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Transit Bus Operational and Maintenance Practices to Maximize Fuel Economy

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ESMAP Mission
The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance trust fund program administered by the World Bank and assists low- and middle-income countries to increase know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth.

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E1. PROJECT OVERVIEW

Buses are the most common form of urban transit but, in the developing world, are often seen as inefficient and polluting. It is well known that buses that are properly tuned and adjusted tend to be cleaner, safer and consume less fuel than poorly maintained buses. Fuel cost is a relatively large fraction of total cost especially when labor and bus costs are low, as in many developing countries. Hence, reducing fuel use through targeted maintenance of fuel inefficient buses can reduce significant expenditures especially in developing countries, freeing up resources for other improved city services. In addition, if city buses do not receive periodic maintenance that is adequate in quality and quantity, their emissions, both local and global, will suffer. In an effort to catalyze solutions for urban transport, the World Bank Group focused on development of a global Knowledge Product in the form of a 'Guidance Note' (GN) on bus maintenance procedures. The GN is directed towards city transit managers and their technical staff in developing countries to enhance the energy efficiency of city transit.

The objective of this work effort is to prepare a Guidance Note (GN) on maintenance best practices that is a practical and useful tool to guide the implementation of a program that will enhance the fuel efficiency of buses. To address this objective, taking stock of existing good programs and approaches and interacting with relevant city fleet operators is critical. The first part of this work was a literature review to assess the state of the art in developing bus maintenance practices. The second part of this effort was to interview leading transit fleets in several developing and developed countries to obtain information on best practices in the field. In the third part, data from interviews with maintenance managers of transit organizations in 8 cities across four countries (Brazil, China, India, and USA) around the world, in combination with data from the literature review, were used develop the guidance note that lays out a series of steps to be implemented by a bus maintenance organization that will result in measurable efficiency improvements. A limited validation was the fourth part of this effort, and the validation testing was conducted in two cities in the state of Andhra Pradesh, India with ICF oversight. A separate validation effort was also conducted independently in Mysore, India. Findings from both efforts were incorporated into this analysis.

E.2. LITERATURE REVIEW AND INTERVIEWS

A global search of papers on the effect of bus maintenance practices on fuel economy showed very limited literature on this topic, and ICF broadened the search to include publications on global fuel efficiency strategies across all businesses. In this case, a recent meta-study by the Pew Center for Global Climate Change has identified a set of core principles by which corporations increase fuel efficiency and this is based on over 70 case studies of corporations. The most important idea that emerges from this meta-study is that fuel efficiency is not obtained from just a simple technical fix, but requires senior management attention, good data and metrics, employee participation and an attainable goal with a well specified technical path to meet the goal. There are “Seven Habits” that have been identified for energy efficient companies, but many of these habits have not been embraced by the bus maintenance community based on our interviews of maintenance managers.

The literature on maintenance practices has also been summarized in meta-studies conducted by the US Transportation Research Board and key elements that have been identified to ensure high quality and repeatable maintenance include

- a written maintenance plan that is updated periodically
- documented repair and diagnostic procedures that mechanics must follow as Standard Operating Procedure
- quality assurance checks on repairs conducted regularly by an internal team and periodically by an external audit team
- good data collection on bus performance in the field complemented by extensive data analysis with fleet management software

The driver has been recognized as a key factor in enabling buses to obtain good fuel economy. Driver training programs, teaching drivers how to drive in a fuel efficient and safe manner, have been developed in many countries and they all share common content. Driver training programs have been shown to improve fuel economy by 5 to 15 %. A key finding is that the benefits are obtained not through classroom training but from actual on-road training with a professional driving instructor.

Interviews with maintenance managers of fleets in 8 locations around the world showed many commonalities in the approach to maintenance as well as some key differences. Most maintenance organizations are measured by senior management for their ability to have a high percentage of buses in the field daily, reduce failures in the field and operate safely. Fuel economy is rarely an important parameter (in spite of senior managements’ claims to the contrary) to trigger maintenance actions and many organizations have the underlying belief that good maintenance automatically maximizes fuel economy, and this is partially true. Few organizations have benchmarked the fuel economy of their buses against the fuel economy of similar buses operating in nearby cities, and even fewer have any targets for fleet fuel economy. In the minority of cases where bus maintenance staff pays a lot of attention to fuel economy, it is driven by senior management commitment and very detailed data collection on fuel economy at the bus and route specific level. Since many factors such as the bus technology and the driving cycle on a route affect fuel economy, collection of data at this granular level is required to institute an effective program to identify low fuel economy buses and repair them. Few organizations have implemented analysis of fuel economy at this level of detail. Hence, many organizations do not reward employees for fuel efficiency simply because they lack the data to identify who should be rewarded.

E.3 OPERATIONAL & MAINTENANCE PROCEDURES DEVELOPED FOR THE GN

The key findings from the background research and interviews drove the development of the operational and maintenance procedures. The procedures recognize that improving fuel economy is not achieved through any simple technical fix. **It is possible only with senior management focus and employee participation, detailed data collection and analysis to benchmark and target efforts, maintenance directed at low fuel economy buses, good maintenance practices and quality assurance of repairs, well trained drivers and widespread communication of fuel economy results to all levels of staff.** These factors, working in synergy, create a culture of fuel economy in the organization and help improve fleet average fuel economy while eliminating low fuel economy outliers from the fleet.

Accordingly, ICF developed a 16 step program that addresses each of the key factors recognized from the background research and interviews. The steps offer a clear and detailed path of the actions required to create this culture of fuel economy so that the benefits are permanently institutionalized in a transit fleet. The 16 steps are summarized in Table E-1.

E.4 IMPLEMENTATION AND VALIDATION OF BENEFITS

The 16 steps outlined in table E-1 are not new but well established in industry. Training drivers in fuel efficient driving methods, and having documented, high quality repair procedures that mechanics must follow are common in urban bus transit operations. What is less common is an organization focus on fuel economy and the supporting data analysis and communication required to implement such a program. Limited data available from programs that have implemented most of the steps suggest that fleet fuel economy will improve by 5% to 15% relative to those fleets where most of the steps have not been implemented. The improvement is expected to occur over a period of years as the culture of fuel economy is established. A validation of the steps presented in this report was completed in two cities in Andhra Pradesh, India, with ICF oversight. Due to time and resource constraints only those steps that could be implemented in the short term (10

Table E-1: Recommended steps for developing transit bus maintenance practices

Level	Step		Action
Management	Step 1		Appoint a senior executive to be in charge of fleet fuel economy and tie part of his/her bonus to meeting fuel economy goals.
	Step 2		Benchmark and set appropriate fuel economy goals by bus type for each year
	Step 3		Communicate the fuel economy results achieved each year to both employees and the public.
Data Collection and Analysis	Step 4		Automate data collection to the extent feasible and use analysis software to support maintenance
	Step 5		Set up data QA/QC procedures
	Step 6		Analyze the data for untangling the effects of driver, route and bus related effects on fuel economy (FE)
	Step 7		Use data to refine periodic maintenance
Bus Maintenance and Repair	Step 8A		Select 10% of the fleet showing the lowest FE and conduct 15 simple checks at depot
	Step 8B		Conduct detailed checks at central facility if bus passes step 8A
	Step 8C		Compare pre-repair and post repair fuel economy data in these buses to estimate program benefits
	Step 9		Check repair quality on a random and periodic basis
	Step 10		Obtain mechanic sign-off on repairs for traceability
	Step 11		Require independent team audit of repairs across depots
	Step 12		Retrain mechanics and update repair procedures periodically
Bus Drivers	Step 13		Train drivers in fuel efficient driving techniques and periodically re-train them
	Step 14		Select the 5 percent of drivers with the lowest fuel efficiency and have special additional training
Employee Communication and Rewards	Step 15		Publicly display the fuel economy performance by driver and bus depot to employees
	Step 16		Reward mechanics at the depot level and drivers individually for exceeding targets

weeks) were evaluated in the validation study. A separate, independent validation with no ICF involvement was also conducted in Mysore, India over the same time frame. The conclusions drawn from the validation testing at the two sites in Andhra Pradesh and Mysore are as follows:

1) Implementation of most of the recommended steps in the Guidance Note was accomplished without much difficulty at three locations in India, suggesting that 16 steps described in the GN can be implemented easily in most locations.

2) The involvement of senior management in implementing the procedure was found to be very useful to help motivate staff and provide high level guidance to the organization.

3) The data, although collected manually, was of reasonably good quality and permitted identification of low fuel economy buses and drivers with relatively good confidence.

4) The regression analysis of the data to identify low fuel economy buses and drivers was found to require a skilled analyst due to the very large size of the data bases (>6000 records per month per depot), the data cleaning requirements, and the need for careful analysis of results for statistical significance.

5) In cases where the buses are designated to specific routes and drivers to specific buses, ICF found that the simple method used by the staff in Andhra Pradesh of averaging monthly fuel economy by bus and by driver and selecting the lowest fuel economy buses and drivers by route, identified virtually the same set of buses and drivers as the regression method. When buses are not dedicated to routes and drivers not designated to specific buses, the results from the two methods diverge but the quality of the results from the regression could not be verified in the limited testing time frame.

6) The diagnostics and repair sequence provided in the GN had a great deal of commonality with manufacturer recommended repair procedures and APSRTC's own internal procedures, and met with mechanics approval.

7) Mechanics at the facilities were competent in performing the required diagnostics and repairs, and they successfully followed the sequence of repairs recommended in the GN to improve the fuel economy of the buses identified.

8) The benefit of repairing low fuel economy buses appears to be a function of vehicle age. Newer diesel buses (4 to 7 years old) appear to obtain an average benefit of about 4 to 5 percent improvement in fuel economy based on the testing in Mysore. Older diesel buses (7 to 14 years old) appear to obtain a benefit of 7 to 8 percent improvement based on the

data from Hyderabad, on average. Surprisingly, even the new (less than 3 years old) CNG buses at Vijayawada showed a benefit of about 5% but this may be specific to CNG buses where ignition system problems can degrade fuel economy significantly.

9) Driver training programs incorporate most international best practices for fuel efficient driving, and the on-road training, in particular, appeared to be very well suited to help drivers facing local driving conditions.

10) The data on the benefits of driver retraining are quite consistent from all depots and suggest that it results in an average fuel economy improvement of 6 to 8 percent. During this validation study, drivers were identified on the basis of low absolute fuel economy, not on route adjusted fuel economy. ICF believes that even better results could be obtained by changing driver selection to be on a route adjusted fuel economy basis.

11) Drivers are highly motivated by the public display of driver specific fuel economy information, and the award for good fuel economy performance inculcates driver pride in their performance even though the monetary value of the award is small.

ICF recognizes that the validation study was conducted over a short time frame and some data and analytical issues related to low fuel economy bus and driver identification could not be resolved in this time. In addition, several steps recommended in the GN had already been implemented by APSRTC for many years. A longer duration validation study in a location where fuel economy has not been a central focus is suggested for consideration.

ICF believes that regression analysis is the most appropriate and scientific method for identifying low fuel economy buses and drivers, but recognizes the difficulty associated with the large data bases and the need for skilled statistical analysts. The simple method of calculating average fuel economy by bus and by driver and selecting the lowest fuel economy buses drivers for attention is a reasonable alternative for at least the initial phases of program implementation. Selection of drivers and buses based on fuel economy relative to the route average is preferable, and can be instituted if buses are dedicated to specific routes and drivers to specific buses.

E.5 COSTS AND BENEFITS

A key question is the size of the benefits obtained at the fleet level from implementing a strong fuel economy program along the lines suggested by this guidance note. A general answer can be misleading as the benefit depends on the following parameters:

- the age composition of the bus fleet.
- the technology of bus maintenance.

- the pre-existing organizational emphasis on fuel economy.
- the characteristics of the routes in the city.

The detailed analysis of fleet-wide benefits was based on the APSRTC January baseline for all buses and the benefits observed for the repaired subset of buses and re-trained subset of drivers. The analysis results show that repair of low fuel economy older diesel buses would result in a fleet-wide average fuel economy improvement of 3.0%, while repair of newer buses (4 to 7 years old) would provide a fleet-wide benefit of 2.1%. Re-training of low fuel economy drivers was estimated to provide a fleet average improvement of 2.7%, for a total improvement associated with maintenance and re-training of 4.8% to 5.7%. These figures are for the APSRTC which already has an aggressive fuel program and the implementation of the GN at other locations where there has been less focus on fuel economy would likely provide larger benefits. This conclusion is supported by the limited data available from other locations where relatively similar programs have been implemented.

Costs were computed for India, where labor costs are low and fuel costs are high, based on cost data supplied by APSRTC. Even with low hourly labor costs, total labor cost was the largest single factor, and other costs associated with capital amortization of new equipment was not very large. For a typical depot with 100 buses, monthly costs for all activities described in this GN were estimated at $2750, while fuel savings per percent improvement in fuel economy was estimated at $1120. Since the expected range of improvement is 4.8% to 5.7%, fuel savings alone will range from $5376 to $6384, **making the program very cost effective with a benefit-to-cost ratio of about 1.94 to 2.31**. In addition, the value of co-benefits associated with reduced emissions is not accounted for in this calculation. We expect that in other cities where no emphasis has been placed on fuel economy, benefits will be even larger. However, such a program may not be cost-effective in a developed country setting where labor costs can be 5 to 8 times as high as in India, but fuel costs may be similar.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The importance of providing mobility to the public has long been recognized globally and urban transit is an important issue in both the developed world and the developing world. In the developed world, transit is an alternative to the private car and a means of reducing congestion, while in the developing world, public transit is a key requirement to provide affordable, low cost mobility to much of the urban population. Buses are the most common form of urban transit while alternatives like light and heavy rail are significantly more expensive in terms of capital expense. Each additional bus provides large benefits. If a bus is reasonably full, it replaces anywhere from 10 to 40 other motorized vehicles (including 2-wheelers as well as cars; in some developing country cities, the primary displacement is of 2-wheelers).[1] The consequent fuel savings, CO_2 reductions, and pollutant reductions can be large. Getting buses on the road, and getting riders onto buses (mainly by offering a service that riders want) is one key strategy for providing energy efficient, sustainable transportation systems. New innovations like Bus Rapid Transit, where buses are operated at higher speeds in dedicated road lanes, can also cause an increase in the popularity of buses.

In many cities around the developing world, buses are often seen as inefficient and a major sources of pollution, noise, and road hazards. City Transit authorities therefore seek efficient, clean and affordable urban bus transit systems that can improve this image and maintain or even improve total mobility, even as incomes grow and cities expand. This is feasible, provided bus companies maintain their existing buses well, leading to high fuel economy and low emissions. In most cities, public transit has to be subsidized to make it affordable, but the current financial problems of most governments worldwide are causing significant changes in transit systems. In the past 20 years, transit systems in many cities have changed from a government owned enterprise with nearly 100 percent market share that transported passengers without regard to cost, to a financially constrained municipal enterprise with emphasis on cost control, innovation and competition.[2]

In many cities, the city transit fleet is dominated by a single municipal or state-owned bus operator who, in some cases, subcontracts its operations to private companies. Usually, both the state-owned and private operators are heavily constrained by the regulatory system within which they operate, which tend to inhibit innovation. The urban bus market is quite small relative to the commercial truck market, and very often, there is almost no choice or very limited choice in the types and efficiency of buses available and the cost of new buses tend to be high. As a result, the financial position of bus fleet operators is weak and may not allow for rapid bus replacement or innovation in maintenance of buses at periodic intervals to ensure their fuel efficient operation. It is well known that buses that are properly tuned and adjusted tend to be cleaner, safer and consume less fuel than poorly maintained buses.

Fuel cost is a relatively large fraction of total cost especially when labor and bus costs are low, as in many developing countries. For example, in Washington DC, the Metro Area Transit Authority (WMATA) reports that bus fuel cost was $49 million, while overall bus system costs were $463 million making fuel 11% of total cost[3]. In contrast, the TCRP reports that in Warsaw, Poland, fuel cost was 18% of total cost[4], while in Andhra Pradesh, India, fuel cost was 31% of total cost.[5] Hence, reducing fuel use through targeted maintenance of fuel inefficient buses can reduce significant expenditures especially in developing countries, freeing up resources for other improved city services. In addition, if city buses do not receive periodic maintenance that is adequate in quality and quantity, their emissions, both local and global, will suffer.

To promote Energy Efficiency (EE) in the delivery of city services the Energy Sector Management Assistance Program (ESMAP) in the World Bank launched a multi-year programmatic initiative, the Energy Efficient Cities Initiative (EECI), in December 2008 to help scale-up energy efficiency improvements in developing country cities around the world.[6] EECI supports client countries in building institutional capacity at the city level to explore and deploy innovative, energy efficient solutions for the delivery of basic urban services and to reduce the costs and environmental impacts of reduced energy use.

In an effort to catalyze solutions on urban transport and to add value to existing in-house World Bank Group Activities, one of the EECI components focused on development of a global Knowledge Product in the form of a 'Guidance Note' on bus maintenance procedures. The GN is directed towards city transit managers and their technical staff mainly in developing countries to enhance the EE of city transit. Against this backdrop, ESMAP selected ICF International, Washington DC, USA and provided funding support to prepare a Guidance Note to help cities develop effective city transit fleet inspection and maintenance practices mainly from a <u>fuel efficiency perspective,</u> while also providing other benefits like reducing tailpipe emissions and ensuring safety.

1.2 OBJECTIVE AND SCOPE OF WORK

The objective of this work effort is to prepare a Guidance Note (GN) on maintenance best practices that is a practical and useful tool to guide the implementation of a program that will ultimately enhance the fuel efficiency of buses. More specifically, the GN covers the following three areas:

i. A technically proactive and rigorous fleet maintenance procedure/protocol;
ii. Indicators to measure and track effectiveness of maintenance practices, from a fuel efficiency perspective; and
iii. Training content and training methodologies for drivers and mechanics.

To address this objective, taking full stock of existing good programs and approaches and interacting with relevant city fleet operators is critical. Hence, the first part of this work was a literature review to assess the state of the state of the art in developing bus maintenance practices. The second part of this effort includes interviews of leading transit fleets in several developing and developed countries to obtain information on best practices in the field. In the third part, data from interviews with maintenance managers of transit organizations in 8 cities across four countries (Brazil, China, India, and USA) around the world, in combination with data from the literature review were used develop the guidance note, that lays out a series of steps to be implemented by a bus maintenance organization that will result in measurable efficiency improvements.

A validation study was conducted as the fourth part of this effort, by implementing the steps in the guidance note in a developing country transit fleet. The validation testing was conducted with ICF supervision in two cities in India, with the assistance of the Andhra Pradesh State Road Transport Corporation (APSRTC). Separately, the Karnataka State Road Transport Corporation implemented the steps in the guidance note in Mysore India, without assistance from ICF. The testing was over a limited duration of about 12 weeks. Results from both validation testing programs were used to gauge the effectiveness of the GN and to refine the steps recommended.

1.3 OVERALL STRUCTURE OF THE GUIDANCE NOTE

The GN is divided into six chapters. An overview of the methodology used for developing this guidance note is provided in Chapter 2. Chapter 3 provides a summary of the background research for the project. A number of papers on energy efficiency strategies, maintenance best practices, fuel efficient driving and improved maintenance technology were collected in this work effort and their findings are summarized. Interviews with eight different bus companies of different sizes around the world were conducted in this effort. One of the key findings of the analysis was that fuel efficiency was not simply a matter of implementing some technical steps, but involved the creation of a culture of fuel efficiency that supported the implementation of the technical steps.

Chapter 4 is the heart of the report and lays out the operational procedures to improve transit bus fuel economy. This work effort resulted in the identification of 16 steps that work together in synergy to improve the fuel economy of the fleet. The steps are applicable to any bus maintenance organization and are based on the best practices recommended in literature and by the maintenance managers worldwide. This chapter was developed so that it can be (with minor modifications) used as a stand alone piece for maintenance managers less interested in the background research and survey findings, and the World Bank intends to publish such a document. Chapter 5 documents the steps validated in the two locations, the data obtained from the validation testing, and the data analysis to show the benefits of these procedures where they were implemented. Finally, Chapter 6 estimates the fleet-wide benefits of implementing the GN and provides a cost-benefit analysis of the recommendations.

Annexes 1 to 9 to this report describe case studies and available maintenance management and driving aid tools to support the conclusions of this report, as well as the data obtained during the validation of the procedures developed.

CHAPTER 2: METHODOLGY AND APPROACH

2.1 TECHNICAL APPROACH

Maintenance procedures documented as formal work instructions (referred to as practices) offer transit agencies many benefits. Practices help ensure that workers with different skill levels perform their duties in a consistent and thorough manner, since the instructions are based on the collective insights held by transit agencies and the industry. This approach minimizes emissions and fuel consumption while ensuring compliance with national and local regulations. There are two levels to this issue of "practices". First is the management and organizational structure to incorporate best practices for vehicle maintenance. This has common elements worldwide but local and national regulations and labor agreements may impose specific national variations to suit these requirements. Second, the specific maintenance or inspection action is the actual practice, and this set of specific instructions for carrying out the inspection and/or repair must be vehicle make/model specific. Hence, the actual repair methods will vary among countries and agencies depending on the specific technology of the vehicle purchased but the general actions are common to all internal combustion engine powered buses, diesel or CNG.

In accordance with the two levels at which this work has to be pursued, the details of management and organizational structure to incorporate best practices were pursued using the guidelines developed in the US and OECD countries. The development of specific maintenance practices were also based on manufacturer recommended practices that correct for poor fuel economy. The project Terms of Reference specified the effort in four tasks and the approach used for each task is detailed below.

2.2 TASK 1: LITERATURE REVIEW AND INTERVIEWS

Task 1 requires a review good maintenance practices in the literature and with 'relevant city operators'. The first part of Task 1 was a detailed review of available literature on this topic. A global search quickly revealed that literature on bus maintenance is quite limited and literature on bus maintenance with **a focus towards fuel economy** was limited to a small handful of papers. Accordingly, the literature review was expanded to include corporate strategies for enhancing fuel efficiency so that the broad lessons from other businesses could be applied to bus maintenance organizations. In addition, it also provided more importance for the interviews with fleet maintenance managers to understand why the focus on fuel economy was not always a top priority. On the other hand, the literature on driver training for fuel efficient driving practices was quite extensive. High quality existing programs developed and disseminated with government sponsorship are available for use by transit bus companies.

The fleet manager interviews were not for a survey of practices but rather, a discussion based approach to understanding the primary drivers for fleet maintenance managers, and to understand the practical limitations present in the real world. The main objective was to gain insights from a range of global locations and a range of bus companies by size to understand how practices differed worldwide. Due to the global capability of ICF, interviews were conducted in several developing countries and developed countries to provide good cross national comparisons. ICF conducted interviews with transit officials in two cities in Brazil , two in China , and two in India, with these nations chosen for their size and scale in bus fuel consumption globally. In addition, ICF conducted interviews in two cities in the US to examine if processes in the developed world were markedly different. The findings from both the literature review and interviews are summarized to guide the development of the GN.

2.3 TASK 2: PREPARATION OF THE GUIDANCE NOTE

Under task 2, ICF prepared a comprehensive guidance note (GN) on maintenance practices and on driver and mechanic training, which if implemented will lead to fuel economy improvement. Originally, the project was conceived of as mostly a technical intervention in maintenance practices. However, the results of Task 1 made it clear that many of the obstacles were due to lack of organizational and administrative focus, as well as the lack of good metrics to examine this issue. Hence, the guidance note focuses on all aspects on the acronym used in industry as "SMART goals" which are Specific, Measurable, Accountable, Realistic and Time bound goals to create a culture of energy efficiency. This involves management focus, employee participation, good data, goals and a well specified technical path to meet the goals

The key indicators used to track the benefit of the practices recommended are the average fuel economy of the fleet (by bus type, if there are several different sizes of buses and fuel types present in the fleet) and the dispersion of buses around the average. The goal is to increase the fuel economy of the fleet (as measured in distance per unit of fuel consumed) and reduce the dispersion of individual bus fuel economy around the average by eliminating the presence of buses with fuel economy much lower than the average.

Data from the interviews and literature review were used to construct the Guidance Note at the organizational and managerial level. In addition, ICF developed a detailed component list for items to be inspected and maintained, that is common to all diesel engines and CNG engines (these are the only two fuel types that investigated in this project). However, the detailed specification of the inspection and repair practices at the mechanic level will vary across agencies and a comprehensive list of procedures covering all makes and models of buses is not included here but easily available from the bus manufacturers for the components specified for inspection.

2.4 TASK 3: VALIDATION

Under task 3, ICF provided oversight of a field test of the GN at three maintenance depots in two cities in the Indian state of Andhra Pradesh over a period of 3 months. The choice of Andhra Pradesh was driven by the interest of the management of Andhra Pradesh State Road Transport Corp (APSRTC). The Executive Director of APSRTC had personally briefed the World Bank on the ongoing fuel efficiency related practices at his organization, and also participated in the development of this Guidance Note by providing useful data on practices found effective at APSRTC.

During the field test, ICF implemented the GN in two developing country cities and assessed the level to which the GN provides useful analyses and recommendations to the City Fleet Managers. Due to time and resource constraints, only the short term actions were evaluated in this validation at selected depots. The validation study implemented the GN at one depot in Hyderabad and two in Vijayawada, cities in the state of Andhra Pradesh, with APSRTC assistance over a period of twelve weeks of testing, with monitoring of fuel economy over the field test period.

Separately, Karnataka State Road Transport Corporation (KSRTC) independently conducted a field test in the city of Mysore using the draft guidance note but with no direct assistance from ICF staff. They provided a summary of their tests and findings which are included in this report. Data from all of the testing, including the tests conducted in Mysore, were used to validate the GN.

2.4 TASK 4: COMPLETION OF THE GN AND SCALE UP TO FLEET LEVEL

Upon completion of the validation testing, ICF refined the procedures contained in the draft GN based on the test results and the feedback received from the city bus corporation/agency. The refined GN also includes the feedback received from APSRTC field staff.

The scale up of the benefits from the validation study to predict fleet-wide improvements over time is based on the principle that repairs to the lowest fuel economy buses will improve them to average or better than average fuel economy levels. In this case, if the bus fleet starts from a distribution of buses which are uniformly distributed in fuel economy space with the 1% and 99% of population between ± 15% around the average (typically observed in practice), then the post-implementation distribution will be truncated since approximately the bottom 40% of the distribution will be moved to the top 60 %.

The **post repair fuel economy data from the validation sample** was utilized to predict where the lowest fuel economy will migrate to in the distribution after repair so that over 4 months (at 5% repaired each month) the bottom 20 percent will have migrated to higher levels and the new bottom 20 percent will now be captured. Based on this type of computation, fleet fuel economy benefits was captured to assess the benefits of this type of program as an increment

Costs for each of the steps to be implemented were obtained from APSRTC and these data were used to compute costs for a hypothetical fleet with 100 buses per depot. Small cities will typically have only about 100 buses, while a large metropolis can have several hundred to several thousand buses. Depot level calculations can be used as indicators for small cities while the 10 depot computation can be used as a cost-benefit indicator for a large metropolis. For the purposes of this evaluation, the only monetized benefit was that of fuel savings; reduced criteria pollutant emission benefits and potential safety improvements are recognized co-benefits that are not directly used in the cost benefit computation.

CHAPTER 3: SUMMARY OF BACKGROUND RESEARCH AND INTERVIEWS

3.1 OVERVIEW

The objectives of the literature search were to examine previous work in the area of bus maintenance practices and how they would affect fuel economy, so that best practices could be identified and recommended in the guidance note. Accordingly, ICF completed a detailed search for papers in this area and examined the records of professional Engineering Societies (such as the Society of Automotive Engineers), as well as organizations related to public transit and bus transit (such as the American Public Transit Association). Surprisingly, the literature related to bus maintenance practices is relatively limited, while the relationship of fuel economy to bus maintenance has received virtually no attention in terms of published studies in this area. Indeed, ICF was able to locate only one paper in this area that dated back from 1990, and many of the other papers related to bus maintenance were not directly related to the subject of this report but focused on aspects of developing maintenance models or estimating life cycle costs and optimal scheduling of maintenance events to minimize costs.

Due to the limited information on this issue, ICF also focused on the broader issue of energy efficiency in industry and the strategy to maximize energy efficiency. While there are hundreds of reports on energy efficiency applications in industry, the strategic aspects of implementing a successful energy efficiency program has also received more limited attention, but there was a recent (2010) meta-study by the Pew Center for Global Climate Change[7] that summarized the broad strategic aspects of bringing about a culture of Energy Efficiency to any organization. This review provided a framework for the subsequent analysis and resulting guidance note.

Bus maintenance is also being revolutionized by new computer based data acquisition and analysis systems which are relevant to all aspects of maintenance including fuel economy. The literature on the impact of such systems was reviewed to estimate its applicability to improving fuel economy.

The work effort also included an investigation of fuel efficient driving practices, and there is a significant amount of literature in this area. There are several government sponsored programs in fuel efficient driving and driver training programs that provide a comprehensive review of the key features of such programs. ICF has reviewed several such programs and has found that a few key features are common to most programs.

