selected based on the potential benefit to public transit properties, the ease or difficulty associated with conducting analysis in the field, and the variety of inventory control areas addressed.

#### **1.4.1 Case Study Participant Selection**

Letters asking for case study participants were developed for distribution to the population of U.S. transit systems that were members of APTA during calendar years 1996 and 1997. The letter described the purpose of the demonstration project and outlined the commitment required to participate. Thirty-four transit systems responded. The table on the following page shows the characteristics of the 34 respondents. These 34 properties represent all geographic areas of the country (northeast, southeast, central, southwest and west coast) and all climate conditions.

**Table 2 Summary of Respondents**

Transit Property	Mode	Size*	Inventory Responsibility	Inventory \$ (000's)	Inventory Staff	Storerooms
A	Bus	Large	Finance	4,750	36	6
B	Bus	Small	Maintenance	75	.5	1
C	Bus/Heavy Rail	Large	Maintenance	650	5	4
D	Bus	Medium	Purchasing	1,000	1	1
E	Bus	Large	Purchasing	850	11	2
F	Bus/Heavy Rail/Light Rail	Large	City Controller	20,000	52	9
G	Bus	Large	Purchasing	3,400	12	2
H	Bus	Medium	Maintenance	200	2	1
I	Bus	Large	Purchasing	5,500	16	1
J	Bus	Large	Purchasing	2,800	2	3
K	Bus	Medium	Purchasing	700	6	1
L	Bus	Medium	Purchasing	1,000	4	2
M	Bus	Medium	Maintenance	619	3	1
N	Bus	Medium	Maintenance	550	4	1
O	Bus	Large	Maintenance	1,130	10	3
P	Bus	Medium	Maintenance	850	4	1
Q	Bus	Medium	County Fleet	81	1	1
R	Bus/Heavy Rail/Light Rail	Large	Purchasing & Materials	15,000	53	5
S	Bus/Heavy Rail/Light Rail	Large	Purchasing & Materials	22,500	45	6
T	Bus/Light Rail	Medium	Materials	600	6	2
U	Bus/Heavy Rail	Large	Operations Support	26,000	55	10
V	Bus	Small	Maintenance	160	1	1
W	Bus	Medium	Finance & Purchasing	1,000	5	2
X	Bus	Large	Materials	14,600	71	8
Y	Bus	Medium	Transit	1,100	Unknown	3
Z	Rail	Large	Purchasing	23,000	50	7
AA	Bus	Medium	Maintenance	700	1	1
BB	Bus	Medium	Finance	750	3.5	1
CC	Bus	Small	Maintenance	160	1	1
DD	Bus	Medium	Maintenance	1,000	7	1
EE	Rail	Medium	Purchasing & Materials	3,300	4	1
FF	Bus	Medium	Purchasing	750	5	1
GG	Bus	Medium	Maintenance	1,000	4	1
HH	Rail	Large	Purchasing & Logistics	54,000	81	6

\*Size based on E-3 survey categories

Small -- 50 or fewer vehicles

Medium -- 51-300 vehicles

Large -- 301-2000 vehicles

Very Large -- over 2000 vehicles

Table prepared by Thomas and Kilpatrick

In order to obtain a cross-section of U. S. transit systems, the five case study participants were selected based on each property's demographics, fleet size and composition, organization, inventory management practices, performance, and technology and information systems. The table on the following page shows the primary characteristics of each of the five properties studied.

**Table 3 Case Study Participant Summary**

Transit Agency	Mode	Size*	Inventory Responsibility	Inventory** \$ (000's)	Public/Private	Inventory Staff**	Storerooms**
A	Bus	Small-Medium	Maintenance	700	Public	1	1
B	Bus	Medium	Purchasing	1,000	Public	4	2
C	Bus	Medium	Maintenance	1,130	Private	10	3
D	Rail	Large	Purchasing	23,000	Public	50	7
E	Bus/Heavy Rail/Light Rail	Large	Controller	20,000	Public	52	9

Table prepared by Thomas and Kilpatrick

\*Size based on E-3 survey categories

Small -- 50 or fewer vehicles

Medium -- 51-300 vehicles

Large -- 301-2000 vehicles

Very Large -- over 2000 vehicles

\*\* Note: These values were provided by the properties when applying for participation in the study. Actual values were identified during the case studies and included in tables in Chapter 2.

Participation in the case study project required the following:

- Executive level commitment and support to sponsor the project within the agency and to ensure that the case study activities receive appropriate priority;
- A designated employee to serve as a Project Coordinator with the responsibility for monitoring on-site activity and coordinating data collection, interviews, site visits, etc.; and
- Availability of selected employees for interviews, discussions and review of results.

#### **1.4.2 Case Study Site Visits**

Site visits were conducted to each of the five case study properties to “pre-test” the project methodology. The initial site visits served to identify the property’s inventory locations and survey the current inventory management organization, procedures, stock characteristics and performance measures. During the pre-test, minor adjustments were made in the case study methodology, as necessary, based on observations. Specific measurement, monitoring and reporting tools were developed for each property based on the property’s current information systems (automated and manual). The format followed in collecting information during the first site visits mirrored the survey used in the initial project. Below are the six areas covered during the case study site visits:

- *Agency Profile.* Characteristics of the service area including geographic location and population.
- *Fleet Profile.* Number and models of vehicle and average vehicle age.
- *Organization Profile.* Reporting relationships, inventory management costs, inventory positions and areas of responsibility.
- *Inventory Management Practices.* Storekeeping, inventory management and replenishment, and catalog and parts.
- *Inventory Management Performance.* Dollars on-hand and usage per month, dollars per vehicle, annual turnover, fill rates, stockouts, days to fill backorder, items out of balance, inventory transactions per person and inventory dollars per person.
- *Technology and Information Systems.* Manual or automated system, age, functions supported and bar coding.

To collect this data, the following activities were conducted:

- Interviewed selected agency personnel, including the appropriate agency executives;

- Reviewed written inventory management policies, procedures and other relevant documents;
- Reviewed inventory records, reports, data files and other related information;
- Reviewed both automated and manual support for inventory activities;
- Reviewed organizational structure and staffing levels;
- Gathered information on selected inventory activities and performance measures; and
- Observed inventory practices and conducted site visits to selected inventory locations.

Each case study lasted approximately four months. Case study participants received two or three visits during the length of the study, depending on the requirements of the particular site.

As information was collected from each case study participant, the raw test data was tabulated and analyzed to determine how effective the five transit agencies were in managing their inventories. The case studies identified the relevant characteristics of the system; the organizational structure of the inventory management operation; unique inventory management issues that the particular system must handle; and performance measurement techniques, including the *quantitative* results (e.g., inventory levels and turnover) achieved. The effectiveness of local inventory control techniques and the key characteristics of successful inventory control methods, procedures and information systems were also documented. This information was used to identify those techniques that can be used in particular operation environments.

Following the analysis, the results were compared with the conclusions reached using the E-3 project survey. The performance measurements studied were summarized and the observed effect of the factors on inventory performance identified. The relationship between the factors and performance indicators was also quantified, where possible. Data was then compared across case study sites to identify the effect of demographic factors and other characteristics. Technical summaries of the case studies, the data analysis techniques and methodology, and the results of the analysis are included in Appendix C.

As a result of the analysis, the *Inventory Management Desk Guide* was revised to further refine the practices and tools used to manage inventory in the public transit industry. The case studies illustrate the application of the various inventory management techniques based on the actual experience in the demonstration project.

## 1.5 ORGANIZATION OF THE REPORT

Chapter 2 presents the findings of the Testing & Demonstration project. Chapter 3 presents a more detailed discussion of the project findings including an interpretation of the effects of current inventory practices on inventory performance and how these practices potentially affected the E-3 study survey results. The chapter also provides an evaluation of the relative merits of the different organizational structures, policies and practices relative to their ability to meet inventory management goals and service objectives. Research findings on the performance indices used for assessing inventory management are also contained in this chapter. Chapter 4 discusses conclusions on how the project results can be applied to other public transit properties, and suggests additional research to further examine and test the findings in this study.

Included in the appendix are (A) case study methodology; (B) glossary of performance measures; (C) case study summaries and analyses; and (D) the revised *Inventory Management Desk Guide*.

## **CHAPTER 2 FINDINGS**

As shown in the previous chapter, six major areas were covered during the case study site visits: agency characteristics including service area, fleet size and age; inventory management organization characteristics; inventory management practices including storekeeping and replenishment; inventory management performance; and technology and information systems. In this section of the report, we present the major findings in each of these areas.

### **2.1 AGENCY, FLEET AND ORGANIZATION PROFILES**

#### **2.1.1 Agency Profile**

In this section, we describe the findings of the five case study agencies. Based on the profiles established during the initial project survey, three of the five case study participants are located in large urban areas with over a million in population. A fourth case study participant is located in a medium size urban area and serves a population base of between 500,000 and 1,000,000. The fifth case study participant is located in a small urban area with a population of between 250,000 and 500,000. As shown in the table on the following page, four of the five case study participants have transit systems that are publicly managed and operated. The fifth case study participant uses a private company to operate and manage its transit system.

**Table 4 Agency and Fleet Profile**

<b>Vehicle Fleet</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Size	Small/Medium	Medium	Medium	Large	Large
Public/Private Operated	Public	Public	Private	Public	Public
Modes	Bus	Bus	Bus	Rail	Bus/Rail
Number of Models -- Bus	6	6	11	N/A	10
Number of Models -- Rail	N/A	N/A	N/A	4	3
Average Age -- Bus	10	9	7	N/A	8
Average Age -- Rail	N/A	N/A	N/A	20	9
Inventory \$ (000)	700	1,000	1,130	23,000	20,000
Climate (Heat/AC)	Cold	Cold	Hot/Dry	Warm/Cool	Hot/Humid

Table prepared by Thomas and Kilpatrick

### **2.1.2 Fleet Profile**

As shown in the table above, three of the five case study participants operate bus fleets, one participant operates a commuter rail fleet and the fifth participant operates bus, heavy rail and light rail fleets. The bus fleets range from a low of six different models to a high of 11 different models. The rail fleets either have three or four different models.

All of the bus fleets and the commuter rail fleet have an average age in the second half on their useful life. According to the American Public Transit System 1998 Transit Vehicle Data Book, the average age for bus fleets is 8.6 years. This compares very well to the average age of the case study fleets. The average age for commuter rail fleets is determined by APTA to be 21 years. Case study participant D has a commuter rail fleet with an average age of 20. While APTA has determined the average age of U.S. heavy rail fleets is 21.6 years; the case study participant operating heavy rail has an average fleet age of 9.

Consistent with the findings of the E-3 project survey analysis, inventory performance indicators did not correlate with any agency and fleet factors except mode (bus versus rail). The sole exception is that the larger the agency, the fewer average inventory transactions were performed per inventory staff person per week.

### **2.1.3 Organization Profile**

As discussed in the previous chapter, five distinct organization structures for managing inventory were identified in the initial TCRP project. These organization types are:

- (1) No formal inventory management function -- inventory responsibility is located in the Maintenance Department;
- (2) Formal inventory management function -- inventory management responsibility located in a department other than maintenance at the sub-department level;
- (3) Formal inventory management function -- inventory responsibility is located in the Maintenance Department;
- (4) Formal inventory management function -- inventory management responsibility located in a department other than maintenance, and;
- (5) Formal inventory management function -- a single dedicated inventory management group at the department level.

As shown in the table on the following page, the case study participants use all five of the organizational types.

**Table 5 Organization Profile**

<b>Profile Summary</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Organization Type	1	2	3	5	4
Inventory Responsibility	Maintenance	Purchasing	Maintenance	Procurement and Materials Management	Controller
Inventory Control/Management Staff	.5	1	2	8	4
Warehouse/Storekeeping Staff	.5	4	7	43	55
Total Staff	1	5	9	51	59
Written Policies and Procedures	No	Some	Yes	No	Yes

Table prepared by Thomas and Kilpatrick

The case studies identified many variations in organization responsibilities and reporting relationships. For the two largest transit systems, responsibilities are split between inventory control/management and warehousing and storekeeping. However, many of the responsibilities overlap.

For example, case study participant A utilizing organization type 1 employs a single dedicated inventory management employee who reports as part of the Maintenance Department. This individual (Parts Manager) is responsible for a single storehouse and performs all duties associated with the management of inventory including the planning, controlling, re-ordering of inventory parts, identifying vendors and obtaining quotes, and organizing and managing the stockroom. The Parts Manager is responsible for processing all inventory transactions, including issuing parts and receiving and recording all material delivered to the agency. This individual is also responsible for performing these activities for non-inventory materials and supplies. Maintenance supervisors have responsibility for the stockroom during hours in which the Parts Manager is not present.

In the second case study B, organization type 2 is utilized. In this case, the inventory control function reports at the sub-department level to Procurement. This transit agency employs an Inventory Control Manager and four Stockroom Clerks at the primary maintenance facility. The Maintenance Foreman, under the “dotted-line” direction of the Inventory Control Manager, manages inventory at a satellite maintenance facility. The Inventory Control Manager is responsible for the maintenance and control of inventories and the planning, organizing and control of all inventoried parts at both storehouses. Specific storehouse management duties include receipt of all shipments and the handling of all in-house logistics and distribution, disposition of all surplus property and equipment, and the accuracy of inventory levels. The Inventory Control Manager is also responsible for the management and supervision of the material control program including the review of current and future supply requirements in coordination with the Maintenance Department, and for tracking buses out of service due to lack of parts. Additional responsibilities include tracking parts usage and conducting cycle counts, periodic audits, annual inventories, and the management and control of all inventory systems.

The third case study participant C employs an organization type where there is a formal inventory management function located within the Maintenance Department. A Parts Manager and eight parts staff are responsible for two storehouses located at separate maintenance facilities. The Parts Department is responsible for ensuring accuracy of the parts, fluids and supplies inventory and ensuring the proper receipt, supply, storage, inventory control and distribution of all parts and supplies for the Maintenance Department. The department is also responsible for limiting Maintenance Department lost service hours due to supply problems. Other responsibilities include inventory planning, error resolution and conducting cycle counts and annual physical inventories.

The fourth case study participant D is the only transit agency in the study with a single dedicated inventory management group at the department level. The inventory management function is divided into two divisions: (1) Inventory Management and (2) Warehousing and Stores. The Inventory Management Division consists of a manager and four analysts and is

responsible for managing inventory levels of consumable materials and supplies. This group also develops short and long-term inventory plans; forecasts the need for consumable items, materials and equipment; and coordinates overall inventory levels. Additional duties include reviewing and approving inventory requisitions, adding new items to the inventory system and inventory tracking and transaction validation. This division is also responsible for managing the computerized inventory system and developing standards for database accuracy.

Warehousing and Stores is responsible for the efficient flow of materials and goods throughout the transit authority. This Division has a manager and a staff of 51 that includes 41 Storekeepers, two Warehouse Supervisors and seven Material Control staff. This division is responsible for managing the Authority's two distribution centers and four storehouses. Specific responsibilities include performing all storekeeping functions, determining material requirements, processing material transfers and allocating material to the proper locations and accounts. The group also administers the warranty program, conducts cycle counts and processes material backorders. Other responsibilities include conducting physical inventories and reconciling discrepancies. There is some duplication of responsibilities between Inventory Management and Warehousing and Stores, particularly in the areas of inventory planning and determining material requirements.

Finally, the fifth case study participant E locates inventory management responsibility within the Finance Department. At this site, inventory management is also divided between two divisions: (1) Inventory Control and (2) Warehousing and Storage. The Inventory Control group is comprised of a Manager and three Stock Control Specialists. Specific responsibilities include processing receipts, issues and transfers for all stock and non-stock material; generating and analyzing stock reports to ensure the accuracy of inventory elements; analyzing and updating re-order points and re-order quantities for stock items; and resolving physical inventory discrepancies. This group enters new parts into the computer system and they also set min/max levels. This group is also responsible for generating manual requisitions for emergency stock requests, entering requisitions into the computer system for non-stock materials, expediting backorders, and identifying and resolving other procurement and accounting related problems. This group replenishes inventory for the central warehouse and the bus stockrooms and is responsible for the operation of the computerized inventory system. The rail departments handle replenishment of rail material.

Warehousing and Storage consists of a staff of 55. This group is responsible for operating the bus central warehouse and providing inventory support for six bus and rail maintenance facilities. Specific duties include issuing and receiving material at all bus and rail storehouse locations, conducting cycle counts and handling component rebuilds. In addition, Stock Clerks at the rail facilities are responsible for replenishing inventory.

For each of the case study participants, top management focus and emphasis on inventory management appears to be influenced by several factors unrelated to organization type or the level to which the inventory organization reports. Such factors as budget requirements can influence cost cutting measures. For the transit system managed by a private company, the profit

incentive also influences inventory levels. Internal and external political situations can also play a role.

Many more staff are assigned to storehouse related activity than to inventory management related activity. With the exception of case study participant A where there is a total of one inventory management/warehousing staff, the ratio of inventory management staff to storehouse staff ranges from 1:4 to 4:55. Our case studies have shown that even those assigned to management positions focus much of their time on transaction oversight. For example, Inventory Control personnel in case study participant E are responsible for such activities as processing receipts, issues and transfers, generating manual requests for emergency requisitions, and resolving cycle count discrepancies.

Our case studies have shown that a large staff size does not necessarily translate into better inventory management. For example, one case study participant has developed a separate inventory control unit within the warehousing group even though a formal inventory management group is in place. This inventory control group is responsible for controlling distribution and making decisions on and processing material transfers throughout the authority. However, the fill rate averages 87.4 percent and approximately 11 percent of items are stocked out. Another case study participant provides much greater storehouse coverage than a similar case study participant but 19 percent of inventory items are out of balance.