Due to the relative paucity of reports on bus maintenance as related to fuel economy, ICF also conducted a series of interviews with bus maintenance or depot managers at transit organization around the world. The objective was **not** to conduct a statistically valid survey of fuel efficiency related practices at transit organizations, but rather to obtain an understanding of the current state of affairs relative to bus fuel efficiency in a range of countries including developing nations and developed nations, small transit organizations with fewer than 100 buses and large organizations with thousands of buses, fleets with many old buses versus fleets with new buses, etc. ICF contacted well regarded organizations in India, China, Brazil and the US to obtain a subjective assessment of the state-of-the-art, and the relative importance of fuel economy in comparison to all the other requirements placed on a transit organization pertaining to its mission of public service.

A detailed presentation of the findings from the literature survey and interviews can be found in Annex 1, and a summary of the key points identified for use in the Guidance Note can be found in Section 3.2 and 3.3.

3.2 SUMMARY OF KEY FINDINGS FROM THE LITERATURE REVIEW

3.2.1 Fuel Efficiency Strategy

A global search of papers on the effect of bus maintenance practices on fuel economy showed very limited literature on this topic, and ICF broadened our search to include publications on global fuel efficiency strategies across all businesses. In this case, a recent meta-study by the Pew Center for Global Climate Change has identified a set of core principles by which corporations increase fuel efficiency and this is based on over 70 case studies of corporations. The **most important idea** that emerges from this meta-study is that fuel efficiency is not obtained from just a simple technical fix, but requires senior management attention, good data and metrics, employee participation and an attainable goal with a well specified technical path to meet the goal. There are “Seven Habits” that have been identified for energy efficient companies, but many of these habits have not been embraced by the bus maintenance community based on our interviews of maintenance managers. Due to the importance of the strategy identified by the Pew Report in formulating the Guidance Note, the Seven Habits are summarized in Box 3.1 overleaf.

3.4.2 Maintenance Practices

The literature on best practices in maintenance is somewhat more extensive but few address the issue of fuel economy and most are focused on keeping the buses “well maintained” and available for service. The underlying idea is that a well maintained bus is also fuel efficient, which is generally but not always true as some fuel efficiency related components may not be captured

Box 3.1: The Seven Habits of Highly Efficient Companies

1. Efficiency is a Core Strategy
- Efficiency is an integral part of corporate strategic planning and risk assessment and not just another cost management issue or sustainability "hoop" to jump through.
- Efficiency is an ongoing part of the organization's aspirations and metrics for itself.

2. Leadership & Organizational Support is Real & Sustained
- At least one full-time staff person is accountable for energy performance.
- Corporate energy management leadership interacts with teams in all business units.
- Energy performance results affect individuals' performance reviews and career advancement paths.
- Energy efficiency is part of the company's culture and core operations.
- Employees are empowered and rewarded for energy innovation.

3. The Company Has SMART Energy Efficiency Goals
- Goals are organization-wide.
- Goals are translated into operating/business unit goals.
- Goals are specific enough to be measured.
- Goals have specific target dates.
- Goals are linked to action plans in all business units.
- Goals are updated and strengthened over time.

4. The Strategy Relies on a Robust Tracking & Measurement System
- The system collects data regularly from all business units.
- The data is normalized and base-lined.
- Data collection and reporting is as granular as possible.
- The system tracks performance against goals in a regular reporting cycle.
- Performance data is visible to senior management in a form they can understand and act upon.
- Energy performance data is shared internally and externally.
- The system is linked to a commitment to continuous improvement.

5. The Organization Puts Substantial Resources into Efficiency
- The energy manager/team has adequate operating resources.
- Business leaders find capital to fund projects.
- Companies invest in human capital.

6. The Energy Efficiency Strategy Shows Demonstrated Results
- The company has met or beat its energy performance goal.
- Successful energy innovators are rewarded and recognized.
- Resources are sustained over a multi-year period.

7. The Company Effectively Communicates Efficiency Results
- An internal communications plan raises awareness and engages employees.
- Successes are communicated externally.

Source: Reference 7

under the “well maintained” definition. Meta-studies conducted by the US Federal Transit Association stress the importance of documented maintenance practices in terms of both recommended practices and standard operating procedures.

The key elements of well developed maintenance plan include the following steps:

- a written maintenance plan that is updated regularly for all vehicles in the fleet
- preventive maintenance checklists that are, at minimum, consistent with manufacturer requirements for buses under warranty
- data based documentation that the existing plan adequately protects assets from deterioration over the buses useful life
- a detailed and permanent record keeping system that can track the maintenance history of each bus

These steps are required by the government in many developed countries and are considered as a baseline for good maintenance. The literature also stresses the need for **written** “Standard Operating Procedures” so that all repairs are performed according to the procedure. This ensures uniformity of repairs across depots and facilitates a strong quality assurance plan.

The next steps are to continuously refine the maintenance plan starting from manufacturer recommendations, but adjusting the plan to make them more suitable for local conditions and to focus on those components that fail more frequently in the field. An auxiliary conclusion is that maintenance intervals which are generally fixed in terms of kilometers of operations should be varied so that older buses and buses on more severe duty cycles are maintained more frequently.

A key auxiliary recommendation is the need to collect complete data on each bus and synthesize the different elements of operational and maintenance data. For example, oil consumption can be tracked to trigger specific maintenance actions like a piston ring change or rebuild. Interestingly, the examples in the literature rarely mention low fuel economy as a trigger of specific maintenance actions. The FTA meta-studies also suggest the use of data management systems to automate the tracking and initiation of maintenance events like normal and special service. Finally, the FTA meta-studies also stress the importance of adequate QA/QC plans to check data acquisition and the quality of repairs. Both regular and surprise audits are recommended, and this is seen as essential for maintaining repair quality at high levels.

3.4.3 Data Management Systems

Collecting good quality data, and analyzing the data with a sophisticated data management system, has produced documented improvements in fleet performance and reduced maintenance costs. All of these systems rely on data inputs from the field and the traditional method of data entry by the bus operator and mechanic are often error prone and incomplete. The newest trend in the developed world is the complete automation of data acquisition. Many of these systems are relative low cost and with increasing computer control of buses and engines, high quality data can be downloaded from the bus as inputs to the data management system. Typical commercially available systems provide tracking of the status of all vehicles in the fleet and automatically signal when a particular vehicle should be serviced, while providing a printout to the mechanic on the items requiring service. The systems track vehicle history to monitor trends in wear, breakdowns and abuse of each vehicle and signal which vehicles need special maintenance or should be scrapped. The process ensures more uniform maintenance and improves scheduling while reducing maintenance related time and expenditures, and the procedures are equally applicable to defects causing poor fuel economy.

3.4.4 Driver Training

Information from several active driver training programs in developed countries (with reports in English) were reviewed, and the driver training procedures from these programs showed that all of them were quite similar in structure and content with all requiring a couple of hours of classroom lectures on fuel efficient driving and 2 to 4 hours of on-road or test track based training with an experienced instructor. The only significant difference noted among programs was that some used driving simulators where the instructor could train the driver prior to the on-road segment. The core principles emphasized in all programs examined that constitute safe and efficient driving are: cutting out unnecessary idling, staying within the speed limit and maintaining engine RPM at optimum levels, accelerating and braking gently, using vehicle momentum to maintain cruise speed, avoiding pumping the accelerator pedal and anticipating traffic ahead to minimize hard braking and acceleration.

The key benefit of the on-road training with the trained instructor is the fact that many drivers have developed habits that they may not be consciously aware of. Pumping the accelerator pedal and clutch riding are apparently quite common without conscious awareness and the instructor can show how the general principles discussed in the classroom can be put to use on the road. On road training has been found in studies to be the most important component of training and can increase fuel efficiency by 5 to 15%, with typical results in the 7% to 9% range. The experience in Edmonton as outlined in Box 3.2 below is illustrative.

Box 3.2: CASE STUDY: CITY OF EDMONTON

The Fuel Sense driver training program was implemented in 2000 for Edmonton Transit and all of the drivers were trained over a period of 10 months. A comprehensive review in 2003 found that fuel economy had improved by 5.5%, and the drivers exhibited very good retention of the driving techniques from year to year. The start-up costs were $60,000 and annual costs were estimated at $45,000. One of the key lessons learned in Fuel Smart was how easily the entire process can be transferred, and how the improvements, though simple, needed to brought together in a practical way. Other lessons learned were the need to coordinate training with workloads so that drivers are not tired when they come to training. A separate but important lesson was the need to communicate results regularly. Drivers benefit from follow-up communications and are more motivated to continue lessons if they are appraised of the results. Management also needs to be kept informed to support the growth of the program and its applications to new areas. See Annex 5 for details.

3.3 SUMMARY OF RESULTS FROM INTERVIEWS

Interviews were conducted with senior depot managers and headquarters staff of eight different bus companies worldwide to provide insight into the factors that lead management to focus on fuel efficiency and maintenance. The interviews were conducted at the state owned Mumbai and Delhi bus transport corporations, two privately owned bus companies in Brazil (Julio Simoes in Sao Paulo and Bel Tour in Rio), Beijing Public Transport Holding (BPT) and the privately owned Beijing Xiang Long (BXL) in China, and the Washington DC and State College Pennsylvania transport authority in the US. The global interviews with bus companies showed many standard global practices and some unique practices. These are discussed by topic.

Management: Senior management has considerable involvement in maintenance in all companies interviewed, but the focus is largely on ensuring bus reliability and availability for service. Management also stated that fuel economy was important but most were unable to point to any practices uniquely geared to fuel economy, and management often expected that fuel economy was automatically realized from good maintenance. Only in one instance (BXL) ICF found fuel economy to be a critical management focus, while in a second instance, it had just become a focus due to management decisions to pay attention to its carbon footprint (Simoes). In no case did ICF find bus companies setting a target for future fuel economy, and fuel economy of new technology (like diesel hybrid buses) is the only area where management has been involved.

Bus Purchase and Scrappage: Bus purchases are driven by regulatory and political decisions and fuel economy rarely enters the picture. In most instances, there is a choice of only one or two suppliers, so there is no real competition in the field. In developed countries, bus companies often require suppliers to install special modifications to suit local conditions, such as a larger radiator for hot weather, but in developing countries, only the standard product is purchased. Bus scrappage is often mandated by regulation at 8 to 10 years, but otherwise, bus life of 15 to 16 years is used as a typical scrappage point. Only one company (Simoes) interviewed used a completely different strategy of selling buses in 4 years to enable the quick adoption of new technology and reduce maintenance to the bare minimum, and this policy relied on an active market for used buses which may be absent in many countries.

Maintenance Practices: The typical maintenance cycle uses daily checks, weekly or bi-weekly checks and checks at 8000 to 10,000 km intervals, with manufacturers specifying the maintenance intervals and specific checks. All companies interviewed regardless of size or location used this type of schedule but larger companies often analyzed the failure data to develop more tailored policies suitable for their local conditions. Small companies (like Bel Tour and CATA) do not have the resources or data to pursue unique strategies, and simply use manufacturer specified maintenance. Larger fleets have also discovered the virtues of written methods to conduct repairs and standard operating practices (SOP) that specify all aspects of diagnosis and repair. This has enabled uniform and repeatable repair results and facilitates moving staff among depots without having to change practices. Mechanics training on the SOP is also a key part of the strategy to introduce uniformity.

Data Collection and Analyses: Most bus companies collect data on daily travel, fuel fill and bus maintenance history for major repairs, but many do not collect data on minor maintenance and service actions like coolant and oil top up. Data collection on daily bus route and driver is also not uniformly done and data QA is done when there is an automated fleet management system in use. The fleet management systems have been very helpful in integrating the response of different divisions to maintenance so the scheduling, parts availability and clear service orders are maximized while down time and incomplete attention to all systems malfunctioning in a bus are minimized. Interestingly, most companies do not use low fuel economy as a trigger for maintenance and only when the fuel economy levels reach very low values (which occurs rarely) does it become a critical parameter. Of the companies interviewed, only one (BXL) performed detailed analysis of fuel economy data and used the data to benchmark fuel economy performance by route.

Mechanics: Virtually all companies hire trained mechanics and send them for training both in-house and at manufacturer sponsored facilities. Their work is typically audited by the chief mechanic in each depot and sometimes by an external QA/QC team. Periodic re-training and retraining when new technology is introduced is common. In small facilities, the mechanic QA is usually based on personal knowledge by the chief mechanic while more data based approaches are common in large fleets with many depots and mechanics. Two innovations that received special mention by WMATA were associated with mechanic sign-off on all repairs to permit tracing back post-repair failures for identification of poor quality repairs, and the use of an external QA/QC team to audit performance across garages within a large system to ensure that individual depots were not slipping in performance.

Drivers: Driver training for safe and efficient driving is common and in many cases a legal requirement for transit bus drivers. The training programs have been available for many decades and most follow well known and standard principles of fuel efficient driving. Most of the larger companies have periodic retraining, but only some have the data capability to track and identify low fuel economy drivers for retraining. In smaller facilities, the operations manager may be informally aware of the most fuel efficient drivers and the worst drivers and send the worst for retraining. Among the companies interviewed, only BXL and BPT had analysis capabilities to identify low fuel economy drivers after adjusting for the type and age of the bus driven and the route.

Employee Rewards: Currently, most employee rewards are for safety and attendance, or for innovative suggestions, but rarely for fuel economy largely because companies do not have the metrics to reward staff for fuel economy. BXL and BPT were the only exceptions and in both companies, each bus route has a bench-marked fuel economy level and range. Drivers exceeding the range are rewarded while drivers falling below are fined (BXL actually computes the value of fuel saved for the reward or fine!). When such detailed benchmarks are not established, rewards for fuel economy have poor acceptance by drivers who believe that the route or bus effects may have penalized them, and at least two companies (Bel Tour and Mumbai) had to reconsider this reward in the face of driver dissatisfaction.

CHAPTER 4: OPERATIONAL PROCEDURES TO MAXIMIZE FUEL ECONOMY

4.1 INCORPORATING CORE PRINCIPLES FOR FUEL EFFICIENCY

While fuel efficiency has been recognized as an important issue in urban bus transit, the goal of attaining better efficiency of the existing fleet through targeted maintenance actions has not received much systematic attention, and very little literature exists in the field to provide a step-by-step guide to implementing such targeted actions. This is partly because bus maintenance organizations are focused on the two most important factors for the public – providing adequate service in terms of passenger miles per day, and operating a safe system that minimizes customer and employee accidents.

Fuel economy of the existing fleet is widely assumed by bus maintenance organizations to be maximized by following proper maintenance procedures, and special efforts to improve fuel economy are typically focused on purchasing new buses with improved technology. While this view is reasonable for new buses, ICF find that targeted actions on older buses can yield overall fuel efficiency improvements that are significant and cost effective. Two main findings from the review in Chapter 3 show that:

- fuel efficiency is obtained from **not** just a simple technical fix. Rather, the organization management and employees must focus on implementing the actions required for fuel efficiency
- improved fuel efficiency will be realized over time as implementation of the steps becomes routine and accepted by all sectors of the organization.

Energy Efficiency has been embraced by all companies in every field, not just bus fleet owners. Analysis of global company strategies by the Pew Center for Climate Change suggests that seven core principles are used globally by all companies that are serious about energy efficiency, as described in Section 3.2.1. These core principles are also very useful for bus maintenance operations.

This guidance note explores how the seven principles translate to actual actions for a bus maintenance organization. The principles apply to **management commitment, data and metrics, employee involvement and clear technical steps**. The four areas work in synergy to improve energy efficiency but any one alone is insufficient to achieve the goal, as illustrated in the Dow Case Study, described in Box 4.1.

Box 4.1: THE IMPORTANCE OF CORPORATE COMMITMENT AND TARGETS DOW CHEMICALS – A CASE STUDY

In most companies energy costs are only 5 to 10 percent of total cost, but for Dow Chemicals, energy accounted for 50 percent of total costs. Under these conditions, Dow already paid attention to controlling energy costs and there was internal skepticism that significant additional savings from energy efficiency could be obtained. In 2006, the Dow CEO made a commitment to reduce energy use by another 25 percent in 10 years. Rather than simply have a press release, the Dow CEO spoke at a special event where detailed targets by division were shown and he provided a corporate vision of the technology and process used to achieve the targets. But Dow shares with other companies the challenges of persuading production managers to change operating practices, as they are focused on product quality and production volume targets. The Dow CEO created special teams at its Tech Centers that reported to the business units. The teams not only develop technology and operational solutions but also build trust relationships with production managers, and work with them to attempt to meet efficiency goals. This way, the production managers are more willing to attempt new strategies for energy savings since they have the corporate support to do so without fear of failure. Savings of 6 percent were attained over the 2006 to 2008 period closely tracking the annual reductions needed to meet the 2015 goal. See Annex 2 for details.

4.1.1 Application to Bus Maintenance

Translating the seven core principles to concrete steps that a bus maintenance organization can implement is a process that accounts for the specific needs of a maintenance organization. This guidance note focuses only on the maintenance of the existing fleet, and not on new bus purchase. It is recognized that bus specifications set by the company for vehicle purchase have a significant impact on fuel economy but the requirements can involve many factors unrelated to fuel economy, such as the available funding, clean air goals, etc., which are too site specific to be considered here.

ICF has translated the seven core principles into a series of sixteen steps covering management functions, data collection and analysis, special maintenance for fuel efficiency, maintenance QA/QC functions, driver training and employee rewards. The 16 steps are based on best practices in bus maintenance organizations obtained from a literature review as well as from interviews with the maintenance management of 8 bus companies across the world. Table 4.1 presents the specific steps recommended in each area.

Table 4.1: Recommended steps for developing transit bus maintenance practices

Level	Step		Action
Management	Step 1		Appoint a senior executive to be in charge of fleet fuel economy and tie some part of his/her bonus to meeting fuel economy goals.
	Step 2		Benchmark and set appropriate fuel economy goals by bus type for each year
	Step 3		Communicate the fuel economy results achieved each year to both employees and the public.
Data Collection and Analysis	Step 4		Automate data collection to the extent feasible and use analysis software to support maintenance
	Step 5		Set up data QA/QC procedures
	Step 6		Analyze the data for untangling the effects of driver, route and bus related effects on fuel economy (FE)
	Step 7		Use data to refine periodic maintenance
Bus Maintenance and Repair	Step 8A		Select 10% of the fleet showing the lowest FE and conduct 15 simple checks at depot
	Step 8B		Conduct detailed checks at central facility if bus passes step 8A
	Step 8C		Compare pre-repair and post repair fuel economy data in these buses to estimate program benefits
	Step 9		Check repair quality on a random and periodic basis
	Step 10		Obtain mechanic sign-off on repairs for traceability
	Step 11		Require independent team audit of repairs across depots
	Step 12		Retrain mechanics and update repair procedures periodically
Bus Drivers	Step 13		Train drivers in fuel efficient driving techniques and periodically re-train them
	Step 14		Select the 5 percent of drivers with the lowest fuel efficiency and have special additional training
Employee Communication and Rewards	Step 15		Publicly display the fuel economy performance by driver and bus depot to employees
	Step 16		Reward mechanics at the depot level and drivers individually for exceeding targets

Since these steps are based on industry best practices, many of them (like driver training for fuel efficient driving) have been widely implemented but several others such as setting specific fuel efficiency goals or employing special maintenance for low fuel efficiency buses, have been implemented only in very few areas. Improving fuel efficiency of the existing fleet is not a simple process and will require implementation of most, if not all, of the 16 steps.

The following sections of the guidance note explain each step in some detail. In some cases, they can be described only generally as the details will be site specific.

4.2 MANAGEMENT FOCUS AND OBJECTIVES

4.2.1 Overview of Three Steps for Management

The interviews with a range of bus maintenance organizations showed that all consider fuel efficiency to be very important but surprisingly few incorporate fuel efficiency in many important issues. This is due to the fact that **most urban transit systems place the highest priority on safety, timeliness (which translates to bus reliability) and maximizing service with their assets** available. The management organization focuses on how many buses are fielded each day, how many accidents occur in the field, the number of revenue passenger miles or kilometers, and how many injuries occur to workers and bus riders. Fuel economy is widely regarded as an outcome and there is the general belief that periodic maintenance that provides good reliability automatically maximizes fuel economy. Typically driver training is the primary area where fuel efficiency is emphasized along with safety and courtesy. This focus and belief are generally correct as the public wants frequent service in clean buses that are safe, but the public have no knowledge of (or interest in) fuel economy. However, incremental management efforts directed towards fuel economy can yield surprisingly good benefits if it becomes an integral part of core management strategy**.** The following three steps provide this focus.

4.2.2 Step 1: Appoint a senior executive to be in charge of fuel economy

In general, maintenance organizations monitor fuel economy closely and take corrective actions against buses and depots that report fuel economy much worse than average. Yet, the fuel economy function is integrated with other operations and maintenance functions and ICF did not find any organization with an executive whose responsibility was to **maximize** fuel economy, with one exception, BXL. BXL has a special management group focused on energy efficiency and has paid considerable attention to this data. In most other companies, there was focus on low performance vehicles but no attention was paid to high fuel economy vehicles to see if their performance could be replicated across the fleet. In addition, even the focus on low efficiency vehicles is typically directed towards those buses that are 15+% worse than average, i.e. the outliers. Moreover, we found no organizations that actually set **targets** for fuel economy for either the short term (within one year) or long term. A senior executive whose responsibility is fuel economy can provide the required management focus. ICF does not intend to imply that this is the only focus of the particular executive but it should be one major focus.

The need for senior management involvement is a key finding of the Pew meta-study and ICF found evidence of how that changes the attitude to fuel economy as in the Brazilian bus company (Simoes), where management is now focused on reducing the carbon footprint.

The key requirements for this step are:

- the executive must have authority over driver and mechanic staff at all depots to install new procedures
- the executive must have the knowledge of maintenance practices and understand the current data reporting and repair procedures
- the executive must have part of his/her bonuses linked directly to fuel economy goals set for the organization.

4.2.3 Step 2: Benchmark fuel economy and set goals

Benchmarking and target setting have been identified by the Pew Study as a key step to enabling a specific path to energy efficiency. Benchmarking the existing fleet's fuel economy is the first step in determining where the current fleet is relative to its peers and to be able to set meaningful goals for future improvement. Benchmarking involves comparing properly computed fuel economy values for similar buses across different organizations. Typically, this will involve some data collection effort as fuel economy results are generally not publicly available.

Variables to be addressed for benchmarking

Bus fuel economy is a function of several variables including bus size (overall length and passenger capacity), engine horsepower, engine emissions certification, air-conditioner use and ambient temperature, as well as route specific drive cycle. The last item cannot be controlled for across cities so that there is an assumption that the average bus fuel economy across multiple routes will be similar. By selecting bus fleets from cities of similar size and congestion levels, the route variability can be minimized but not entirely eliminated. In addition the comparisons must be across:

- **Identical bus size with the same engine**. This is usually possible since bus sizes are standardized in most countries and only 1 to 3 engine suppliers compete within a national market.
- **Buses of similar age and emissions certification**. In most countries, the emissions certification level changes every few vehicle model years, so that age and certification level go together. It is important to benchmark fuel economy for engines with the same certification level as technology changes to meet emission standards will affect the comparison otherwise.
- **Fuel economy data collected for the same month**. This minimizes ambient temperature and air conditioner use related fuel economy variability.

<u>Setting Targets for the Future</u>

Once the reference fleet is benchmarked with respect to its fuel economy relative to comparable buses in other cities of similar size, it will be possible to set reasonable targets. If the reference fleet has average fuel economy that is at least 5 percent worse than the best fleet in the benchmarking comparison, the best fleet's fuel economy is a reasonable target that can be attained over a two year period to allow time for these procedures to be put in place and implemented correctly.

If the reference fleet has the best fuel economy, or is very close to the best (difference less than 4%), then an alternative method can be used to set targets. In any fleet, there is a distribution of fuel economy from the worst to the best and typically, the available data suggests fuel economy varies around the average by $\pm$ 15 to 20 percent, i.e., if the average is 4 km/L, the variation among buses will be from 3.2 to 4.8 km/L. The average fuel economy of the top quartile of buses which in this example case could be 4.6 km/L is selected as the target for the fleet average in the future. This is referred to as the "top runner" method and the target is set at the level of the average fuel economy of the highest 25 percent of buses in the reference fleet.

4.2.4 Step 3: Communicate the results of FE programs to employees and the public

In general, fuel economy numbers for buses by bus or route are rarely made public, and the success or failure of efficiency programs not known outside management. The lack of information also extends to the executives who may be unaware of the fuel efficiency of similar buses in other cities both within the country and outside. ICF found that there were significant differences in fuel efficiency for identical models of buses across different cities (e,g., Washington and State College); while local congestion and weather may account for some of the differences, this was by no means obvious, and the reported fuel economy differences were sizeable (10 to 15%) across cities. The importance of communications is illustrated by the case of Toyota, one of the world's leading companies in the area of energy efficiency (see box 4.2).

Communicating these differences to the public will lead to more open information flow and cause management to benchmark their organization against the best reported fuel economy. In addition it will sensitize policy makers to the impacts of fuel and technology choice, and motivate employees to compete informally with other cities.

Box 4.2: SETTING AND COMMUNICATING TARGETS TO EMPLOYEES
CASE STUDY – TOYOTA

Toyota is widely known for its efficiency in all aspects of production, and it is also one of the most energy efficient auto-manufacturers in the world. They have an empowered division called Energy Management Organization (EMO) which acts as a service organization to the production staff. The EMO has set up key energy performance indicators for all aspects of production and runs a competition called "Race for the Greenest". Once a month, shop captains and managers meet and participate in "race" where tiny cars are paced on a board and moved ahead based on the points earned in the previous month on energy use efficiency. The Race for the Greenest competition epitomizes Toyota's energy strategy. Energy performance indicators are reported regularly, and the process engages the whole organization from senior management to shop staff. There is a certain amount of fun in these monthly gatherings and it is not just about the performance numbers, it is about how employees see themselves and what they take pride in. The Toyota system creates a culture that is about engaging employee pride and ingenuity for collective gain.

What sets Toyota apart from the average company is the added levels of data monitoring and reporting. Shop captains have access to energy use data at very disaggregate levels that enables them to look deeply at energy use. Shop captains know they must pay attention to this information to meet their "key performance indicator" targets. If their monthly performance starts deviating significantly from the targets, they will request EMO staff for additional assistance. Individuals are encouraged to develop and submit kaizen (continuous improvement) ideas to the EMO system and the database is available to Toyota employees worldwide. See Annex 3 for details.

4.3 DATA COLLECTION AND ANAL YSIS

4.3.1 Importance of Data Collection

Developing any type of fuel economy program must rely on a robust tracking and measurement system. Hence collection of bus travel, route, fuel use, other fluid (oil, coolant) use and maintenance data at the most granular level – daily for each bus and driver – is essential. In general, most large bus operators do collect such data but at somewhat different levels of detail. As noted in Chapter 3, in many bus fleets, maintenance tends to be performed at two different levels. Routine checks, oil and coolant addition and minor adjustments are made at the depots, while more major repairs are conducted at a centralized facility. In many instances, the data from routine checks and daily inspections/ additions are not part of the database.

There is more variation in the data acquisition systems and types of analysis across bus maintenance organizations. The use of commercial or purpose developed software to manage and analyze the data is required and most organizations do have software for maintenance support. Annex 6 of this note provides some example commercial software and is illustrative of the capabilities available. Based on our survey of facilities ICF recommends the following bus data collection and analysis steps:

4.3.2 Step 4: Automate data acquisition and analysis to the maximum extent

Historically, bus daily use data, fuel consumption and maintenance records were recorded manually and typed into databases, with errors from both the recording process and the data input process resulting in less confidence in the data. While many developing country bus fleets and smaller bus fleets around the world still use manual data acquisition systems, the trend to automatic data acquisition is now occurring on a global basis. In most developed countries, fully automated data acquisition systems are now being used as part of the "Smart garage" system of bus maintenance management. The literature on maintenance documents the benefits of automated data acquisition systems, as detailed in Section 3.2.3. At the most basic level, the bus entering the garage sets up automatic data acquisition. The bus is recognized by the system through a bar code, and the bus electronic control system automatically downloads the daily travel and speeds, as well as any system problems through on-board diagnostics. The fuel filler system also reports the fuel fill data to the computer system. Only maintenance related items such as oil addition, coolant addition or part replacement is manually input, and these data are needed only occasionally.

With automatic data acquisition systems becoming relatively cheap and reliable, automation is a good step to ensure more complete and accurate data acquisition. First, modern heavy duty bus engines incorporate engines with electronic control to meet emission standards starting from the Euro III level, so that much of the data is already available for almost no cost except for the bus to central computer electronic link interface. Second, transit agencies report that fuel dispensing management systems can be installed at a cost of about $15,000 per garage. Third, bar code readers installed in the garage doorways are low cost at a few hundred dollars per installation.

Some systems can also report data on the condition of vehicle components such as brakes, electrical systems and ventilation/air-conditioning systems to a central Mobile Data Terminal for use and analysis.

More advanced systems now entering the field communicate with the vehicle continuously and the Automatic Vehicle Location system can track vehicles while obtaining real time system performance information. Such systems can spot break downs as they happen or predict the possible occurrence and reroute the vehicle back to the garage before serious damage occurs. The systems also allow bus location information to be provided to consumers but this level of performance is not required to maximize fuel economy, but to provide other benefits.

Data analysis software to integrate all fleet maintenance activities are available commercially (see Annex 6 for examples and their capabilities) and are an essential counterpart to good data collection. The software can also be used to track fuel economy at the route and bus type level. Automated maintenance management software has a proven track record of improving maintenance quality, lowering costs and increasing bus availability[8]. The benefits that have been noted by users include the following:

- Automated tracking of all fueling and repair events
- Automated scheduling of buses for maintenance and repair
- Parts ordering and inventory control to maximize parts availability, minimizing down time for repairs
- Identification of low fuel economy or low reliability buses for additional repairs
- Automated generation of reports for senior management to provide near real time tracking of important fleet performance variables

Box 4.3 discusses results documented by users of fleet management software.

Box 4.3: MAINTENANCE MANAGEMENT SOFTWARE BENEFITS

Commercial maintenance management software is now widely used by bus fleets and truck fleets in the US and Europe. Several surveys have been undertaken to understand the benefits of implementing such software, and studies of transit fleets reported 70 percent of responding fleets were very pleased with the benefits. Other studies of bus and truck fleets have also found similar results. A survey conducted by the Aberdeen group found demonstrated cost savings by 80 percent of organizations that switched to fleet management systems. In addition, the research revealed

- a 13 percent improvement in vehicle utilization due to reduced breakdown rates
- a 11 percent reduction in maintenance costs
- a 12 percent increase in service organization profitability
- improvements in driver compliance with defect reporting

However, there are few reports of specific fuel economy improvements as most MM software is geared towards reducing breakdowns and reducing service cost. The State of Utah reported a 2.5 percent decrease in fuel consumption but specific fuel economy figures or total miles driven were not reported. (Reference 20)

4.3.3 Step 5: Set up specific data quality assurance systems for FE variables

Error checking the data is a key requirement for a robust system, but many locations do not have specific data QA/QC procedures related to fuel economy, unless fleet management software automatically signals data errors. As a result, managers do not trust daily outputs and rely only on monthly indicators where the data errors are evened out.

The plan to be followed for improving fleet fuel efficiency is that the ten percent of buses with the lowest fuel economy be selected for additional maintenance. Since fuel economy is computed from two variables, fuel use per day and miles per day, the error rate to ensure that at least 9 of 10 buses selected are correctly selected requires each variable to have error rates less than one percent maximum. It is imperative to have a QA procedure for data that holds errors to less than 1% of data recorded, and this is particularly true for manual data acquisition systems. The data fields required for the analysis and preferred and maximum error rates are presented in Table 4.2. The preferred error rates are those commonly used by maintenance management software sold commercially.

Table 4.2: Data quality assurance on fuel efficiency variables

Variable	**Description**	**Check**	**Preferred Error Rate**	**Maximum Error Rate**
Bus Number	Unique bus identifier	Corresponds to in-service bus	0	<0.1%
Odometer In and Out	Odometer reading when bus leaves garage and re-enters garage after shift	Odometer out = previous day in. In-out within specified limits	<0.1%	<1%
Fuel Added	Gallons/ Liters of fuel added to fill tank	< tank size, limit against daily travel	<0.1%	<1%
Driver Name or Number	Driver identifier	Corresponds to driver reporting for shift	0	<0.1%
Bus Route number	Route identifier	Valid route number	0	<0.1%
Breakdown Indicator	Indicates if Bus did not complete shift per schedule	Validate from time re-entering garage	0	0
Fill indicator	Indicates if tank was filled to maximum	No check	0	0
Time stamp	In/out date and time	Validate against standard shift times	0	0

4.3.4 Step 6: Special Analysis for Fuel Efficiency Data

Many bus maintenance organizations rely on commercial fleet maintenance management systems that automatically flag mal-performing buses while also signaling the need for a periodic maintenance event, printing out the specific maintenance actions required and tracking the maintenance plan. A number of fleet management software suppliers offer maintenance management solutions that can also be customized to some extent to meet the fleet's requirements. Others rely on specialized in-house programs to provide similar functions. Our check and interviews found that **most programs only report average fuel economy** by bus, and only a few flag those that fall outside of a relatively wide band of acceptable fuel economy values.

It is well known that bus fuel economy depends on the bus type, route characteristics, driver and bus passenger load, which is why a relatively wide range of fuel economy falls in the "acceptable" range. The simple averaging method to identify low fuel economy buses and drivers requires the following:

1) determine the average fuel economy by route
2) determine the average fuel economy of each bus (and bus type if many different types of buses are used on the same route) and each driver
3) compare the bus and driver specific fuel economy to the route average for the route and bus type that each bus and driver is assigned to.
4) Select the 10% of buses with the lowest fuel economy relative to the route/bus type average.

When the routes and drivers assigned to each bus are different every day, the separation of the individual bus, driver, and route effects cannot usually be accomplished by simple averages. A simple mathematical regression will solve this problem and the regression can be specified as

$$\textit{Fuel Consumption (Km/L)} = A + B*(Bus) + C*(Driver) + D*(Route)$$

Where A, B, C and D are the regression constants and Bus, Driver and Route are dummy variables. The term "dummy variables" is used to denote discrete independent variables. Typically, independent variables like the bus weight or route average speed are continuous variables but the bus number and route number are discrete variables and the dummy variable concept treats each bus, driver and route with a dummy variable that is a zero or one variable. For example, all buses travelling on a specific route like Route 4A will have the route variable become 1 when the regression is being done, and the coefficient D (Route 4A) will be the fuel economy effect of that route relative to the average. If the D value computed for Route 4A is a negative number, that implies buses running on this route will have worse fuel economy than if they were running on the reference route.

If a bus with fuel economy close to or equal to the fleet average is picked as the reference, then negative values for coefficients B and C indicate low efficiency buses and poor drivers after controlling for the route effect. Box 4.4 describes the data needed for the regression and the outputs obtained. This is a better way to indicate where attention should be given rather than relying on simple averages. Mathematical regression packages are widely available and the simple linear regression used above can be implemented in an Excel spreadsheet, for example.

Box 4.4: IMPLEMENTING THE REGRESSION ANALYSIS

A regression analysis can be conducted through the use of most common spreadsheet programs such as Excel. The data needed are the **daily records** for each bus that have the following variables

1) Date/time 2) Bus number 3) Route number 4) Driver Number
5) Odometer out 6) Odometer in 7) Fuel Dispensed

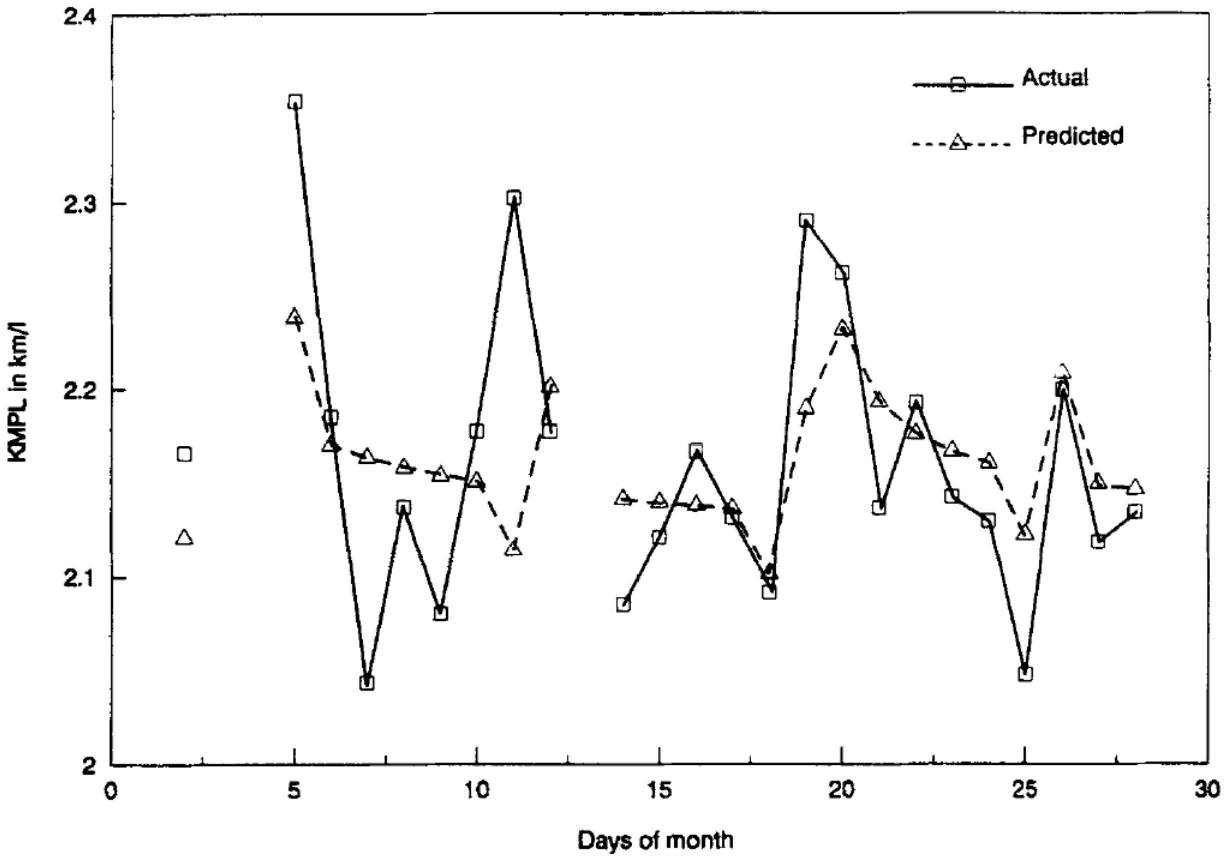
The steps are to first check the data as detailed in step 5, eliminate the records failing the quality check and then determine fuel economy using the formula

Fuel economy = (Odometer in – Odometer out)/ Fuel Dispensed

for each set of daily records. The regression is then defined with the fuel economy computed as the dependent variable (Y) and the independent variables are specified as the Bus number (X1), the driver number (X2) and the Route Number (X3). The regression input must also specify that X1, X2 and X3 are dummy variables signifying that they are labels for the bus, driver and route. One bus close to the fleet average fuel economy can be specified as the reference. Instructions in the spreadsheet will usually guide the user on how to run the regression. The regression output will provide the average fuel economy of the reference bus and a number for each bus, driver and route. If the number is positive, then the particular bus, driver or route experiences better fuel economy than the reference bus while negative numbers indicate worse fuel economy. Hence, the regression provides immediate analysis for which buses and drivers are performing poorly.

The regression methodology has been used by Ang and Deng[9] to model bus fuel economy and the effect of maintenance and mileage. They did not have data on the bus driver so they were not able to incorporate a driver related variable in the regression but the model they developed was successful in explaining half the variation in fuel economy observed with the other half coming from the driver and from weather related effects. Figure 4-1 shows the predicted fuel economy using the regression for a specific bus and the actual measured fuel economy. The quality of the prediction is substantially improved after the middle of the month when the same 2 drivers operated the bus, indicating the sensitivity to the driver variable.

Figure 4-1: Regression predicted fuel economy vs. actual fuel economy for a transit bus.



The validation study showed that the data bases for even a small sample of about 300 buses were very large, running to about 20,000 records per month. Performing regressions on such large data sets to produce meaningful results required careful data preparation and cleaning, specifying the reference bus and route number for each regression, and examination of results for statistical significance. While the regression method is the most scientific approach, it may be difficult for road transport corporations in developing countries to implement this unless trained statisticians are employed. The validation study showed that if buses were largely assigned to unique routes and drivers to the same bus, the simple averaging method where the average fuel economy average is determined by route, bus and driver, provides near equivalent results to the regression provided that the lowest fuel economy buses and drivers are selected **relative to the route average** fuel economy for the route they operate on. In other words, a bus with a fuel economy average of 5km/L may be designated a low fuel economy bus if the buses on the route it operated on averaged 5.6km/L, but may be a normal bus if the route average was 4.9 km/L. It is important to adjust for route effects to achieve results near equivalent to the regression method. ICF suggests that transit organizations start with the simple averaging method but attempt to migrate to the regression method once enough confidence has been established in the process.

4.3.5 Step 7: Use the data to refine periodic maintenance intervals

In general, maintenance organizations adopt manufacturer recommended maintenance intervals but rarely modify them to suit local conditions. The data can be used to extend some maintenance intervals while shortening others, or make the maintenance a function of bus age, with more periodic inspections for older buses. Many organizations like WMATA do refine intervals for parts that fail more frequently than normal, but rarely use data to modify standard maintenance intervals. Warranty requirements may make these intervals inflexible for the first 5 years typically, but intervals on older buses can be adjusted.

One method for determining maintenance intervals is to examine the mean time between failures (MTBF) for older buses and determine which components are failing at a rate faster than their service intervals. Those with low mean time between failures can be serviced more frequently. Conversely, manufacturers usually over-specify maintenance to provide a cushion against unexpected failures and it is possible that MTBF data will indicate some components need less frequent service, saving some maintenance costs.

4.4 BUS MAINTENANCE FOR GOOD FUEL ECONOMY

4.4.1 Overview of Two-Step Special Maintenance Program

The identification and repair of low fuel economy buses is second only to driver training in maximizing fleet fuel economy. Once a bus has been identified as a low fuel economy unit, a plan must be incorporated to ensure its performance returns to average or better. This guidance note recognizes that some simple steps need to be taken first at the depot and if these do not work, a second tier of more complex steps (at a central or more specialized repair facility) needs to be taken. Most larger transit organizations follow the two step method for maintenance as documented in Chapter 3 from the interviews. The specific method to conduct the inspection and repair are bus make and model dependent and cannot be specified here. However, ICF has provided a general check list applicable to most diesel and CNG powered buses that should be incorporated into the program. A key recommendation from our interviews and literature review is that **repair procedures should be documented in writing and provided to all mechanics**. This will ensure consistent repair procedures, and allow for future updates as required.

4.4.2 Step 8 A: Tier I Checks Implemented at the Depot

The two tier check list requires that low fuel economy buses be subjected to the first tier of inspection (and repair if necessary) at the depot and its fuel economy rechecked. If this does not solve the problem, then a second tier of more complex inspection and repair should be performed at the central maintenance facility. The first tier repairs do not require a maintenance hoist or inspection pit and can be easily performed by junior or mid-level mechanics. The set of first steps have been compiled from the actual checks recommended. In general, these checks will eliminate easily correctable defects that can hurt fuel economy by creating an extra load on the engine through additional friction. Nineteen specific checks are suggested in Table 4.3, but some may not be applicable to specific technologies such as automatic transmission equipped vehicles. Examples of more specific procedures for Tata and Leyland buses operated in India are shown in Annex 9.

If no problems are found in the tier I repair set, the bus should be sent to the centralized or more capable facility ("pit maintenance") and the more detailed checks performed per the list below. Unless there is visible smoke, the detailed maintenance can be coordinated with the periodic maintenance date of removal from service.

4.4.3 Step 8B: Tier II Checks at the Central Maintenance Facility

The 14 checks compiled in Table 4.4 from manufacturer recommended checklists should be implemented with trained mechanics. The specific method to carry out the above generic inspection items is unique to each engine/bus combination but all of the above are standard items for maintenance, and the methods documented in maintenance manuals.

Tables 4-3 and 4-4 are provided to set up a checklist and may not be comprehensive for some unique engine types. In general, ICF anticipates that the tier I and tier II checklists will bring all buses into compliance with fuel economy requirements. However, local conditions may also impose special problems such as salt corrosion in snowy locations, or engine overheating in very hot locations. The list should be modified using the knowledge of local mechanics as appropriate.

Table 4.3: Tier I - Checks for implementation at the local bus depot

Component	**Check**	**Pass/ fail criterion and repair**
Tires/ Wheels	1.Check tire inflation 2. Check for free rolling of wheels 3. Wheel bearing lubrication	Pressure meets specification, or add air Wheels rotated easily by hand or check brakes (see below) No grinding noise in bearings or lubricate as required.
Brakes	4. Check for free play of brake pedals 5. Check gap between brake liners and drum/disc 6. Check caliper boot and wear adjuster cap 7. Check for brake retraction after pedal release	Excessive free play requires brake pedal linkage adjustment Gap must be visible or liners reinstalled Wear adjuster should not be at setting limit, or replace liner Liners move away from rotor on brake release, or else check for brake hydraulic/air line defects
Driveshaft/ Axles	8. Check lubrication of driveshaft joints, axle bearings and differential 9.Examine tightness of driveline and gearbox mounts	Lack of visible lubricant and/or noise in joints and bearings signify need for lubrication Visible driveline and gearbox vibration indicates need to tighten mounts
Accelerator/ Clutch pedal	10. Check clutch pedal linkages 11. Check Accelerator linkages 12. Check accelerator return spring	Excessive play requires linkage adjustment Excessive play requires linkage adjustment Accelerator snaps back on release or else replace spring
Engine related	13. Check air cleaner for clogging 14. Check exhaust pipe for blockage 15. Check on-board diagnostics if applicable 16. Check for visible smoke on snap acceleration	Visible dirt on air cleaner, replace Check for any foreign objects or broken catalyst in pipe. Electronics check for diagnostic codes indicating any failure Smoke opacity over 20% indicates engine problem, send to central maintenance facility
Air conditioner related	17. Check tension in compressor belt drive 18. Check for refrigerant pressure. 19.Check for compressor damage	Tighten belts as required or replace if worn significantly. Low pressure indicates refrigerant leaks and leaks should be identified and fixed. Replace or repair as required.

Table 4.4: Tier II - Checks for implementation at the central bus maintenance facility

Component	Check	Pass/Fail Criterion and Repair
Wheels	1.Check wheel alignment 2.Check tire camber	Set to manufacturer specification Set to manufacturer specification
Clutch	3.Check condition of clutch facings 4, Check clutch release bearing	Replace clutch facing if worn Replace bearing if worn/ failed
Fuel System (Diesel/ CNG)	5.Check fuel lines and tanks for leakage	Check for fuel drops on floor under bus (diesel) or use gas detector (CNG). Replace lines or tank as required
Engine (Diesel)	6.Check Fuel Injection pump timing and maximum fuel stop 7. Check FI pump pressure 8. Pull and check fuel injectors for leakage or clogged spray holes 9. Check turbocharger bearings (if turbocharged) 10. Check cylinder compression 11. Inspect cylinder head for cracks, bolt tightness 12. Check piston rings if oil consumption is high 13. Check for engine coolant loss/ overheating	Set timing and stop to manufacturer specifications Low pressure indicates pump rebuild Asymmetric spray indicates need for injector cleaning or replacement Turbo rotor must rotate freely or else replace bearings Low compression requires head gasket, ring check or engine rebuild Torque head bolts to manufacturer spec., replace cracked head Replace worn rings Radiator or hose leaks should be patched.
Engine (CNG)	6A. Check air-fuel mixer settings 7A Check gas pressure regulator 8A. Check ignition system wires and spark plugs for misfire 9A. Check turbocharger bearings (if turbocharged) 10A. Check cylinder compression 11A. Inspect cylinder head for cracks, bolt tightness 12A. Check piston rings if oil consumption is high 13A. Check for engine coolant loss/overheating	Set to manufacturer specifications Output pressure must be within specifications or replace Replace broken wires and fouled spark plugs Turbo rotor must rotate freely or else replace bearings Low compression requires head gasket, ring check or engine rebuild Torque head bolts to manufacturer spec., replace cracked head Replace worn rings Radiator or hose leaks should be patched.
Exhaust System	14. Inspect exhaust brake valve if used.	Valve not opening freely should be cleaned or replaced

4.4.4. Step 8C: Once the buses go through the repairs in step 8A and /or 8B, the next months data will provide information on the post repair fuel economy value. The fuel economy value should be compared to the pre-repair value and the percent improvement used as the indicator for fleet benefits.

4.4.5 Maintenance Oversight and QA/QC

All maintenance organizations have a series of checks on mechanics work as part of the quality assurance and quality control procedure on repairs performed. Mechanics are typically graded by seniority with junior mechanics trained by senior mechanics, and the Chief or Supervisory mechanic checking the work of all mechanics on a regular or intermittent basis. The use of an independent team to check the work of all mechanics is less common but also used, especially for large fleets. Based on the data obtained from interviews, the following suggestions for maintenance QA/QC appear to be very useful in the field.

4.4.5.1 Step 9: Require mechanics to sign-off on the repairs they perform

Mechanics should sign-off on the repairs they perform. This step is very useful to track repair of chronic defects that recur in the field. In this case, individual mechanics associated with repeat failures can be identified and their repair practices monitored carefully. The actions required are:

- The maintenance organization must maintain a log book for each bus documenting maintenance actions
- After every maintenance action, the key repairs performed should be identified and the mechanic performing the repair must be identified.
- The mechanic must sign off on the repair or note any issues with the repair that could not be solved.

Mechanics not following procedures with resulting failures and low fuel economy can be re-trained or disciplined, as appropriate. In small organizations, it may be possible to informally identify which mechanic serviced which bus, but even here, the sign-off requirement could make mechanics more careful.

4.4.5.2 Step 10: Institute both random and periodic checks of repairs

Supervisory mechanics or the Chief Mechanic should institute a series of random and periodic checks to check on repair quality. Specifically

- Supervisory mechanics could focus on repairs of chronic failures to improve performance by checking the repair after the mechanic has finished, ensuring adherence to SOP. This could also result in changes to the SOP if better procedures can be developed.

- Supervisory mechanics should conduct regular checks of all mechanics, but surprise checks may also reveal mechanics who may be taking un-specified short cuts from the SOP to complete the repairs quickly.
- Mechanics with higher than average repeat failure rates should be checked more frequently. In this context, analysis of the data on repeat failures from the log book can identify mechanics who need more attention from the supervisory mechanic.

4.4.5.3 Step 11: Develop an independent QA/QC team

The use of an outside QA/QC team for checking mechanic performance and repair quality has been found to be helpful in preventing internal collusion between mechanics in a depot and also in making procedures more uniform across the various repair depots in a large organization. Such teams also help knowledge transfer as some mechanics may have found specific repair or part improvements that help reduce chronic or periodic problems, and the independent team can also act as a consolidator of the knowledge base for the organization. Box 4.5 presents the case of WMATA to demonstrate need for an independent system wide audit team to ensure the procedures are strictly followed.

**Box 4.5: BENEFITS OF HAVING AN INDPENDENT QA/QA TEAM
THE WASHINGTON TRANSIT AUTHORITY EXPERIENCE**

The Washington Metro Area Transit Authority (WMATA) operates a fleet of about 1500 buses across several counties and has multiple garage facilities that operate and service different makes and models of buses, including CNG, diesel and clean diesel buses. Over the last few years, WMATA has made a large effort to standardize maintenance procedures across different facilities by having written detailed step-by-step procedures that identify the checks, repairs and tools to be used, which are referred to as Standard Operating Procedures. Historically, they have found that individual garages develop their own methods to deal with problem repairs which may not necessarily reflect the best practice. By having an independent system wide audit team, WMATA has been able to standardize procedures across the entire maintenance system and ensure that procedures are strictly followed. The result is that maintenance costs have been reduced while mean time between failures has been improving for a given technology type (some new technologies have higher failure rates which affects the behavior of the average rate). A side benefit has been that mechanics moving from one location to another find identical tools, procedures and practices in place. St. Louis Metro reports similar benefits (see Annex 4)

4.4.5.4 Step 12: Update procedures and re-train mechanics periodically

Both vehicle and diagnostic technology continues to change with the advent of electronic controls, which are only now being offered in developing country environments. Sending mechanics to special re-training classes is more important now with the changing requirements, but attending centralized classes also affords informal exchange of best practices in the industry. This is normal procedure for all large fleets interviewed in this study. Procedures for repair also need to be periodically reviewed and updated to reflect industry best practices as well.

4.5 DRIVER TRAINING

4.5.1 Need for Fuel Efficient Driving Practice

The driver's behavior is an important component of fuel economy attained on the road, and driver training has been widely implemented by most urban transit authorities. The near universal use of driver training is currently driven by legal requirements to ensure safety for the general public, but fuel efficient driving is also incorporated into courses that teach safe driving. As a result this Guidance Note merely emphasizes the need for such training with periodic re-training to ensure the driver maintains best practices.

There are a number of commercial and government sponsored courses that teach fuel efficient driving for heavy duty vehicles. These courses have been developed for city driving and courses for transit bus drivers also teach aspects of bus rider safety and public safety. The main aspects of the course are a short classroom review of the steps for safety and fuel efficiency, followed by a simulator driving course (if a simulator is available) or instructional video, followed by on-road training with a professional instructor, who monitors driver behavior. The **on-road driver training is the most important component** of the course as most drivers are generally aware of good driving practices but may have developed many inefficient habits that they may not even be aware of, which typically include clutch riding, pumping the accelerator pedal and improper gear shift. The professional instructor can spot these bad habits and show the driver how to correct them.

4.5.1 Step 13: Core Principles of Fuel Efficient Driving

Fuel efficient driving is a technique that any driver can use. The basic steps to fuel efficient driving are:

- cutting out unnecessary idling
- staying within the speed limit and maintaining engine RPM at optimum levels
- accelerating and braking gently
- using vehicle momentum to maintain cruise speed
- avoiding pumping the accelerator pedal
- anticipating traffic ahead to minimize hard braking and acceleration.

Driver training programs have been established commercially and the use of a human trainer and a training video is common. Periodic re-training (every two to three years) is required to ensure that drivers do not slip back into inefficient practices. Annex 7 describes some commercial driver training programs available in developed nations. However, similar programs can be found in most countries. The quality of the driver training program and its effect on driver behavior towards fuel efficiency is typically a function of the quality of the on-road instructor, class room material (see Box 4.6).

As an example of a well regarded program the United Kingdom's Safe and Fuel Efficient Driving (SAFED) program incorporates all of the key features required in a good driver training program and can serve as a guide to what elements should be incorporated. The SAFED classroom topics covered and Driver Handbook contents are listed in Annex 7.3.

4.5.2 Step 14: Retraining the Worst Drivers

The recognition of poor drivers based on data analysis (as described in Step 6) and their re-training can lead to significant improvements in fuel economy. Some of the best run organizations recognize and send the poorest 10 percent of their drivers in terms of fuel economy for counseling and re-training. Drivers who do not improve their driving even after repeated counseling are often subject to disciplinary action or discharge. These types of actions are required to motivate all drivers to take the program seriously, and are also recommended for incorporation into a driver education program.

Box 4.6: THE BENEFITS OF ECO-DRIVING

Training drivers in fuel efficient driving methods has been popular for over 20 years but the benefits claimed by proponents is often not based on scientific research, and many of the claims of 15 percent (or more) fuel economy benefits are unsubstantiated. A scientific study by Monash University in Australia operating heavy duty vehicles on a test track with specific speed profiles for driving was conducted employing a control group of untrained drivers as well. The study found that those who received classroom only training did not improve, but those who had both classroom and on road training were able to reduce fuel consumption by 27 percent, on average. Even here, there were large variations among drivers so that the result was not statistically significant at the 95% confidence level, but were significant at the 90% confidence level. However, the number of gear changes and brake applications were substantially reduced and the changes were significant at the 95% confidence level. Drivers were retested after 6 and 12 weeks, and the fuel economy benefits were retained for the trained group over that period. Importantly, the study found the size of the benefit in fuel economy to be constant over the period, and the savings did not require an increase in travelling time or any decrease in average speed over the course. The study cautioned that the magnitude of the reduction observed on the test track would not likely be replicated in actual service. (Reference 26)

4.6 EMPLOYEE REWARDS

4.6.1 Employee Motivators

Motivating employees is a key part of any strategy to create a culture of fuel efficiency and examples in industry have shown that management and employee motivation, not technology, explains much of the difference between fuel efficient and fuel inefficient operations. Currently, information provided to employees is focused on safety ratings and the number of buses fielded each day, or total bus revenue kilometers, and employees or entire depots are rewarded for safety performance and revenue performance. ICF found only a few instances where there are employee rewards for fuel economy, and those awards are for good drivers. In those instances, there appears to be a lot of motivation on the part of drivers to win the award. It is suggested that awards be provided at three distinct levels. At the system-wide level, the executive in charge of fuel economy can be rewarded for meeting system goals and targets for fuel economy as suggested in Step 1. ICF also suggest rewards at the depot level, and at the individual level.

4.6.2 Step 15: Communicate Fuel Economy Data

Providing information to employees on fuel economy performance by publicly posting this data is key to motivating individuals to perform well. A second and closely related aspect requires both managers and employees to have good awareness of how well they are doing **relative to others** in the group. This type of information sets up friendly competition for employee participation in implementing the recommended steps towards fuel efficiency. This is documented in the Toyota case study (Annex 3).