Only two of the case study participants have comprehensive and detailed written policies and procedures. The presence or lack of written procedures may not necessarily mean that there are not standard procedures being followed. Standard forms and reports with instructions or policies usually can mitigate the lack of procedures (but may not totally replace them).

## **2.2 STOREKEEPING PRACTICES**

Storehouse network configurations vary with storage locations falling into four general categories: (1) central warehouses that serve other storage locations; (2) dual warehouses that serve other storerooms and operate as an additional storeroom; (3) satellite warehouses that receive material from a central or dual warehouse; and (4) independent storerooms. Only two of the case study participants have central warehouses; four of the case study participants have dual warehouse(s)/stockroom(s). Two sites also utilize independent stockrooms and four of the five case study participants have at least one satellite stockroom

**Table 6 Storekeeping**

Storekeeping Practices	A	B	C	D	E
Number of Central Warehouses	0	0	0	1	1
Number of Dual Warehouses/Storehouses	0	1	1	1	0
Number of Satellite Storehouses	0	1	1	4	4
Number of Independent Storehouses	1	0	0	0	2
“Parent/Child” Replenishment	N/A	Yes	Yes	Yes	Yes
Satellite Drop-ship Replenishment	N/A	No	Yes	No	Yes
Cycle Count Program	No	Yes	Yes	Yes	Yes
Physical Inventory	Annual	Annual	Annual	2-3 years	Discontinued
Secure Storerooms	Yes	Yes -- many keys	1 Yes/1 No	Yes	Yes
Full Coverage during Maintenance Hours	No	No	1 Yes/1 No	Yes	Yes
Responsibility when not Staffed by Inventory Personnel	Maintenance Supervisor	Maintenance Foreman	Maintenance Foreman	N/A	N/A

Table prepared by Thomas and Kilpatrick

Replenishment varies and is not necessarily dependent on storeroom network structure. Some satellite storehouses order and receive material directly from vendors as well as from central warehouses. Some warehouses issue material directly to maintenance as well as supply satellite locations. For example, case study site A has a single independent storeroom. Case study participants B and C have a storehouse at the primary maintenance facility that also serves a satellite storehouse at a separate maintenance facility. Case study D has two warehouses that supply material to satellite storehouses. One of the warehouses also supplies a maintenance facility located at the same site. The other warehouse operates as a distribution center. The fifth case study participant has a bus central warehouse that provides inventory support for the three bus stockrooms and the overhaul shop. All material to the bus maintenance facilities goes through the Central Warehouse with the exception of some items for major repair that are shipped directly to the shops. These items include plywood, steel, drums, water, etc. Both the heavy rail and light rail warehouses are stocked directly from suppliers.

Four of the five case study participants have cycle count programs. Those with cycle count programs focus on resolving specific discrepancies and making the correct inventory adjustments. On-going accuracy improvement and root cause analysis for discrepancies is not a primary focus. Items are selected for cycle counts based on a variety of factors such as bin sections, number of bin trips, negative balances, and at the stock clerk's request.

All participants have secure (locked) storerooms with limited access, however actual access varies based on local practices, particularly during hours when storerooms are not staffed. For example, in some instances storehouses are not secured during hours when inventory personnel do not staff the storehouse. In all cases, storerooms that are open without inventory staff are the responsibility of maintenance supervisors and foremen. The accuracy of transactions recorded by maintenance during off-hours is affected by several factors, including the methods used to record the transactions, the normal responsibilities of maintenance (such as looking up part numbers) and the emphasis placed on the task by maintenance management. In one case, approximately a dozen non-inventory staff also have keys to the storeroom. In addition, in every case, maintenance departments do not enforce requirements to record items removed from the storerooms when inventory personnel are not on duty. This results in a lack of attention paid to the importance of cycle count and record accuracy. The percent of items out of balance as a result of cycle counts ranged from 7.8 percent to 48 percent for the five case study participants.

Physical inventories are the primary means of adjusting inventory balances for those without cycle count programs. For those with cycle count programs, physical inventories play a lesser role -- one case study participant does a physical inventory every two to three years and another has discontinued the program.

### **2.3 INVENTORY MANAGEMENT/REPLENISHMENT PRACTICES**

The make-up of inventory varied among participants. For example, case study participant A excludes most non-revenue material (such as that for facilities) and engines. Rebuild

components are included at no cost; new items are included at cost. Case study participant B excludes rebuilt components and selected low dollar items. Case study participant C excludes body parts and low dollar items. Rebuilds are included at \$.01; new components are included at the average cost. The fourth case study participant includes all rebuilds in inventory and new components with a dollar value greater than \$1,000. Components with a one year expected life are included at zero cost. All other items are included at the purchase cost. Inventory at this transit agency also includes facilities, radios and fare system equipment. Case study participant E includes rebuilt items at the rebuild cost. The cost of new components is averaged with the cost of the repaired components. This site also includes facilities and radio equipment as part of the inventory.

The number of stockkeeping units (SKU's) managed by the case study participants ranged from 5,900 to 78,900 and the inventory dollars ranged from \$710,000 to \$24,500,000. This range reflects the size of the transit property, inclusion of rail vehicles and the number of transportation modes.

The case study participants used a variety of methods to stratify inventory. Each participant had a slightly different method of identifying items that require the most attention. These included the Part Manager's experience, unit cost over \$5, fast moving items defined as the number of units and/or transactions, and fast moving items defined as the number of bin trips.

One primary method was used by the case study participants used to replenish inventory: min/max or a variation. In addition, some agencies specified selected items as "order on request only" (ORO). Most participants used fixed formulas to calculate replenishment parameters, such as min/max levels and order quantities and applied the results to all items. In many cases, the formulas were arbitrary, such as the maximum level equals twice the minimum level, or order enough to keep a month's worth on-hand. Individual item factors, such as usage and historical lead-time were considered only intermittently.

Lead-time calculations are generally a mixture of historical vendor lead times and internal administrative time. Internal administrative lead-time is usually a fixed quantity regardless of the method in which material is procured. In one case, total lead-time was fixed (one week) for all items. Most participants treated each inventory replenishment as a separate procurement to be filled using a standard purchase order. In one case where blanket purchase order (BPO) contracts were used, bids were still obtained from multiple BPO vendors.

**Table 7 Inventory Management Replenishment**

<b>Inventory Management/ Replenishment</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Number of SKU's	5,900	6,200	16,300	78,900	75,150
Inventory Dollars	\$710,000	\$2,300,000	\$968,000	\$24,500,000	\$18,800,000
Annual Usage	\$566,000	\$2,600,000	\$1,900,000	\$13,600,000	\$18,500,000
Transactions per Week	315	1,262	1,800	3,741	Not available
Material Classifications Used	Parts Manager's estimate of high usage; No ABC	None, ABC in computer but not used	> or < \$5 unit cost; high usage dollars. No ABC	Fast moving items; by replenishment method--standard, ORO, obsolete; Minimal ABCD	Fast moving items (bin trips), No ABC
Replenishment Method(s)	Manual review	Min/Max	Min/Max	ROP with manual quantity (min, no max) ORO	Min/Max, some ORO for rail
Replenishment Strategy	Parts Manager's demand estimate; experience	Max = 2 x Min	>\$5 = 1 month on-hand; 2 months on-hand for everything else.	ROP = (lead time + Mo. Demand) x 2; QTY = annual usage	Manually set min/max, computer adjusted based on usage
Lead Times	Manual estimate	1 week (all items)	Manually adjusted by Parts Manager	40 days + historical vendor lead time	Vendor lead-time + 20 or 30 days admin.
Forecast/Plan Demand	No	No	Partial	Yes, "time to stockout"	No
Purchasing Method(s)	Standard PO	Standard PO	Standard PO	Standard PO, minimal BPO	County BPO/Contract
Obsolete Inventory Review	Yes; annual	As needed	As needed	Quarterly	As needed
"Nuts and Bolts" Management	Floor Stock/ Outsourced	In Stockroom/ Outsourced	Floor stock but in inventory/ Outsourced	Floor stock/ Outsourced	Floor stock provided from warehouse
Planning with Maintenance	Annual/Monthly	Weekly	Weekly	Weekly	No regular planning
Inventory Exclusions/ Inclusions	Excludes most non-revenue, facilities and engines. Includes other rebuilds at no cost; new at cost	Excludes rebuilt components and selected low \$ items	Body parts excluding low \$ items. Includes rebuilds at \$.01; new average at purchase cost	Includes all rebuilds and new >\$1000, 1 year life at 0 cost, others at purchase cost. Includes facilities, radio, fare system equipment	Includes rebuilds at rebuild cost, new cost average with repaired. Includes facilities, radio equipment

Table prepared by Thomas and Kilpatrick

None of the participants use ABC analysis, except minimally (although most systems have the capability). One participant used “D” items to designate slow moving or obsolete items. Some participants reviewed inventory for obsolete material on a regular basis and others only perform the review when directed by management or when conditions change (such as fleet retirements).

All participants except one outsourced the replenishment of nuts and bolts to external vendors. However, there were some variations in how these items were treated for control purposes. Most were on the floor as free stock but one participant kept them in the storeroom and another participant carried their value in inventory and expensed them based on periodic counts.

Participants had varying degrees of success in joint planning with maintenance. Most met regularly with maintenance but felt that planning and communication could be improved. None of the participants comprehensively forecasted item usage and inventory levels.

## **2.4 INVENTORY MANAGEMENT PERFORMANCE INDICATORS**

All case study participants have common challenges associated with maintaining and supplying inventory for aging fleets with a large number of different models. These challenges are irrespective of whether the fleet is publicly or privately managed and operated, the number of storerooms and maintenance facilities, dollars invested in inventory or the number of inventory staff. The table on the following page shows the values of inventory management performance indicators for the case study participants compared to each other and to the responses from the survey conducted in the previous project. (For omitted items, the data required for the calculations was not available or the indicators were not included in the survey.) The E-3 survey analysis found some performance indicators to be significantly different for bus and rail inventory. Indicators with significant differences are calculated separately for bus and rail. For other indicators, the survey analysis found no significant difference, so these are calculated for total inventory.

**Table 8 Inventory Performance Indicators**

Inventory Performance Indicators	Case Study Participants					Survey Results			
	A	B	C	D	E	Mean	Median	20 <sup>th</sup> Percentile	80 <sup>th</sup> Percentile
Bus Inventory Dollars per Vehicle	\$6,054	\$9,333	\$3,709	--	\$9,756	\$5,027	\$4,604	\$2,566	\$7,234
Rail Inventory Dollars per Vehicle	--	--	--	\$36,663	\$74,856	\$37,498	\$27,418	\$12,660	\$47,668
Annual Bus Inventory Turnover	0.80	1.15	1.97	--	1.95	1.74	1.43	0.75	2.54
Annual Rail Inventory Turnover	--	--	--	0.55	0.60	0.71	0.56	0.51	0.99
Bus Percent Demand Filled	97.9%	--	98.7%	--	94.8%	89.0%	95.0%	85.0%	98.0%
Rail Percent Demand Filled	--	--	--	87.4%	99.4%	86.1%	90.2%	84.4%	98.3%
Percent of Items Stocked Out per Week	2.67%	--	0.70%	0.14%	--	1.52%	0.17%	0.05%	1.54%
Percent of Items Stocked Out	42.9%	7.6%	27.8%	11.1%	23.3%	--	--	--	--
Average Days to Fill Bus Inventory Backorder	9.1	--	2.8	--	--	16.4	10	3	30
Average Days to Fill Rail Inventory Backorder	--	--	--	55.7	--	25.3	18	14	45
Percent of Items Out of Balance	7.8%	48.0%	19.3%	40.3%	20.8%	7.8%	5.0%	1.4%	10.0%
% Absolute Dollar Variance	1.5%	25.2%	13.3%	3.4%	35.6%	--	--	--	--
Inventory Transactions per Person (Week)	314.6	252.3	200	65.6	--	181.8	138.5	61.1	225.6

Table prepared by Thomas and Kilpatrick

Participants used few of the inventory management indicators identified in the previous study. Two participants tracked the fill rate and some tracked inventory turnover. None of the others were used. In addition, none of the participants tracked inventory accuracy on a regular basis. Cycle count results were used primarily for adjusting inventory.

Only a couple of the systems captured demand so that fill rates could be calculated. Fill rate information used in the case studies had to be extrapolated from various forms and was not very reliable. For example one participant's forms did not capture demand if maintenance could find the part elsewhere (e.g. cannibalism or running to another facility). Another was missing forms only intermittently filled out by second and third shift maintenance personnel.

Stockouts also proved to be not a very meaningful measure. Many items are carried at zero inventory or allowed to stockout on purpose either as order on request only (ORO), carried for reference, or being discontinued. In addition, many stockouts are filled before the item being needed. Finally, vendor agreements and other imaginative replenishment options will make zero inventory acceptable for some items.

As discussed previously, each of the five case study participants included or excluded different items from the inventory or valued specific material at different rates. The inclusion or exclusion of non-vehicle parts or high dollar value items such as engines will affect such performance measures as dollars per vehicle and inventory turnover. Valuing rebuilt components at actual repair cost versus at a penny also will affect inventory performance measures.

Table 8 summarizes the inventory performance indicators for each of the five case study participants. For each indicator, the following measures are presented:

- Mean -- the average value
- Median -- the middle value (equal number of respondents above and below)
- 20<sup>th</sup> percentile -- the value greater than 20 percent of the responses
- 80<sup>th</sup> percentile -- the value greater than 80 percent of the responses

As shown in the table below, bus inventory dollars per vehicle were calculated for four of the five case study participants. The fifth case study participant is a rail property only. "Inventory dollars per vehicle" is the average amount of inventory dollars on-hand to support a vehicle in the transit agency's fleet. This indicator measures the size of inventory, in dollars, that the transit agency holds to support a vehicle. It eliminates the effect of fluctuations in fleet size when monitoring inventory levels across time. It is also useful when comparing the relative size of inventory across fleets with different numbers of vehicles, different makes and models, different modes, etc.

For the case study participants, bus inventory dollars per vehicle ranged from a high of \$9,756 to a low of \$3,709. Of interest is the low dollar value of \$3,709 because this transit system has the highest number of vehicle types (11). This is also the only privately operated transit system. Both case study participants B and E were above the 80<sup>th</sup> percentile. While case

study participant E also has a large number of bus models (10), case study participant B has a relatively low number of different models.

Property E has more than twice the rail inventory dollars per vehicle as does property D, however property E also has almost twice the annual rail usage dollars as property D. While property D is near the average of the previous study, property E is well over the 80<sup>th</sup> percentile.

“Inventory turnover” is the number of times the “total inventory dollars” are used by inventory customers in a given period of time. Inventory turnover indicates inventory size, in dollars, relative to the amount of inventory that is used during a given time period. As an indicator, inventory turnover attempts to compensate for the size of demand when monitoring inventory levels, and is widely used to compare inventory performance across time and between different organizations. Since an objective of inventory management is to minimize inventory levels, the higher the inventory turnover, the more efficiently the inventory level is managed relative to the demand for inventory items (usage).

Two of the case study participants have an annual turnover of nearly two. This means that each year the transit agency uses two times the average amount of dollars it holds in inventory. Only one property has a turnover of less than one. This means that it takes more than one year for the inventory to turnover. As shown in the chart, the average bus inventory turnover from the survey was 1.74. Half of the bus survey participants turned over their inventory more than 1.43 times per year. Both of the rail properties have turnover rates near the survey median of 0.56.

The “percent of demand filled”, or the “inventory fill rate”, is the percent of items requested from inventory that are provided from inventory at the time of the request. This indicator measures the level of availability of inventory items.

Inventory fill rates were only available from or could be calculated from three of the bus properties. All three properties were at or above the average from the earlier survey. One property was above the 80<sup>th</sup> percentile. One of the rail properties was at the survey mean while the other exceeded the 80<sup>th</sup> percentile.

The “percent of items stocked out” measures the percent of the total number of inventory items (i.e. part numbers or “stockkeeping units” or SKU’s) that reach a zero balance during a given period of time. This indicator provides a measure of exposure to unfilled requests that is relative to the size of the inventory, in SKU’s. Three of the five case study participants were able to provide data to measure the percent of items stocked out per week. The percent of items ranged from a low of .14 percent for the project’s rail only case study to a high of 2.67 percent for the smallest property in the study. All case study participants were able to provide information on the number of stock items that currently have no quantity on hand. This performance indicator was not captured in the original survey but case study responses ranged from a high of 42.9 percent to a low of 7.6 percent. No correlation was apparent with the number of bus or rail dollars spent.

The “average days to fill inventory backorders” is the average time it takes to provide an inventory item that is unavailable at the time of request. The time to fill a backorder is the time period beginning with a request for an unavailable inventory item and ending at the time the item is provided to the requestor. These instances are averaged over a period of time to yield the “average time to fill backorders”. This indicator measures inventory management performance in resolving unavailable inventory items. Only two of the bus properties could provide this information. Case study participant A averaged 9.1 days, which is near the survey median of ten. Case study participant C averaged 2.8 days, which is well below both the mean and the median. (Case study participant C was able to fill many backorders from its other stocking location rather than through new purchases). The only rail property measuring average days to fill inventory backorders averaged 55.7 days, which is well over the 80<sup>th</sup> percentile.

The “percent of items out of balance” is the number of items (SKU’s) with a discrepancy between the actual and computer balances divided by the total number of items in inventory. It measures the overall accuracy of perpetual inventory balances relative to the size of inventory, in SKU’s. This indicator can be used to compare the overall accuracy of inventory balances between organizations or over time, regardless of the number of items stocked in inventory. Four of the five case study participants were well above the survey mean of 7.8 percent and were over the 80<sup>th</sup> percentile threshold.