4.6.3 Step 16: Mechanic and Driver Awards

Good maintenance is a key aspect of fuel economy performance but it is difficult to reward individual mechanics for fuel economy performance as they will perform repairs on many buses that may be randomly assigned to them, after the buses have had a breakdown or have been selected for additional maintenance. Since bus assignment is not within their control, the depot mechanics can be rewarded for meeting fuel economy goals and failure rate goals that are specific to the make/model of the buses housed and serviced at the particular depot. Note that this involves setting fuel economy goals at the bus type or depot specific levels (see Step 2).

The driver can have an effect on vehicle fuel economy through the use of Eco-driving. Currently, drivers are rewarded by many transit systems for safe driving by having an accident free and consumer complaint free record, but rewards for fuel economy performance are relatively rare. Drivers can also be recognized for good performance in both safety and fuel economy metrics. Determining fuel economy performance at the driver level is complicated by the fact that absolute fuel economy depends on bus model, its age and condition, the route and the driver (see Box 4.7).

Hence, the key issues for providing driver awards (as illustrated by BXL) for fuel economy are:

- the route and bus adjustment be made for each driver's performance,
- the adjusted performance for all drivers be publicly posted,
- the adjustment factors and their fairness can be evaluated by the drivers so that they will accept its fairness over time (or have it changed to reflect factors that only drivers may be aware of).

The regression method of data analysis provides the bus and route specific adjustment factors that can be used as an initial estimate and potentially refined to meet driver complaints if any. The simple averaging method by route is useful and similar to the regression method if buses and drivers are typically allocated to the same routes most of the time. Clearly, the statistical method has some uncertainty in the estimates of fuel economy ranking, and to avoid problems the top 10 percent of drivers should be recognized and rewarded.

Box 4.7: THE DIFFICULTY IN IMPLEMENTING REWARDS FOR FUEL ECONOMY PERFORMANCE

Transit bus operators have tried to institute awards for fuel economy performance with mixed success. In some agencies such as Bel Tour in Brazil, the awards had to be withdrawn as they caused resentment and unrest among drivers and mechanics. Since fuel economy is also bus and route dependent, the drivers and mechanics believed that winners of the award unfairly benefitted from having the best buses or the least demanding routes, and these perceptions had a basis in fact. Few transit agencies subject the fuel economy data to the level of analyses required to untangle these effects, and the data were also not subjected to rigorous quality checks.

In the agencies where such awards have been accepted and are popular, the data on fuel economy is stratified to the route level. More importantly, the data are available to the drivers and they can see the own performance relative to other drivers on similar routes and become comfortable with the quality of data. This illustrates the synergy between the different steps recommended in this Guidance Note – without the efforts on open communications, ensuring data quality and performing more advanced data analysis, it becomes impossible to fairly reward employees and create a culture of employee pride in fuel economy performance.

5. VALIDATION TESTING

5.1 OBJECTIVES OF THE VALIDATION STUDY

The draft guidance note (GN) developed to assist transit bus operators to maximize the fuel economy of their fleet specifies 16 steps to be implemented by the bus operating authority. The objective of the validation study conducted was to examine the effects of implementing key steps at a transit bus operator in a developing country setting, and objectively determine if the implementation of these steps improves the average fuel economy of the fleet under study. The plan to validate key recommendations in the guidance note was accomplished with the assistance of the Andhra Pradesh State Road Transport Corporation (APSTRC) in India. The validation testing was carried out at two locations and at three depots, one in Hyderabad and two in Vijayawada. The depots at each location were selected by APSRTC according to their ability to implement the testing. The validation testing was conducted over 10 weeks starting at the end of January 2011, which implies that steps for longer range improvements specified in the GN were not examined. A mission by ICF staff was completed during the week of January 17, 2011 to initiate the validation testing, and to agree on specific protocols with the APSRTC on the conduct of the validation testing and data reporting. After that point, APSRTC field staff provided periodic data to ICF for review and analysis but operated independently. This data is the main focus of our analysis, as documented in Section 5.2

Separately, the Karnataka State Road Transport Corporation (KSRTC) conducted its own validation testing of the procedures in Mysore, India without any involvement by ICF staff. They have reported their results to the World Bank and those results are described in Section 5.3.

5.2 VALIDATION TESTING AT APSRTC

5.2.1 Characteristics of the APSRTC fleet

Data obtained from the APSRTC was used to identify the types of buses and the age distribution of the fleet, so that the validation would occur primarily based on testing of buses that would be outside the typical warranty period of 3 to 4 years (<400,000 km). The characteristics of the fleet by age are as follows for the Hyderabad fleet (which are all diesel powered.) and the Vijayawada fleet which includes both CNG and diesel buses.

The data reported by APSRTC is in terms of odometer, with 100,000 km accumulation comparable to an age of about 1.25 years since buses accumulate about 80,000 km/year. The distance based measure provides a better indicator of wear and tear. From Table 5-1, it appears that there is a large selection of diesel buses over 5 years of age (i.e, over 400,000 km) but most CNG buses are quite new.

Table 5-1 Odometer Distribution of Hyderabad and Vijayawada bus fleets in mid-2010

Age (odometer in km)		0 to 100K	100,000 to 400K	400K to 800K	800K to 1200K	1200K+	Total
Hyderabad (D)		18.4 %	26.4 %	21.4%	21.3%	12.5%	3290
Vijayawada (D)		0	6.2%	21.4%	58.4%	14.0%	257
Vijayawada (CNG)		59.7%	40.3%	0	0	0	211

In Hyderabad, almost all of the buses under 4 years old are Euro-3 emissions certified, and 176 of the 606 buses that are new (0 to 100K odometer) are housed in 2 depots that have no older buses (Miyapur and Mushirabad), while the other depots have 10 to 30 of the new buses. The age distribution of the fleet in the 21 other depots show limited variance and all depots have a wide range of buses of different ages. Most of the Euro-2 and older diesel buses in Hyderabad are sourced from Leyland. It should be noted that APSRTC is purchasing many new buses in the 2010 to 2011 period so that the distribution is changing constantly over time. During the course of the validation testing, some older buses were retired from service

In Vijayawada, most new bus purchases are CNG vehicles and the diesel vehicles are mostly over 4 years old. Vijayawada has only 4 bus depots for city buses. 124 of the CNG buses operate out of Vidhyadharapuram depot which has almost no diesel buses. The other two depots utilize mostly diesel buses, but the third (Governorpet-2) has 64 CNG buses and 46 diesel buses with the diesel buses being phased out at this depot as new CNG buses arrive. Hence, the choice of depots for validation testing is limited, and Governorpet 1 and 2 were selected for study. Most of the diesel buses in Vijayawada are sourced from TATA and are Euro-1 or Euro-0 emission certification.

5.2.2 Vehicle Technology Characteristics

The vehicle types in the Hyderabad and Vijayawada fleets include diesel engines with different levels of emission certification, but the older diesel buses are all sourced from Tata or Leyland with naturally aspirated engines rated at 96 kW for Tata and 83 kW for Leyland. The newer Euro-

3 certification buses use more powerful turbocharged engines rated at 132 kW for Tata and 123 kW for Leyland buses. APSRTC also operates a few low floor Euro 3 buses from Leyland and air-conditioned buses from Volvo. The characteristics by make and certification level are presented for buses operating in Hyderabad and Vijayawada in Table 5-2.

Table 5-2 Technical Description of Buses and Average Fuel Economy (FE)

Bus type		Leyland	Leyland	Leyland	Tata Semi Low floor	Volvo Low floor	Tata	Leyland
Location		Hyd.	Hyd.	Hyd.	Hyd./Vij.	Hyd.	Vij.	Vij.
Engine		Hino 83kW	Hino 83kW	Hino 123kW	Cummins 132 kW	Volvo 216kW	Tata 96kW	Hino 91kW
Certification		Euro-1	Euro-2	Euro-2 turbo	Euro-2 turbo	Euro-3 turbo	Euro-0/1	Euro-3
Fuel Type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	CNG
F E (km/L)		5.01	4.84	4.26	3.88	2.16	5.22	4.42

It is clear that more stringent emissions certification level associated with Euro 3 as well as the higher power ratings of the newer Euro-3 certified buses result in significantly lower fuel economy. Hence, it is important to set the benchmark appropriately for each, engine type or certification level. Because the Euro -3 buses are relatively new, testing focused only Euro-2 and earlier diesel buses. Among CNG buses, there is no choice as most buses are relatively new.

APSRTC has selected the following depots for validation testing, and their current bus fleet size and average fuel economy in 2010 is shown below

- Bharkatpura, Hyderabad (BKPT) : 139 buses, 5.03 km/L
- Governorpet-1, Vijayawada, (GVPT-1): 120 buses, 5.26 km/L
- Governorpet-2, Vijayawada (GVPT-2): 111 buses, 5.27 km/L

5.2.3 Management and Long Range Steps not Validated

As noted in the overview, some of the GN steps are implemented over a year and hence cannot be validated in the context of a 10 week validation study. The steps are as follows:

Step 4: Automate data collection to the extent feasible. Automation of data collection is a desirable long range goal but cannot be implemented in the 2 months of validation testing. Currently, most data is entered manually by APSRTC so data cleaning by removal of outliers was found to be essential.

Step 7: Use data to refine periodic maintenance intervals. Refining the maintenance intervals requires multiple year data and cannot be accomplished within the validation study period.

Step 12: Retrain mechanics and update repair procedures periodically. Mechanic re-training and repair procedure updates are conducted annually or biennially. Hence, they will not be done during the short term validation study,

Step 15/ 16: Rewards for mechanics and drivers. These rewards are suggested for annual performance metrics and cannot be included in the validation plan. However, APSRTC is already implementing a reward system and ICF has documented the APSRTC system and its acceptance by the employees.

5.2.4 Steps Implemented Before the ICF Mission

The pre-mission activities were related to choice of depots for testing, designation of managers at depots to serve as contact points and preliminary data analysis to allow start of validation testing during the mission.

Step 1: Appoint a senior executive to be in charge of fleet fuel economy and tie his/her bonus and career to meeting fuel economy goals. The Managing Director of APSRTC appointed the Executive Director of Engineering for this role, but no specific inputs regarding compensation are included in the validation. The executive director of APSTRC had direct oversight over the validation testing and he appointed managers at each of the depots involved to oversee the testing and report results to ICF. Results of the study were reported to senior management at APSRTC

Step 2: Benchmark and set appropriate fuel economy goals: The data requirement for this step is the average fuel economy by bus type and depot**.** This data was supplied to ICF in July 2010 and was based on data collected fleet-wide over the previous 3 month period. The data on depot averages from this period is adequate for the purposes of setting the targets as the best fuel economy does not change very much over the course of a year. Based on the initial contact with APSRTC, ICF has used the top runner method and has set the target based on the average fuel economy of the top depots in each city, as defined in Step 2 of the GN. The top runner method averages the top 10% (or 2 highest for small samples) of depot average fuel economy levels as the target. The preliminary goals based on the data from APSRTC by bus type as follows

- Euro-0 and Euro-1 Leyland: 5.40 km/L (average of 5.52, 5.44, 5.36, 5.26)
- Euro-2 Leyland: 5.11 km/L (average of 5.21, 5.17, 5.14, 5.03)
- Euro -0 and Euro-1 Tata: 5.34 km/L (average of 5.36, 5.32)

Since CNG buses are used primarily in one location in Vijayawada, we set the goals based on the top 10% of buses within the depot. For the Hino SLF buses we have set the target at 4.64/km/kg based on the data supplied.

Step 5: Set up data QA/QC procedures. In order to select buses for repair, very recent data is required or else some of the buses go through repair and maintenance cycles between the time the data is collected and the validation testing is initiated. Recent data from the selected depots has been provided to ICF before validation testing start. ICF received data from January, 2011 for use as a reference baseline. ICF used the recommended QA/QC checks on the data to identify error rates and data rejection rates. As described in the following sections, data from all 3 depots in the test program had reasonably good data quality for this study.

Removing fuel economy outliers: About 60 records from BKPT and about 10 records from each of the 2 depots in Vijayawada had some missing data and were removed from analysis. Fuel economy numbers lying outside the ± 50% difference from average levels were considered to be potentially as a result of data errors and were treated as outliers. The fuel economy data from Vijayawada showed only 2 outliers, 1 each in GVPT-1 and GVPT-2 from a total of about 3500 records at each location, which is a very low error rate by any standard. The data from BKPT showed a total of 75 fuel economy outliers out of 4537 records for an error rate of 1.65%, which is a little higher than the desired maximum 1% rate but acceptable for manually entered data. These erroneous data were removed prior to regression analysis of fuel economy in Step 6.

Additional data quality checks: In contrast to the small number of outliers in the fuel economy data, the kilometers per day records showed a large fraction of buses with low daily travel (<100 km/day) and very high daily travel (>350 km/day) at both depots in Vijayawada. The fractions were 5.8% and 8.6% in Governorpet-1 and 7.2% and 6.5% in

Governorpet-2 respectively. In Hyderabad, the fractions were 12.6% and 0.66% respectively. The buses with low daily travel may be due to some buses operating only a single shift, or coming in early due to a mechanical problem. The large numbers of buses having high daily travel in Vijayawada were used in suburban rather than city routes. We have retained most of the records in the fuel economy analysis since the fuel economy data looks acceptable. However, a small number of buses showed daily travel under 50km implying that it did not complete even one shift, and these records were dropped from the analysis as it indicates that the bus had some problem on that day. (APSRTC concurred with this assessment). Table 5-4 lists the records dropped from each depot.

Table 5-4: Listing of records dropped from analysis

Depot	Original Records	Filtered due to Km< 50/day	Filtered due to FE <2.5 km/L	Filtered due to FE >7.5 km/L
BKPT	4202	62	46	27
GVPT-1	3381	86	1	0
GVPT-2	3854	44	0	1

Step 6: Analyze the data. The data provided and cleaned was analyzed by ICF using the regression method. The data was then sorted by bus technology type as all of the analyses was conducted separately for each bus technology. This resulted in 4 technology groups in BKPT, 3 in GVPT-1 and 3 diesel and 2 CNG bus types in GVPT-2, for a total of 12 groups that were analyzed separately. The regression method identifies the lowest fuel economy buses and drivers in each depot, and bus type.

Since the different bus type and engine technology combinations have different average fuel economy as shown in Table 3 in the previous subsection. ICF conducted 12 separate regressions, one for each bus technology type. The regression model is identical for all bus technology types and is of the form

Fuel Economy (FE) = A + Bi* (route i) + Cj *(bus j) + Dk *(driver k)

where A is the constant term and Bi the co-efficient that corrects fuel economy for route effects (one for every route, i), Cj the co-efficient that corrects for the bus effect (one for each bus, j) and Dk the coefficient that corrects for driver effects (one for each driver, k, in a given bus type, as drivers may switch buses). The lowest or most negative values of the coefficient identify the lowest fuel economy routes, buses and drivers. The advantage of the regression method is that all three effects are considered together for the ranking of routes, buses and drivers. The coefficients **can be thought of as a ranking system**, so that a bus with a high Cj coefficient can be considered as having better than average FE after correcting for the route and driver effects, while a bus with a low coefficient is lower than average FE after the route and driver corrections. In this context it should be recognized that the regression can recognize a bus as a low FE bus even if its absolute FE is close to the average, as it may be operated on a route which is not crowded and other buses on that route are showing much higher fuel economy than the depot average. If buses are generally dedicated to single routes, and typically use the same drivers, then the simpler method of averaging FE first by route, and then by bus and by driver can be utilized, as this method can produce equivalent results to the regression.

The data set for the 3 depots combined is very large, with 11,698 records after cleaning. Each of the depots houses over 110 buses and employs about 300 drivers. Hence, the total number of regression coefficients is also very large but finding the lowest coefficients is not difficult as they can be stacked by value. We have selected the 10 percent of buses with the lowest coefficients (Cj values) relative to the average Cj for that bus type and the 5 percent of drivers with the lowest relative Dk values in each depot. It should be noted that the results for both depots in Vijayawada showed less fuel economy dispersion than the one in Hyderabad with most buses close to the average.

Table A9-1 in Annex 9 identifies the lowest fuel economy buses and lowest fuel economy drivers in each depot for January 2011. Euro 3 buses are not included in this analysis as they are very new. The results from both depots in Vijayawada were statistically significant in most cases and the buses and drivers identified by the regression had significantly lower fuel economy than the target values for each bus. Some of the driver coefficients were not statistically significant at 90+ % confidence but still indicated the low FE drivers correctly. The one exception is that the selection of low FE drivers for CNG buses in GVPT-2 recorded FE values close to the average, and appear to have been selected by the regression on the basis of the route specific fuel economy. This is because the CNG buses are quite new and most buses are in good condition, hence route based effects become dominant.

Data from Hyderabad (BKPT) was not as good quality as from Vijayawada, as noted, earlier, and it appeared that buses and drivers were switched more frequently between routes, leading to high variability in daily fuel economy. The data in table 5-5 shows that for some technology groups, drivers could not be identified as low FE drivers with 90+% confidence as the daily variability in fuel economy is quite high. However, even in these cases, the lowest Dk values did point to drivers whose absolute average fuel economy was significantly lower than the target values except in 2 cases. In addition, 1 bus with relatively good fuel economy (close to target) was identified as a low FE bus due to the route it was operating on.

5.2.5 Steps Implemented During the Mission

The mission was designed to allow ICF staff to check if the procedures followed at each depot during field testing is in accordance with the steps specified by the guidance note, and to establish channels of communication with depot managers to clear up questions during field testing.
ICF staff visited the Governorpet-1 and 2 depots in Vijayawada on the 19th and 20th, and the Bharkatpura depot in Hyderabad on the 21st of January. During the visit to each of the 3 depots, ICF staff

- met with depot managers
- examined the depot facility for maintenance
- met with mechanics and checked how repairs are being conducted
- met with drivers and driving instructors to check fuel efficient driving practices.

In general, ICF staff received a very high level of cooperation from APSRTC staff at the meetings. ICF found that all 3 depots followed nearly identical procedures which have been standardized across APSRTC bus depots. Variations observed across bus depots were relatively minor; in order to avoid repetition of the same findings at each depot, the report is organized by topic area and depot specific variations noted as required. In addition, fuel efficient driving training was conducted in a separate training facility, one for Vijayawada and one for Hyderabad. ICF staff visited each facility and interviewed expert trainers, and reviewed the classroom training at each facility. The Vijayawada training facility was visited on the 20th and the Hyderabad facility on the 22nd of January, 2011.

5.2.6 Meeting With Depot Managers

The findings from each of the 6 steps in Worksheet 1 detailed in annex 9 are summarized below

Communications: It was agreed that all communications between ICF and APSRTC would be channeled through the Chief Mechanical Engineer, with the Chief of Human Resources Development, serving as backup. Since both of them are based in Hyderabad, the Chief Engineer at Vijayawada served as the local contact for any special questions related to Vijayawada data. E-mail addresses and phone numbers for all staff members were provided to ICF. In addition, the senior staff at APSTRC were given the responsibility by the Executive Director of APSRTC to ensure that depots conduct the validation testing per the agreement.

Regression Analysis: ICF compared the findings of the regression analysis with APSRTC estimates of the lowest fuel economy buses and drivers at each depot for the month of November 2010 where ICF had been given 20 days data.

At all 3 depots, the regression based identification of the worst 10 buses was exactly matched by APSRTC identification of low FE buses, with the sole exception of CNG bus in Governorpet-2 that was misidentified in the data file sent to ICF as a diesel bus and one bus at BKPT which was identified by the regression but not by the APSRTC method. The APSRTC list also included an additional 2 to 4 buses per depot, since the ICF list was based on the lowest 10% of buses whereas the APSRTC list was based on the lowest by route.

In contrast, the list of drivers from the regression was very poorly matched with the APSRTC list based on the lowest fuel economy bus by driver. In all 3 depots only 2 or 3 of the 15 to 18 drivers identified by the regression were also in the APSRTC list. In addition, the average fuel economy by driver computed by ICF did not match the average fuel economy computed by APSRTC. This result was very strange given that the bus data matched exactly. The data processing manager, who was called into the meeting, confirmed that the data supplied to ICF in November was not from the depot records directly but were "derived" from the depot records (not clear exactly how this was done) and suggested that the driver numbers may have been misallocated to the records.

As a result, ICF was given the depot records directly without intermediate data processing. However, all of the data issues could not be resolved over the limited time frame of the testing.

Communicate the fuel economy (FE) results achieved. ICF verified the method of communication of FE data by APSRTC at each depot. The weekly average data on the top 5 fuel economy drivers and the bottom 5 fuel economy drivers are prominently displayed on a board placed next to the fueling station at each depot. However, the names on the board are based on absolute fuel economy being low, i.e. the top 5 and bottom 5 were not identified based on the route served. (The driver awards are based on route specific fuel economy, but according to

APSRTC managers, this does not cause any confusion or resentment among drivers) Drivers listed as the worst are apparently embarrassed by the list and strive to improve performance.

Obtain mechanic repair sheets and sign-off on repairs for traceability. ICF ensured that mechanics' report on the specific repairs being conducted and his sign-off on repairs is available. Each depot maintains a log book of repairs conducted weekly and ICF inspection of the log book showed a summary of repairs conducted with the mechanic conducting the repairs identified.

Require independent team audit of repairs across depots. The APSRTC has an independent audit team that audits each depot, but the audits are focused on the consistency of procedures, not on individual repairs. ICF staff met with the auditor, and any incorrect repair procedures identified during the February-March time frame at Governorpet 1and 2 and Bharkatpura were communicated to us. Repairs conducted on low FE buses were audited by the chief mechanic at each depot, and any deficiencies noted were reported to ICF.

Depot Walk Through. During the walk through, ICF staff examined daily bus inspection procedures and fuel fill and data recording procedures. In general, the depots have aging structures and are cramped, but well maintained and clean. Daily inspections are conducted both by a mechanic who checks tire pressure and fluid levels, and the driver, who does a walk around check. The fuel tank for diesel buses is filled at the end of every day (2 shifts), and there is a dedicated refueling operator who checks if the fuel tank is consistently filled to the maximum by actually dipping his finger into the refueling neck for diesel buses. The wetting of the finger tip by diesel fuel ensures that the fill level is near identical, and APSRTC staff described this procedure as accurate to within 200 mL. The fuel fill for CNG buses is based on a pressure reading so that fill repeatability is quite good. The fueling operator provides this data to the conductor and driver, who note the values in their own log by hand and transfer the data to depot IT staff, who also record revenues and trips completed. Since all this is done manually, staff conceded the possibility of error but noted that their data analysis shows it to be rare with under 1% of records showing spurious values. However, the depot walk-through revealed three issues. First, the buses are refueled only after two shifts so that the fuel economy per driver is not known, and the two drivers are assigned the same average value daily. Hence, consistent pairing of a good driver with a bad driver will result in both drivers being assigned an average rating. This could result in biased driver specific ratings but there is no easy solution as there is no time between shifts to refuel twice a day.

Second, daily fluid top up levels are not entered into the data base but maintained in a log book. Hence, it is up to the mechanic doing the top-up to notice engines with excessive oil consumption, although this could be noticed as blue smoke in the exhaust.

Third, the daily kilometers of travel are **not** based on odometer readings but on standard trip distance for the specific route times the number of trips. This may be accurate enough, but ICF staff requested that a small number of random checks be instituted to check odometer readings against the standard route distance to ensure that it is correct.

5.2.7 Meeting With Mechanics

At each depot, ICF staff met with mechanics who conduct repairs on the buses. In all 3 depots, there are one or two mechanics specialized in the repair of low FE buses and ICF reviewed the procedures to be followed. The formal checks employed for the Tata and Leyland buses are listed in Annex 8. The mechanics do not usually have written instructions but have been trained by manufacturers to conduct the repairs according to the requirements listed in Annex 8, and all mechanics appeared knowledgeable and professional, and showed ICF their work with pride.

Conduct Checks and Repairs on the 10% of the Fleet with the Lowest FE. ICF examined the procedures employed for each of the Tier 1 and Tier 2 checks, to obtain APSRTC mechanic concurrence on the checks to be performed and the exact diagnostic and repair method followed.

The depot staff conducts both the Tier I and Tier II checks at the depot. However, the failure of a Tier II check at the depot results in a parts replacement at the depot with the faulty part being shipped to the central Workshop for disassembly and repair. Typically, items like the clutch disc, transmission assembly, injection pump and injectors are simply replaced at the depot and sent to the workshop for repair or rebuild. At the end of the engine useful life, the entire engine is replaced and sent to the Central Workshop for rebuild. The Tier I check Worksheet 2 and the Tier 2 check Worksheet 3 listed in Annex 9.2 were reviewed with mechanics.

The primary checks conducted by APSRTC mechanics were identical to the recommendations in the GN with one exception, the fuel leak check, which ICF had placed at the Tier II level but APSRTC believed was an early check. In addition, the sequence of checks also followed the numerical order provided in Worksheet 2, with the one change relative to the earlier report, for fuel leaks. Exhaust blockage was generally not checked as this was rare and mechanics felt would be obvious from exhaust noise changes.

The Tier II checks, although conducted at the depot, are done only if the Tier I checks reveal a likely problem. For example, the clutch is disassembled only if the adjustment of clutch linkages fails to solve a slipping clutch problem. Mechanics concurred with the GN checks except in the turbo check area, where they stated they had no failures so far. In addition, wheel alignment was checked at every service interval and mechanics stated that any wheel misalignment will show up very quickly in abnormal tire wear, often consuming a tire within a week; hence, wheel misalignment would be quickly identified and fixed outside of the low FE checks. In the CNG engine area, the gas mixer and air-fuel ratio electronics service have been subcontracted to Leyland, the bus supplier, but this has not been an issue since the buses are relatively new.

5.2.8 Meeting With Drivers/ Trainers

Train drivers in fuel efficient driving techniques. ICF staff visited two training facilities that are at remote sites and reviewed the video provided to all new drivers. During the visit at one of the locations, a class for new drivers was in progress allowing ICF to inquire directly with drivers on the benefits of driver training as perceived by them. All new drivers hired have commercial vehicle licenses and are typically truck drivers who are then retrained in the APSRTC way. After the initial training, all drivers come back for retraining every 2 to 3 years, with low fuel economy drivers returning more frequently. The training session includes both classroom training and on-road training with an experienced instructor, and key features of the program are summarized in the worksheet below, with additional discussion of the findings following Worksheet 4 listed in Annex 9.2.

The classroom training emphasizes two areas not directly related to driving. One is the importance of saving fuel and what fuel costs mean to APSRTC. Second, the classroom training also stresses driver motivation, to do a good job not only to improve their pay but also as a means to serve society. These aspects have been suggested by many international programs such as the UK Fuel Efficient Driver Handbook, but receive considerable emphasis in the APSRTC program. The same video training is provided to all training campuses in AP and emphasizes the key aspects of fuel efficient driving

- smooth acceleration and deceleration
- anticipating traffic to avoid sudden braking
- using the bus' momentum to maintain speed
- avoiding accelerator pumping
- shifting gears to maintain engine speed in the optimal range

The video does not explicitly discuss reduction of idle or avoidance of clutch riding, but the class room instructor stated that these were covered in the class lecture. ICF staff asked one of the students present and he answered correctly that idle time should be restricted to 2 minutes maximum and the foot should be off the clutch pedal when the gears are not being shifted. In addition, the video suggested shifts at 10/20/35/50 km/hr as optimal for the Tata and Leyland buses.

ICF staff was also shown the on-road training with the expert instructor and he demonstrated how he observes accelerator pumping and clutch riding with new students. In addition, he demonstrated the optimal gear shift technique using and engine sound method that appeared to be better and more rational than the fixed shift points advocated in the video. He explained three types of engine sound: humming, sizzling and thrusting and showed how the general shift should be from “sizzling to sizzling”, but on uphill and heavily loaded conditions, it should be from “thrusting to thrusting”. Since the buses do not have a tachometer, this appears to be a good way to optimize shifting under different conditions. The difference between the video and the instructor’s method was noted but APSRTC staff suggested that video was for more general guidelines while the on-road training provided more specific procedures.

ICF also questioned the drivers and trainers on the usefulness of the procedures, and they all stated that the increased concern on fuel efficiency was a priority and they found many of the techniques taught at the training center new and useful in spite of having driven trucks. However, they conceded that given the dense and chaotic traffic in cities, it was quite difficult to brake smoothly and use momentum in the city, and much of the benefit in fuel economy came only from proper gear shifting. The major issues that we found are:

- there is no monitoring of driver behavior outside of fuel economy. The use of a tachograph or engine monitor may be useful, and an RPM gauge on the bus may help driver responses.

- the video based training the gear shift is not completely consistent with the on-road training, but on-road training provides the right shift methodology

- many of the procedures are useful only on suburban and un-crowded routes and we expect that driver training will have smaller impacts on city route fuel economy.

5.2.9 Field Testing Phase - Results

During the field testing phase, APSRTC sent ICF data approximately every 10 days on all buses at each depot used for validation testing. APSRTC also sent their list of low fuel economy buses and drivers by the 20th of February and March. ICF originally intended to analyze the data monthly and provide APSRTC with any changes to the list of low fuel economy buses and drivers in early February and March, but the delayed receipt of data from APSRTC plus the time required for ICF to assemble and analyze the data made our intervention too late for useful inclusion into the monthly repair list.

5.2.9.1. Regression Analysis

Data from February and March were analyzed using the regression technique and compared to the results from the APSRTC simple averaging method (only February results available for this draft). The regression results for the 10 lowest fuel economy buses at each depot were found to be in good agreement with the APSRTC list for the Governorpet 1 and 2 depots, with 9 out of 10 common in Governorpet-1 and 9 out 10 common in Governorpet-2. The match between regression results and APSRTC results was less good at the Bharkatpura depot, with only 6 of buses matching, which was worse than the results for November 2010 data where there was almost an exact match.

In the case of drivers, we encountered the same problems as before with only about 40 to 50% of the list of low fuel economy drivers being common to both analysis techniques across the 3 depots. ICF analysis revealed that the selection at APSRTC was based on ranking drivers by absolute fuel economy level being the lowest whereas the regression results are **based on route adjusted fuel economy being the lowest. While the lowest absolute fuel economy does select some of the same drivers, the regression method also selects drivers that may have higher absolute fuel economy but lower route adjusted fuel economy.** As an example, the regression may select a driver with an average fuel economy of 5km/L as a low FE driver if the route average is 5.7 km/L (he is 0.7 km/L below average) while not selecting a driver with a fuel economy of 4.9km/L if the route average for that driver is only 5 km/L (he is only 0.1km/L below average). Of course the variation of fuel economy between routes is usually not as large as in the example and the low fuel economy buses on an absolute basis have overlap with the route adjusted low fuel economy buses, as illustrated from the data.

Due to the very compressed time frame for the validation study and the time required by APSRTC for data assembly and analysis, all of the data issues and statistical issues could not be resolved within the period of the validation. APSRTC used its own methodology for bus and driver selection for repair and retraining respectively. ICF recommends that data and statistical issues be studies in a longer and more extensive validation study if possible.

5.2.9.2 Baseline Fuel Economy Distributions

The fuel economy of buses is distributed over a range due to variations in route driving cycle characteristics, driver behavior and the state of maintenance of the bus. Typically, a plot of bus average fuel economy (averaged across and routes for the month) is distributed around the average reflecting all of the variables. For large samples of buses (>500) the distribution would approach a normal distribution with a "tail" of buses that are ones with some mechanical defect causing low fuel economy. In smaller samples, the distributions can be skewed but will still have similar broad overall characteristics.

Two examples of the actual distributions obtained from the data at one depot (GVPT-1) are shown in Figures 5-1 and 5-2. In figure 5-1, the distribution of fuel economy clearly shows a "tail" of mal-performing buses with fuel economy ranging below 4.7 km/L or approximately 10% below the fleet average of 5.19 km/L, and this distribution is for older Euro-1 certification CMVR buses. The distribution of fuel economy for the newer Euro-2 turbo (Cummins powered) fleet is shown in Figure 5-2 and the tail is less obvious with only a smaller sample fraction below 4.7 km/L, even though the average is quite similar to the Euro-1 buses at 5.23 km/L.

Although not all of the distributions are shown in this report, the general pattern is similar with older buses fleets showing a longer fuel economy "tail" in the distribution. In the relatively new CNG bus fleet meeting Euro-3 emission levels, however, there were always a few buses (~ 5%) with significantly lower fuel economy and it is possible that CNG buses have a different distribution relative to diesel buses due to the potential for ignition system mal-performances in CNG buses which can have a large fuel economy effect

Figure 5-1: Fuel Economy Distribution of Euro-1 CMVR Buses in GVPT-1

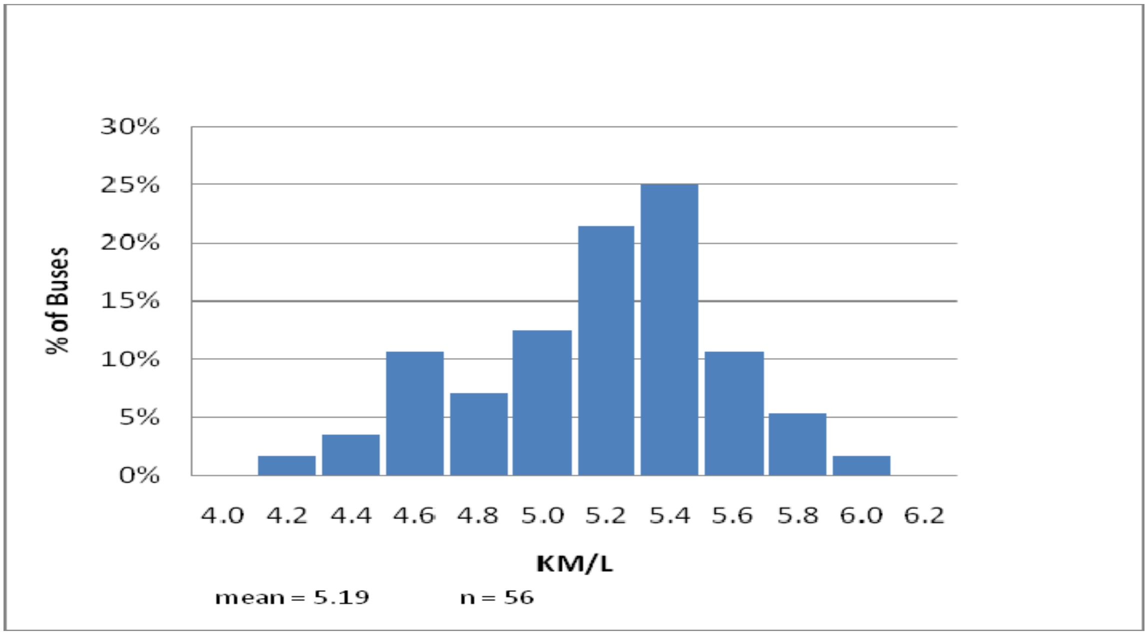
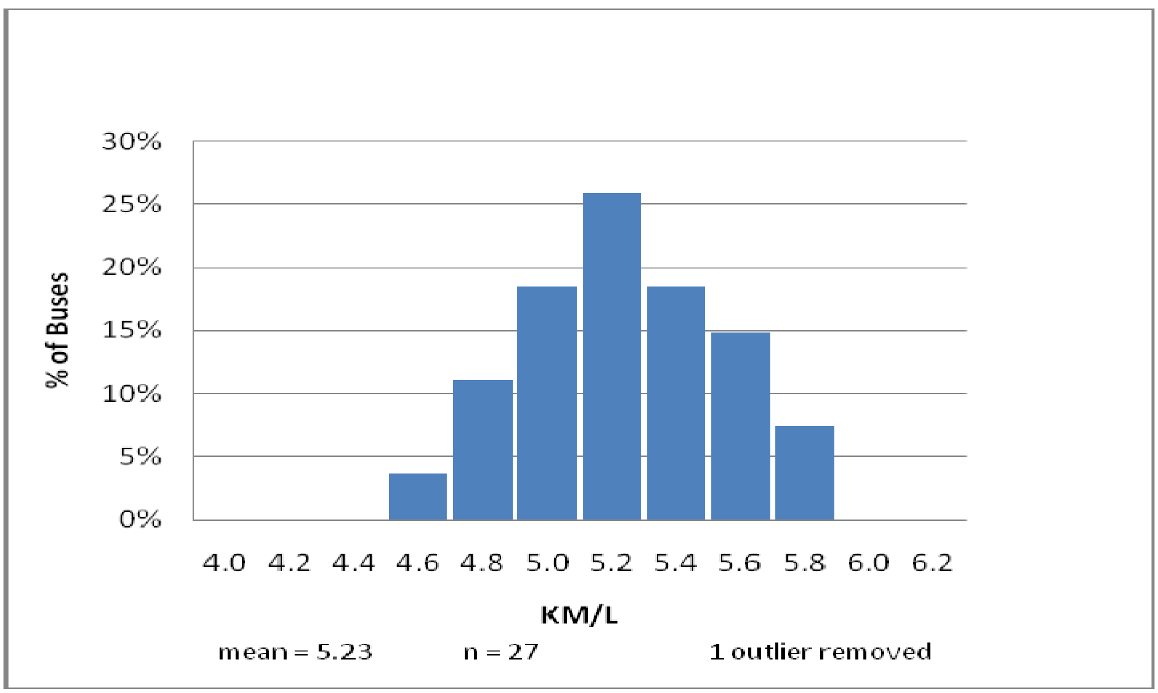


Figure 5-2: Fuel Economy Distribution of Buses with Euro-2 Turbo Engines in GVPT-2



5.2.9.3 Low Fuel Economy Bus Improvement

Pre and post- repair fuel economy was monitored by APSRTC and reported to ICF, and this data was analyzed by ICF. It is recognized that the validation period of 12 weeks was relatively short and a longer validation test period is desirable, but data from the limited validation is useful in estimating the approximate value of fuel efficiency benefits obtained. During the validation period, about 10 buses received maintenance at each depot monthly for improving fuel economy and the total sample of repaired buses across the three depots in 2 months was about 60, spread over different technology types. In real world data, errors in data recording or unusual factors can result in occasional data "outliers" which do not have a large effect on computed averages if the sample is large, but can influence the averages in small samples. Some buses can also report fuel economy declines after maintenance, either due to data errors, or due to incorrect repair, but the project schedule did not permit determination of the cause of the decline. In addition, small positive and negative changes in the range of plus or minus 3 percent for the monthly average fuel economy can occur simply due to the typical variations in weather and driving conditions over a month and only larger numbers can be considered as showing a significant benefit or dis-benefit to fuel economy. However, very large positive or negative changes in excess of 15% are also unlikely and could be a result of erroneous input data; such data are considered as outliers in the analysis. Since the sample at the bus technology type level was only on the order of 10 to 20 buses, the data analysis presented below includes a careful consideration of such outlier data. All of the validation data from each of the three depots is presented in Annex A.9.3

Data reported for the GVPT-1 depot showed that some of the buses identified by ICF as low FE buses **were not included in the repair process** but others were substituted. In the GVPT-1 depot, the average improvement noted for the 10 repaired buses in the February sample was quite small at only 2.06%. This was, however, due to the fact that 3 of 10 buses showed large reductions in fuel economy of -6% to -9%, indicating that the cause of the low fuel economy was likely improperly diagnosed. In particular, the older Euro-0 buses showed an improvement of only 0.7%, and the performance was repeated in the March sample with an improvement of only 1.9%. In contrast, the March sample showed that the Euro-1 buses improved by 9.4% and the Euro-2 turbo buses by 11.05%. The average for all buses except the Euro-0 buses was 6.91% for the two month combined sample. The range of results and average by bus technology is shown in Figure 5-3

Figure 5-3: Percent Fuel Economy Improvements from Repair at GVPT-1

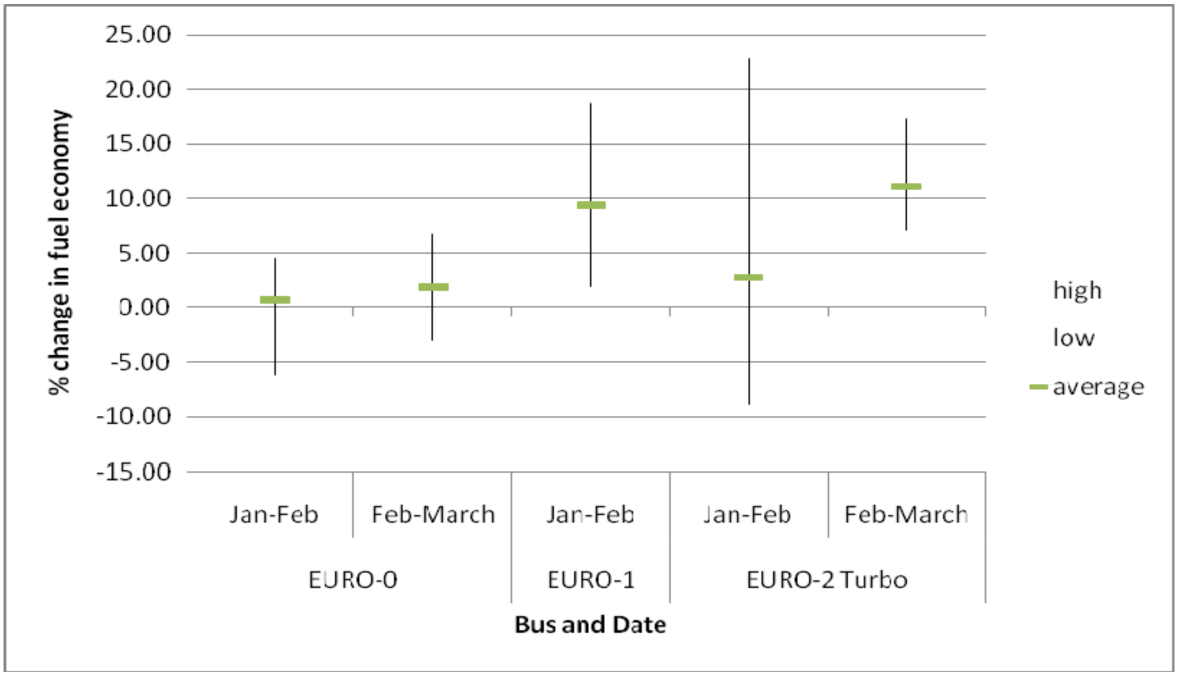
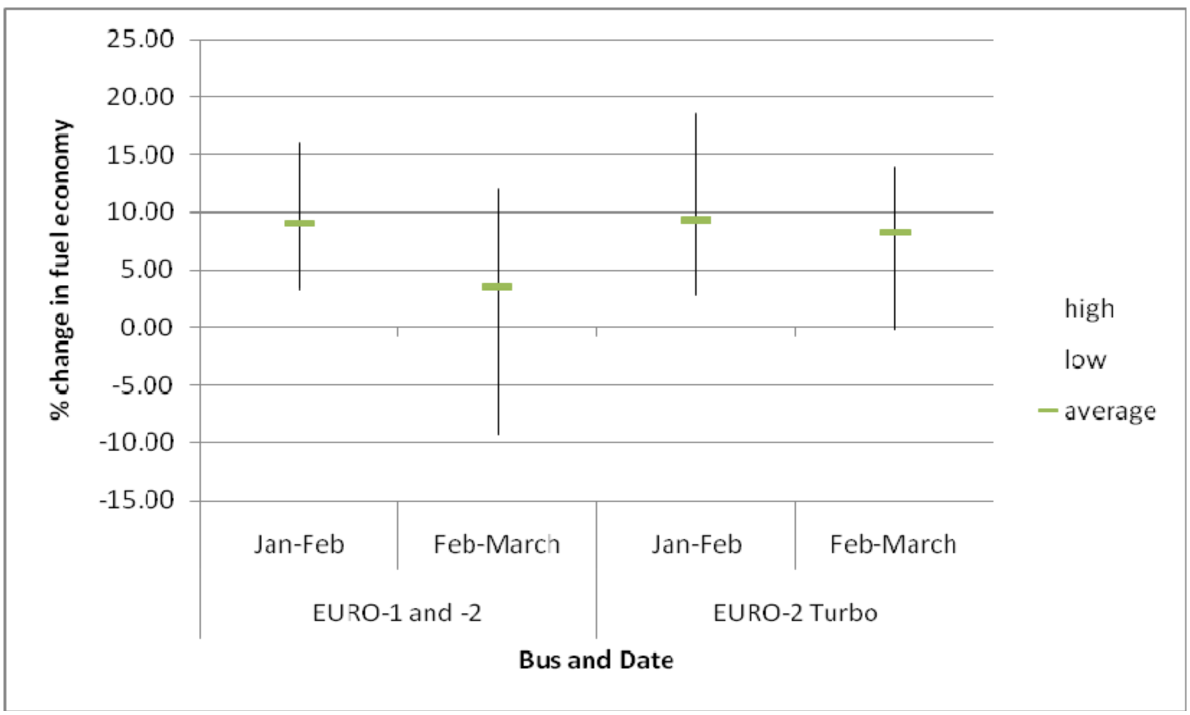


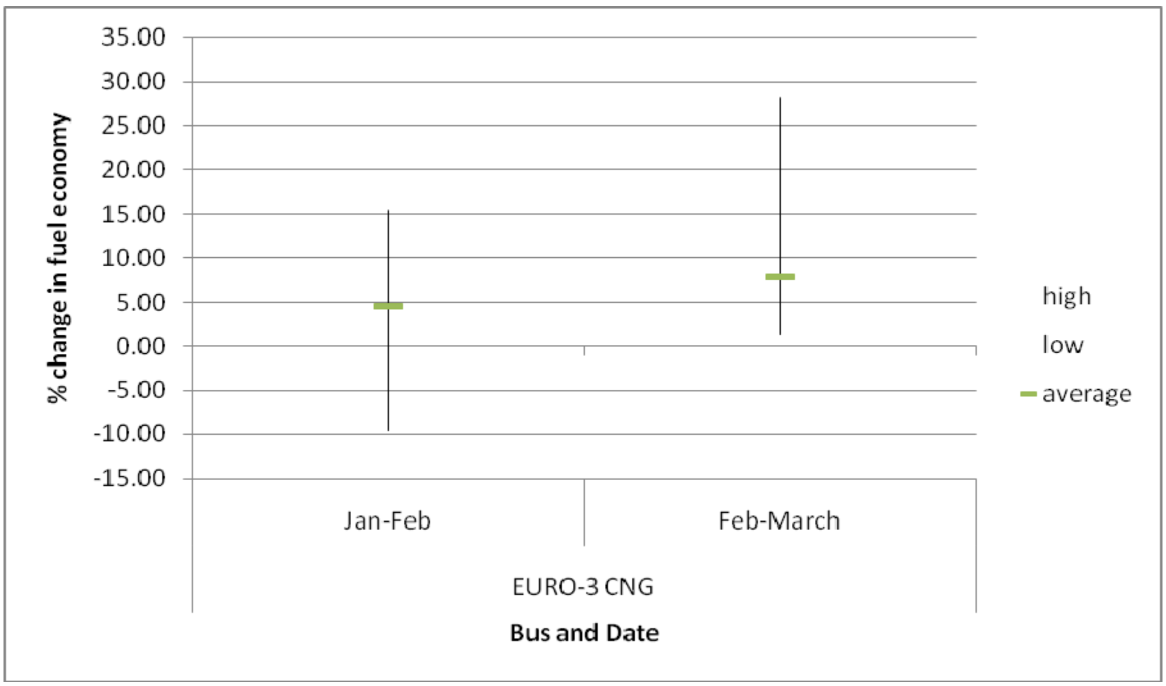
Figure 5-4: Percent Fuel Economy Improvements from Repair at BKPT



At the BKPT depot, 14 low fuel economy buses were repaired and they reported a fuel economy improvement of 9.15% on average for the February sample. The benefit dropped to 6.18% in the March sample of 14 buses. Hence the average improvement over the 2 months was 7.66% with approximately equal performance benefits for the Euro 1/2 engine and Euro-2 turbo engine fleets, as shown in Figure 5-4.

In GVPT-2 (which has an all CNG fleet), the reported improvement was 4.59% for a 10 bus sample in February, but 4 of buses reported negative fuel economy benefits (although only one was a large negative at -9.7%). In the March sample of 10 buses, the average fuel economy improvement was 7.78% with no buses reporting fuel economy declined, but one bus showed a very large increase of 28.1% which suggests potential data errors. Removing this bus from the sample results in the average improvement being reduced to 5.51%, and this is quite similar to the February result with the negative outlier removed. The results are shown in Figure 5-5.

Figure 5-5: Percent Fuel Economy Improvements from Repair of Euro-3 CNG Buses at GVPT-2



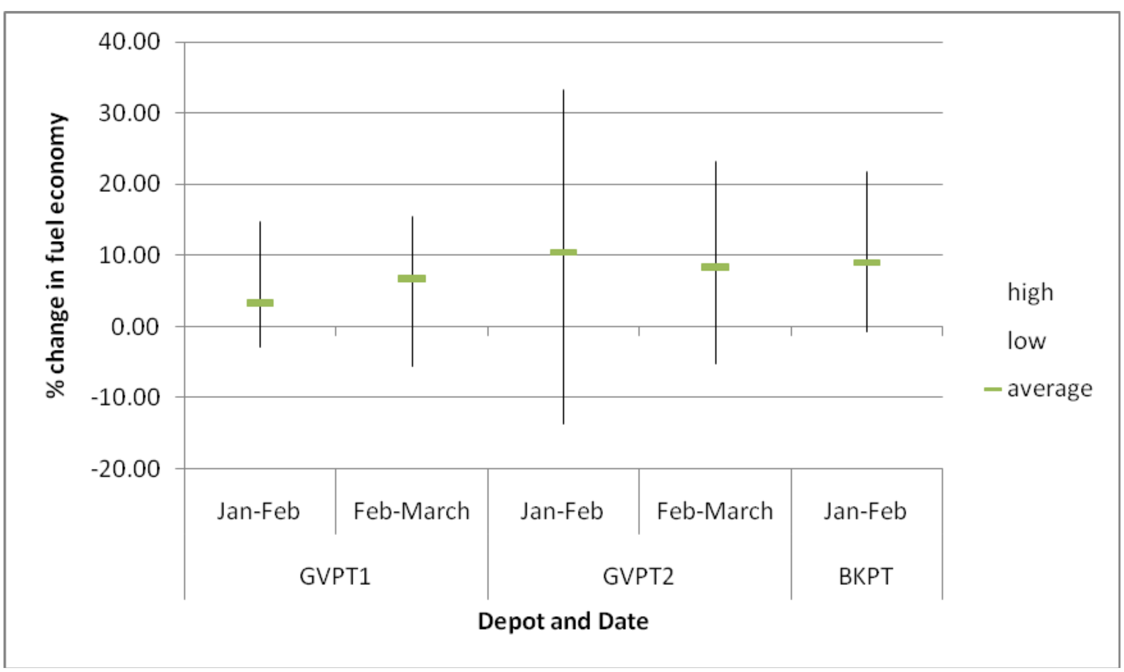
The BKPT and GVPT results are encouraging due to the average improvements being outside the typical noise range of plus/minus 2%. Both the BKPT and the GVPT-1 data on older diesel buses suggest that average benefit from repair of older diesel buses is in the 7 to 8% range. Surprisingly, even the Euro-3 CNG buses show an average improvement of about 5%, which may be unique to CNG since ignition defects can cause significant fuel economy degradation.

5.2.9.4 Low Fuel Economy Driver Improvements

Low fuel economy drivers were selected by APSRTC based on the lowest average fuel economy but were not route adjusted. Unlike the bus case, the pre and post training data for the drivers showed un-ambiguously positive results. In BKPT, 20 drivers were retrained and the data submitted by APSRTC showed an average improvement of 9.06% in their fuel economy, with no drivers reporting significant fuel economy declines. Four of the 20 drivers had reported fuel economy gains of over 15% which are suspiciously large, but even removing these outliers from the data resulted in an average improvement of 6.46% for the 16 drivers. Data for March was not provided in time for this analysis. 20 low fuel economy drivers counseled at GVPT-1 had a reported average fuel economy gain of only 3.3% in February. This was due to the fact that 10 drivers showed no significant change in fuel economy, i.e. the fuel economy change was within the plus/minus 3% noise band. The remaining 10 drivers showed a benefit of 6.26%. The March average for a sample of 19 drivers (one of the 20 drivers left the program) was 6.73% with only 2 drivers in the plus/minus 3% band.

At GVPT-2, 20 low fuel economy drivers were counseled and showed an average improvement of 10.38% in February. However, 2 drivers had reported gains of 33.3% and 32.1% respectively which lies outside the range of possible improvement and is potentially due to data errors rather than actual improvement. Even after removing the 2 suspiciously high data points, the average was 7.59% for the 18 drivers. In March, the 19 driver sample average was 8.37% with only one outlier at 22.2%. Removing this outlier drops the average to 7.54%, consistent with the February corrected average. The average data as reported is summarized in Figure 5-6.

Figure 5-6: Fuel Economy Improvement of Drivers from Training



It is clear that the reported averages are strongly influenced by the presence of positive and negative outliers, and adding more data will improve the quality of the averages. The fact that the clean data suggests an average improvement of 7 ± 1 percent after correcting for outliers across the three depots is very encouraging as this level of improvement has been noted across many driver training programs as described in Annex A1.1.4 and Annex 5.

5.3 VALIDATION IN MYSORE BY KSRTC

5.3.1 Overview

The validation of the key guidelines/ recommendations in the GN was also conducted independently by the Karnataka State Road Transport Corporation (KSRTC) - India. KSRTC is a state owned transport organization operating bus transport system in the state of Karnataka. It has a fleet of 7000 buses operated through its 13 divisions. Mysore City Transport Division is one of its divisions operating city bus services with a fleet of 400 buses in Mysore city where the validation testing by KSRTC was conducted, in three depots of Mysore City Transport Division. Essentially it entailed a 3 month testing phase with focused attention on a sample of poorly performing buses and drivers.

At initial stage the World Bank requested information from KSRTC to plan their field testing regarding city wide fleet size, depot particulars, depot size, fuel economy, sample selection of buses and sample selection of drivers. This was initiated with the forwarding of preliminary data of Mysore City Transport Division, Mysore on city wide fleet size, depot particulars, depot size, sample selection of buses and sample selection of drivers etc, on 3rd February 2011 to World Bank staff. The detailed and organized daily KMPL bus data for 15 days was forwarded to World Bank for identifying poor performing buses and drivers for GN validation exercise.

KSRTC officers visited Hyderabad and Vijayawada on 22nd and 23rd of February 2011 to obtain information about the validation procedures and activities which were being carried out at APSRTC. The officers accompanied World Bank staff during their visit to APSRTC and participated in the meeting and field visits at APSRTC. A meeting was conducted on 25th Feb 2011 at Mysore under the Chairmanship of the Chief Mechanical Engineer of KSRTC. KSRTC officials and driver instructors were present in the meeting. During the meeting, the objectives of the GN were discussed in detail and decisions were taken for –

- Setting of benchmark KMPL values for identified Euro-I and Euro-II vehicles.
- Calculation of base line KMPL
- Identification of 20% low performing vehicles among selected vehicles.

- Identification of 10% low performing drivers.
- Adoption of Tier-I and Tier II checks for maintenance.
- Providing on-road training to the drivers.
- Acquisition of data.

5.3.2 Characteristics of the Mysore City Fleet

Data obtained from the Mysore City Transport Division (MCTD) was used to identify the types of the buses and the age distribution of the fleet, so that the validation would occur primarily based on testing of buses that would be outside the typical warranty period of 3 to 4 years. From Tables 5-6 below, it can be seen that the target fleet are the 154 diesel buses over 4 years of age.

Mysore City Division has 3 depots where validation testing has been conducted, and their current fleet size and average fuel economy as of Dec-2010 is shown below.

City-1 (Bannimantap) : 158 buses.
City-2 (Kuvempunagar): 158 buses.
City-3 (Sathagalli): 84 buses.

Euro-1 and Euro-2 compliant buses vehicles which are more than 4 years old were selected for this test. These vehicles are spread over 3 depots namely City-1, City-2 and City-3 depots. The distribution of the test fleet by depot is shown in Table 5-7.

Table 5-6: Age Distribution of MCTD Buses

Age in Years	**EURO-1**	**EURO-2**	**EURO-3**	**TOTAL**
0 to 1	0	23	36	**59**
1 to 2	0	10	120	**130**
2 to 3	0	24	0	**24**
3 to 4	0	32	0	**32**
4 to 5	**02**	**53**	**0**	**55**
5 to 6	**26**	**25**	**0**	**51**
6 & above	**47**	**01**	**0**	**48**
TOTAL	**75**	**168**	**156**	**399**

Table 5-7: Distribution of Validation Test Fleet by Depot

Depot	EURO-1	EURO-2	TOTAL
City-I	19	23	**42**
City-II	33	40	**73**
City-III	22	17	**39**
TOTAL	**74**	**80**	**154**

The vehicle types in Mysore city division use diesel engines with different levels of emissions certification. The older diesel buses are all sourced from Tata or Leyland. The newer Euro-3 certification buses are more powerful turbo charged engines. It is clear that more stringent emissions certification level associated with Euro-3 as well as the higher power rating of the newer- Euro-3 certified buses result in significantly lower fuel economy. Hence it is important to set the benchmark appropriately for each engine type or certification level. Because the Euro-3 buses are relatively new, testing included only the comparatively older Euro-1 and Euro-2 diesel buses. The characteristics by make and certification level are presented for buses operating in Mysore city division in the table 5-8.

Table 5-8:. Make and Model Types of Buses in MCTD.

Bus Type	LEYLAND		TATA	Leyland FESLF	Tata RESLF	Volvo	Total
No. of buses	75	46	125	79	41	33	**399**
Engine	Hino 83KW	Hino 83kw	Cummins 96kw	Hino 126kw	Cummins 138kw	Volvo 223kw	
Certification	Euro-1	Euro-2	Euro-2	Euro-3	Euro-3	Euro-3	
Fuel Economy (4/10 to 12-10)	5.18	5.11	4.98	3.79	2.95	2.20	**4.30**

Using the methodology used to set targets for APSRTC, the preliminary targets based set by KSRTC were 5.38 km/L for Euro-1 buses and 5.35 km/L for the Euro-2 buses.