The “percent absolute dollar variance” is the sum of dollar variances due to discrepancies regardless of whether the variances are positive or negative (“absolute dollar variance”) divided by the total value of all items that were counted. It measures the overall accuracy of inventory values relative to the size of inventory, in dollars. This indicator can be used to compare the overall accuracy of inventory value between organizations or over time, regardless of the total value of inventory. While this measure was not captured in the previous survey, all five case study participants were able to provide information on the number. Absolute dollar variances ranged from a low of 1.5 percent to a high of 35.6 percent.

The last performance indicator, “inventory transactions per person” is the average number of inventory transactions (issues, receipts, transfers, returns) per person for individuals with inventory management and control responsibility. This indicator measures the activity level of inventory material flow relative to the number of people in the inventory organization. It can be used to compare relative workload of inventory personnel across different organizations. Four of the five case study participants were able to provide information on this measurement. However, only one was below either the mean or the median and two were above the 80<sup>th</sup> percentile. Although the case studies do not represent a statistically valid sample, this was the only indicator that appears generally related to the relative size of the property. The larger the property, the less transactions per person per week.

## **2.5 TECHNOLOGY AND INFORMATION SYSTEMS**

All participants used automated systems to support inventory management. Platforms spanned mainframe, mini and microcomputers. All but one of the participants had outdated

inventory systems that are planned to be replaced either in 1999 or 2000. None of the participants currently used bar code, but three of the five are planning to implement some level of bar coding in the next two years.

Only two of the five systems were integrated with a work order system for vehicle maintenance while four of the five were integrated with a purchasing module.

**Table 9 Technology and Information Systems**

<b>Technology and Information Systems</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Automated Inventory System	Yes	Yes	Yes	Yes	Yes
Customized or Package	Package	Package	Package	Package	Custom
Platform	IBM S/36	IBM AS/400	PC LAN	Mainframe	Mainframe
Age/Status	Outdated	Outdated	Current	Outdated	Outdated
Barcode	No	Planned	Planned	No	Planned
Other Technology	None	None	None	None	None
Integrated with Work Orders	Yes	No	Yes	No	No
Integrated with Purchasing	Yes	Yes	Yes	No	Yes
Plans to Upgrade/Replace	Yes/1999	Yes/2000	No	Yes/1999	Yes/1999

Table prepared by Thomas and Kilpatrick

## CHAPTER 3 INTERPRETATIONS, APPRAISAL AND APPLICATION

The case studies provided significant insight into the actual inventory management policies and procedures of the participants. In particular, the case studies provided an opportunity to identify and examine the qualitative and sometimes informal practices, decisions and other attributes that affect inventory management performance but could not be captured in a survey. In addition, the case studies allowed a more detailed review of how formal inventory management decisions are applied on a day-to-day basis. This chapter interprets the effect of current practices on inventory management performance, and appraises how the factors potentially influenced the findings from the survey conducted during TRB project E-3.

### 3.1 THE EFFECTS OF CURRENT PRACTICES ON INVENTORY MANAGEMENT PERFORMANCE

Inventory management performance is the result of a complex interaction of several factors including inventory attributes, management decisions, policies and practices. Each case study presented a unique mixture of these factors to review, analyze and evaluate. Comparing and contrasting the five case studies, as well as interpreting inventory management results within each transit property, yielded the following items as key inventory performance factors.

- *The degree of focus of executive management on inventory performance goals.* Most organizations focus on the objectives that upper management identifies as important. Inventory management personnel are no different. Inventory performance indicators usually were positively affected in proportion to the emphasis received by executive management. For example, the case study participant managed by a private company gets assessed a fee (or capitalization charge) by their Corporate Office for the dollars tied up in inventory. Since transit management's evaluation is partially based on financial results, the inventory dollars per vehicle is well below the average for bus properties. Conversely, those that did not emphasize inventory dollar investment had higher than average dollars per vehicle. Case study participants that report vehicles out of service due to parts to executive management take much less time to get the needed parts than the average (days to fill back orders).

Inventory personnel in the case studies generally did not set goals and did not measure performance in the areas not emphasized by executive management, even if the measure is normally associated with inventory performance. In addition, the emphasis or lack thereof by executive management affects several of the other factors presented below, such as the performance indicators that are measured, the level of inventory management staff, etc.

- *The capability to accurately measure inventory performance indicators.* The capability to gather and report on various inventory performance measures varied significantly

among case study participants. This capability is influenced some by the emphasis of executive management but is mostly a result of the capabilities of the automated inventory system. Inventory accuracy provides a good example of the effect of this factor. Case study participants' computer systems did not have the capability to capture the percent of counted items for which the actual counted quantity did not match the quantity on hand in computer records. To track inventory accuracy, the case study properties focused on measures that the system provided, such as the net dollar adjustments or the number of items adjusted, and were unaware of the overall accuracy of their inventory balances. As a result all but one participant had a significantly higher percentage of discrepancies in inventory balances than average and were well above the 80 percentile for all survey respondents.

- *The staff time actually spent performing inventory management functions.* Four of the five case study participants have inventory staff assigned to positions with inventory management responsibilities. For some of the case study participants, much of the inventory management staff time is actually dedicated to non-management functions, such as operating the computer system, overseeing inventory transactions, correcting errors, generating inventory reports, generating purchase orders, and similar functions. As a result, the “effective” staffing levels for inventory management are much lower than the organization chart depicts. The attention of inventory management personnel is often directed to other areas to the detriment of inventory management performance.
- *The reasons and strategy behind configuring a storehouse network.* Four of the five case study participants have some version of central storage with satellite facilities. Traditionally, central stores are used in distribution networks to reduce the level of inventory required to meet a given demand. Supplying satellite stockrooms from a central warehouse averages the fluctuations in demand for all stockrooms and requires less material to meet this demand. The result can be a significant reduction in overall inventory investment. The case study participants utilized central stores for a variety of reasons, including space considerations and improved control of receipts and bulk material. In addition, some central storage facilities double as storerooms to support maintenance directly and some satellites receive material directly from vendors. As a result, the nature of the storehouse network has varied affects on the traditional inventory management strategy of reducing inventory through central storage.
- *The extent to which multiple replenishment methods are fully utilized.* All case study participants used more than one method to replenish inventory. However, the degree to which the full benefits are realized vary considerably based on how replenishment parameters are determined and how replenishment is administered. Most case study participants use general rules of thumb, rather than statistical methods to set the values of replenishment parameters, such as minimum and maximum values. Examples from the case studies include fixed vendor lead times for all items and doubling the minimum value to calculate the maximum. In addition, with the exception of using external vendors to replenish “nuts and bolts”, the replenishment method was only generally matched to specific types of items. For example, one participant used replenish “on

request only” (ORO) for all new items added to inventory regardless of the projected usage of the item. Finally, the case study participants only rarely used time-based replenishment methods, such as fixed period or fixed schedule replenishment. The benefits of multiple replenishment methods can be maximized by matching the method of replenishment with the demand characteristics of each item and calculating replenishment parameters based on statistical data.

- *The types of items included in or excluded from inventory and how inventory is valued.* Inventory management performance is affected by which items are included in inventory. For example, if repairable components are included in inventory at repair cost, inventory investment will be higher. If “nuts and bolts” are included in inventory, then service levels can be higher, since it is less costly to meet demand for lower cost items. The definition of an inventory item varied among case study participants. All included some components but the valuation varied from no cost to full repair cost.
- *The classifications used for managing inventory items.* All case study participants stratified inventory only intermittently using a variety of factors. “Nuts and bolts” and components were generally singled out for different management practices and varying attention was given to “high usage” items. Traditional “ABC” classifications were not fully utilized. The ability to manage thousands of inventory items and positively affect inventory performance can be improved by stratifying inventory and focusing management strategy accordingly.
- *The level of joint planning between inventory and maintenance personnel.* Inventory personnel for all but one of the case study participants met regularly with maintenance personnel to plan material needs. However, the case participants reported varying judgments regarding the quality of the information received from maintenance and the ultimate value of the planning sessions. Generally, case study participants reporting a higher level of planning success had performance better than the average of the survey participants.
- *The extent to which multiple procurement methods are used.* Most case study participants treated each inventory replenishment as a new procurement requiring the full procurement cycle. Participants rarely used blanket orders, annual contracts or staged delivery agreements. When these techniques were used, participants tended to gain the same approvals and follow procedures similar to a standard PO. As a result, lead-time reductions and the associated inventory management measures, (such as the time to fill back orders) were not necessarily improved through alternate procurement methods.
- *The level of discipline associated with record keeping during non-covered storehouse hours.* Case study participants without full coverage of storerooms by inventory personnel relied on maintenance personnel to record parts issues and secure the storeroom. In addition, policies regarding access to the storeroom during off-hours varied considerably among case study participants. The accuracy of transactions recorded by maintenance during off-hours is affected by several factors including the methods used to

record the transactions, the normal responsibilities of maintenance (such as looking up part numbers) and the emphasis placed on the task by maintenance management. The higher the level of discipline and importance placed on this task by maintenance management personnel the less accuracy suffered as a result of storeroom coverage.

The importance of storekeeping discipline was not limited to non-covered hours. Some case study participants allowed maintenance personnel in the stockroom during hours in which inventory personnel were present. In general, smaller storerooms with a storekeeper that “owned” the storeroom tended to elicit more record keeping discipline. The case study participant with one storeroom run by one person had the highest accuracy level, even though no cycle counting program was in place.

- *The focus of the cycle counting program.* The existence of a cycle program does not in itself guarantee accurate inventory records. Three of the five case study participants have cycle counting programs in place. Of the two that do not, one had the highest accuracy and the other had the lowest. In addition, the three with cycle count programs had inventory accuracy significantly below the survey average. The case study participants focused on resolving the specific inventory balances that were found to be in error during cycle counts. As discussed above, overall inventory accuracy was not measured and tracked. In addition, the participants did not attempt to identify and resolve the root cause of cycle counting problems in order to prevent future errors. As a result, overall inventory accuracy was not lower for those with cycle counting programs.
- *The level of inventory responsibility assigned to non-inventory personnel and inventory tasks omitted.* The number of inventory transactions handled by inventory personnel (efficiency) varied among case study participants in proportion to the total number of inventory personnel. Those with more personnel generally had fewer inventory transactions per person. Those with fewer personnel either left some tasks unperformed (such as cycle counting) or assigned tasks to non-inventory personnel (such as issues from the storehouse during off-hours). The result is a higher number of transactions for the property performed by fewer personnel.

The above items are the primary examples of factors related to actual inventory management practices at transit properties that can significantly affect inventory performance.

### **3.2 THE POTENTIAL EFFECT ON SURVEY RESULTS**

A survey was conducted during TRB study E-3 to isolate the factors and management decisions that affect inventory performance. Most of the analyses conducted on the survey results were inconclusive and produced only a few isolated findings with a level of statistical significance over 90%. Most of the expected relationships between inventory management decisions and inventory performance were not confirmed through statistical analysis of the survey results. For example, properties with locked storerooms and regular cycle counting programs did not have inventory accuracy that was statistically different from properties without

these practices. The case studies provided the opportunity to look closer at the relationship between inventory management decisions and inventory performance and provided insight into the potential effects on the survey results.

The previous section presented several factors identified during the case studies that could not be adequately captured in a formal survey. All of these factors can potentially affect inventory performance, skew the analysis and produce unexpected statistical relationships. The following are a few examples of how these factors can confound the survey results:

- The organizational structure for inventory management is not necessarily consistent with actual inventory management responsibilities. The survey analysis classified the inventory management organization structure of transit properties into five categories and examined the inventory management performance. The case studies show that inventory management responsibilities can be assigned independent of the actual formal organizational structure, thereby confounding the effects of structure on performance.
- Actual storeroom access varies, even when policy calls for locked storerooms. The survey results did not support the anticipated conclusion that locked storerooms resulted in higher inventory accuracy. The case studies show that various personnel, both inventory and non-inventory, have access to locked storerooms. In addition, other factors such as record keeping discipline can compensate for unlocked storerooms.
- The actual definition and measurement of inventory performance indicators can vary significantly between transit properties. The survey instructions attempted to standardize the definition of the inventory performance measures. However, the case studies show that the performance indicator values are affected by several variables including the capability to capture and calculate the indicators, the types of inventory items included in the calculations (such as components), and the capabilities of the computer systems.
- Replenishment and procurement methods can be utilized without gaining the full benefits associated with the techniques. The case studies show that several short cuts are used in the actual application of replenishment and procurement techniques. For example, min/max replenishment is used but the minimum and maximum levels are determined by a rule of thumb rather than statistical analysis of demand patterns and lead times. Blanket purchase orders provide another example. A property can require the same approvals and procedure for a blanket order release as for a standard PO, thereby foregoing the potential reduction in lead-time offered by establishing a BPO.

The implication from the case studies is that there are many individual circumstances that can affect statistical analysis and potentially lead to insignificant differences when trying to isolate the effect of specific factors on inventory performance. The analysis documented in project E-3 is an illustration of how these hidden factors can confound the results and lead to conclusions that are inconsistent with traditional inventory management concepts.

## CHAPTER 4 CONCLUSIONS AND SUGGESTED RESEARCH

The case study assessments provide a basis for extrapolating conclusions that are generally applicable to inventory management in transit properties regardless of size, mode, geographic location and other demographic and operating factors. This section presents these conclusions and suggests additional follow-up research to further examine and isolate the effect of these factors on inventory management performance.

### 4.1 CONCLUSIONS

Based on an assessment of case study results, we can conclude that the following general actions can have a positive effect on inventory management performance in most transit properties:

- **Elevate the focus of inventory management personnel from an inventory transaction orientation to an inventory management orientation.**

The primary focus of case study inventory management personnel is on monitoring and controlling specific inventory transactions, including reordering inventory material and correcting cycle count discrepancies. The case study analysis reveals that only intermittent attention is directed at managing overall inventory performance, usually in the form of annual budgeting activities or one-time edicts to reduce inventory or material expense. Progress is generally made in the targeted areas of inventory performance during the limited periods of attention, particularly with inventory reduction. Elevating the focus of inventory management personnel will result in a more consistent influence on inventory performance and ensure a more appropriate balance between reducing inventory and increasing service levels.

- **Define specific performance indicators for inventory, set goals and track actual performance versus goal.**

Measuring and tracking inventory performance indicators are prerequisites for improving inventory management performance. By setting goals, executive management can underscore the importance of inventory management and provide direction for inventory management personnel. Tracking inventory performance will also allow inventory management personnel to more effectively evaluate the effects of changes and management activities, and to establish continuous improvement as a significant factor in inventory management decisions.

- **Use “ABC” stratification as a tool for focusing inventory management effort.**

Case study participants use a variety of techniques to stratify inventory for management and control purposes. “ABC” stratification will allow inventory management personnel to more effectively direct attention to the inventory items that can have the most significant effect on performance and ensure that all items are appropriately managed. ABC classifications based on annual usage dollars can be used for determining item replenishment methods and safety stock levels, cycle counting frequency and error tolerances, and service level targets and other inventory management activities. (See the Inventory Management Handbook for a complete discussion on ABC analysis.)

- **Increase interaction and joint material planning with Maintenance and other “customers”.**

Most formal inventory management techniques rely on historical information on factors such as demand and usage, lead times and prices. However, this information can be misleading as changes are made to fleet make-up and maintenance practices. In particular, major overhauls, campaigns and capital projects can skew inventory statistics and adversely affect inventory management decisions. The case study participants had varying degrees of success in working with maintenance to project material requirements and identify changes in demand patterns for inventory items. Inventory management performance can be improved significantly by increasing the effectiveness and the quality of information resulting from joint planning with maintenance. Continued efforts are warranted to ensure that the benefits of joint planning are realized.

- **Use multiple replenishment methods based on actual statistics and maintenance projections.**

Inventory items can be replenished using different methods depending on the nature of the demand for the item and other characteristics. For example, items with stable usage, such as filters replaced during regular inspections, can be scheduled for regular delivery of a fixed quantity (e.g. 10 per week.). Conversely, items with usage that is difficult to predict can be replenished using trigger quantities, such as reorder points or minimum levels. Case study participants used variations of these replenishment techniques, but with parameters that were often based on general rules of thumb or, in some cases, arbitrary. Order points, order quantities, safety stock, lead times, min/max quantities and other replenishment parameters should be calculated for each item based on historical data and statistical formulas that ensure the most effective replenishment. (See the Inventory Management Handbook for more detail on replenishment calculations). These parameters should then be adjusted based on regular maintenance planning sessions and changes in maintenance material requirements.

- **Utilize a full range of purchasing methods depending on the specific characteristics of the purchase.**

There are many options in configuring a purchase, even within the constraints of public procurement requirements and internal approval procedures. Most case study participants used standard purchase orders for the overwhelming majority of purchases for inventory material and treated each inventory replenishment as a separate purchase. Alternative purchasing methods, such as blanket purchase orders and releases, multi-year purchase agreements, staged deliveries, annual contracts, consignment agreements, vendor-owned/controlled stock, and other purchasing methods can be used depending on the nature of the items being purchased, the vendor relationship, marketplace and industry characteristics, and other factors. (See the Inventory Management Handbook for more information on purchasing methods). By matching the purchasing method to the situation, transit properties can potentially shorten lead times, increase buyer productivity, improve vendor performance, reduce prices and develop a more secure and reliable source of supply.

- **Initiate a cycle counting program with emphasis on resolving the root cause of discrepancies.**

Most inventory management decisions are based on data developed and maintained in automated inventory systems. The accuracy of computer inventory data directly affects the quality of these decisions. In spite of the fact that three of the five case study participants have a cycle counting program, improving inventory accuracy is an area with significant opportunity for improvement. Making adjustments to correct inventory differences is an important part of a cycle counting program. However, cycle counting programs can reduce errors and maintain a high level of inventory accuracy if the focus of the program includes diagnosing the cause of discrepancies and eliminating the conditions that produce inventory errors and imbalances. Examples of causes include mislabeled bins, sloppy housekeeping, confusing procedures for recording transactions, and improper storehouse security.