5.3.3 Validation Test Results

ICF did not have detailed oversight over the implementation of all steps, but communications from KSRTC suggested that their method of implementation mirrored the implementation at

APSRTC. ICF has performed no evaluation of the actual implementation in Mysore but the results of the testing as reported by KSRTC are provided here.

The methodology used for selecting the low fuel economy buses and drivers appeared to use absolute fuel economy levels rather than the route adjusted levels recommended by ICF. In addition, the 15 lowest fuel economy buses in the Euro-1 type category and the 16 lowest in the Euro-2 category were selected each month for repair, which is 20% of the two fleets respectively, and these were selected across all 3 depots rather than by depot. All of the validation test data for Mysore are listed in Annex 9.4

Data was available for 2 months so that a total of 29 Euro-1 (one bus retired from service) and 32 Euro-2 buses were selected and repaired. The data for Euro-1 buses showed a consistent but small improvement of 2.42% in one month and 3.96% in the next, with all except one bus repair providing positive results. However, only 8 of 16 buses in the first month had an improvement over 2%, the minimum for significance. In the next month, 13 of 14 had results that were over 2%. This improvement may also reflect some organizational learning on how to diagnose fuel economy related defects.

Data on the Euro-2 buses showed slightly larger fuel economy improvements relative to the Euro-1 buses, with an improvement of 4.20% percent in the first month and 5.28% in the second month. 4 of 16 buses showed improvements of less than 2% in the first month with 2 negative outliers affecting the averages, while this was true of only 2 of 16 buses in the second month. ICF concludes that the improvement levels for both Euro-1 and Euro-2 buses are very similar at 4 to 5% and this is not surprising given the relatively narrow age range of the buses tested. The bus data are summarized in Figure 5- 7

Data on low fuel economy bus drivers was also available for 2 months, with 18 such drivers being retrained each month. The data were consistent across drivers and months, with all drivers improving fuel economy with average gains of 5.0% in February and 4.0% in March. Interestingly, the Mysore data showed no obvious outliers, with no drivers having reported fuel economy increases of over 15% in either month. The driver data are summarized in Figure 5-8

Figure 5-7: Fuel Economy Improvements from Repair in Mysore

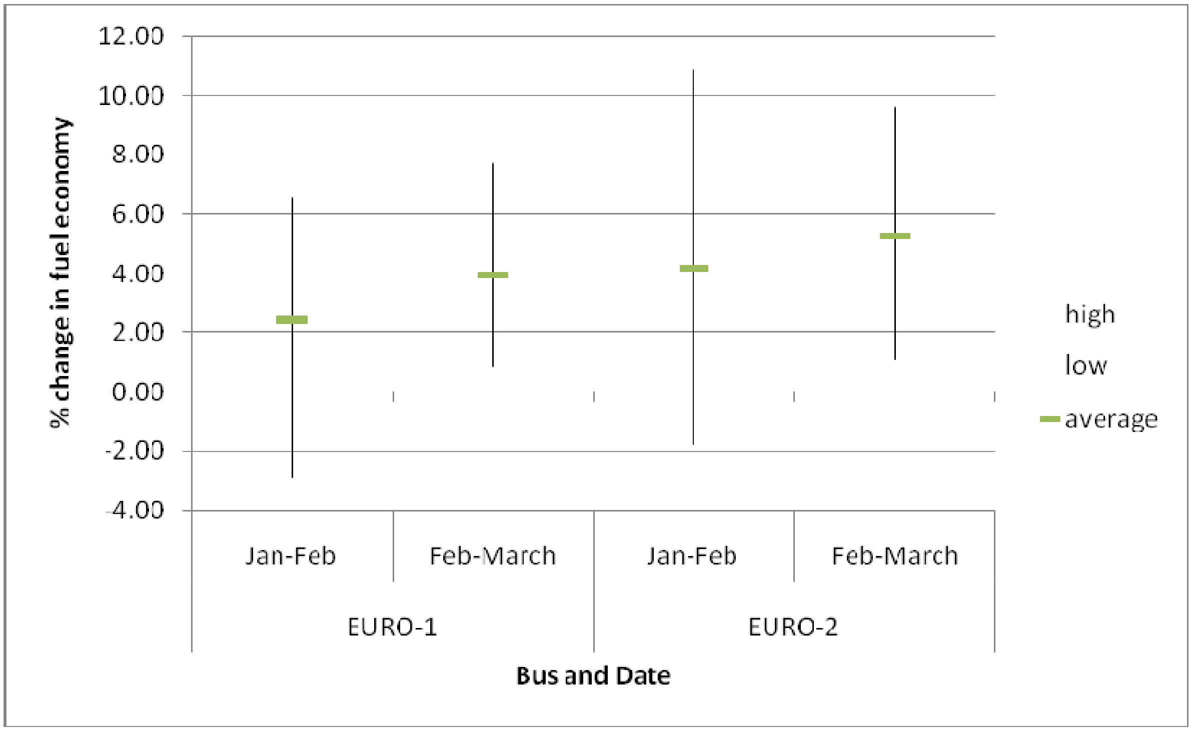
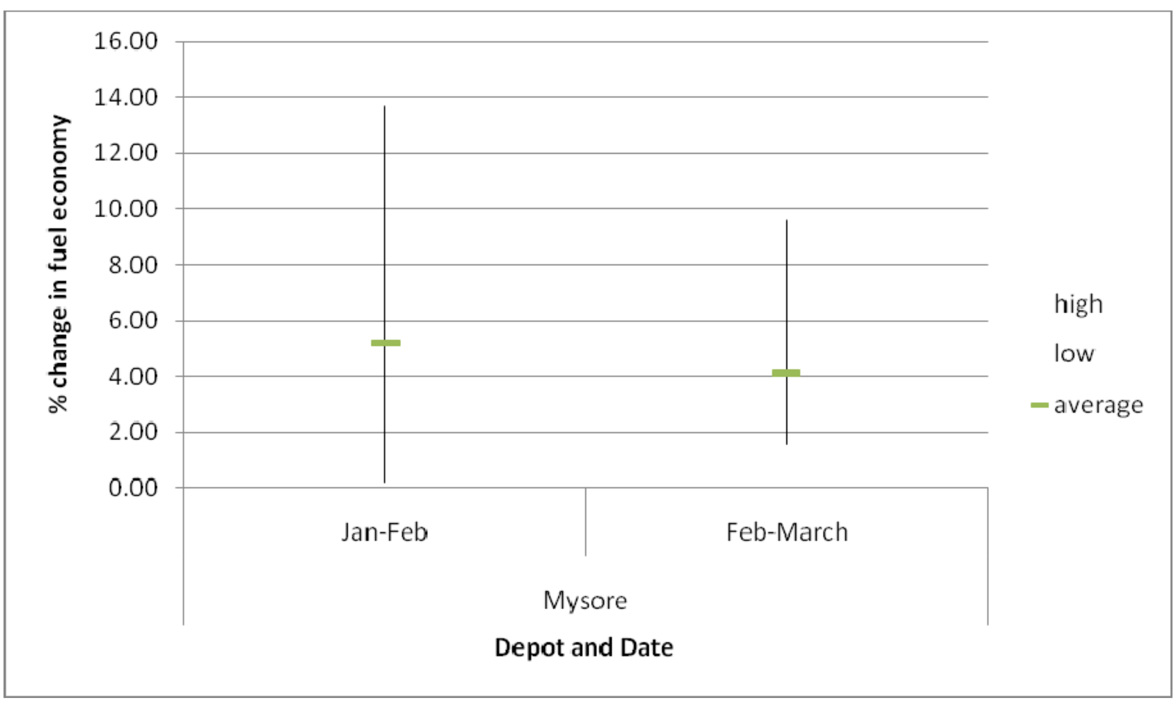


Figure 5-8: Fuel Economy Improvement of Retrained Drivers in Mysore (all depots)



5.4 SUMMARY OF FINDINGS

The conclusions of the validation testing at APSRTC and KSRTC are as follows:

1. Implementation of most of the recommended steps in the Guidance Note was accomplished without much difficulty at several locations in India, suggesting that 16 steps described in the GN can be implemented in most locations.
2. The involvement of senior management in implementing the procedure was found to be very useful to help motivate depot staff and provide high level guidance to the organization.
3. The data, although collected manually, was of reasonably good quality and permitted identification of low fuel economy buses and drivers with relatively good confidence.
4. The regression analysis of the data to identify low fuel economy buses and drivers was found to require a skilled analyst due to the very large size of the data bases (>6000 records per month per depot), the data cleaning requirements, and the need for careful analysis of results for statistical significance.
5. In cases where the buses are designated to specific routes and drivers to specific buses, ICF found that the simple method used by APSRTC of averaging monthly fuel economy by bus and by driver and selecting the lowest fuel economy buses and drivers by route identified virtually the same set of buses and drivers as the regression method. When buses are not dedicated to routes and drivers not designated to specific buses, the results from the two methods diverge but the quality of the results from the regression could not be verified in the limited testing time frame.
6. The diagnostics and repair sequence provided in the GN had a great deal of commonality with manufacturer recommended repair procedures and APSRTC’s own internal procedures, and met with mechanics approval.
7. Mechanics at the facilities were competent in performing the required diagnostics and repairs, and they successfully followed the sequence of repairs recommended in the GN to improve the fuel economy of the buses identified.
8. The benefit of repairing low fuel economy buses appears to be a function of vehicle age. Newer buses (4 to 7 years old) appear to obtain an average benefit of about 4 to 5 percent improvement in fuel economy based on the testing in Mysore. Older buses (7 to 14 years old) appear to obtain a benefit of 7 to 8 percent improvement based on

the data from Hyderabad, on average. Surprisingly, even the new (less than 3 years old) CNG buses at Vijayawada showed a benefit of about 5% but this may be a finding specific to CNG where ignition system defects can degrade fuel economy significantly

9. Driver training programs incorporate most international best practices for fuel efficient driving, and the on-road training, in particular, appeared to be very well suited to help drivers facing local driving conditions.

10. The data on the benefits of driver retraining are quite consistent and suggest that it results in an average fuel economy improvement of 6 to 8 percent. During this validation study, drivers were identified on the basis of low absolute fuel economy, not on route adjusted fuel economy. ICF believes that even better results could be obtained by changing driver selection to be on a route adjusted fuel economy basis.

11. Drivers are highly motivated by the public display of driver specific fuel economy information, and the award for good fuel economy performance inculcates driver pride in their performance even though the monetary value of the award is small.

5.5 DATA LIMITATIONS AND SUGGESTIONS FOR IMPROVEMENT

The validation study was time and resource constrained and not all aspects of the problem could be studied thoroughly. Key areas where some additional effort is desirable in the future are listed below:

1) Data quality and data analysis issues could not be fully resolved in the limited time frame of the validation study. The large volumes of data generated by even a fleet of few hundred buses make these issues difficult to resolve quickly, and ICF recommends that the World Bank study these issues more thoroughly over a longer time frame

2) The identification of low fuel economy buses and drivers is an issue related to the data quality and volume. The draft GN had recommended a regression analysis method, and the validation study experience showed that data cleaning and regression expertise were essential to implementing this step with many thousands of data points. This expertise may be lacking at many transport corporations, and a simpler monthly averaging method can be used to identify buses and drivers needing attention, although this is not as good as the regression method in theory. If this averaging method is used, ICF suggests that low fuel economy buses and drivers be identified on a route specific basis.

3) Due to the small sample of buses repaired and drivers retrained in this validation study, the estimates of average repair benefits by vehicle technology or age and average driver retraining benefits are highly influenced by the presence of a few “outliers” exhibiting relatively large positive or negative benefits. At this stage, the inclusion or exclusion of specific outliers does involve some subjectivity, but more data collection will minimize this problem.

4) Some steps involving long range activities could not be evaluated in the validation study, and key steps such as automating data collection, employee motivation through bonuses, and the long range evolution of the fleet should be examined if possible in a year-long study, ideally at a location where fuel efficiency has **not** been a central focus.

ICF believes that regression analysis is the most appropriate and scientific method for identifying low fuel economy buses and drivers, but recognizes the difficulty associated with the large data bases and the need for skilled statistical analysts. The simple method of calculating average fuel economy by bus and by driver and selecting the lowest fuel economy buses drivers for attention is a reasonable alternative for at least the initial phases of program implementation. Selection of drivers and buses based on fuel economy relative to the route average is preferable, and can be instituted if buses are dedicated to specific routes and drivers to specific buses.

5.6 FEEDBACK

The World Bank has requested that ICF provide APSRTC a questionnaire to obtain their feedback on the usefulness of the GN steps. The response to this questionnaire from APSRTC is provided in Annex 9.5 and is very positive about the impact of the GN steps.

CHAPTER 6: IMPLEMENTATION STATUS, COSTS AND BENEFITS

6.1 CURRENT IMPLEMENTATION STATUS

As noted in previous sections, several of the implementation steps in this Guidance Note have been implemented widely, while some have been implemented in very few locations. Table 6-1 provides a summary of current implementation status in major transit bus fleets worldwide based on inputs received form transit managers interviewed worldwide and from literature reviews, and should be regarded as an opinion based result rather than a result from a comprehensive survey.

Table 6-1: Summary of current implementation status in major transit bus fleets

Step		Action	Implementation Status
Step 1		Appoint a senior executive to be in charge of fleet fuel economy and tie his/her bonus and career to meeting fuel economy goals.	Fuel economy (FE) performance generally not tied to manager's goals or compensation
Step 2		Benchmark and set appropriate fuel economy goals by bus type for each year	Goals for failure rate and maintenance cost control are common but goals for FE are very rare
Step 3		Communicate the fuel economy results achieved each year to both employees and the public.	Information on fuel economy by bus type rarely provided to employees or public
Step 4		Automate data collection to the extent feasible	Common in developed countries, starting in others
Step 5		Set up data QA/QC procedures	QA/QC done with commercial fleet management software
Step 6		Analyze the data for untangling the effects of driver, route and bus related effects on fuel economy	Rarely done
Step 7		Use data to refine periodic maintenance intervals	Common in many large bus fleets, rare in small fleets
Step 8		Select 5% of the fleet showing the lowest FE and conduct 16 simple checks at depot	Rarely done
		Conduct more detailed checks at central maintenance facility if bus passes step 7	Rarely done

Step		Action	Implementation Status
Step 9		Check repair quality on a random and periodic basis	Common in large organizations
Step 10		Obtain mechanic sign-off on repairs for traceability	Common in large organizations
Step 11		Require independent team audit of repairs across depots	Usually audited internally at each depot
Step 12		Retrain mechanics and update repair procedures periodically	Relatively common, especially for new technology introduction
Step 13		Train drivers in fuel efficient driving techniques and periodically re-train them	Widely done
Step 14		Select the 5 percent of drivers with the lowest fuel efficiency and have special additional training	Implemented in most large organizations
Step 15		Reward Mechanics at the depot level for FE performance	Rarely done for fuel economy, common for reduced time between failures.
Step 16		Reward drivers individually for exceeding FE targets calibrated to the bus and route	Rarely done for fuel economy, common for safety

6.2 POTENTIAL BENEFITS FROM PROGRAM IMPLEMENTATION

A key question is the size of the benefits obtained from implementing a strong fuel economy program along the lines suggested by this guidance note. A general answer can be misleading as the benefit depends on the following parameters:

- the age composition of the bus fleet. Obviously, the newer the fleet, the less influence that maintenance improvements will have on fuel economy as new vehicles need little maintenance initially

- the technology of bus maintenance. Modern buses with electronic diagnostic systems take the guess work out of diagnostics for many engine related faults and automatically signal the need for repair. Hence, the marginal benefits are smaller with new technology engines.

- the pre-existing organizational emphasis on fuel economy. If management has already made fuel economy a priority, then the marginal benefits will be smaller.

- the characteristics of the routes in the city. If the city has relatively moderate traffic with smooth traffic flow, the benefits of driver training are reduced relative to a city with dense stop-and-go traffic.

ICF has assessed the benefits based on the initial (January 2011) baseline data received from APSRTC and the post repair fuel economy benefits reported in Chapter 5 of this report. In a typical situation, some buses will be getting worse fuel economy over time as their components deteriorate over time or experience some random failures. Hence, in the first month, the procedures to identify and repair the lowest 10% of buses will not completely eliminate the low fuel economy buses as some other buses would have migrated downwards. Over a period of 12 months, the attention to the lowest 10% of the fleet would cause slow migration of the entire distribution of the fleet to a more fuel efficient distribution as all below average buses would have been checked and repaired at least once over the period. The actual fleet average benefit obtained depends not only on the average benefit obtained by repair but also on the initial distribution of the fleet in fuel economy space. To compute the net benefit, ICF utilized the actual January distributions for two cases. One case was older diesel buses in Bharkatpura certified to Euro 2 standards, and the second case was newer diesel buses with Cummins Euro-2 turbo engines. In the first case, the average benefits from repair were estimated as 7.7% fuel economy improvement per the data supplied, and in the second case, the benefit was estimated as 4.5% which was obtained after elimination of outliers in the data.

Figure 6-1 shows the distribution in fuel economy space of the 65 Euro-2 buses at BKPT for the initial state, and the estimated distribution after one year. As can be seen, the very lowest fuel economy buses (<4.7 km/L) are eliminated but some buses continue to remain at the 4.8km/L level with slightly over 25% of the buses below the baseline average level. Hence, the new average is 5.19 km/L which is a 3.0% improvement for the fleet which had a baseline of 5.04 km/L. In the case of the newer Euro-2 turbo buses as illustrated in Figure 6-2, the initial distribution has fewer very low fuel economy buses at less than 4.7 km/L which partly explains the smaller repair benefit obtained. The new average after one year is 5.34 km/L which is only 2.1% better than the starting average of 5.23 km/L. Although one might simplistically expect that half the fleet would obtain the average repair benefit, the effect of some buses getting worse over time reduces the net fleet-wide benefit to a lower level and only about 40% of the total repair benefit is obtained .

The driver training benefit is similar across all depots at about 7 $\pm$ 1 percent, but the distribution of fuel economy of drivers independent of bus effects is not available. ICF assumed that driver fuel economy is normally distributed and based on the fuel economy of the lowest 10% of drivers, we have calculated the standard deviation is 7.6% of the mean (this implies that 95% of drivers have fuel economy that is within $\pm$ 15.2% of the mean or 2 standard deviations and this

Figure 6-1: Fuel Economy Distributions: Baseline (Pre-repair) and After One Year (Post-repair) for Euro 2 Buses.

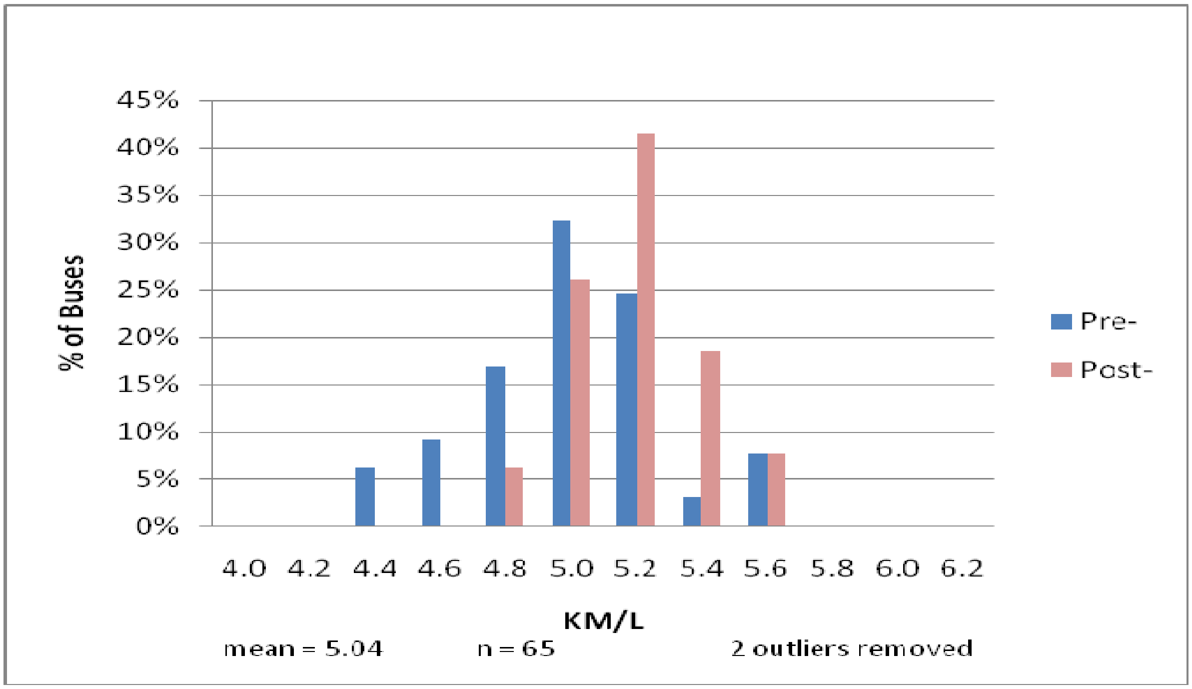
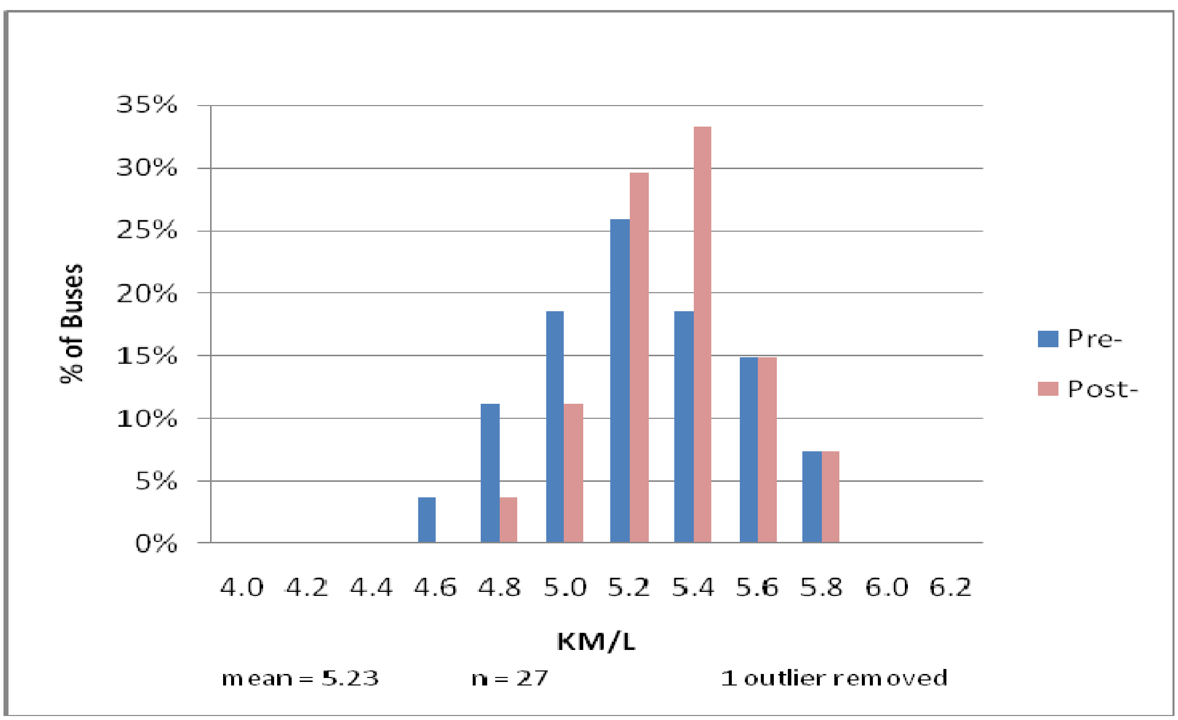


Figure 6-2: Fuel Economy Distributions- Baseline (Pre-repair) and After One Year (Post-repair) for Euro-2 Turbo Engine Powered Buses



appears to be approximately correct for the data obtained. If over the course of a year, the lower 40% of drivers can be trained to improve their fuel economy by 7%, the net fleet wide benefit is estimated at 2.7%. As with the buses the average benefit is smaller than half the retraining benefit since more drivers are clustered towards the middle of the distribution.

Comparisons to Results Cited in Literature

As noted in Section 3 of this report, the city of Edmonton reported results from a driver training program and found that fleet fuel economy had improved 5.5% starting from a no-training baseline, which appears consistent with the 2.7% estimated from the validation starting from a baseline with previous training. Detailed analysis of the benefits of fleet fuel economy focused maintenance program is not available in the public literature but the Ang and Deng study on maintenance effects on buses conducted in Singapore in 1990 indicates the size of the fuel economy benefits from major maintenance to be 3.2%.[10] This is also very consistent with the validation study estimate of 2.1% and 3.0% for older and newer diesel buses respectively More recently, the UNEP reported[11] that nine bus companies in Jakarta participating in an inspection and maintenance program that improved fuel economy by 5% (higher than the estimates from the validation study, but starting from a different baseline) and reduced particulate emissions by up to 30 %.In addition, the Jakarta program reported a 10% fuel economy improvement from a driver training program.

Some inference on the size of the benefit can also be obtained from reported fuel economy across several cities within a region. For example, the city of Hyderabad reports fuel economy for identical bus types to be 10 to 12 percent higher than the values reported by Mumbai and Delhi. Although there are differences in route congestion and weather between these cities, much of the benefit can be attributed to the focused program to improve fuel economy in the state of Andhra Pradesh. In addition, the cities along the North-East Coast of the US also report fuel economy variations for the same bus types in the order of 10% suggesting that some organizations are more focused on fuel economy than others. Due to the many different issues affecting fuel economy, it is difficult to make definitive statements in the absence of a careful controlled study, but the data suggests that the **combination of driver training and organizational focus on fuel economy could provide fuel economy benefits in the 7 to 15 percent range** for organizations where fuel economy has not been a focus.

The record of fuel efficiency in the Andhra Pradesh State Road Transport Corporation[12] (APSRTC) illustrates the benefits of the program over time. APSRTC has incorporated many of the 16 steps described and has had a long standing program to improve efficiency. The 30 year trend in fuel efficiency is noteworthy in that the fuel economy has improved from 4.1 km/L in 1981 to almost 5.3 km/L in 2010. The relative stagnation in fuel efficiency in recent years is partially due to the fact that less fuel efficient new bus technology has been added to the fleet and this includes CNG buses and more powerful air-conditioned buses, which pull down the average. In addition, it is common for most programs to experience the largest gains in the early years when the new procedures are adopted. Comparable buses in Delhi and Mumbai report fuel efficiencies in the 4.2 to 4.5 km/L range.

Emissions benefits must also be estimated since there are few emissions studies of heavy duty buses as a function of maintenance. At the most basic level, if fuel economy is hurt due to increased friction in the drive train (from a slipping clutch to an under-inflated tire), then the engine has to perform more work per unit of travel. Emissions from heavy duty vehicles are regulated in terms of grams of pollutants per unit of work, so that if work increases 10%, fuel consumption and emissions also increase by about 10%. However, engine related defects that cause poor fuel economy will have a much more severe effect on emissions. Tests of in-use engines with defects have shown that a leaky injector can increase hydrocarbon (HC) and particulate (PM) emissions by 100% or more, while the combination of mis-timed injection pump and leaky injectors can increase HC and PM emissions by 300 to 400%. To the extent engine related defects are fixed by this type of program that would otherwise have not been serviced, HC and PM emissions benefits will be larger than the fuel consumption benefit.

6.3 COST AND BENEFIT ANALYSIS

The costs and benefits of instituting the procedures in the guidance note can be calculated for a hypothetical depot with a fleet of 100 buses, and a corporation with 10 depots, as follows. Costs for India were provided by APSRTC. Cost data relevant to the calculation of total costs are summarized below.

Capital cost investments are required for compensating for buses pulled from service, software for data analysis, and for the automation of data collection procedures (which is not essential but preferable). However, data automation allows many other improvements in inventory control and cost control, so this cost cannot be all allocated to improved FE.

Variable costs will be incurred for the time spent by a senior executive to focus attention on fuel economy, time spent by a data analyst on identifying low FE buses and drivers, time spent by mechanics on repairing the buses, time spent by trainers on re-training the drivers and the driver wages during training. Additional costs may be incurred in awards to the most efficient drivers and mechanics. Variable costs of parts and equipment for the repair should **not** be included in the analysis since these repairs would have been done eventually under the normal maintenance system, and the repair of low FE buses represents only a pull-ahead of the repair, not a new cost. In addition, ICF does not recommend that the lost revenue from pulling a bus be accounted for, since pulling a bus also reduces operating costs, and in most urban transport corporations, revenues barely cover operating costs.

The addition of buses in the capital cost calculation allows the comparison on an equal service basis. The benefits are all in fuel savings and a typical urban bus is used for 6000 km per month. In the APSRTC case, fuel economy is around 5 km/L, so that the depot uses 120,000 litres of fuel per month. Each 1% fuel saving depot wide is equivalent to saving 1200 litres of fuel. (At current fuel prices of Rs. 42/L in India, this saves about Rs. 50,400 per month).

Costs include some fixed costs, some variable costs which increase in a step ladder function since buses and mechanics need to be added in integer units, and some purely variable costs. In the 100 bus depot case, the GN recommends maintenance on the 10% of the fleet with the lowest FE, implying the 10 buses will be pulled from service for 1 to 2 days per month. The total service of 100 buses per month is 3000 bus-days (100 x 30), and the lost days account for at most, 15 to 20 bus days which is 0.50% to 0.60%. Hence, the total fleet size needs to increase by 1 bus for every 160 buses in the fleet and smaller bus fleets will have some scale inefficiency due to the need to have one extra bus . In the APSRTC case, non air-conditioned city buses cost Rs. 2.7 to 3.0 million, depending on the engine and size and have a life of about 15 years (180 months) so that the monthly straight-line depreciation charge is Rs. 16,000 approximately. For a 100 bus fleet at a depot, one extra spare bus is needed so that the monthly depreciation charge is the charge for 1 bus. The capital cost of software and hardware are quite small (Rs. 60,000 each) and if depreciated over 4 years, the monthly charge is in the Rs. 2500 range total. Since data automation is not being done at this time, it is not relevant for APSRTC.

The cost of labor in India is low and table 6-2 lists the input costs for all personnel. Table 6-3 shows the details of the benefits and costs computations for four different fleet sizes from 50 to 200 buses to illustrate the step function changes in some costs. Based on that data, total applicable labor costs are Rs. 106,000 per month for the 100 bus case. It should be noted that even with low labor costs in India, labor costs are by far the largest component of costs. Hence, the total cost including the amortized capital cost is in the range of Rs.124,500 per month per depot with 100 buses. However, savings are also large and the program breaks even if a 2.5 percent improvement in fuel economy is realized. As noted, anticipated improvements are about 3.0% from

Table 6-2 Cost Data Summary

STEP	COST TYPE	NOTES
1) Appoint Senior Executive	Cost of Senior Executive time towards FE program	One Senior Executive for 10 depots. Burden per depot is Rs.8000/-
2) Benchmark and Set goals	Cost of annual exercise to set FE targets by bus type	One person with a PC and suitable software is sufficient to meet the requirements of steps (2), (3), (4), (5) & (6). Monthly salary of supervisory staff is around Rs.30,000/-
3) Communicate results to employee	Cost of preparing weekly driver FE data and posting at each depot	See above
4) Automate data collection	First cost of data collection hardware and software	Not applicable for short term
5) Set up data QA/QC procedures	Cost to incorporate data QA/QC into software and cost of cleaning data	See above
6) Analyze data to identify low FE buses and drivers	Cost of data analysis	One time investment of Rs.100,000 on Hardware & software is to be spent.
7) Use data to refine maintenance procedures	Cost of annual or biennial program to identify key components requiring extra maintenance	One exclusive Mechanic for 100 buses is to be provided to carry out item (7) & (8). In a month, about 10 buses out of total 100 will be diagnosed and attended by him. Monthly salary is Rs.40,000/- including the salary of one assistant.
8) Diagnose and repair the lowest FE buses	Average cost of mechanics time per low FE bus (Note - cost of parts not included)	
9) Repair quality check **	Random audit by chief mechanic at depot	The Chief Mechanic/In-charge Supervisor acting as Shift In-charge can also be made responsible for random checking of the repair quality. Hence, no additional cost is incurred.
10) Obtain mechanic sign-off on repairs	Trace - back of repairs	No cost, because the Mechanic entrusted with repairs has to certify the works.
11) Independent audit across depots**	Cost of team to review and standardize repairs across depots	Two persons for 10 depots incurring cost of Rs.50,000/- i.e., Rs.5,000/ depot per month.
12) Retrain mechanics periodically**	Cost of training mechanics	Expenditure on each mechanic and assistant in a year on refreshing is Rs.3000/- including cost of training school.
13/14) Train drivers in fuel efficient driving techniques	Cost of driver training program	About 20 drivers will be trained for low Fuel efficiency in every month. One day salary and other expenditure on training one driver is Rs.1500/- which includes the salary of the trainer.

15) Display fuel economy results publicity	Cost of disseminating annual information on fuel economy performance of fleet	Negligible cost
16) Reward drivers and mechanics	Cost of monthly award to best driver and annual award to mechanics	About 30 rewards/awards should be given at each depot to driver/mechanic in a year for their contribution to positive results spending Rs.1000/- per reward i.e., total Rs.30,000/- per depot in a year.

Table 6-2: Cost Data Summary (continued)

maintenance of older buses, or 2.1 percent from maintenance of newer buses and 2.7 percent from driver training for a total of 4.8 to 5.7 percent, resulting in savings of Rs. 241,920 to Rs. 287,280. **Hence the benefit to cost ratio is 1.94 for newer buses and 2.31 for older buses for the reference 100 bus case.** This estimate is for the APSRTC which is already focused on fuel economy, and ICF estimates the benefit would be typically higher at other locations where the baseline is lower. However, at much higher labor costs then costs in India and similar fuel costs, the program may not be attractive from a cost benefit standpoint. The benefit to cost ratio improves with more buses in the fleet due to scale economies with fixed costs.

The benefit to cost ratio becomes smaller as the number of buses at a depot decreases, due to the fixed costs of a spare bus and a specialized mechanic and helper for fuel economy related repairs. As shown in Table 6-3, the analysis indicates that the program is near break-even (i.e., a benefit to cost ratio close to 1) when the number of buses at a depot is around 50. Since these costs are computed for India, where labor costs are quite low, and minor cost elements not included in the computation, the analysis suggests that the program be implemented when the minimum number of buses exceeds 70 to 100, depending on local labor cost and fuel cost, to ensure a strongly favorable benefit to cost ratio.

NUMBER OF BUSES		50	100	150	200
FIXED COSTS					
SENIOR EXECUTIVE		8000	8000	8000	8000
DATA ANALYST		30000	30000	30000	30000
COMPUTER / SOFTWARE		2500	2500	2500	2500
PERIODIC AUDIT		5000	5000	5000	5000
STEP VARIABLE COST					
SPECIAL MECHANIC/ HELPER		30000	30000	60000	60000
AMORTIZATION - SPARE BUS		16000	16000	16000	32000
MECHANIC RETRAINING		3000	3000	6000	6000
VARIABLE COST					
DRIVER TRAINING		15000	30000	45000	60000
TOTAL COST		109500	124500	172500	203500
FUEL SAVED NEWER BUSES LITRES		2880	5760	8640	11520
BENEFIT -NEWER BUSES		120960	241920	362880	483840
BENEFIT/COST RATIO NEWER BUSES		**1.10**	**1.94**	**2.10**	**2.38**
FUEL SAVED OLDER BUSES		3420	6840	10260	13680
BENEFIT - OLDER BUSES		143640	287280	430920	574560
BENEFIT COST RATIO OLDER BUSES		**1.31**	**2.31**	**2.50**	**2.82**

Table 6-3: Cost and benefit as a function of fleet size

ANNEX 1

FINDINGS FROM THE LITERATURE REVIEW AND FIELD STAFF INTERVIEWS

A1.1 LITERATURE REVIEW

Table A1- 1 lists the 25 papers and reports reviewed that dealt with bus maintenance to illustrate the breadth of the search, but only some of these were useful to the study and those reports from which information relevant to this report was obtained are identified in section A.1.2.

A1.1 Energy Efficiency Strategies

The Pew Center for Global Climate Change[13] developed an analysis of leading edge strategies that has summarized the core elements into "seven habits" common across a wide variety of industries. The Seven Habits are company-wide principles, cutting across internal operations, supply chains, and products and services. The Seven Habits framework are borne out in the Pew Center's survey results and case studies, and they have also come to light in earlier work, notably the U.S. EPA's ENERGY STAR program, in which a set of similar energy management guidelines were developed by the Global Business Network and published in a report[14]. The Superior Energy Performance program developed at the U.S. Department of Energy and envisioned as a self-governing organization, follows similar conceptual principles and is part of a wider effort to develop an organization level energy management standard (ISO 50001) over the next few years. The following sub-sections summarize and quote from the key findings in the Pew report (with permission from Pew).

1. EFFICIENCY IS A CORE STRATEGY

For companies with leading strategies, energy efficiency is an integral part of corporate strategic planning and risk assessment. It is not treated like just another cost management issue, but is part of an ethos and a corporate culture in which energy efficiency is essential. The companies profiled as case studies in the Pew report (Dow, IBM, UTC, Toyota, PepsiCo, and Best Buy) all show these characteristics.

2. LEADERSHIP AND ORGANIZATION SUPPORT IS REAL AND SUSTAINED

When energy efficiency is a core part of the organization, its leaders understand the details. When a CEO of UTC or of Dow (see Annex 1) talks about energy, leadership commitment to efficiency shows up in many forms, in multiple media, and such communications are frequent and

Table A1-1: LIST OF LITERATURE REVIEWED

1.Akbarov, A., & Wang, W. (2008). *Problem identification in maintenance modelling: a case study*. International Journal of Production Research , 103 -1046.

2. Ang, B. W., & Deng, C. C. (1990). *The effects of maintenance on the fuel efficiency of public buses*. Journal of Energy , 1099-1105.

3. Barbera, F., Schneider, H., & Kelle, P. (1996). *A Condition Based Maintenance Model with Exponential Failures and Fixed Inspection Intervals*. The Journal of the Operational Research Society , 1037-1045.

4. Bardi, E. J., & Tracey, M. (1993). *Transportation Maintenance Outsourcing: A Survey of US Practices.* Journal of Physical Distribution & Logistics Management , 15-21.

5. Beruvides, M. G., Simonton, J. L., Waters, N. M., Ng, E., Chaivichitmalakul, S., Chiu-Wei, C.-C., et al. (2009). *The Concept of a Regional Maintenance Center*. Journal of Public Transportation , 105-118.

6. Bivona, E., & Montemaggiore, G. B. (2010). *Understanding short- and long-term implications of "myopic" fleet maintenance policies: a system dynamics application to a city bus company.* System Dynamics Review , 195-215.

7. Chamberlain, E. S., & Di Bello, L. A. (1997). *Iterative Design and Implementation: A Model of Successful Scheduled Maintenance Technology Deployment.* Transportation Research Record: Journal of the Transportation Research Board , 42-49.

8. Clark, N. N., Zhen, F., Wayne, W. S., & Lyons, D. W. (2007). *Transit Bus Life Cycle Cost and 2007 Emissions Estimation.* Washington, D.C.: Federal Transit Administration.

9. Desa, M. I., & Christer, A. H. (2001). Modelling in the Absence of Data: A Case Study of Fleet Maintenance in a Developing Country. *The Journal of the Operational Research Society* , 247-260.

10. Dutta, H., Maze, T. H., & Cook, A. R. (1986). *Performance of Bus Transit Maintenance (Discussion and Closure*). Transportation Research Record , 46-59.

11. Finegold, D., Robbins, M., & Galway, L. (1998). *Closing the Knowledge Gap for Transit Maintenance Employees: A Systems Approach.* Washington, D.C.: National Academy Press.

12. Finley, Bruce, A *Three Year Comparison of Natural Gas and Diesel Transit Buses,* SAE paper no. 1999-01-3738, November 1999

13. Goyal, S. K., & Gunasekaran, A. (1992). *Determining economic maintenance frequency of a transport fleet*. International Journal of Systems Science , 655-659.

14. Haghani, A., & Shafahi, Y. (2002). *Bus maintenance systems and maintenance scheduling: model formulations and solutions.* Transportation Research Part A: Policy and Practice , 453-482.

Table A1-1 (Continued)

15. Huang, J.-Y., & Yao, M.-J. (2008). *On the coordination of maintenance scheduling for transportation fleets of many branches of a logistic service provider.* Computers & Mathematics with Applications , 1303-1313.

16. G. Ivanovic, et al., *The Fix-it Subsytem of Motor Vehicle Maintenance Information Systems,* SAE paper 2001-01-3196, October 2001

17. Kiernan, V. (1998). *Internet Information Sharing for Transit Maintenance.* Washington, D.C.: Transportation Research Board.

18. Márquez, A. C., & Herguedas, A. S. (2004). *Learning about failure root causes through maintenance records analysis.* Journal of Quality in Maintenance Engineering , 254-262.

19. Schiavone, J. (2005). *A Guidebook for Developing and Sharing Transit Bus Maintenance Practices.* Washington, D.C.: Transportation Research Board.

20. Schiavone, J. (1997). *Monitoring Bus Maintenance Performance.* Washington, D.C.: National Academy Press.

21. Shum, Y.-S., & Gong, D.-C. (2006). *The application of genetic algorithm in the development of preventive maintenance analytic model.* The International Journal of Advanced Manufacturing Technology , 169-183.

22. Simoes, A., Farinha, T., Fonseca, I., Barbosa, F. M., & Marques, V. (2009*). Buses Degradation Based on Exploration Conditions*. Proceedings of the 3rd WSEAS Int. Conf. on Energy Planning, Energy Saving, Environmental Education , 141-149.

23. U.S. DOT Federal Transit Administration. (2008). *Transit State of Good Repair: Beginning the Dialogue.* Washington, D.C.: Department of Transportation.

24. Venezia, F. W. (2004). *Maintenance Productivity Practices: A Synthesis of Transit Practice.* Washington, D.C.: Transportation Research Board.

25. Zanini, M., et al., *Mobile Assets Monitoring for Fleet Maintenance*, SAE Paper no. 2005-01-1436, April 2005

prominent, inside the company and out. More specific aspects of leadership commitment and organizational support include:

- **At least one full-time staff person is accountable for energy performance.** 60 percent of the Pew Center survey respondents reported having full time energy managers.
- **Corporate energy management leadership interacts with teams in all business units.** Today's best efficiency strategies build an energy management organization that looks across divisions.
- **Energy performance results affect individuals' performance reviews and career advancement paths.** Today, energy performance is a review factor in most leading companies for both facility and plant managers (87 percent of survey respondents) and officer-level management (more than half of survey respondents).
- **Energy efficiency is part of the company's culture and core operations.** In leading companies, the energy issue is owned by whole teams and/or whole departments and does not fade away when champions move on to other causes.
- **Employees are empowered and rewarded for energy innovation.** Sustaining an energy efficiency strategy requires rewarding people as individuals and as teams on a consistent basis over time. Leading companies are finding that the most effective ways of rewarding people may not involve money. Instead, validating ideas, acting on recommendations, and funding projects motivates people by recognizing their contribution to the company's sustainability goals.

3. THE COMPANY HAS SMART ENERGY EFFICIENCY GOALS

SMART is a well-known acronym for Specific, Measurable, Accountable, Realistic, and Time-bound, and has been used in mission and goal-setting exercises for years. The Pew Center report makes the SMART concept specific and unique to energy efficiency strategies as follows:

Goals are organization-wide. Today's best efficiency strategies engage most facilities, plants, and organizational units, instead of focusing on specific plants, facilities, or processes.

Goals are also translated into operating/business unit goals. Effective strategies need to be set at the operating unit level as well as corporation-wide.

Goals are specific enough to be measured. Effective efficiency strategies set goals with numbers and metrics that enable independent parties to verify whether the company met its targets.

Goals have specific target dates. Without a timeframe, there is no way to gauge how much effort or investment is needed, nor much urgency to prioritize energy efficiency compared to other needs. Respondents to the Pew Center survey averaged an eight-year timeframe from the base year to the year in which the target was to be met.

Goals are linked to action plans in all business units. Effective strategies back up goals with action plans; they do facility assessments to identify the best efficiency opportunities, develop technical assistance networks, develop best-practice checklists, and make solutions accessible across the organization via web-based information, active peer networks, and other means.

Goals are updated and strengthened over time. The leading companies have been at their efficiency strategies long enough to show that a successful strategy reveals additional efficiency potential, leading to a reassessment point at which goals are renewed and typically increased.

4. THE STRATEGY RELIES ON A ROBUST TRACKING AND PERFORMANCE MEASUREMENT SYSTEM

The adage that "you can only manage what you measure" applies to energy efficiency strategies as much as any critical cost factor or performance indicator. What makes an energy tracking and performance measurement system challenging in larger organizations is that energy use tends to be both *pervasive* and *indirect*, in that it is consumed in virtually every part of every facility; it is indirect in that except for certain manufacturing processes, energy plays a supporting role to enable the company to run its business.

The first job of an effective energy tracking and performance system is to collect the energy data, reconnect it in a timely manner to the people that actually use the energy, and give those people metrics they can use to understand their performance. The Pew report identified the following key characteristics of world class energy tracking and performance measurement systems:

- **The system collects data regularly from all business units.**
- **The data is normalized and base-lined,** to turn raw data into performance metrics, using one or more factors the organization considers critical to its overall performance.
- **Data collection and reporting is as "granular" as possible.** The challenge for energy managers is to develop as much specificity in the reporting system as is feasible.
- **The system includes feedback mechanisms that support corrective action.** In the companies studied by Pew, senior management sees tracking reports monthly or quarterly and communicates with lagging facility or plant staff to seek ways to get them back on track. In these programs, leaders not only see performance information, but have practical channels to act on it. In addition, facility-level staff is supported by project data or operating checklist guidance they can tap to improve their unit's performance.

- **Performance data is effectively visible to senior management.** Senior management has to see energy performance data regularly and in a form they can understand and act on. Many companies do not lack data as much as information tools that raise the quality of key data into useful form.
- **Energy performance data is broadly shared internally and externally.** Today, modern IT combined with public corporate commitments drives a broader and more accessible energy information platform. For proprietary reasons, not all data is fully transparent, but most systems post data for external viewing on an aggregated, company-wide basis.
- **The system is linked to a commitment to continuous improvement.** The best energy management programs go beyond a compliance approach and tap into a broader cultural ethic of continuous improvement, using the energy reporting system as a tool to empower people to find new efficiencies and associated innovations.

5. THE ORGANIZATION PUTS SUBSTANTIAL AND SUSTAINED RESOURCES INTO EFFICIENCY

Any effective effort in an organization requires resources—people, capital, systems, etc. Energy efficiency is no different. The leading companies in this field, however, have not necessarily relied primarily on capital investments to drive energy efficiency results, but have obtained substantial savings through operational practice changes and moderate-cost technologies. Companies studied for the Pew project primarily shifted priorities to include energy. The most frequent response to the survey question about how companies obtained resources for their programs was “reassignment of existing staff.”

Based on the survey results and case study interviews, three broad observations can be made about the way leading companies funnel resources to efficiency programs.

The energy manager/team has adequate operating resources. Corporate energy managers are not necessarily given blank checks to hire people or draw personnel from other business units, but they are given the resources needed to set up and maintain tracking and performance measurement systems, do facility assessments, hold meetings, and educate staff. In most cases, these resources were provided in-kind within the organization, helped by the fact that senior management had committed to the program.

Business leaders find capital to fund projects. While finding additional capital is always difficult, the leading companies could all point to a significant list of projects that had been implemented through the efficiency program. This suggests that expectations should be calibrated along the following lines: “there is never enough money for projects, but we are seeing more investment and getting more results than we used to.” Particularly in the recent deep recession, capital budgets have been trimmed, yet some energy efficiency projects move forward. This is an area in which relative shifts in priorities matter more than absolute dollars from year to year.

Companies invest in human capital. The ascendancy of human capital—people—over technological capital is a recurrent theme in the Pew study. The best companies do not just invest in hardware—they invest in their people through formal education, or provide training and education internally, like PepsiCo’s Sustainability Summit that brought over 400 people together for four days.

6. THE ENERGY EFFICIENCY STRATEGY SHOWS DEMONSTRATED RESULTS

A winning strategy has to show winning results. The companies in this study not only conceived and launched their strategies, they followed through with operational changes and capital projects, and captured the results through their energy performance measurement systems. The key features of leading programs in this respect include:

The company met or beat its energy performance goal. Leading companies in this study set goals of varying aggressiveness and with different time horizons, with many meeting or exceeding these goals, or at least making significant progress if the target year is still in the future.

Successful energy innovators are rewarded and recognized. The program’s success needs to be mirrored in recognized achievements of individuals and teams. For an effective company-wide program, this should be people on the corporate energy team, and in the operating units. This encourages their peers to pick up the ball, and ingrains the program across the corporate culture.

Resources are sustained over a multi-year period. The annals of industrial psychology show that many new work practices or technology innovations can create performance improvements—temporarily. The hard part is sustaining success and institutionalizing change. The best companies in this study had not only set up their programs and met their initial targets, but were expanding their goals as the program’s innovation wave produced new savings opportunities.

7. THE COMPANY COMMUNICATES ENERGY EFFICIENCY RESULTS

The best companies in this field do make energy efficiency a living part of their story and place efficiency successes prominently in both internal and external communications. Energy efficiency becomes a part of the story the company tells about itself, part of its identity and culture. Key features of leading companies’ efficiency strategies include:

An internal communications plan raises awareness and engages employees. There is no lack of creativity in companies' internal communications efforts. Internal newsletters are quite common, and energy efficiency success stories get prominent play on a regular basis. Toyota Motor Manufacturing Kentucky's (TMMK) NASCAR "Race for the Greenest" combines internal communications with friendly competition, hard-number results, and an element of fun.(see annex 2 for a summary of this case study)

Successes are communicated externally. Companies with world-class energy efficiency strategies tell their stories externally in prominent ways. Efficiency goals and successes show up in annual reports as well as public sustainability reports. Companies whose products and services include efficiency-related features make efficiency part of their paid media campaigns.

The Seven Habits described in this section form the core of a successful energy efficiency strategy. They are primarily organization-wide principles and practices, though many can also be applied at the individual facility level. An effective strategy, however, does not stop at simply embracing these principles. It must go deeper into the nuts and- bolts details of the management systems, the technology analyses, and the other resources needed to support an ambitious effort. And it must be sustained over time—not just years but ultimately over decades. Box 3.1 summarizes the key points of the Seven Habits.

A1.1.2 Reports Directly Related to Bus Maintenance

Of the reports listed in Annex 1, the reports that have been published through the Transit Cooperative Research Program in the US were found to be most useful as they bring together many aspects of maintenance practices to develop a maintenance strategy and identify best practices. The Program is sponsored by the US Federal Transit Administration (US FTA) and the research is coordinated by the US National Academy of Sciences' Transportation Research Board (TRB). A comprehensive review of literature in Table 3-1 showed the following reports to be good summaries of the state of the art:

- Transit State of Good Repair[15]
- Maintenance Productivity Practices[16]
- Guidebook for Developing and Sharing Bus Maintenance Practices[17]
- Preventive Maintenance Intervals for Transit Buses[18]

Of course, many of the same topics are covered in more than one report and the section below provides a summary of the major points on good maintenance practices derived from a review of the reports. However, a key point to be noted is that <u>none of the literature with one exception, provided any specific focus on reducing fuel consumption</u>, while all of the actions are focused on reducing breakdowns and providing good drivability. The specific exception is the paper by Ang and Deng[19] where the authors measured the fuel efficiency of buses before and after maintenance, and is discussed in the following paragraph. The four reports listed above are the major sources of information for the following summary on best maintenance practices. The key findings in these publications are reported below.

The Ang and Deng report (Ref. 19) studied the effects of both major maintenance and minor maintenance on fuel economy, where they defined major maintenance as the manufacturer recommended service requirement every 30,000 km while minor maintenance was defined as the 5000 km minor service done at depots. The analysis tracked the daily fuel economy of 24 buses over 3 months. The data showed that the effect of minor maintenance on fuel economy was not statistically significant, but major maintenance was found to increase fuel economy on average by 3.2%. Corrective maintenance (i.e., correcting part failures) had larger but more variable impacts but occurred too infrequently in the sample to provide statistically significant results. Another significant finding was that the effects of maintenance decline with mileage accumulation after major service, so that after about 10,000 km the benefits of major maintenance have been largely lost, as shown in Figure A1-1 taken from reference 19.

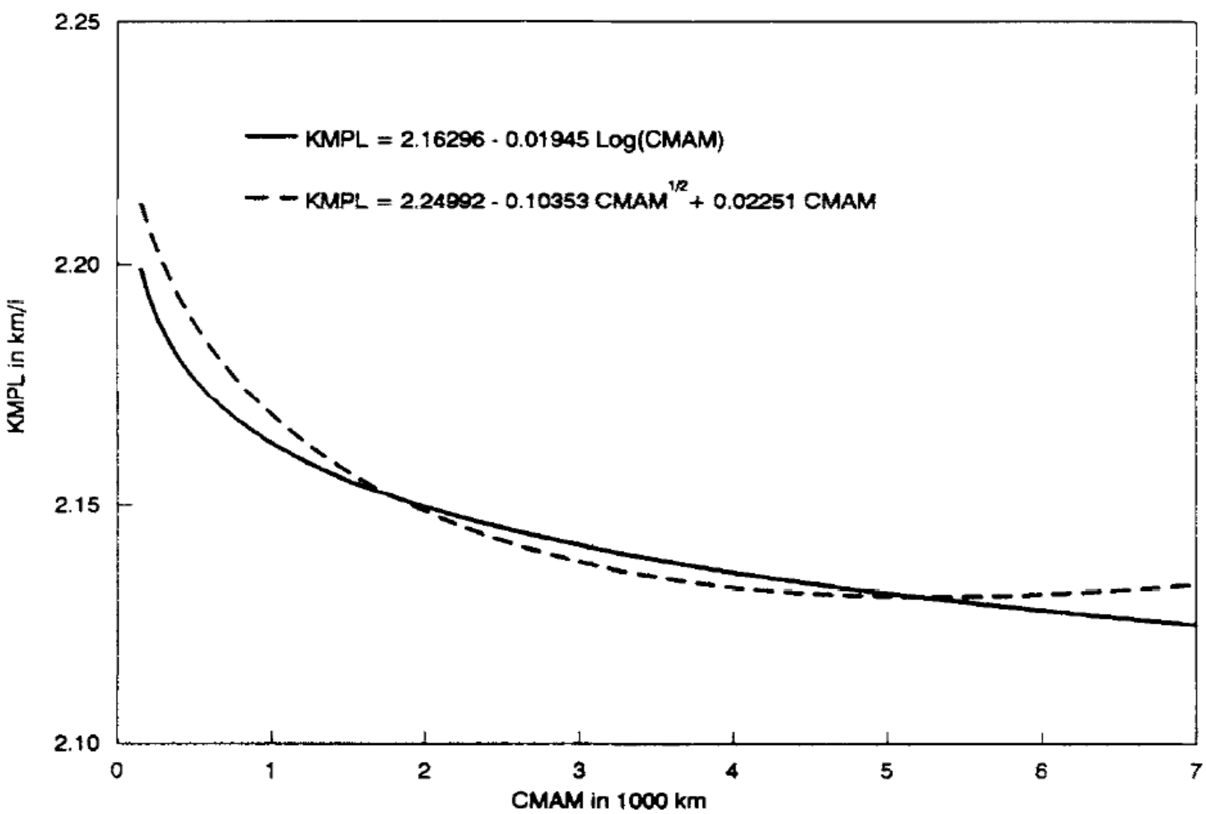


Figure A1-1: Effect of Cumulative Mileage After Maintenance (CMAM) on Bus Fuel Economy

Maintenance practices are written instructions for carrying out specific job tasks and a variety of terms are used to describe these instructions, such as process sheets, recommended practices (RP), standard operating procedures (SOP), work standards, and others. Without these instructions, workers can approach jobs in a manner that may not be efficient, comprehensive, safe, or in keeping with the agency's expectations for overall work quality. Understanding that agencies have dissimilar resources and needs, most guidebooks must be designed to offer flexibility in selecting an approach that works best for each maintenance operation.

Need for Practices

Due to the deteriorating financial condition of transit agencies, they are finding it increasingly difficult to send maintenance personnel to meetings where they can make contacts and exchange information on a variety of technical subjects. This lack of communication opportunity comes at a time when bus technology is becoming increasingly complex, workers are required to do more with less, and employee turnover is more prevalent. Budget cuts have also forced some agencies to abandon apprenticeship programs that pass down valuable knowledge from senior mechanics to new hires. As a result, guidebooks should tap into that knowledge to:

1. Get agencies to understand the benefits and importance of using maintenance practices;
2. Provide agencies with the guidance needed to write practices based on their own needs, abilities, climate, and shop conditions;
3. Make the guidance easy to understand and apply; and
4. Build a library of practices that agencies can share with their peers.

Specific Benefits to Bus Transit

Many transit agencies already understand the benefits of using practices. In a survey of 62 agencies conducted by the US FTA, over 56 percent reported that they use maintenance practices. The primary benefit to workers is that practices provide a clear set of instructions on how to accomplish specific maintenance tasks that can be referred to over time. The instructions impart the agency's collective wisdom based on its own experiences and the knowledge gained from others. As new information becomes available, practices can be updated to reflect optimal methods for repair.