- **Upgrade automated systems and technology for inventory management support.**

The inventory systems and related technology available in today's marketplace can provide improved tools for managing and controlling inventory. Examples of potential automation and technology tools include:

- flexible inventory management and “work flow” software providing the capability to support improved inventory processes and tailor the user interface for specific functions
- report writers and query tools to improve inventory information, analysis and performance tracking

- interfaces with e-mail and general office systems to provide automatic notification and exception reporting
- bar code and other electronic data gathering technology to reduce input errors and increase productivity
- electronic parts catalogs and imaging to simplify the identification of parts and part numbers
- electronic data interchange (EDI) and e-commerce capabilities to reduce lead times for inventory replenishment and increase supply reliability.

## **4.2 SUGGESTED RESEARCH**

The case studies provide affirmative evidence that “real world” analysis of inventory management at public transit properties can yield valuable insight into the relationship between inventory management decisions and performance. The results of the case study analysis have advanced the work begun with the survey in project E-3 and have contributed significantly to understanding the conclusions reached during the survey project. In addition, the case study analysis has presented several conclusions that can be examined further through longer-term on-site studies with public transit properties. The logical next step in examining the effects of inventory decisions on inventory performance is to develop empirical evidence to test the conclusions reached in this study.

Developing empirical data requires a longer-term study in which specific changes are introduced into inventory management practices at selected transit properties and the resulting effect on inventory performance is measured. In particular, the study would have the following general tasks:

- Task 1: Review prior research and develop a preliminary design for conducting on-site research at ten selected transit properties.
- Task 2: Select ten transit properties to participate in the study representing a cross section of size, mode, geographic location, climate and service area.
- Task 3: Visit each transit property to finalize the experimental design and set-up specific procedures for conducting the research.
- Task 4: Begin the research by measuring selected inventory management performance indicators for a minimum period of six months prior to introducing changes.
- Task 5: Introduce selected inventory management changes into each of the ten transit properties designed to test the conclusions reached in the case study project.

Continue to gather measurements on the selected inventory performance indicators for a minimum of one year.

Task 6: Analyze the data and identify the effects of introducing the changes at each of the ten transit properties.

Task 7: Prepare a report to document the results of the study.

This study should be designed to produce direct evidence of changes, or lack thereof, in inventory management indicators as a result of changes in specific inventory management practices, policies and procedures.

## APPENDIX A      CASE STUDY METHODOLOGY

1. ***Notify the property of selection to participate in study.*** Send a letter to the property contact informing him or her that they have been selected to participate in the study (cc: property executive). The letter should:
  - re-state the responsibilities of the agency as a participant
  - describe the Project Sponsor and Project Coordinator roles in detail
  - summarize the general approach and timeframe for the case study
  - describe the first visit agenda in detail
  - ask the Sponsor to issue a memo internally announcing the study to appropriate personnel
  - state that we will call soon to discuss the initiation of the project and potential start dates
  - ask for reply in writing formally accepting participation in the project
  
2. ***Obtain letter from each transit property formally stating their agreement to participate in the project.***
  
3. ***Conduct a preliminary telephone discussion with the Sponsor of the selected property.*** Conduct a conference call between the Principal Investigators and the Project Sponsor. The phone call will cover the following:
  - welcome the agency to the project
  - formally introduce the Principal Investigators and briefly describe their experience
  - assign the Project Coordinator
  - agree on potential dates for the first visit, including the executive interview
  - answer questions
  
4. ***Conduct a follow-up telephone discussion with the Project Coordinator.*** Conduct a conference call between the Principal Investigators and the Project Coordinator. The phone call will cover the following:
  - introduce the Principal Investigators to the Project Coordinator
  - discuss the project approach and the Coordinator's role
  - describe the information request that we will send to the Coordinator
  - finalize dates for the first visit
  - answer questions
  
5. ***Send a written request for information to the Project Coordinator.*** Develop a written information request and send it to the Project Coordinator so that data can be gathered and forwarded to the Principal Investigators before the initial visit. The information to be provided

by the Project Coordinator includes general information on the property, specific information on inventory management (policies, procedures, practices, performance, systems, etc.) and suggested personnel to interview during the initial visit.

6. ***Review information provided by the Project Coordinator and finalize first visit itinerary.*** Review the written information provided by the Coordinator and finalize the itinerary for the first visit as follows:

- identify missing information or items that need to be examined further during the visit
- analyze current inventory performance and identify potential areas for study
- identify potential sources for data collection during the study
- review and classify the agency's policies and inventory management decisions
- develop a list of employees to interview and inventory sites to visit
- finalize first visit itinerary, including the number of days and the general activities for each day
- revise the standard orientation package/presentation and finalize orientation meeting attendees

7. ***Finalize first visit plans with the Project Coordinator.*** Conduct a phone discussion with the Project Coordinator to finalize plans for the first visit (this may actually take more than one call):

- discuss the preliminary analysis of the written information with the Coordinator
- solicit the Coordinator's response to potential areas for study, data collection, etc.
- confirm interview list, site visit plans, orientation attendees
- confirm date/time for executive interview
- finalize itinerary with the Coordinator.

8. ***Conduct first visit to property.*** Conduct the initial visit to:

- meet and orient all agency personnel involved with the case
- conduct the "commitment and attitude" interview with the Executive Sponsor
- document and confirm current practices and measures
- confirm formal and informal organization and decision making
- diagnose current problems, issues, and opportunities
- use E-3 findings to highlight specific factors potentially affecting inventory performance
- identify specific performance measures and set up data collection methods
- present case study design to Project Coordinator and others
- initiate case study data collection processes

Sample first visit itinerary (average of three days depending on the size of the agency and number/location of inventory sites):

Day 1: Orientation Session (2 hours)

Executive interview/attitude survey (1 hour)  
Review additional information gathered before the visit (as required)  
Begin interviews/facilities tours (4 hours)

Day 2: Continue interviewing, analysis/diagnostic review (as required)  
Revise preliminary case study data collection methods/design (2 – 4 hours)  
Review case study design with Coordinator and revise (as required)

Day 3: Complete case study design (as required)  
Present case study design/train participants to collect data (2 hours)  
Set-up regular communication and monitoring methods with Coordinator  
Conduct visit closeout meeting with Coordinator (1 hour)

9. ***Monitor case study activities.*** Monitor activities with the Project Coordinator through regular bi-weekly progress reports and follow-up telephone calls when needed. In addition, the Project Coordinator should contact the Principal Investigators at any time when questions and issues arise. The regular weekly report should contain the following:

- the performance measurements and other data collected during the week
- summary of any changes or special conditions affecting management factors
- a brief summary of any unusual circumstances, issues, or other problems
- any anticipated issues or special conditions anticipated for the following week

The bi-weekly report should be transmitted in electronic format, preferably through e-mail, whenever possible.

10. ***Conduct second visit to directly monitor case activity and make adjustments as necessary.***

The purpose of the second visit to the agency is to:

- observe all case activity at the inventory sites
- review the case study design against actual case study activities
- identify areas requiring adjustment or revision to either the design or the activities
- confirm the integrity of data gathering activities
- address and resolve issues or problems
- identify opportunities to vary inventory management factors to directly observe the subsequent affect on performance measurements
- implement any changes to case study activities, scope, design, and/or data collection

The second visit will take place during the second or third month, depending on the progress and status of the case study. Exceptions will be made if the case study faces issues or problems that cannot be resolved through the regular monitoring process.

Sample second visit itinerary (2-3 days depending on the size of agency and number/location of inventory sites):

Day 1: Review meeting with the Project Coordinator (2 hours)  
Site visits to inventory locations and case study activity review (4 – 8 hours)

Day 2: Continue site visits and case study activity review (as required)  
Resolve issues, identify and design changes (1 - 4 hours)  
Review changes with Project Coordinator (2 hours)  
Finalize changes and plans for the remainder of the case study (2 hours)

Day 3: Present changes to case study design and train appropriate participants (2 hrs)  
Conduct status meeting with the Project Sponsor/Executive (1 hour)  
Conduct visit closeout meeting with the Project Coordinator (1 hour)

11. **Conduct third visit to close out study.** The purpose of the third and final visit is to:

- closeout the case study
- gather all remaining case related data and documents for analysis
- review the case and results with Project Coordinator
- conduct a case study closeout session with all participants
- conduct a closeout session with the Project Sponsor/Executive describing the general observations from the case, the analysis process, and when to expect project findings

The third visit will take place at the end of the fourth month of the case study.

Sample third visit itinerary (2 days):

Day 1: Review meeting with the Project Coordinator (2 hours)  
Site visits to dismantle case study activities/data collection (2 – 4 hours)  
Prepare closeout session (revise standard presentation)

Day 2: Conduct closeout session  
Conduct closeout meeting with Project Sponsor/Executive  
Conduct closeout meeting with Project Coordinator

## APPENDIX B            GLOSSARY OF PERFORMANCE INDICATORS

### Inventory Amount Indicators

**Total Inventory Dollars.** “Total inventory dollars” is the total cost to the transit agency of all items held in inventory at a given point in time. It is calculated by multiplying the number of units for each item times the item's unit cost, and summing across all items. This indicator measures the size of inventory in terms of the dollars that the transit agency has tied-up in inventory assets. It is best used to monitor changes in the size of inventory (increases and/or decreases) by examining the value at different points in time.

**Inventory Dollars per Vehicle.** Inventory dollars per vehicle is the average amount of inventory dollars on-hand at a point in time to support a vehicle in the transit agency's fleet. It is calculated by dividing the “total inventory dollars” by the number of vehicles using items from the inventory. This indicator measures the size of inventory, in dollars, that the transit agency holds to support a vehicle. It eliminates the effect of fluctuations in fleet size when monitoring inventory levels across time. It is also useful when comparing the relative size of inventory across fleets with different numbers of vehicles, different makes and models, different modes, etc.

**Inventory Turnover.** Inventory turnover is the number of times the “total inventory dollars” is used by inventory customers in a given period of time. For example, annual turnover is calculated by dividing the total dollar value of the items used from inventory during the year by the average total dollar value of items held in inventory during the year. The average total dollar value of items held in inventory for the year can be calculated by taking the average of “total dollar inventory” levels measured at different times during the year (for example, at the end of each month, or the beginning and ending levels for the year). Turnover can be calculated for any time period. For example, monthly turnover is calculated by dividing total monthly dollar usage by the average total dollar inventory for the month.

Inventory turnover indicates inventory size, in dollars, relative to the amount of inventory that is used during a given time period. For example, an annual inventory turnover of 2.5 means that the transit agency uses two and a half times the amount of dollars it holds in inventory. In other words, inventory is “turned over” 2.5 times during the year. Since an objective of inventory management is to minimize inventory levels, the higher the inventory turnover, the more efficiently the inventory level is managed relative to the demand for inventory items (usage). As an indicator, inventory turnover attempts to compensate for the size of demand when monitoring inventory levels, and is widely used to compare inventory performance across time and between different organizations.

**Months on Hand.** “Months on hand” is the number of months that a transit agency's inventory will last if no additional items are added to inventory. Months on hand is the inverse of monthly

inventory turnover. It is another way to measure the size of inventory relative to the demand for inventory over a specific time period. It is calculated by dividing the average “total inventory dollars” for a month by the total dollars used from inventory during the month. The fewer months that a transit agency must keep on hand to support the demand for inventory items, the better the performance relative to minimizing inventory levels. This indicator can also be calculated for different time periods, such as “days on hand” or “years on hand”.

Months on hand is a figurative rather than a literal indicator in that it is a measure of how long an agency's inventory dollars will last. This measure assumes that the items on hand are exactly the items that will be used during the time period. Like turnover, it attempts to compensate for the effects of demand levels on the size of inventory.

### **Availability/Service Indicators**

**Percent Demand Filled (Fill Rate).** The percent of demand filled, or the inventory fill rate, is the percent of items requested from inventory that are provided from inventory at the time of the request. It is calculated by dividing the total number of items requested from inventory into the total number of items issued from inventory at the time of request during a given time period. This indicator measures the level of availability of inventory items. It also defines the probability that an item will be available from inventory when it is needed. The fill rate is used to monitor how well the items held in inventory match the items that are needed over a given period of time. It also is used to compare inventory management performance, regarding availability, between organizations.

**Number of Stockouts.** The number of stockouts is the number of unanticipated times that inventory items reach a zero balance on hand during a specified time period. This indicator measures the exposure of inventory to potential unfilled requests. Only unanticipated stockouts are counted because, at times, some items are carried at zero balance on a planned basis (such as seasonal items or items that are ordered only on request). Unanticipated stockouts are counted regardless of whether there is an outstanding request for the item. The fill rate measures the ultimate availability of inventory material, but the number of stockouts indicate the degree to which fate is tempted.

**Percent of Items Stocked Out.** The “percent of items stocked out” measures the percent of the total number of inventory items (i.e. part numbers) that reach a zero balance during a given period of time. The total number of inventory part numbers are called “stockkeeping units” or SKU’s. This indicator is calculated by dividing the number of unanticipated stockouts during a given period of time by the total number of SKU’s held in inventory. This indicator provides a measure of exposure to unfilled requests that is relative to the size of the inventory, in SKU’s. It provides a measure that can be compared across time regardless of the number items added or removed from inventory, or between organizations with different numbers of SKU’s in inventory.

**Number of Open Back Orders.** The “number of open backorders” is the number of unfilled requests for inventory material that exist at a given point in time. It is calculated by counting the number of inventory items that have been requested and are currently unavailable from inventory. It is used to focus inventory management activity and to monitor the status of the availability of inventory items at a given point in time.

A similar indicator is the “average number of open back orders”. This indicator measures the typical status of inventory availability by averaging the number of open back orders at several points in time.

**Time to Fill Backorders.** The “time to fill backorders” is the average time it takes to provide an inventory item that is unavailable at the time of request. The time to fill a backorder is the time period beginning with a request for an unavailable inventory item and ending at the time the item is provided to the requestor. These instances are averaged over a period of time to yield the “average time to fill backorders”. This indicator measures inventory management performance in resolving unavailable inventory items. It can also be used to compare performance across organizations.

**Vehicles Out of Service.** “Vehicles Out of Service” is the number of times a vehicle is held out of service due to unavailability of inventory items. A vehicle is counted each time it misses a service run, even if the same part is unavailable. This indicator measures the effect of inventory availability on transportation service provided by a public transit agency over a specified period of time.

**Percent of Fleet Out of Service.** The “percent of fleet out of service” is the percent of a transit agency's fleet that is held out of service due to unavailable inventory items. It is calculated by dividing the “vehicles out of service” for a service run by the total number of service vehicles. This indicator can be averaged over a period of time to provide the average percent of fleet out of service. This indicator measures the effect of inventory availability on transportation service, relative to the total fleet size. It can be used to compare inventory performance across different fleet sizes and different organizations.

### **Inventory Accuracy Indicators**

**Dollar Variance.** The “dollar variance” is the difference between the “total inventory dollars” based on a transit agency's inventory records (book value) and the “total inventory dollars” based on a physical count of inventory items. This indicator measures the effect of inventory accuracy based on the aggregate dollar value the inventory. It tells how inaccurate an agency's records are based on total inventory dollars, and is used to adjust the book value of inventory.

**Absolute Dollar Variance.** The “absolute dollar variance” is the sum of the dollar variances for each individual inventory item (SKU). It is calculated by summing the absolute value of the difference between the dollar value of each item based on inventory records and the dollar value based on a physical count of the item. In using the absolute value, variances that are negative

and positive will not cancel each other out. This indicator provides a more comprehensive picture of the accuracy of individual inventory item values and an overall measure of the accuracy of “total inventory dollar” records. It presents the upper limit of the potential inaccuracy of book value by adding all variances regardless if they are negative or positive.

**Percent Absolute Dollar Variance.** The “percent absolute dollar variance” is the “absolute dollar variance” divided by the “total inventory dollars”. It measures the overall accuracy of inventory values relative to the size of inventory, in dollars. This indicator can be used to compare the overall accuracy of inventory value between organizations or over time, regardless of the total value of inventory.

**Item Variance.** The “item variance” is the difference between the number of units on hand of an individual item based on a transit agency's inventory records and the number of units based on a physical count of the inventory item. This indicator measures the accuracy of each items perpetual balance records, and is used to adjust the “quantity on hand” records for each inventory item. This measure is not normally summed to give a variance for the total number of units, however it can be averaged to give the average variance for an inventory item. This “average item variance” measures the average number of units that an item's physical count varies from the inventory records.

**Number of Items Out of Balance.** The “number of items out of balance” is the total number of inventory items (SKU's) for which and “item variance” exists. It is determined by counting the number of items for which the physical count does not match the inventory records for quantity on hand. While the average item variance measures the average size of the discrepancy between the physical count and the inventory records, this indicator measures the actual number of items that have a discrepancy.

**Percent of Items Out of Balance.** The “percent of items out of balance” is the number of items (SKU's) out of balance divided by the total number of items in inventory. It measures the overall accuracy of perpetual inventory balances relative to the size of inventory, in SKU's. This indicator can be used to compare the overall accuracy of inventory balances between organizations or over time, regardless of the number of items stocked in inventory.

### **Management Cost Indicators**

**Percent Inventory Carrying Cost.** The “percent inventory carrying cost” is the cost of maintaining inventory divided by the total dollar value of the inventory. The cost of maintaining inventory includes the following components:

- storage cost, the cost of storage space and equipment
- insurance cost, the cost, if any, of insuring inventory
- obsolescence, the cost of items that become obsolete (e.g. due to changes in fleet series)

- shrinkage, the cost of inventory items that become missing, damaged, spoiled, decayed or otherwise unusable
- capital cost, the opportunity cost associated with investing dollars in inventory rather in other assets

This indicator measures the “overhead” costs involved in maintaining inventory. One or more of the above components may be excluded from the calculation if it does not apply. For example, in some cases storage space is absorbed by other transit functions (such as vehicle maintenance).

**Percent Obsolete Inventory.** The “percent obsolete inventory” is the cost of obsolete inventory items divided by the total dollar inventory value. Although this indicator is also a component of carrying cost, many organizations track it separately. Items may become obsolete due to changes in the mix of vehicle series in the fleet, changes in parts design, changes in part quality specifications, etc. If these items remain in inventory, the transit agency will incur the cost of carrying items that it cannot use. This indicator assists in measuring the degree to which inventory management anticipates and reacts to changes in fleet mix and part storage requirements.

**Inventory Dollars per Person.** “Inventory dollars per person” is the total inventory dollars divided by the number of people with inventory management and control responsibility. Inventory management and control personnel are the entire inventory staff, including stores personnel, inventory planners, clerical personnel, etc. This indicator provides a measure of inventory management and control staffing levels relative to the size of the inventory, in dollars. It can be used to compare staffing levels across different organizations.

**Inventory Dollars to Personnel Dollars.** “Inventory dollars to personnel dollars” is the ratio of total inventory dollar value to the total cost (salary and fringe) of the personnel charged with managing and controlling the inventory. This indicator provides a measure of the cost of inventory management and control personnel relative to the size of the inventory, in dollars, that is being managed. It can be used to compare staffing costs across different organizations.

**Inventory Transactions per Person.** “Inventory transactions per person” is the average number of inventory transactions (issues, receipts, transfers, returns) per person for individuals with inventory management and control responsibility. This indicator measures the activity level of inventory material flow relative to the number of people in the inventory organization. It can be used to compare relative workload of inventory personnel across different organizations.

**APPENDIX C      CASE STUDY REPORTS**

## Case Study A

### Agency Profile

This small to medium sized transit agency is publicly owned and operated. It is located in a small urban area with a population of between 250,000 and 500,000.

### Fleet Profile

The fleet is comprised of between 51 and 300 large buses (four different models) and between 0 and 50 small buses (two different models). The average age of the fixed route bus fleet is 11.9 years. The average age of the paratransit fleet is 4.6 years. Material expenses for fiscal year 1998 totaled approximately \$560,000.

### Inventory Management Organization Profile

This transit agency employs one dedicated inventory management employee. This employee (Parts Manager) reports to the Superintendent of Maintenance who reports to the Director of Maintenance. The Parts Manager is responsible for performing all duties associated with the management of inventory including the planning, controlling, re-ordering of inventory parts, identifying vendors and obtaining quotes, and organizing and managing the stockroom. The Parts Manager is responsible for processing all inventory transactions, including issuing parts and receiving and recording all material delivered to the agency. This individual is also responsible for performing these activities for non-inventory materials and supplies.

Maintenance supervisors have responsibility for the stockroom during hours in which the Parts Manager is not present.

Currently, there is no written procedures manual for inventory management. However, there is a fairly detailed job summary sheet that describes the essential functions of the Parts Manager.

### Inventory Management Practices

#### Storekeeping

This case study participant has one storehouse that serves a single maintenance facility. The storehouse is locked at all times and is generally organized by vehicle system (electrical, suspension, brakes, body, etc.). Hours of storehouse operation where the storehouse is staffed by the Parts Manager are Monday through Friday from 8:00 A.M. to 5:00 P.M. In addition, there are two additional shifts where the Maintenance Supervisors are responsible for giving out parts. These shifts are Monday through Friday, between the hours of 4:00 P.M. to 8:00 A.M. the following morning, and from 8:00 A. M. to midnight on Saturday and 11:30 A.M. to 8:00 P.M.

on Sunday. During the shifts when the Parts Manager is not present, the Maintenance Supervisors are responsible for manually recording parts issued out of the storehouse using a paper form.

The Parts Manager enters issue transactions once per day from completed work orders. There is no regular cycle counting program in place. An annual inventory is the primary tool for checking inventory balances. In addition, the Parts Manager checks any unusual balances (e.g. a negative balance) that appear on regular computer reports.

### Material Planning

The Parts Manager works with the Maintenance Manager to plan aggregate inventory as part of the regular budgeting cycle. The budget for materials is established based on the prior year's expenditures, anticipated increases in parts price books and any changes in the fleet. Monthly meetings are held with Maintenance to discuss material that will be needed.

### Inventory Management and Replenishment

Individual inventory parts are managed on an as needed basis to support current maintenance activity, usually in response to requests from mechanics to stock a part. Although the Parts Manager generally knows which parts have high usage, there is no formal stratification of inventory.

The computer system has the capability to generate replenishment reports based on reorder points and quantities. However, since parts issued to work orders are not entered until the work order is complete, the balances in the system are not current. As a result, inventory replenishment is mostly a manual process (although the Parts Manager does periodically review the automated report). The Parts Manager checks the number of remaining units in a bin when a part is issued and records the part number on a form if the on hand quantity is "low" or if the last part is taken. Maintenance supervisors use this form when the Parts Manager is not available. In addition, maintenance personnel use this form to record requests for the purchase of non-inventory parts or parts to be added to inventory. The Parts Manager also periodically checks bins, especially for fast moving parts, and adds parts with low on-hand quantities to the form. Parts with zero on-hand or for which a work order is waiting, are marked as "out" or "hot", respectively. The Parts Manager relies on his experience with the demand for parts, vendors and lead times, and requests from mechanics to determine when a part is "low" and to determine the order quantity.

Parts are ordered daily from vendors using a standard PO. Orders over \$10,000 must have Board approval; others can be awarded based on three quotes. The agency does not regularly use blanket orders or annual contracts with vendors for vehicle parts.

"Nuts and bolts" are stored in the maintenance area as floor stock. An outside vendor monitors usage and replenishes the floor stock as necessary, with oversight from the Parts Manager.

### Catalog/Parts

The inventory for this property contains approximately 5,900 SKU's (including 260 non-stock items carried in the catalog) valued at approximately \$710,000.

Inventory generally consists of revenue vehicle parts and maintenance supplies. All vehicle parts are added to the catalog when initially ordered. If quantities will not be stocked for a part, the part is later removed from the catalog. The Parts Manager reviews manufacturer recommended parts lists for new vehicles and determines what to stock.

The Parts Manager reviews parts annually for obsolescence. Parts that have not moved in two years are examined and discarded if appropriate. Typically, approximately \$5,000 in obsolete items are identified annually.

## **Inventory Management Performance**

### Inventory Accuracy

During the annual physical inventory ending October 1998, 85.5% of inventory items were in balance with computer system records. Five thousand six hundred and five items were counted. Total inventory dollars on-hand were \$705,968. Eight hundred thirteen (14.5%) items were out of balance for an absolute dollar variance of \$33,172 or 4.7%. The net dollar variance was \$11,246 or 1.59%.

Based on cycle count sampling during the 16-week period of the case study, item accuracy was 92.2%. Five hundred eighty-seven items were counted representing \$70,340. Forty-six items (7.84%) of items were out of balance. The net dollar variance of the cycle count period was \$11,246 or 1.6%. In absolute dollars, the variance was \$33,172 or 4.7%.

### Inventory Usage

The average dollar usage per month during the case study was approximately \$58,831.

Total inventory transactions per week for receipts and issues for the 16-week period of the case study averaged 314.6.

### Inventory Availability

Stockouts per month were figured using the "Parts and Materials to be Ordered" form. Approximately 21.6 items were stocked out (zero on-hand after an issue) on average for the nine months from August 1998 to April 1999. This figure represents .36% of the total SKU's or 2.67% of the total active SKU's. Using the Reorder Report for the months of January and February 1999, stockouts for items below the re-order point (which includes items at 0 on-hand)

averaged 454 items per month. Zero on-hand items were calculated at an average of 346 per month, representing 5.9% of the total SKU's or 42.9% of the active SKU's. Using the "Stockouts from Inventory on Order Report" for the period of mid-December 1998 through April 30, 1999, stockouts averaged 101 with 42 at zero on hand. This represented 0.7% of the total SKU's or 5.2% of the active SKU's.

The percent fill rate and time to fill backorders were calculated from the "Parts and Materials to be Ordered" form and Receipt Reports. For the period November 1998 through April 1999, 140 were stocked out on average, representing 2,505 orders (from an expense distribution report) or 94.4% of the total orders from the period. This figure also represents 6,513 issues (a sample value of 2.57 issues per Work Order) or a 97.9% fill rate. Time to fill backorders averaged 9.1 days.

Inventory transactions per Inventory person were calculated at an average of 314.58 per week for the period November 1998 through April 1999.

Using a sampling of 783 work orders from the current fiscal year, material issues per work order averaged 2.57.

### **Technology and Information Systems**

At the time of the case study, this agency was using an outdated IBM System 36 based software package to support materials management. The software also included a work order system for vehicle maintenance, as well as a purchasing module. The agency is currently replacing this software with a new PC-based fleet maintenance system that will provide increased support for inventory management, including cycle counting and on-line processing. There are no current plans to implement bar coding.

## Case Study Data Collection and Analysis

The following forms and reports were requested to collect data. Minor modifications to normal data collection procedures were included.

1. Please provide the following reports from the computer system once at the beginning of the study:
  - Inventory Listing by Part Number
  - Item Analysis by Issues

2. The form “PARTS & MATERIALS TO BE ORDERED”. Please continue to use this form during the study and save all forms. On the form, please clearly designate:
  - Any part added to the list because the last item was issued from inventory.
  - Any part added to the list and the part is out-of-stock (zero on hand).
  - Dates for all entries.

Also, please add an item to the list every time it is needed for a work order, even if the item is already on order.

3. The following reports from the computer system:
  - Parts Issued from Inventory (Monthly)
  - Parts Received Report (Monthly)
  - Inventory Parts on Order (Weekly)

In addition, any other reports that list inventory transactions for the week (or month).

4. Reports (manual) of vehicles held out of service due to parts – copies of all reports.
5. Cycle counting sheets. Please use the attached counting sheets to count at least 10 items each day (50/week).
6. Accounting data. Please provide the following at the end of each month:
  - Inventory Dollar Balance

- Inventory Expense for the Month
- Inventory Adjustments for the Month

**Inventory Item Cycle Count Form**

Date: \_\_\_\_\_

<b>Item No.</b>	<b>Computer Balance</b>	<b>Count</b>	<b>Item Unit Cost</b>

The property provided the requested reports and forms throughout the case study. The information used to calculate performance measures was as follows:

- Dollars per vehicle:
  - Total Inventory Dollars calculated from monthly computer reports (issues and receipts)
  - Total number of vehicles identified during site visit
- Inventory Turnover:
  - Annual Usage Dollars from the Expense Distribution Report
  - Total Inventory Dollars calculated from monthly computer reports (issues and receipts)
- Percent of items stocked out and Stockouts per Month:
  - Items listed as “out” on the Parts and Materials to be Ordered Form
  - Items at zero on the Reorder Report
  - Items at zero on the Parts on Order Report
- Percent of demand filled:
  - Unfilled orders from the Parts and Materials to be Ordered Form
  - Total work orders from the Expense Distribution Report
  - Average issues per work order through sampling work order forms during site visit
- Time to fill backorder:
  - Date of unfilled demand from the Parts and Materials to be Ordered Form

Date of receipt from the Parts Received Report

- Transactions per person per week:

Total transactions from computer reports and work order sampling

Staff levels from site visit

- Percent of items out of balance:

Cycle Count Sheets – items counted and items with count variances

- Absolute Dollar Variance:

Cycle Count Sheets – value of items counted and absolute value of variances

- ABC Analysis:

Revised from the Annual Usage Report

## **Case Study B**

### **Agency Profile**

This medium sized property is publicly owned and operated. It is located in a medium size urban area with a population of between 500,000 and 1,000,000.

### **Fleet Profile**

The fleet is comprised of between 51 and 300 large buses (five different models) and between 0 and 50 small buses (one model). The average age of the fixed route fleet is approximately nine years. The average age of the paratransit fleet is approximately six years. The total inventory value for fiscal year 1998 was approximately \$1,967,293, including major components.

### **Inventory Management Organization Profile**

This transit agency employs an Inventory Control Manager and four dedicated Stockroom Clerks at the primary maintenance facility. The Maintenance Foreman, under the “dotted-line” direction of the Inventory Control Manager, manages inventory at a satellite maintenance facility. The Inventory Control Manager reports to the Director of Procurement who reports to the General Manager. The Inventory Control Manager is responsible for the maintenance and control of inventories and the planning, organizing and control of all inventoried parts at both storehouses. Specific storehouse management duties include receipt of all shipments and the handling of all in-house logistics and distribution, disposition of all surplus property and equipment, and the accuracy of inventory levels. The Inventory Control Manager is also responsible for the management and supervision of the material control program including the review of current and future supply requirements in coordination with the Maintenance Department, and for tracking buses out of service due to lack of parts. Additional responsibilities include tracking parts usage and conducting cycle counts, periodic audits and annual inventories and the management and control of all inventory systems.

The Inventory Control Manager has recently completed developing inventory procedures; however, more detailed procedures are planned with the advent of a new inventory management system.

### **Inventory Management Practices**

#### Storekeeping

This case study participant has a primary storehouse that serves the primary maintenance facility. A secondary storehouse serves a satellite maintenance facility. The primary storehouse is locked at all times; however, several individuals have keys (including all maintenance foremen and several directors throughout the organization). The primary maintenance facility operates on a 24/7 schedule. Hours of staffed operation for the primary storehouse are 7:00 A.M. to 11:00 P.M. Monday through Friday and 7:00 A.M. to 3:30 P.M. on Saturday. Three Stockroom Clerks are on duty from 7:00 A.M. to 3:30 P.M. Monday through Thursday. One Stockroom Clerk is on duty from 3:30 P.M. to 11:00 P.M. Monday through Thursday. Two Stockroom Clerks are on duty Friday from 7:00 A.M. to 3:30 P.M. and one Stockroom Clerk is on duty during the day shift on Saturday. At all other times, the Maintenance Supervisors and Foremen (and several other staff) have access to the storehouse. During the shifts when parts staff are not present, Maintenance Foremen are responsible for manually recording parts issued out of the storehouse.

The satellite maintenance facility is operated 7:00 A.M. to 3:30 P.M. Monday through Friday. The Maintenance Supervisor at this facility is responsible for ordering and receiving parts. The Supervisor also conducts periodic cycle counts. Mechanics manually record issues on a log sheet as they remove parts from inventory. Both storehouses are organized by part group, i.e., all engine parts are together, all air conditioning parts are together, etc.

Nuts, bolts, brake cleaner and some miscellaneous items are all non-stock items that are stocked by the vendors (vendors come in and replenish as needed). These items are kept inside the stockroom. New body shop parts are stored in the stockroom and mezzanine. Used body shop parts may be stored outside of the stockroom near the body shop.

Currently, cycle counting is being conducted manually by storeroom personnel daily. However, cycle counting is planned for the near future following the purchase and implementation of new inventory software. Bar coding capability will also be implemented at this time.

Space is a big issue with the current facility. Future plans call for a move into a new storage facility with an automated bin storage system for small parts. Nuts and bolts will be moved out of the stockroom to floor stock.

### Inventory Management and Replenishment

Inventory is stratified by ABC classifications in the computer system but the classifications are currently not used. Min/max is the inventory replenishment method used at the primary inventory storehouse. Min/max levels are set once, when new material is added to the inventory and adjusted as needs change. The Inventory Control Manager works with the Maintenance Department to determine material usage and on-hand quantities, however Maintenance has the final responsibility for min/max settings. Material order lead-time is not tracked formally even though the computer system has the capability to do so. The maximum order amount is calculated as twice the minimum. Lead-time is calculated on average as approximately one week; however, lead times for other items are applied as required.

The satellite storehouse does not utilize a formal method of replenishment. When a mechanic removes a part from the storehouse, a line on the "Material Request Log" is completed. The Maintenance Supervisor then orders material as it is needed using a "Stock Order Sheet" from the primary storehouse, usually via fax. The Stockroom Clerks at the primary facility then fill the order and complete the "Stock Order Sheet" with the date, number of issues, etc. When complete, the sheet is sent to Purchasing for entry into the computer system. The material is transferred in the computer system to the secondary storehouse from the primary storehouse. Material is delivered to the secondary storehouse weekly.

As material is used and the inventory on-hand quantity reaches the minimum level, or reorder point, the management information system tracks the material for reorder. A "Reorder Report" is then generated semi-weekly by the Purchasing Agent. The Inventory Control Manager generally talks with the Purchasing Agent on a daily basis to update the report and alert the Purchasing Agent to any changes. The Purchasing Agent is then responsible for the actual material purchases. The formal bid threshold is \$2,500 (written quotes required). Blanket purchase orders are not frequently used as a type of purchasing instrument for material replenishment. Annual contracts are also only used occasionally for such orders as oil analysis kits.

### Material Planning

The Maintenance Department is responsible for determining whether an item should be stocked in the inventory. If the decision is made to stock the item, an "Add to Inventory" form is completed and given to the Inventory Control Manager. The Inventory Control Manager then updates the system with the new information and creates an order.

In order to improve the availability of parts, the Inventory Control Manager, in cooperation with the Maintenance Superintendent, has begun to develop lists of parts by job and also by vehicle type. These lists were created external to the computer system using Excel spreadsheets. Mechanics can check the parts required for each job and submit the sheet to the storehouse. However, due to an extended leave of absence by the Maintenance Superintendent, this activity has been put on hold and the spreadsheets have had limited use. In addition, formerly weekly meetings with the Superintendent to discuss material requirements and upcoming projects and campaigns have been discontinued for the time being.

### Catalog/Parts

Inventory consists of a total of approximately 6,200 SKU's valued at \$2.3 million and has increased about \$.5 million over the past two years, due to new min/max levels. This value includes new components. Component repair is done both in-house and by outside vendors. Rebuilt components are not brought back into the inventory and do not have a rebuilt "value". Components are processed in the computer system as a separate inventory location.

When material is out of stock, the Stockroom Clerk notifies the Inventory Control Manager who submits an order for the material and updates the computer system if there is a

discrepancy on actual amount on-hand (0) versus the amount shown in the computer system. If no Stockroom Clerk is on duty, the Maintenance Foreman fills out a "Parts Shortage" form. When an item is stocked out, and it is an emergency, the normal ordering process is bypassed. A manual Purchase Order form is completed and the Purchasing Clerk gives the Inventory Control Manager a manual purchase order number. The Inventory Control Manager then calls the vendor and orders the material. If the material is already on order, the Inventory Control Manager calls the vendor to expedite the order. If the ship date is not soon enough, the Inventory Control Manager either picks up the part or authorizes an overnight shipment.

Material inspections are conducted when material is received. The Stockroom Clerks compare the packing list and the physical count numbers of the shipment to the purchase order to verify that the shipment is correct. The quantity received and the quantity in stock are then noted on the packing list. The Stockroom Clerks forward the annotated packing list to the Purchasing Department where the information is entered into the computer system. If the purchase order is complete, it is also forwarded to Purchasing. If the purchase order is incomplete, it is returned to the receiving file. The Inventory Control Manager makes adjustments to items received and issued prior to receipt of the invoice by the transit system in the computer system.

A "Purchase Order Report" is generated semi-weekly by the Inventory Control Manager and used to check on back orders. Approximately 75-100 purchase orders are late at any given time. When an order is late, the Inventory Control Manager then contacts the vendor and expedites the order.

Mechanics must have a valid job order and bus number to get material. As parts are issued they are charged out in the system and the job order is manually annotated with the part number and quantity issued. Material usage is updated real-time in the computer system but a batch update is run nightly to process the accounting information. However, it can take a number of days for the system to be updated with the proper accounting information. Inventory material is expensed when issued and charged to the using department at both inventory locations. Inventory material that does not go on a bus or is used for minor maintenance, is charged out to a specific account and a "For Parts with No Job Order" form is completed.

## **Inventory Management Performance**

### Inventory Accuracy

Physical inventory data was not available. However, based on cycle count sampling during the four-month period of the case study, 52% of the items are in balance with the computer system. Forty-eight percent of items were out of balance. Two thousand three hundred fifty-four items were counted representing \$688,259. The net dollar variance of the cycle count period was \$93,654 or 13.6%. In absolute dollars, the variance was \$173,374 or 25.19%.

### Inventory Usage

Total inventory transactions per person per week averaged 252 based on the Inventory Activity Report for 1998.

Bus inventory dollars per vehicle were calculated at \$9,333. Annual inventory turnover was figured at 1.15 turns per year.

### Inventory Availability

Fill rates could not be calculated with the information available.

Stockouts were figured using the ABC report, which shows the current quantity on-hand. Total active stock keeping units (SKU's) were 6,181. Of this total, 469 items were stocked out (items with 0 on-hand). This figure represents an average of 7.6% stocked out.

## **Technology and Information Systems**

This transit agency is currently using an IBM AS/400 based automated management information system that was installed in 1993. The software offers capabilities for fleet management, fleet maintenance and inventory, purchasing and accounting. The software has some limitations for inventory management. For example, the system does not allow material to be stored in multiple bin locations and there is no report that provides a summary of activity for a single item.

Bar coding is currently not being done. However, in the next several months, plans are to implement bar coding for issuing parts. Information will then be downloaded nightly. There are plans for moving to RF (radio frequency bar coding) some time in the future. Using bar coding for receiving will not be done at this time due to the limitations of the computer software.

## Case Study Data Collection and Analysis

The following forms and reports were requested to collect data on a bi-weekly basis. Minor modifications to normal data collection procedures were included.

1. Completed copies of the Excel form used by mechanics to draw inventory (parts list by job/vehicle). On each form, please clearly designate:
  - Date the part was issued
  - Quantity requested and quantity issued (even if zero)
  - Add any part number that is not on the list
  - Have a stock clerk complete the form if a mechanic doesn't
  
2. Begin a log sheet and log the following information for all Parts Shortage forms:
  - Date requested
  - Quantity requested
  - Part number
  - Location (storehouse)
  - Date ordered
  - Date issued
  - Consequence of shortage (bus held from service, bus remains in service)
  
3. The following reports from the computer system (on diskette):
  - Parts transactions for the bi-weekly period
  - Months inventory (at the end of the month only)
  
4. Accounting data. Please provide the following at the end of each month, if not on the computer reports:
  - Inventory Dollar Balance (by storehouse)
  - Inventory Expense for the Month (by storehouse)
  - Inventory Adjustments for the Month (by storehouse)
  
5. Cycle counting sheets. Please use the counting sheet below to count at least 10 items each day (50/week).

## Inventory Item Cycle Count Form

Date: \_\_\_\_\_

Item No.	Computer Balance	Count	Item Unit Cost

The property encountered problems collecting both forms 1 and 2 above, and was only able to provide selected computer reports and completed cycle count sheets. The computer reports included ABC Analysis and Inventory Transaction reports. The information used to calculate performance measures was as follows:

- Dollars per vehicle:
  - Total Inventory Dollars from the ABC Report
  - Total number of vehicles identified during site visit
  
- Inventory Turnover:
  - Annual Usage Dollars from the ABC Report
  - Total Inventory Dollars from the ABC Report
  
- Percent of items stocked out:
  - Items with zero on hand from ABC Report
  - Total items from ABC Report
  
- Transactions per person per week:
  - Total transactions from Inventory Transaction Report
  - Staff levels from site visit
  
- Percent of items out of balance:
  - Cycle Count Sheets – items counted and items with count variances
  
- Absolute Dollar Variance:
  - Cycle Count Sheets – value of items counted and absolute value of variances

- ABC Analysis:

Revised from the ABC Report

## Case Study C

### Agency Profile

This medium sized transit agency is publicly owned but managed by a private company. Oversight is provided at the local government level. The system is located in a large urban area with a population of over one million.

### Fleet Profile

The fleet is comprised of between 51 and 300 large buses with 11 different models. The transit agency also has a sizeable fleet of small buses; however, they are treated as a separate entity and are therefore not part of this study. The average age of the fixed route fleet is approximately 7 years. The total inventory value for calendar year 1998 was approximately \$1,265,417.

### Inventory Management Organization Profile

This transit system employs a Parts Manager and eight parts staff at two maintenance facilities. The Parts Manager reports to the Director of Maintenance who reports to the General Manager. The General Manager of the system is responsible for day-to-day operations under the direction of the county.

The Parts Manager is responsible for managing the Parts Department for the maintenance facilities. In addition to the Parts Manager, the Department employs a Parts Supervisor, two Senior Parts Clerks, four Parts Clerks and a Parts Runner. The Parts Department is responsible for ensuring accuracy of the parts, fluids and supplies inventory and ensuring the proper receipt, supply, storage, inventory control and distribution of all parts and supplies for the Maintenance Department. The department is also responsible for limiting Maintenance Department lost service hours due to supply problems. Other responsibilities include inventory planning, error resolution and conducting cycle counts and annual physical inventories.

The Policies and Procedures Manual is current and provides direction on the functions of receiving, shipping, issuance of parts, purchasing of parts, daily work assignment, parts running, and warranty. In addition, the job descriptions are comprehensive and describe specific parts duties by responsibility area.

### Inventory Management Practices

#### Storekeeping

This case study participant has a primary storeroom that serves the primary maintenance facility. This storeroom also has a central receiving dock that provides service to both the fixed route satellite facility and the paratransit facility. All body, brake, engine, transmission and major component work is done at this facility. In addition, approximately 60% of fixed route maintenance work is done at this facility. A secondary storeroom serves a satellite maintenance facility. Approximately 40% of fixed route maintenance is done at the secondary facility.

Both the primary maintenance facility and its storeroom operate on a 24/7 schedule. In addition to the Parts Manager, this storeroom is staffed by a Parts Supervisor and four Parts Clerks, two of whom are part-time employees. The primary storeroom has been “locked” for approximately two months prior to the beginning of the case study. The satellite maintenance facility also operates on a 24/7 schedule. A Senior Parts Clerk who works during the day shift Monday through Friday staffs this storeroom. A Maintenance Foreman covers the parts storeroom on the second and third shifts. In the absence of parts personnel, mechanics are instructed to complete a “Request” form identifying parts that are removed from inventory.

Inventory material with a unit value greater than \$5.00 is valued at average price in the computer system. Material to be used for bus maintenance with a value greater than \$5.00 is charged to a bus account and posted in the work order system. All non-bus maintenance material is charged to a non-bus account when issued. Bus parts with a value less than \$5.00 are held in inventory at their actual value then expensed to a general “fleet” account when they are issued, rather than being posted to a work order. Rebuilt components are valued at a penny and are averaged in with the cost of new components. In addition, since a private company manages this property, a “capital” charge is assessed for dollars invested in inventory.

Both storage facilities are organized primarily by vehicle system (electrical, chassis, engine, etc.). Some high usage items are located near the storeroom window and are replenished from “bulk stock” in the storeroom using a “two-bin” system.

Cycle counts are conducted primarily for specified bin location ranges. Although no formal ABC classification is used for conducting cycle counts, the Parts Manager adds high usage items to the computer generated cycle count schedule. Inventory is counted three times per year at the primary facility. The Parts Clerk on the third shift is responsible for counting the non-bus account inventory. At the satellite facility, inventory is counted approximately twelve times per year. This is due to the lesser number of items stocked and to the fact that the storeroom is covered on only one of three maintenance shifts. When a discrepancy is found, the Parts Clerks fix what they can but do not make computer adjustments. Only the Parts Manager or the Supervisors can make these adjustments. Annual physical inventories have been done in the past but will not be done this year since three complete cycle counts have been conducted.

### Inventory Management and Replenishment

Inventory replenishment at both storerooms is accomplished using the min/max method. Min/max levels are set once, when new material is added to the inventory. Material order lead-

time can be tracked using the computer system but it is not used for all parts. The Parts Manager generally tries to keep a month's inventory on-hand for expensive material (unit cost greater than \$5.00) and two month's supply on-hand for inexpensive material (unit cost less than \$5.00). The Parts Manager may lower or raise the minimum inventory levels depending on the current vendor's lead-time. Body parts are expensed as they are received and are not tracked in the inventory system.

The computer system generates a reorder report weekly to identify items below the minimum and creates purchase requisitions. The Parts Manager can approve requisitions up to \$2,000 but in practice obtains approval from Maintenance Management for orders over \$1,000. The Purchasing Department buys inventory material using standard purchase orders. Blanket purchase orders and annual contracts are infrequently used to replenish material.

"Nuts and bolts" and other selected hardware items are open stock on the maintenance floor and are serviced by a vendor once per week under the Parts Manager's oversight. In addition, other low dollar "fleet" items are on the maintenance floor, but are carried in inventory. A Parts Clerk counts the items once per week and expenses the items that have been consumed.

#### Material Planning

The Parts Manager works with the Maintenance Department to determine material usage and on-hand quantities. The Parts Manager is also responsible for obtaining information on parts when a new series of bus is ordered.

In order to improve the availability of parts, the Parts Manager holds weekly meetings with Maintenance Management and the Storeroom Supervisors. Monthly meetings are held with all parts staff. Maintenance is proactive in letting the Parts Department know about upcoming projects and campaigns.

#### Catalog/Parts

The inventory catalog for this property consists of over 8000 part numbers at each facility, of which 34% have usage in the last year. The average inventory value during the case study was \$968,000.

Material for both facilities is ordered from and received at the primary storeroom. When material at the secondary storeroom hits the reorder point, the Parts Manager either orders material or restocks the secondary storeroom from the primary facility, depending on the item. In most cases, the item is transferred from the primary facility.

If the part is not in stock at either of the two storerooms, the Parts Manager meets with the Maintenance Foreman to assess the urgency. If the material is needed the next day, the Parts Manager either obtains a Purchase Order number from the Purchasing Department and contacts the vendor or faxes the request to Purchasing. The Parts Manager expedites material that is less

than 30 days overdue. The Purchasing Department expedites material that is over 30 days late. Maintenance tracks “buses awaiting parts” on a manual form.

Mechanics must have a valid work order number and bus number to obtain material. The mechanic fills out a “Parts Request” ticket with the bus number. All vehicle components are broken down into approximately 70 codes. This maintenance code can also be added. The “fits” code identifies the material that “fits” a particular type of bus. The Parts Clerks are responsible for looking up the part number in OEM parts manuals based on the mechanic’s request. (Parts are identified in the computer system using the OEM part number or the vendor number for the original part purchase. Although cross-reference files are used, there are some problems with similar part numbers from different OEMs and with unreliable parts books). As parts are issued, they are charged out in the system. Material usage is updated on-line in the computer system, usually by the end of the shift.

For new material, the Parts Manager reviews all requisitions. The Parts Manager has authority to approve requisitions up to \$2,000 but generally seeks approval from Maintenance Management for purchases over \$1,000. The requisitions are then sent to the Purchasing Department for entry into the computer system with the corresponding commodity codes.

Material is inspected when received at the primary storeroom. The Parts Clerks compare the order against the packing list or the invoice. If the packing list or invoice is not on-hand, a form is made out with the relevant information such as item description, manufacturer’s part number and quantity received. The items received are then matched against the computer system purchase order file. If there is a mismatch, the item is received and the paper work sent to either Purchasing or Accounts Payable for resolution. Material is then transferred to the secondary storeroom as required, using the Parts Runner. Because this facility runs off a separate database from the primary storeroom, the secondary storeroom Parts Supervisor must switch between two systems.

All returns to vendor are also handled from the primary maintenance facility by either the Parts Manager or a Parts Supervisor. If the material received is incorrect, it is still received into the computer system in order to get a credit. Purchasing then debits the account. Warranty material is handled by the Purchasing Department.

## **Inventory Management Performance**

### Inventory Accuracy

Physical inventory data was not available. However, for a twelve-week period, cycle count item accuracy for both storerooms was approximately 81% for items with a dollar value greater than \$5.00. Approximately 19% of items were out of balance. A total of 3,371 items were counted with a dollar value of approximately \$312,476. The net dollar variance of the cycle count was approximately \$1,112 or .4%. In absolute dollars, the variance was \$41,360 or 13.2%.

### Inventory Usage

Total inventory transactions per inventory staff for receipts, issues, adjustments, transfers and cycle counts for the 12-week period of the case study averaged 200.

Bus inventory dollars per vehicle were calculated at \$3,709. Annual inventory turnover was figured at 1.97 turns per year.

### Inventory Availability

The bus percent demand filled, or the fill rate, was calculated at 98.7%. This fill rate serves as an upper boundary, since there are some requests for material that are not captured on the manual form. The actual fill rate could be lower.

Total active stock keeping units (SKU's) were approximately 16,364 (both storeroom locations). Of this total, 8,347 items showed 0 on-hand. Items with usage were 5,554 and items with usage and 0 on-hand were 1,546. The percentage of total items with 0 on-hand was 51.01%. Approximately 0.7% of items were stocked out per week and approximately 28% of total inventory items were stocked out (0 balance on-hand).

The Parts Manager estimates that less than 1% of the fleet is out of service awaiting parts. The average days to fill a bus inventory backorder (bus out of service) were 2.8.

## **Technology and Information Systems**

This transit agency is currently using a PC LAN based automated fleet management information system. Although the agency recently upgraded to the latest GUI version of the software package, there are several shortcomings in the software's capabilities that create problems for a transit agency of this size with multiple facilities.

Bar coding is currently not being done. However, in the next several months, plans are to implement bar coding for receiving and issuing material and cycle counting. Information will then be downloaded nightly.

## Case Study Data Collection and Analysis

The following forms and reports were requested to collect data. Minor modifications to normal data collection procedures and some ad hoc reports were included.

1. Please gather and/or provide the following information one time (on diskette or e-mail if possible):
  - A listing of parts (for each fixed route facility) containing the part number, description, unit cost, on-hand quantity and total value (unit cost times on-hand quantity).
  - A listing for each fixed route facility showing total annual usage items and dollars by part number containing: part number, description, total usage units, unit cost, total usage dollars (total usage units times unit cost). Sort in descending order by total annual usage dollars for each facility.

Please provide the following weekly or bi-weekly (on diskette or e-mail, except for forms):

2. A listing of parts usage during the period, by part number, for each fixed route facility showing total units issued, unit cost, total dollars. Include parts issued to a work order (1202) as well as parts issued to fleet expense. (One line per part is sufficient, however if not available, a listing containing each transaction is acceptable.)
3. A listing of parts purchased during the period, by part number, for each fixed route facility showing total units purchased and the purchase price (PO Received Report).
4. Weekly requisition report that is used to reorder parts, showing on-hand quantity and reorder point information for each part.
5. Copies of all shift turnover forms showing parts requested by maintenance that were not provided from stock with those holding a bus out of service circled.
6. Copies of all cycle count forms, both discrepancy sheets showing actual count differences before reconciliation and logs showing the discrepancies after reconciliation.
7. Inventory dollar value and part number count by location (end of month).
8. Month-end spreadsheet showing inventory reconciliation.
9. Copies of bus down forms for each fixed route facility (Summary: Out of Service Coaches).

The property provided the requested information throughout the case study, however the shift turnover forms were not completed consistently for all shifts. The information used to calculate performance measures was as follows:

- Dollars per vehicle:  
  
Average Inventory Dollars calculated from month-end inventory reconciliation  
Total number of vehicles identified during site visit
- Inventory Turnover:  
  
Annual Usage Dollars extrapolated from issues on month-end inventory reconciliation  
Average Inventory Dollars calculated from month-end inventory reconciliation
- Percent of items stocked out per week  
  
Items with zero balance on the Weekly Requisition Report  
Total items with usage from parts listings
- Percent of items out of stock  
  
Items with usage and zero on-hand on parts listings  
Parts listings for total items with usage
- Percent of demand filled:  
  
Total issues from parts usage listings  
Parts unavailable from Shift Turnover Report
- Average time to fill backorders:  
  
Date parts unavailable from Shift Turnover Report  
Receipt date from PO Received Report
- Percent of items out of balance:  
  
Completed Cycle Count Forms – items counted and items with variances
- Absolute Dollar Variance:  
  
Completed Cycle Count Forms – value of items counted and absolute value of variances

- Transactions per person per week:

Transactions from ad hoc queries using computer files  
Staffing from site visit

## **Case Study D**

### **Agency Profile**

This large transit system is publicly owned and managed. It is located in a large urban area with a population of over one million.

### **Fleet Profile**

The fleet is comprised of between 301 and 2,000 rail cars with 4 different models. The average age of the fleet is approximately 20 years. The total inventory value for calendar year 1998 was approximately \$24,527,528.

### **Inventory Management Organization Profile**

The materials management function at this agency is divided between two divisions -- Inventory Management and Warehousing/Stores. Both divisions report to the Procurement and Materials Management Department. This department reports to the Assistant General Manager Administration.

The Manager of Inventory Management is responsible for inventory control and manages a staff of four Inventory Analysts. The Inventory Management Division is responsible for managing inventory levels of consumable materials and supplies; developing short and long-term inventory plans; forecasting the need for consumable items, materials and equipment; coordinating overall inventory levels; and reviewing and approving inventory requisitions. This division is also responsible for managing the computerized inventory system and developing standards for database accuracy. Two of the Inventory Analysts are responsible for reviewing and approving requisitions. An Inventory Technician is responsible for adding new items to the inventory system, inventory tracking and transaction validation. The Senior Inventory Analyst is responsible for assisting the other staff with their work, conducting analyses of inventory performance indicators and also performs special projects as required.

The Manager of Warehousing/Stores is responsible for the efficient flow of materials and goods throughout the transit authority. This position manages a staff of 51 that includes 41 Storekeepers (including seven leads), two Warehouse Supervisors, five Material Control Analysts, one Material Control Supervisor and a Material Control Clerk. The Warehousing/Stores Division is responsible for managing the Authority's two Distribution Centers and four storehouses. Specific responsibilities include performing all storekeeping functions, determining material requirements, processing material transfers and allocating material to the proper locations and accounts. The group also administers the warranty program,

conducts cycle counts and processes material backorders. Other responsibilities include conducting physical inventories and reconciling discrepancies.

There is no comprehensive Policies and Procedures Manual. Job descriptions are fairly comprehensive and describe specific duties.

## **Inventory Management Practices**

### Storekeeping

This case study participant maintains six stores locations to service four maintenance facilities. Two of the stores locations serve as central warehouses. The Warehousing/Stores Division manages all warehouses and storerooms. The first warehouse serves as both a central warehouse supplying rolling stock parts and components to all locations, and a local stockroom for the adjacent maintenance facility. This warehouse operates on a 24/7 schedule and employs a Senior Storekeeper and 15 Storekeepers. The second central warehouse stocks material for maintenance of way, communications, fare collection equipment, elevators and escalators, janitorial and other non-revenue parts. This warehouse operates both a day shift and a swing shift Monday through Friday and a day shift only on Saturday and Sunday. A Senior Storekeeper and 10 Storekeepers are assigned to this location. Both of these locations provide material and supplies to the four satellite storerooms.

Three of the four maintenance facilities operate on a 24/7 schedule. The satellite storerooms servicing these facilities also operate on a 24/7 schedule and employ a total of three Senior Storekeepers and nine Storekeepers. The fourth maintenance facility is responsible for automatic fare collection, train control and communications. This facility and the storehouse that serves it are open on the day and swing shifts Monday through Friday. A Senior Storekeeper and a Storekeeper staff this facility.

Some items, such as filters are replenished from the warehouse to the satellite storerooms on a two or three week schedule. Nuts and bolts are stocked by the vendors (vendors come in and replenish as needed) and administered by the Maintenance Department.

### Inventory Management and Replenishment

An "Inventory Value Classification" report, which uses ABCD analysis to value items, is generated twice a year. The "D" category includes obsolete items, "insurance" items, spares, items that have had zero issues in the past 12 months and items that have been purchased in the past year but have had no usage. All new items are typically set up as "D" items. ABCD analysis is used primarily only for ad hoc reports. These classifications have been used in the past for other inventory management tasks, but are not currently being used.

An "S-1" inventory classification scheme (not ABC analysis) is used for conducting cycle counts. This classification scheme was created to identify fast moving items and is used to re-

value the inventory quarterly. S-1 items are items with at least 48 units issued per year or 36 issue transactions per year. The Inventory Management group generates a count schedule. Storekeepers must conduct the counts within two weeks. Approximately 300 to 400 items are counted monthly. Additional items are counted as the Storekeepers see fit. Some items such as escalator parts are counted weekly. When counts are complete, they are sent to Material Control. The Material Controllers are responsible for tracking the number of items counted and the number of items with variances. When a discrepancy is found, the using department is charged if the count is below the expected level. If users will not accept the charge, the variance goes into an inventory control account. Cycle count reports are generated monthly by the Warehousing/Stores group.

Both the warehouses and satellite storerooms use the min/max method of replenishment. However, there is currently no maximum set. As a result, the Inventory Management group determines re-order quantities for the warehouses based on demand, space availability, etc. The management information system does have a forecasting module; however, it is not used because demand is based only on current usage. Instead, as items near the re-order point, the Inventory Management group conducts analyses to determine the material and quantities for order. Order quantities are based on 12-month usage and the lead-time. (Lead-time is calculated as 40 days administrative lead time plus historical vendor lead-time. Safety stock is calculated as lead-time plus average demand. The order point is calculated as two times the safety stock. The order quantity is calculated as the order point plus the quantity issued for the past 12 months minus the on-hand quantity.)

When material hits the minimum at one of the satellite storerooms, the Material Controllers in the Warehousing/Stores Division are notified. After the transfer request is researched to determine that the quantities requested are correct, the Material Controller delivers a "move ticket" to the warehouse. "Move tickets" contain the bin number for put away. (The system allows only one fixed bin location per item.) A transfer is then generated from the warehouse to the satellite location or from one storeroom to another when necessary. Material Controllers track maximum order quantities "in their heads" because the information is not available in the computer system.

Inventory is replenished by one of three methods. The first method is for ordering new items for inventory. An "Item Master Sheet" is used to add an item to inventory, change the parameters of an already existing item, or to delete an item from the system. The Engineering Department generally determines that a new item is to be added or the status of an existing item changed. If the item is not vehicle related, the using department makes the recommendation. Inventory Management then screens the items and either accepts or rejects the adds or changes.

Inventory material can also be ordered using "Backorder Requests". Mechanics complete an "Issue Request" to withdraw material from inventory. If no parts are available in the system at the requesting location but are available at another storeroom location, the mechanic completes a "Transfer Request". The part is then transferred to the requesting location. If the item cannot be located anywhere in the system, the mechanic completes a "Backorder Request". The Maintenance Foreman must sign this request. "Backorder Requests" are then forwarded to

Material Controllers for review. If the request is approved, it is then forwarded to the Inventory Management Group for Processing.

The third method for replenishing material is through the “sweeps” process. “Sweeps” are used to catch any inventory movement in the past 12 months that was not captured by the computer system (due to a software glitch that does not always capture complete usage). Using the computer system, 40,000 items are checked for usage. Data on usage in the past 12 months is then picked up. The usage is then compared to the system generated “Re-order Report” and the “PO Report”. If the items are not included on either of these two reports, then these items are held for further analysis. Re-order notices are then printed for the items picked up during the “sweeps”. Approximately 450 re-order notices are generated per month for both vehicle mechanical and non-vehicle (maintenance-of-way, communications, etc.) related usage. Approximately 80 to 90 of these items actually end up being reordered. As a result of the “sweeps”, the inventory analysts manually adjust the computer system’s annual demand so that the system bypasses the automatic calculation.

The Purchasing Department then receives the requisitions and places the orders. Blanket purchase orders and annual contracts are infrequently used to replenish material. The Purchasing Department also expedites late material.

#### Material Planning

The Inventory Management group performs material Planning. Projects and campaigns are usually done at only one location. The Warehousing/Stores Division has weekly meetings with the Maintenance Supervisors. The Vehicle Maintenance Engineering Group develops the project schedule including the material needed, schedule, etc. Material planning for planned maintenance is based primarily on historical parts usage.

#### Catalog/Parts

All inventory material is valued at average price in the computer system. Items at all inventory locations are assigned to storehouse location according to space availability. Inventory information available at the warehouses and storehouses includes average cost, items on-hand, issues, items stock out, transfers and items on order.

New material is tracked in the inventory system at average unit price. New components with a value over \$1,000 and with a life of over one-year are tracked as fixed assets at \$0. New components with a value of \$1,000 or less and with a life expectancy of one year or less are tracked in the inventory system at the average unit price. This transit agency operates a component rebuild shop that operates two shifts per day, five days per week. The Warehousing/Stores Material Control unit makes decisions on how much to rebuild. Rebuilt components are tracked as a fixed asset at \$0. Rebuild shop costs (including labor) are expensed.

As orders are delivered to one of the two warehouses, it is received into the warehouse. Material is manually logged in. If the vendor did not supply a purchase order number, the

storekeepers investigate and identify the material. The packing slip is then compared against the order. If the order is incorrect, an “Exceptions Report” is completed. Two copies of the packing slip are made and a “Receiving Report” generated. Storekeepers complete the “Receiving Report” and enter the receiving information into the computer system. The material is then put into quality inspection. Material is generally inspected on the day shift and put away on the swing shift. Rejection rates are normally three to five percent. Rejections are logged manually and returned to the vendor. Material is picked for next day delivery on the third shift using pick tickets sorted by part number (not bin location).

After material leaves inspection, the Maintenance Department’s inspection unit inspects all material (before actual system receipt). Some items are inspected 100% of the time, others 50%, and some inspections are random. If the material passes inspection, it is either shelved or used to complete an order.

Storekeepers make scheduled deliveries daily from the warehouses to the satellite storehouses. One run is made per day to each storehouse on both the day and swing shifts. Stores personnel are on call for parts deliveries during the third shift. All material is expensed and issued to the distribution trucks when it leaves one of the two warehouses. The material is tracked via cost center and work order number. There are no direct shipments from vendors to the satellite storehouses. Time from receipt to distribution is normally 24 hours, depending on inspection time. “Hot” items can be delivered within 30 minutes.

Mechanics must have a valid part number and completed “Issue Ticket” to remove material from inventory. The Storekeeper checks the computer system to determine if the item is in stock and where it is located. If the item is in stock, the storekeeper signs off on the ticket and picks the parts. If the requesting location is out of stock, a “Back order/Stockout Request” is completed. If the material is in stock at another location, material is transferred. If the material is not available anywhere in the system, the Storekeeper will check to see if the material has been ordered. If the material is not on order, a “Back order/Stockout Request” is completed with the stockout box checked. If the material is on order, the form is still completed with the backorder box checked. The Inventory Management Group receives two batches of issues and returns per shift per facility.

Returns to stock are handled in the reverse of issues. They are credited to the appropriate department at the average inventory value.

## **Inventory Management Performance**

Few formal performance measures other than transaction volumes are currently used. The “Transaction Error Listing Report” provides some information on storekeeper accuracy. The Inventory Management group monitors error rates. Cars out-of-service awaiting parts are also reported via the “Transit Vehicle Out-of-Service Report”. This report monitors total vehicles out-of-service for any reason and is generated by the maintenance system.

### Inventory Accuracy

Physical inventories are conducted every two or three years. The last physical inventory was conducted in 1996. Therefore, no up-to-date physical inventory data is available.

This property conducts regular cycle counts and attempts to reconcile differences, but does not formally track cycle count statistics. Based on a sample of 1,006 items cycle counted by this property, 40.3% of items have different on-hand quantities than that recorded in the computer system (% of items out of balance). This represented an absolute dollar variance of 3.4% and a net dollar variance of 1.3%.

### Inventory Usage

Total inventory transactions per inventory staff for receipts, issues, adjustments, and transfers for the last two quarters of 1998 averaged 65.6.

Rail inventory dollars per vehicle were calculated at \$36,663. Annual inventory turnover was figured at .55 turns per year.

### Inventory Availability

The current computer system does not track demand. However, the quantities requested and filled are captured manually using an Issue Ticket. A sample of 2,850 line items requested from inventory during the case study resulted in a fill rate of 87.4% of line items requested and 91.9% of units requested. This sample consists of "Standard" items. The Maintenance Department controls items classified "AR" for "as required". These items are generally kept at 0 on-hand. When these items are needed, a "Backorder Request" is generated. Backordered AR line items take an average of 6.5 days to fill a request. Backorders are also used when standard items are not available. Backordered standard items take an average of 12.5 days to fill, giving an overall average of 9.2 days to fill a backorder.

Stockouts are defined at this site as when consumable parts go below the minimum order level, however stockout statistics are not formally tracked. Based on stock status information during the case study, 11.1% of standard items with usage in the last 12 months are at zero quantity on-hand (33% of total standard items). Backorders for standard items occur at the rate of 0.14% per week (percent of total items with usage in the last 12 months). "As required" and other item classifications were excluded from the stockout calculations.

## **Technology and Information Systems**

This transit agency is currently using an outdated automated management information system primarily designed for manufacturing/distribution businesses. Plans are currently underway to replace the system with a new software package for Y2K compatibility. However, bar coding is currently not being done and there are no plans to introduce bar coding capabilities.

## Case Study Data Collection and Analysis

The following forms and reports were requested to collect data. Minor modifications to normal data collection procedures were included.

1. A file listing all stock items by storeroom location with the following data (one time at the beginning of the study):
  - Stock Code
  - Part Description
  - Unit Cost (Average Unit Price)
  - Quantity on Hand
  - Average Monthly Demand
2. Random sample of issue tickets. Please sample 10 items from each of the six storerooms each day using the attached form. (Send or e-mail completed forms each week.)
3. Time to fill backorders.
  - a. Please sample 50 backorders from the past few months listing the part number, request date for the back order from the Back Order form, receipt date from the computer system. (One time at the beginning of the study)
  - b. Provide the same information for all backorders created during the study. (Send or e-mail a file each week).
4. Provide a list for each of the six storerooms of ST (standard) and NO (insurance) items with zero balance on hand and last 12 months usage >0. Include part number, storeroom, annual usage and unit cost. (Send or e-mail a file each week).
5. Provide completed S1 Cycle Count forms (with actual counts and adjustments) for each month during the study, beginning with January. (Send or e-mail monthly).
6. Provide "Transit Vehicle Out of Service Report". (Send or fax monthly).

## Issue Ticket Sampling Form

Date: \_\_\_\_\_

Storeroom	Item No.	Quantity Requested	Quantity Issued

The property provided the requested information throughout the case study. The information used to calculate performance measures was as follows:

- Dollars per vehicle:
  - Total Inventory Dollars calculated from item values in item listings
  - Total number of vehicles identified during site visit
  
- Inventory Turnover:
  - Annual Usage Dollars calculated from usage dollars in item listings
  - Total Inventory Dollars calculated from item values in item listings
  
- Percent of items stocked out per week
  - Sampling of Back Order forms for number of stockouts (standard items only)
  - Item listings for total items with usage (standard items only)
  
- Percent of items out of stock
  - Items with usage and zero on-hand on item listing (standard items only)
  - Item listings for total items with usage (standard items only)
  
- Percent of demand filled:
  - Quantity requested from sample of Issue Tickets
  - Quantity issued from sample of Issue Tickets

- Average time to fill backorders:

Back order date from sample of Back Order forms

Receipt date from sample of Back Order forms

- Percent of items out of balance:

Completed Cycle Count Forms – items counted and items with variances

- Absolute Dollar Variance:

Completed Cycle Count Forms – value of items counted and absolute value of variances

- Transactions per person per week:

Transactions from Transaction Summary spreadsheets (from site visits)

Staffing from site visit

## Case Study E

### Agency Profile

This large transit system is publicly owned and managed. However, unlike most systems, the transit agency is a county department. It is located in a large urban area with a population of over one million.

### Fleet Profile

The authority maintains a large bus fleet (between 301 and 2,000 vehicles) with ten different models of bus. The average age of the bus fleet is approximately 7.8 years. This case study participant also has a mid-size heavy rail fleet (between 51 and 300 vehicles) with one vehicle model. The average age of the heavy rail fleet is nine years. In addition, the agency also has a small fleet of between 1 and 50 light rail vehicles (two models). The total inventory value for calendar year-end 1998 was approximately \$18.5 million. Of this figure, approximately \$5,600,000 was bus inventory. Heavy rail's inventory was approximately \$7,900,000 and the inventory for light rail was approximately \$4,000,000. An additional \$1,000,000 was allocated to facilities and the radio shop

### Inventory Control Organization Profile

The materials management function at this agency is divided between two divisions -- (1) Inventory Control; and (2) Warehousing and Storage. Both divisions report to the Chief, Materials Management Division. Purchasing is also under this Division. The Materials Management Chief reports to the agency's Controller in the Office of Financial Services.

Inventory Control is responsible for performing advanced inventory control and the operation of the computerized inventory system. The group includes a Manager of Inventory Control, a Lead Stock Control Specialist and two Stock Control Specialists. Specific responsibilities include processing receipts, issues and transfers for all stock and non-stock material; generating and analyzing stock reports to ensure the accuracy of inventory elements; analyzing and updating re-order points and re-order quantities for stock items; and resolving physical inventory discrepancies. The Lead Stock Control Specialist serves as the liaison for all storerooms and is responsible for entering all new parts into the computer system and for setting min/max levels. This group is also responsible for generating manual requisitions for emergency stock requests, entering requisitions into the computer system for non-stock materials, expediting backorders and identifying and resolving other procurement and accounting related problems. This group replenishes inventory for the Central Warehouse and the bus stockrooms.

The Warehousing and Storage group is responsible for operating the bus Central Warehouse and providing inventory support for six bus and rail maintenance facilities. Specific

duties include issuing and receiving material at all bus and rail storehouse locations, conducting cycle counts and handling component rebuilds. In addition, stock clerks at the rail facilities are responsible for replenishing inventory. Staff includes the Warehousing and Storehouse Manager, seven Supervisors and 47 Stock Clerks. Nine of the Stock Clerks are assigned to the bus Central Warehouse; eighteen are assigned to bus maintenance facilities; five to major overhaul for bus, eight to heavy rail maintenance; five to light rail, and two are vacation relief.

There is a fairly comprehensive Policies and Procedures Manual. Stock Clerks are unionized and must follow stringent work rules.

## **Inventory Control Practices**

### **Storekeeping**

Warehousing and Storage is responsible for managing the bus Central Warehouse. The group also provides support for three bus operations and inspection facilities, a bus major overhaul shop, one heavy rail facility and a light rail facility. The Central Warehouse provides inventory support for the three bus stockrooms and the overhaul shop. All material to the bus maintenance facilities goes through the Central Warehouse with the exception of some items for major repair, which are shipped directly to the shops. These items include plywood, steel, drums, water, etc. Both the heavy rail and light rail groups order and receive material directly from suppliers. Except for common material, they do not use the Central Warehouse. In addition, an unmanned rail “layout” area is used for storing large and bulk items for heavy rail (such as track and related items).

The Central Warehouse operates from 7:00 A.M. to 6:00 P.M. Monday through Friday. It does not operate on weekends. If there is an emergency during the evening shift or on the weekends, warehouse staff will come in. The three bus operations and inspections facilities operate on a 24/7 schedule. The storehouse at the major overhaul facility operates from 7:00 A.M. to 6:00 P.M. This is also the maintenance schedule for the overhaul facility. All facilities are staffed during operating hours and locked to non-inventory personnel at all times. The radio shop storehouse also operates on a 24/7 schedule.

The heavy rail storehouse is staffed by eight employees and operates from 6:00 A.M. to 12:00 Midnight seven days a week. This storehouse is closed to the maintenance staff during other hours. The storehouse Supervisor is on call 24 hours per day for emergencies. In addition to the normal inventory materials, the Stock Clerks at this facility also handle scrap, hazardous waste and uniforms.

The light rail facility storehouse is staffed by 5 employees, operates on a 24/7 schedule and is locked to non-inventory personnel.

Bus warehouse space is organized dynamically, i.e., parts are stored wherever space permits. All locations are numbered and tracked in the computer system. The stocking clerk

assigns bin numbers for new material. They then become a fixed location. Slow moving parts are stored in the mezzanine.

#### Inventory Control and Replenishment -- Bus

Inventory Control is responsible for replenishing inventory material for the bus Central Warehouse. The three bus operations and inspection facilities and major overhaul are supplied from the Central Warehouse under the direction of Inventory Control.

All bus and rail inventory warehouses and storerooms use the min/max method of replenishment. Reorder points for fast moving items are fixed in the computer system manually. Reorder points are then automatically readjusted based on usage. When the item min/max in the storehouse reaches the minimum, the system automatically generates a transfer ticket. Storeroom Supervisors can also request a transfer. Transfers are batch processed every night including weekends. The Inventory Control Division receives the transfer tickets and sorts by storeroom. The Warehousing and Storage Central Warehouse Stock Clerks receive the requests by 9:00 A.M. the next day. Stock Clerks pull material by bin order for each shipment location. Material for shipment is staged in the back of the warehouse for shipment the following day. Stock is delivered to each location once per day. Inventory Control is responsible for resolving discrepancies for in-transit material based on a computerized shipping and receiving exceptions report.

The system generates a non-usage report for the twelve-month period but the system will automatically update the min/max as required. The computer system does not automatically track lead-time; it must be entered manually. Administrative lead-time is set at 20 or 30 days. It is set once for the entire system. Vendor lead-time is assigned for each item and is not automatically calculated. The system has the capability to generate reports for actual lead-time but this feature is not used.

#### Inventory Control and Replenishment -- Heavy and Light Rail

The storeroom Supervisors are responsible for replenishing inventory material for the heavy and light rail maintenance facilities. At the heavy rail parent storeroom, material is received directly from vendors except for common material that is supplied from the bus Central Warehouse. The transfer process described under inventory control and replenishment for bus is used to obtain common material. The heavy rail Stores Supervisor controls the inventory database, sets lead times and min/max's, generates requisitions, forwards requisitions to the Foremen for review and forwards to Inventory Control for data entry. The Rail group uses the same information system, forms and procedures as bus. Rail min/max's are set both manually and automatically by the system, depending on the commodity.

The County General Services Administration sets up multi-year contracts and blanket purchase orders for the purchase of material and services for bus and the two rail groups. These contracts and blanket purchase orders are based on the transit agency's commodities. Transit agency buyers become involved with setting up the technical specifications. The transit agency

contracting unit is responsible for setting up contracts for such services as security, computer hardware and software, etc. In addition, some material that is not covered by blanket purchase orders is publicly bid. Materials Management is also responsible for bus warranty monitoring. Heavy and light rail maintenance personnel are responsible for monitoring their own warranties.

### Cycle Counts -- Bus and Rail

ABC classifications are not used to stratify the inventory for cycle counts. Instead, cycle counts are based on the number of bin trips (set at 14 or 15 system-wide), a zero or negative balance, or new parts added to the system. In addition, if there is a discrepancy in a transfer between two locations, the system will automatically generate a count for both locations. Everything in the inventory system is counted at least once every two years. Storekeepers also have the ability to manually request a cycle count. Cycle counts (blind counts) are done at the end of the last shift and are entered into the computer system first thing the following morning. Counts are done daily depending on the situation. Count sheets go to Inventory Control. If there is a discrepancy outside the tolerance, someone else will do a recount. The tolerance is pre-specified and set for the entire inventory. Reconciliation is done weekly. Inventory Control receives a monthly cycle count adjustment report (“Automatic Adjustments for Storeroom Report”) that shows the automatic adjustments that were made to the inventory if the variance was within the pre-specified tolerance. If the variance is outside of the system tolerance, the system will suggest adjustments but not make them automatically. Inventory Control will manually make these adjustments.

Rail physically monitors such items as rail, track and signal and they do a physical count; however, this material is not tracked in the computer system.

### Material Planning

Bus and rail maintenance are responsible for requesting items to be added to the inventory. Each maintenance division determines what material goes into the inventory and they also determine how much material will be used. Bus and rail maintenance provide the manufacturer’s part number, drawings, etc., when ordering new material. Inventory Control is responsible for the final decision on whether the item becomes part of the inventory. If the item is accepted, Inventory Control assigns min/max values with input from maintenance. Initially, each new item is set up in the system as a new part request. There is little formal planning for material usage between Maintenance and Inventory Control, especially for campaigns and other major changes.

Based on a County directive, an active campaign to reduce was conducted during the last couple of years. The current inventory represents a reduction of approximately \$5 million in inventory levels and \$1 million in annual purchases through lower in min/max levels and a redistribution of inventory. In addition, obsolete inventory was removed for sale.

## Catalog/Parts -- Bus

New material is tracked in the inventory system at average unit price. Repaired Components are tracked at the rebuild cost (excluding the core cost). The purchase cost of new components is averaged into inventory with repaired. Vendors do some component rebuilds for bus but most are rebuilt in-house. When a component fails, the Stock Clerk fills out a "Defective Rotable Manifest". The item ("bad core") then either goes directly to the component Rebuild Shop for rebuilding in-house or to the bus Central Warehouse for shipment to an outside vendor. Most internally repaired items are on min/max and have a bill of material. When the mechanic gets ready to repair a unit, he or she completes a "Repairable Component Packing List". This list then goes to Inventory Control for data entry. When the repair is completed, "good" or rebuilt components are sent to the Central Warehouse and entered into the inventory system.

The process for receiving material at the Central Warehouse and then transferring the material to a maintenance facility takes approximately two to three days. All bus parts sent out of the Central Warehouse are transferred -- never issued. Inventory Control is responsible for expediting late or partial shipments with the vendor. Inventory Control obtains the transfer requests, divides by storehouse and sends to the Central Warehouse to fill the order. One run is made to each storehouse daily. Central Warehouse personnel are on call for emergencies when the warehouse is closed. Material is expensed when issued to mechanics. Material is tracked via work order number. There are few direct shipments from vendors to the bus storehouses. Time from receipt at the Central Warehouse to distribution is normally two to three days.

Each vendor is required to put the requisition number on the packing list. The Stock Clerk responsible for receiving material obtains a paper copy of the "Receiving Ticket". As material is received, the Stock Clerk annotates the receiving ticket with the shipment information (shipment quantity, date received, requisition number and received by and stocked by information) and forwards to Inventory Control. Inventory Control then updates the computer system with receipt information (system allows under-shipments but not over-shipments). Inventory Control and the Stock Clerk resolve any receiving discrepancies.

If the shipment was incomplete, the Stock Clerk receives the partial amount shipped and annotates the "Receiving Ticket". The following day, a new "Receiving Ticket" is generated with the backorder quantity.

Parts are issued from a maintenance storeroom to Mechanics who have a valid work order number. The Maintenance Supervisor completes a "Work Assignment Log" each day and forwards to Inventory. Mechanics go to the storehouse window and tell the Stock Clerk the part they want, the work order number and the bus number. The Stock Clerk verifies that the Mechanic is assigned to the work order. The Stock Clerk must also determine the correct part number from either the work order or discussions with the Mechanic. If the part is available, the Stock Clerk creates a "Material Issue Ticket" and issues the material to the appropriate work order. The Mechanic must sign for the part. Everything issued to the maintenance work order shows up on the "Maintenance Equipment Issue Report". This report captures both the requested and issued quantity. Tickets are closed out at the end of each shift so the mechanics can add

parts to the work order and Issue Ticket. The Inventory Supervisor gets a “Backorder Status Report” weekly. Maintenance keeps track of buses down for parts and the Supervisor uses this report to notify Inventory Control to expedite material with the vendor. When material is received, the system generates a “Backorder Relief Issue Ticket” (batch process).

If the storehouse is out of the material, maintenance can either have the material transferred from the Central Warehouse or from another storehouse. Inventory Control receives notice of automatic transfers, divides by storehouse and sends to the Central Warehouse to fill the order. If the material is an emergency, the requesting storeroom completes a manual transfer (approximately ten per day). Inventory Control enters the information if it comes from the Central Warehouse. The shipping storeroom updates the manual transfer in the system and automatically backorders each time material is requested. As material comes in, the system generates a “Backorder Relief”. The system fills the oldest backorders first. Most transfers from another storehouse are manual, do to the batch system. If the transfer is manual, the Supervisor must go into the system and manually clear the out-of-stock status (its an instant transfer from one division to another). A “Return to Stock Form” is completed when material is returned to the inventory. The process for returning the item to inventory is handled in the reverse of issues.

#### Catalog/Parts -- Heavy and Light Rail

The Rail Storeroom Supervisor conducts meetings with rail maintenance daily. Maintenance sets up a monthly work order for each maintenance-of-way division (track, buildings and grounds, signal, right-of-way, etc.). (Expenses are not charged to a specific repair activity.) The purpose of the monthly work order is to capture expenditures at the aggregate level. Vehicle maintenance generates specific work orders for each vehicle repaired. Some grant funded work orders can be open for a year or more. Rail mechanics look up parts in catalogs and then come to the window with the part number. Stock Clerks enter transactions on paper and then into the system. Material in the bulk storage yard (track and other large items) is not tracked in the inventory system. The Stock Clerk performs a physical inventory once per year and charges maintenance for the material that is used.

Rotables and serialized parts are also tracked in a separate PC database by serial number so that the storehouse can keep track of repairs. However, these items are not tracked in the inventory computer system by serial number. Defective components are tagged and stored in a maintenance staging area. When the reorder point is hit, the computer system generates a requisition. Stores collects data from the tags and interviews rail maintenance to make sure the component actually needs repair. The item is then checked in the serialized database to determine if the item has had previous repairs and to check for warranty information. This database also tracks whether the item is repaired in-house or by an outside vendor. The storehouse either ships the material to a vendor for repair or notifies the rebuild shop.

If the item is repaired in-house (computer boards, electronic, valves, brake parts, etc.), it is treated the same way as items sent to outside vendors except that the rail shops are the vendor. When the shops need parts, rail production coordinates with inventory but does not usually provide information on the specific parts to be ordered. The storehouse is responsible for

determining the parts needed in inventory. The component shop only operates when there are components to be repaired and production volumes vary significantly. Repaired components then come back to the storeroom and are returned to the inventory.

## **Inventory Control Performance**

Few formal performance measures are currently used.

### Inventory Accuracy

Physical inventories are no longer conducted since all inventory is counted every two years though the weekly cycle counts. Therefore, no up-to-date physical inventory data is available.

Cycle count data showed 20.8% of the items have on-hand quantities out of balance with the computer system. This figure was based on sampling cycle count data for 1766 items from the Central Warehouse as well as bus and heavy rail storehouses. Dollar variance information was not available for either heavy or light rail or for the bus maintenance facilities. However, the absolute dollar variance percentage for the Central Warehouse sample of 486 items was 35.6%. The net dollar variance was 9.3%.

### Inventory Usage

Inventory transactions per staff member per week are not available. The computer system reports total unit quantities transacted by part number each month, but not total transactions.

Bus inventory dollars per vehicle were calculated at \$9,756. Rail inventory dollars per vehicle were calculated at \$74,856. Annual inventory turnover is 1.95 turns per year for bus and .60 for rail.

### Inventory Availability

The percent of demand filled for the bus division was calculated at 99.4% and at 94.8% for the rail division. The computer system calculates fill rates based on units requested and units filled. Stockout rates per week were unavailable for this case study, however a sample of inventory lines showed 35.5% of bus items and 15.4% of heavy rail items to be at zero on-hand. Stockout information for light rail was unavailable.

## **Technology and Information Systems**

This transit agency is currently using an automated management information system that was installed in 1986. Software modules include inventory, warehousing and purchasing. The system is part real-time and part overnight batch. The system has the capability to specify by line

items which items are to be transferred from the Central Warehouse and which are to be shipped directly from the vendor.

The software was developed specifically for maintenance inventory and has many beneficial features. However, the software vendor is no longer in business and the system is not supported. As a result, the system has not incorporated the reporting and ease of use features found in systems that are more modern. Plans are currently underway to upgrade the system for Y2K compatibility and to replace the system in 2000. Bar coding is not part of the current system, however, there are plans to acquire bar coding with the acquisition of the new system.

## Case Study Data Collection and Analysis

The following information was requested to be provided by the computer system, preferably in electronic form where specified.

### One-time Information

1. A file listing all stock items in the computer system by storeroom location with the following data:
  - Stock Code
  - Part Description
  - Unit Cost (Average Unit Price)
  - Quantity on Hand
  - Average Monthly Demand

### Monthly Information

2. Copies of the following monthly inventory reports from the computer system:
  - Monthly Inventory Operations Report – Summary (All, Non-Rotables, and Rotables) – paper or file
  - Automatic Service Level Report – Summary by Location – paper or file
  - Monthly Receiving Report by Storeroom – file

### Weekly Information

3. Copies of the following weekly inventory reports from the computer system (file):
  - Backorder Status for Storeroom xxx (for each storeroom)
  - Copies of all Cycle Counting reports for each storeroom (file):
    - Physical Inventory Requested for Storeroom xxx
    - Delinquent Inventory Requests
    - Automatic Adjustments for Storeroom xxx
    - Recommended Inventory Adjustments for Storeroom xxx

The property was only able to provide standard paper reports from the computer due to the lack of a user report writer and the workload of the MIS department. The reports were

sampled during site visits. The information used to calculate performance measures was as follows:

- Dollars per vehicle (Bus and Rail):  
  
Total Inventory Dollars calculated from Monthly Inventory Operations Report  
Total number of vehicles identified during site visit
- Inventory Turnover (Bus and Rail):  
  
Annual Usage Dollars calculated from issues (Monthly Inventory Operations Report)  
Total Inventory Dollars calculated from Monthly Inventory Operations Report
- Percent of items stocked out:  
  
Percent of items with zero on-hand on Stock Status Report (sampled during a site visit)
- Percent of demand filled (Bus and Rail):  
  
Demand from Automatic Service Level Report  
Issues from Automatic Service Level Report
- Percent of items out of balance:  
  
Cycle Count Sheets – items counted and items with variances (sampled during site visit)
- Absolute Dollar Variance:  
  
Cycle Count Sheets – items counted and items with variances (sampled during site visit)  
Delinquent Inventory Requests – item values (sampled during site visit)

**APPENDIX D**

**HANDBOOK ON INVENTORY MANAGEMENT IN A  
MAINTENANCE ENVIRONMENT**

Appendix D has been published as *TCRP Research Results Digest 40*, “Revised Inventory Management Desk Guide.”