For new hires and seasoned workers alike, practices serve as a convenient refresher to ensure that all job procedures have been correctly followed. Practices can also provide workers with other essential information, such as safety procedures, replacement parts and tools needed for the job, a glossary of terms to promote universal understanding, and proper disposal and handling of any hazardous materials generated from the job.

The primary benefit to management is that practices help ensure consistency between jobs regardless of who performs the work. Practices can also include a standard repair time (SRT), allowing management to monitor worker performance, schedule work, determine staffing levels, and estimate job costs. The costing information could be used for budgeting purposes and to determine if outsourcing certain jobs is more cost effective. Written practices are also useful to management in that they can easily become part of the agency's training curriculum. Several agencies with in-house training programs use their practices as teaching aids. For those without training programs who hire qualified technicians or rely on outside training, written practices take on even greater importance because they provide uniform work instructions to employees regardless of how and where they were taught. And for those who monitor worker performance, practices are absolutely essential in that they serve as a "common denominator," where all workers are measured against the same set of work instructions and expectations.

Determining the Need for Specific Practices

Written practices may **not** be needed for all maintenance tasks, but Preventive Maintenance Inspections are certainly a good place to start because they are central to every good maintenance operation. Additionally, having detailed PMI practices for each vehicle type and key components is required by government transit oversight agencies in most developed countries. In the USA, for example, the FTA has a Triennial Review of all urban transit operators with very specific requirements. FTA requires fleets to show proof that they have a documented maintenance plan for federally funded buses and facilities, and the requirements include:

- A maintenance plan that is current for vehicles and facilities
- PMI checklists consistent with the current operating fleet and with the manufacturer's minimum maintenance requirement for vehicles under warranty
- Specific maintenance procedures for wheelchair lifts and other accessibility equipment
- Proof that the grantee's maintenance plan and PMI activities ensure that assets are protected from deterioration and reach their maximum useful life
- A record-keeping system that permanently records the maintenance history of facilities and equipment
- A schedule for facility/equipment PMI.

To help prioritize the need for maintenance practices, a set of questions for US operators have been developed by the FTA. The questions are:

1. Are there regulatory requirements that would be better served by having documented practices in place?
2. Is there a need to document compliance with any specific requirement?
3. Are there excessive shop comebacks and/or road calls that result from improper repair or inspection activities?
4. Is there a lack of consistency in performing certain inspections or repairs from one mechanic to another, or from one maintenance facility to another (e.g., those with different lifts, layout, and equipment)?
5. Are the tasks on a particular job transferred to another mechanic on a different work shift (i.e., where the second mechanic would need to know where the first left off)?
6. Is there a risk of warranty loss due to improper maintenance in specific areas?
7. Would there be a benefit in establishing time standards and monitoring compliances with those standards for specific repairs or inspections?
8. Would there be a benefit in documenting the need for special tools, safety precautions, or the handling of hazardous waste for specific inspections or repairs?
9. Would there be a benefit in identifying in advance all of the parts (individual or kits) needed to perform a specific maintenance job?
10. Would instructions in another language improve the quality of inspections/ repairs?
11. Would there be a benefit in identifying the total cost (i.e., parts and labor) for specific maintenance jobs?
12. Would there be a benefit in ensuring consistency between classroom training and the way maintenance jobs are carried out in the shop?

The issues raised in these questions can all be addressed by maintenance practices. A logical approach would be to first develop or improve practices pertaining to PMI and then move on to specific areas that generate the most road calls, repeat failures, and other unscheduled maintenance activities.

Developing Maintenance Practices

Existing agency practices can be a valuable source for reference material because they were developed by agencies that operate similar equipment. Bus and major component manufacturers support their products through a variety of maintenance- and repair related materials, which serve as the foundation for developing agency-specific maintenance practices for two important reasons. In a perfect world, bus manufacturers would supply manuals that could be used "as is" to guide agencies through repair and maintenance tasks. According to the research in these reports cited, the reality is that tailoring repair and maintenance procedures to match the actual vehicle produced and specific agency conditions is the exception, not the rule. Larger agencies typically have more success in getting OEMs to tailor their maintenance materials, while those with fewer resources must make due with available materials. An inherent problem with producing "tailor made" procedures is that so many of the components used in buses are produced by a variety of vendors, making it difficult to accurately reflect the specific vehicle produced for a given agency. Another problem is that bus manufacturers often supplement their own procedures with material produced by component suppliers. As a result, a "gap" often exists where the bus manufacturer–developed procedures leave off and the component-specific procedures begin. In other cases, bus OEMs simply use a single procedure to describe similar components supplied by many vendors, and this procedure may not reflect the actual component installed.

Tailoring Practices to Local Conditions

A survey was conducted on the US Transit Agencies regarding the need to tailor maintenance practices as a result of certain local conditions.   The most important local condition noted by agencies responding was severe weather. Included in this category were severe heat, cold, dust, and road salt. Transit agencies and equipment OEMs were contacted for their insights into special steps taken to address unique local conditions.

Two primary conclusions were identified from this research to tailor maintenance to local conditions. First, most transit systems are so focused on their own maintenance work that they do not view any of their procedures as being "unique." For example, if they only have pits in their shop, they have adapted all their maintenance procedures around this shop condition. The second conclusion is that weather-related conditions are virtually the only conditions for which special maintenance practices have been developed. Bus age is a factor due to the changing engine and emissions technology.

Suggestions for specific weather-related maintenance practices include the following:

Cold weather suggestions:

- When road salt is used, steam clean the bus undercarriage before each PMI.
- New de-icing salt solutions can cause premature corrosion of transmission filters, electrical components, and other exposed bus components.
- Include an undercarriage wash and a high-pressure wheel wash during daily service line inspections.

• Check air dryers more frequently for moisture content.

• Conduct wheelchair lift PMIs more frequently to remove road salt and add lubrication.

• Check auxiliary engine heaters.

• Sandblast and recoat the bus chassis as part of a mid-life program.

Warm weather suggestions:

• Conduct an extensive air conditioning PMI in preparation for summer.

• Clean out radiators monthly with a suitable solvent, and flush with water to prevent overheating.

• Tighten hose clamps during each PMI, and use clamps that apply a constant torque.

• Check air system integrity.

• Use special bearing lubricants.

Miscellaneous seasonal suggestions:

• Blow out radiators with air pressure to remove tree leaves in autumn months.

• Blow out radiators with air pressure to remove build up of seeds and leaves from trees.

• Add a wire mesh screen over the radiator door to catch leaves. Clean the wire mesh screen often to prevent clogging of the radiator.

• Flush brakes with clean fresh water after significant rain to remove abrasive debris carried into the brakes by the rain.

These types of actions are more local in nature, but many transit agencies have found it important to establish these additional PMI steps in reducing mean time between failures.

Maintenance Intervals

For component specific maintenance, there are four ways to establish the maintenance interval:

- Condition based maintenance based on physical observation
- Fixed Mileage maintenance, typically used by manufacturers to establish many common inspections and replacements
- Operate to Failure, where all maintenance actions are only after failure. This is often used for non-critical components.
- Design Out, where the entire assembly design is changed. This is often used during the bus replacement cycle.

Many transit agencies use fixed mileage maintenance for most systems, while condition based maintenance is used for long cycle replacement parts like brake linings. Operate to failure and

Design-out are much more rare and used for parts where failure is very infrequent and the part is typically expected to last the life of the buses.

The essential elements of setting maintenance type and interval is to first establish a foundation PMI system as described in the previous sections and then to monitor and benchmark both scheduled and unscheduled maintenance. Once the foundation PMI system has been benchmarked in terms of service interruptions or poor performance related to driver complaint, the modifications can be made. The modifications can be to address local conditions as described above and also to address bus model specific weaknesses – for example, some models are known to be more prone to overheating in summer, while some specific transmissions may be the source of gearshift failures.

The modified PMI program must then be benchmarked against the foundation program to prove that the modifications have provided positive value in reducing breakdowns and maintenance costs. An **essential element of this process is a quality assurance** (QA) program that ensures that staff is following procedures and that the PMI and associated repairs are being correctly performed. A **second essential element is data acquisition and analysis** since all of the benchmarking relies on accurate data and good analysis of the data to recognize underlying system problems.

A1.1.3 New Technology, Data Acquisition and Analysis

There are a number of commercially software programs that can be adopted by fleets of almost any size, and will operate on common PC operating systems. Typical commercially available systems like Fleetmate, Fleet Maintenance Pro and TATEMS provide tracking of the status of all vehicles in the fleet and automatically signal when a particular vehicle should be serviced, while providing a printout to the mechanic on the items requiring service. The systems track vehicle history to monitor trends in wear, breakdowns and abuse of each vehicle and signal which vehicles need special maintenance or should be scrapped. More details of automated software systems for maintenance are provided in Annex 5. Maintenance Management Systems technologies[20] include the following:

- electronic inspection aids
- fluids management systems
- spare parts inventory management
- interactive mechanics training
- remote vehicle diagnostics

- maintenance records management
- warranty monitoring
- vehicle health monitoring

All of these systems rely on data inputs from the field and the traditional method of data entry by the bus operator and mechanic are often error prone and incomplete. The newest trend in the developed world is the complete automation of data acquisition systems[21]. The Smart Garage system (used widely in Europe) is activated when a bus approaches the garage door. Based on sensor inputs, the bus number is automatically recognized and directed to a specific parking stall. The bus operator then connects the bus to a smart plug at the stall which can download information on engine condition, odometer reading, fuel consumption, etc. New fuel pumps automatically transfer information to the system on the number of gallons dispensed into each fuel tank.

Most modern engines feature electronic engine control systems and the control unit is usually equipped with on-board diagnostics. Hence, the driver is provided with a failure mode indication, while the mechanic is informed on exactly what system has failed, removing troubleshooting expertise as a necessary skill except in specific instances where the computer diagnostics are not verifiable. In addition, the smart plug also obtains failure mode data, except when the breakdown happens in the field and the bus has to be towed back to the shop or fixed on the road. Many agencies are careful to record such data as well by manual input since engine breakdowns on the road happen rarely. (Most on road break down is associated with tire failure or accidents).

Operators using fleet maintenance software systems have reported significant benefits in operational reliability, fuel savings and reduced oil consumption. Fuel savings of 10 to 15 percent have been reported by some users whose software includes driver and mechanic accountability systems. Many use fleet position tracking software through GPS based systems for routing, scheduling and route optimization, although this is more for delivery trucks than for buses whose routes and schedules are generally fixed.

In Germany, several transit organizations are using radio transponders on buses to improve the ability to obtain real time information on bus duty cycle, breakdowns and other malfunctions, as well as to be able to track bus location and provide information to passengers on bus arrival time. Radio Frequency Identification (RFID) is a relatively simple, low cost technology where a tag with a chip stores the bus number and the chip transmits a stored number to reader. When the bus comes near a reader, the tag automatically transmits the number and any other stored information to the reader. This stored information can include the diagnostic codes generated by the bus' electronic control unit. Real time information on maintenance issues has been found to be helpful but not essential in developing state-of-the art maintenance systems. However, it is very useful in bus tracking and scheduling and many organizations have realized labor cost reductions and more efficient use of the fleet through RFID based systems.

A1.1.4 Fuel Efficient Driving

There is widespread recognition that the driver of any vehicle (light or heavy) has a large influence on fuel economy, and there is a substantial body of work that has gone into developing fuel efficient driving programs. Such programs were developed in the 1980s in Europe, many with government assistance, and the programs have spread to North America and the developing world in the late 1980s and early 1990s. Hence there is over 20 years experience in most OECD countries and almost as much experience in major developing countries. For example, our interviews with bus operators in China, India and Brazil (described in section 3.3 of this report) showed that all of them had training programs for drivers that emphasized both safe and fuel efficient driving techniques, and such programs have been in place for a long time.

ICF collected information from several active driver training programs in developed countries (with reports in English) and found several well documented programs such as the city of Edmonton's driver training program[22], the Smart Driver program developed by Government of Canada's Office of Energy Efficiency[23], the UK Government's Safe and Fuel Efficient Driving (SAFED) program[24], and the State of Oregon's Bus Driver Training Program.[25] This is by no means a comprehensive list as almost every state in the US and province in Canada has similar programs but a collection of literature from well developed programs that have been in place for many years and have been evaluated for results. The review of the driver training procedures from these programs showed that all of them were quite similar in structure and content with all requiring a couple of hours of classroom lectures on fuel efficient driving and 2 to 4 hours of on-road or test track based training with an experienced instructor. The only significant difference noted among programs was that some used driving simulators where the instructor could train the driver prior to the on-road segment of the training. Box 3.2 provides a description of how the driver training was implemented in Edmonton and what lessons were learned.

The classroom training typically provides information on the driver's role in fuel efficiency, and how fuel efficiency can affect costs, and the costs of excessive idling and speeding. Some programs also emphasize that driver attitude plays a significant part and request the drivers to think about fuel economy when they drive, to avoid driving when they are angry and upset, and to plan for the trip before setting out. They also suggest that the driver visually examine the bus and tires before the trip to ensure that the maintenance staff has done their job.

The core principles emphasized in all programs examined that constitute safe and efficient driving are:

- cutting out unnecessary idling
- staying within the speed limit and maintaining engine RPM at optimum levels
- accelerating and braking gently
- using vehicle momentum to maintain cruise speed
- avoiding pumping the accelerator pedal
- anticipating traffic ahead to minimize hard braking and acceleration.

Most buses in developed countries have automatic transmissions but with manual transmissions (in trucks), there is also emphasis on shifting gears at the proper engine speed (RPM) and not "riding" the clutch, which is useful in developing countries where buses with manual transmissions are common. These factors are covered in the classroom as well as during actual or simulated driving.

The key benefit of the on-road training with the trained instructor is the fact that many **drivers have developed habits that they may not be consciously aware of**. Pumping the accelerator pedal and clutch riding are apparently quite common without conscious awareness and the instructor can coach the driver on how to break their inefficient driving habits. The instructor can also show how the general principles discussed in the classroom can be put to use on the road.

Evaluations have been performed by most governments on the benefits of driver training but many of them rely on subjective or unsubstantiated evidence, or do not employ scientific evaluation techniques. A study performed by researchers at Monash University in Australia[26] employed rigorous evaluation techniques including a control group and trained group, but tests were conducted on a test track. Interestingly, they found very little improvement in fuel efficiency for drivers that received classroom only training, but significant improvement from those receiving on-road training. Driver to driver variability in improvement was large and the results were significant at the 90% confidence level only. Figure A1-2 shows how the fuel consumption of the group with on-road training ('Trained') was significantly lower than per-course baseline, the group receiving class room only training and the control group showed no significant difference in fuel consumption. Figure A1-1 also shows the size of the variability in fuel economy between different drivers as error bars.

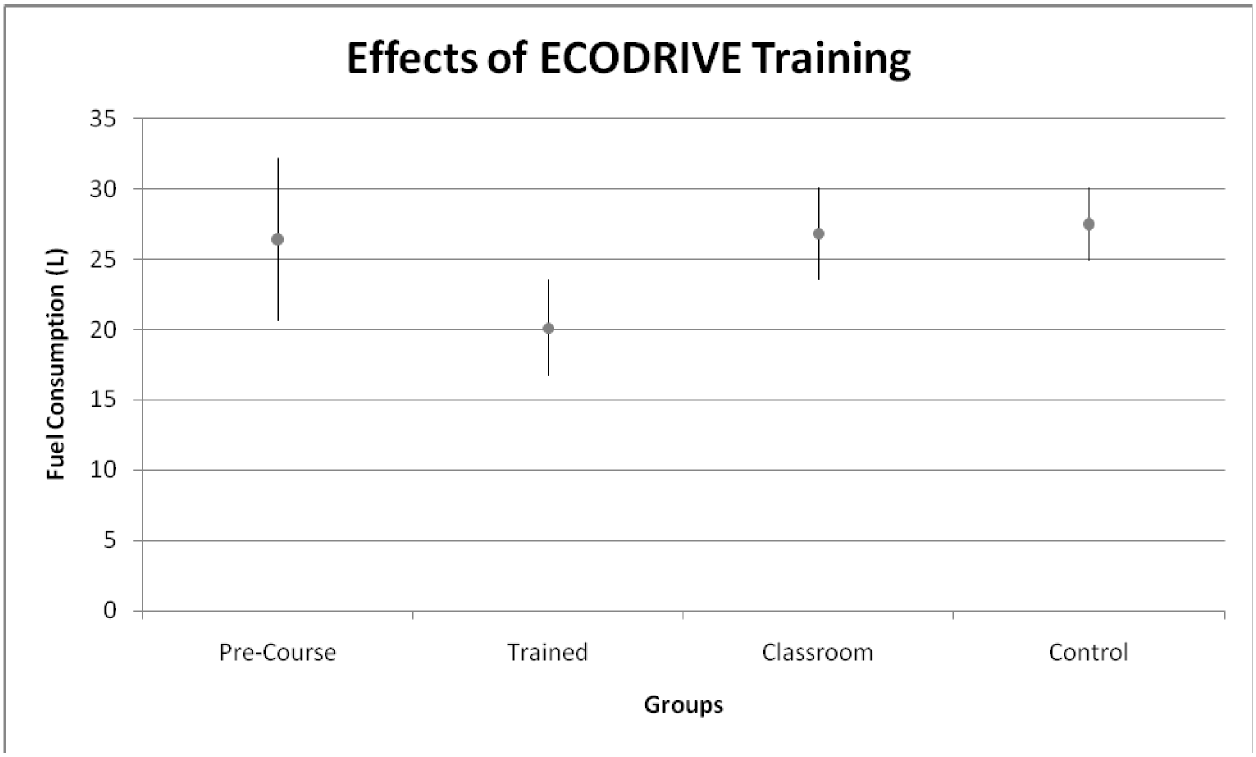


Figure A1-2 Fuel Consumption Results from ECODRIVE Study (Ref. 26)

These results substantiate the importance of on-road training and also show that only some drivers (presumably those with poor driving habits) show large improvements in fuel efficiency. The typical claims in literature cited above indicate fuel efficiency increases by 5 to 10 percent on average, but this would depend on how well trained the drivers are to begin with. The case study in Edmonton (annex 6) showed fuel consumption reductions of 5.5% which is typical (see Annex 6 for details on the program).and also show how the general principles discussed in the classroom can be put to use on the road.

A1.2 INTERVIEWS WITH BUS FLEET MAINTENANCE MANAGERS

Due to the relative paucity of reports on bus maintenance as related to fuel economy, ICF also conducted a series of interviews with bus maintenance or depot managers at transit organization around the world. The objective was **not** to conduct a statistically valid survey of fuel efficiency related practices at transit organizations, but rather to obtain an understanding of the current state of affairs relative to bus fuel efficiency in a range of countries including developing nations and developed nations, small transit organizations with fewer than 100 buses and large organizations with thousands of buses, fleets with many old buses versus fleets with new buses, etc. ICF attempted to contact well regarded organizations in India, China, Brazil and the US to obtain a subjective assessment of the state-of-the-art, and the relative importance of fuel economy in comparison to all the other requirements placed on a transit organization pertaining to its mission of public service.

Meetings were conducted with 8 organizations, two in each country, and six of the meetings were face-to-face while two had to be conducted on the phone due to logistical difficulties in scheduling the visits. In general, actual site visits were often more revealing since ICF staff found that the depot or maintenance managers' input was sometimes an idealized version of what was actually happening on the shop floor. However, the shop floor visits only lasted for a short time (~15 to 30 minutes) so that the impression obtained may not necessarily be accurate at all times. The interviews were held after sending a questionnaire to the organization's management to obtain their agreement to conduct the interview though, in some cases, the depot managers did not receive a copy of the questionnaire in advance of the ICF visit. It should be noted that the questions presented in checklist form in Table A-2 were used to trigger a discussion rather than to have the interview only as a question and answer session.

A1.2.1 Interview with BEST, Mumbai

ICF staff met with the General Manager of Operations and his staff, and also visited a depot as well as the Central Maintenance Facility. BEST (Bombay Electric Supply and Transport) fields about 4500 buses in greater Mumbai, India and this number is expected to increase to almost 5000 in the next two years. About 2500 of the buses are CNG powered while the remainder is diesel. Most of the buses are from Leyland but the newer CNG buses are being procured from both Tata and Leyland. BEST has also procured about 250 low floor buses and continues to operate a small number of double-decker diesel buses. The buses are housed in 25 depots with 150 to 200 buses per depot. In general, buses are run about 200km/day or 70,000 km/year. Buses are rebuilt in house after about 500,000 km (7.5 years) and scrapped at 15 years. Scrapped buses are not resold for use elsewhere but stripped down for metal scrap.

TABLE A1-2

CHECKLIST AND INTERVIEW OUTLINE

1) Go over contract scope and objectives

2) Types of buses

What makes and models of buses are serviced at this depot?

What kind of engine do they have (size and type of fuel)? What kind of transmission (automatic/ manual)?

What is the typical annual use in kilometers? How many years are the buses retained before they are sold or scrapped? How do they decide when to scrap or sell a bus? Is the bus then reused by some other company?

How do they decide what type of new bus to buy (always the same model or do they have any competition?) Is fuel efficiency part of the purchase decision?

3) Maintenance

Who sets the maintenance program for the buses (internally developed or bus manufacturer recommended?)

Are all buses inspected daily? Does the inspection include the engine? What is the list of components inspected and who does the inspection – driver or mechanic? Is a smoke test done every day? If the bus fails inspection is it repaired immediately or does it have to wait for a mechanic?

What is the frequency of regular service/? Can we get a list of items on regular service intervals? Are the same service intervals used for new versus old buses? Is the diesel engine injection pump calibrated frequently?

What percent of the fleet breaks down on the road in a typical month? What are the usual causes of a breakdown? Do any relate to the engine or transmission?

When are engines taken out of the bus and completely rebuilt? Is this based on engine condition or the age or kilometers used?

Are there any maintenance items focused on fuel efficiency? Are there any procedures for buses that are using too much fuel?

Table A1-2 (Continued)

4) Maintenance and bus data

Is there a daily log of bus data on number of kilometers and amount of fuel used?

If there is a daily inspection, are the results of the inspection entered into a database/ is the data computerized? If oil or coolant is added, is the amount of oil/coolant added entered into the database?

Are all service items entered into the data base? If a bus breaks down on the road, is that information captured in the database, including reason for the breakdown and the type of repair conducted?

Are the data collected analyzed in any systematic way? Do they use a special program for data analysis?

Does the data base analysis include an analysis of fuel efficiency of each bus by day/week/ month? What is the average fuel efficiency and how much variation is there among buses of the same make and model? Is the analysis program capable of calculating average fuel economy by route and by driver?

If some buses or some drivers get much lower fuel efficiency than the average, is this reported to the manager? Do these buses and drivers get special attention? If yes, then what is the type of special maintenance done?

Typically, how many buses receive special maintenance for fuel efficiency in a month?

5) Mechanics

Do the employees have to be certified by a school as a mechanic for buses? Is the school training sufficient for them to work on their own right away or do they receive additional training?

Are the mechanics given some training every year by the bus company or the bus manufacturer? How often is the training given?

How is a mechanics work checked? Are there chief mechanics who follow up on the repairs to check the quality of repair?

If mechanics are not properly repairing the vehicles, are they subject to some correction?

Table A1-2 (Continued)

How are chief mechanics qualified and selected? How many chief mechanics are there in the depot?

Are there any special bonuses or rewards for mechanics who do good work? Is fuel efficiency ever considered for this type of reward?

6) Drivers

Do drivers receive any specific training to drive in a fuel efficient way?

Is bus fuel economy by driver available from the data? If yes, is this data ever reviewed by management?

How does the data analysis separate driver effects from route or daily variation in fuel economy?

Are very fuel efficient bus drivers recognized by management? Are they given any awards or bonuses?

Are poor fuel efficiency bus drivers warned or given additional training?

7) Management

Does senior management place emphasis on fuel economy? if so, how is this done?

Does senior management request information and data on bus fuel economy? Do they look across bus depots to see which depots are performing the best in terms of fuel efficiency/

Has senior management instituted any system of rewards for depot managers for getting good efficiency? Do they actually check the reported values against fuel purchases?

Bus purchase decisions are not based on fuel economy, since supply is limited to two sources, Tata and Leyland. With the decision to purchase CNG buses, even this choice is not really a choice since both bus manufacturers rely on the same CNG engine supplier (Cummins) and use the same transmission (Allison). Hence, vehicle price and the desire to foster some competition among the two suppliers are the factors affecting purchase decisions. However, BEST continues to research new technologies for possible adaptation into the fleet.

BEST conducts service in a 2 stage program. Minor maintenance at 3750/7500/15,000 km is conducted at the depots at 15 to 20 day intervals. Major checks at 45,000 km intervals are conducted at the central repair facility. Daily checks on fluid levels and tire pressure are also conducted before the bus leaves the depot in the morning BEST has created its own maintenance manual that starts from the manufacturer requirements for warranty but expanded and updated based their own field experience. There is considerable emphasis on preventive maintenance. In addition BEST has its own R&D cell which studies field problems, and develops technical solutions that sometimes involves modifications or retrofits. However, ICF was not able to find any special maintenance procedures geared to fuel economy, and the general operating assumption was that the maintenance program would result in fixing all defects including those related to fuel economy.

BEST managers stated that they collects data on all fluid consumption (fuel, lube oil, coolant) and also on all maintenance history data including service, parts replacement, list of breakdowns and repair actions, etc. All of the data is forwarded from the depots to the Central Office and is available on a computerized data base. They do not use any commercial data analysis packages but have their own package developed in house. As far as ICF could determine, the data are summarized monthly. BEST stated that the data was examined for “abnormal” variations in critical parameters to take corrective actions. One of the parameters is apparently an abnormally low fuel economy, although it was not possible to determine how often this parameter is the basis for actions on maintenance.

During the course of the depot visit, it was not clear if daily check results were computerized and small lube oil additions, etc. noted in the data base. ICF also examined some printouts at the depot and some obvious errors in the data suggested that data had not been subjected to quality checks at the depot. In addition, depot staff could not recall any recent instance where the bus was pulled from service because of low fuel economy but this may have been specific to the depot visited. In addition, there appeared to be no specific data analysis to identify the lowest fuel economy buses or drivers, or combination of bus and driver.

BEST recruits only skilled mechanics that have completed apprenticeship training and passed the qualifying exam. They have an in-house training center as well as mobile training van, and provide regular training to mechanics to use proper tools and good work practices. For ensuring work quality, they have instituted checks at every level with supervisory staff ensuring the work quality of mechanics, a foreman ensuring the work quality of supervisory staff, and the General Foreman ensuring the work of Foreman. In addition, staff from the engine calibration unit and vehicle inspection stations at the central (Dadar) workshop is deputed to depots for surprise inspections and quality control checks. Surprise inspections are also carried out by team of senior depot officers to ensure the work at depots. In general, the quality of the maintenance at BEST is very professional and well organized although ICF was unable to verify if all the procedures are followed in reality. During the visit to the Central Repair facility in Dadar, very little actual activity was observed at about 2pm and it may be that the influx of new buses has resulted in overstaffing of repair personnel.

BEST also has an extensive driver training program. The program emphasizes safety and also has a component on fuel efficient driving. Instructors provide on-road training to drivers and all drivers must undergo training when joining BEST and periodically thereafter. Details of the training were not obtained during the interview as most of the staff ICF met with were involved in maintenance. To the best of our knowledge, no awards for drivers with the best fuel economy are given.

Management takes an active role and maintenance planning and procedures are initiated by senior management. They also play an important role in formulating procedures and updating them periodically. Supervision and control of maintenance is exercised by middle management. Apparently, management carefully reviews monthly average data, but their focus is on bus utilization, breakdowns per 10,000 km and earning per revenue kilometer. However, fuel economy does not seem to be a metric on senior managements' list of performance metrics for which they are rewarded. The only issue with fuel economy appears to be triggered by a low monthly average at any depot, which results in follow up action. As far as ICF could understand, low individual bus fuel economy may be recognized at the depot level but not at the senior management level.

Maintenance quality at the depot level is measured on the basis of breakdowns per 10,000km and percent km. loss for maintenance, and depot maintenance staff is given monetary awards based on the performance level. Safety Trophies are also presented to depots achieving zero accidents and Cleanliness Trophies to those depots achieving optimum performance based on good housekeeping, proper storage of materials, roof and floor cleanliness, etc. No awards for fuel economy were given and apparently management had contemplated such awards but had not examined their ability to recognize the best performers on this metric.

A1.2.2 Delhi Transport Corporation (DTC)

The DTC fleet is in a state of flux as it is rapidly being converted from a fleet of old style, high floor diesel and CNG buses to an all CNG powered fleet of low floor buses with and without air-conditioning. The DTC has 3175 of the new buses that have been delivered or will be delivered in the near future, while some 700 older diesel buses are being retired over the next two years and presently serving suburban locations only. ICF visited a depot in central Delhi (the Sarojini Nagar depot) which has about 123 low floor CNG buses only. In addition, DTC has decided to contract all maintenance to the bus manufacturers themselves with guarantees on cost and availability of buses over the life of the buses. The manufacturers had, in turn, hired many of the DTC mechanics and trained them on CNG bus repairs, so that the DTC has little impact on bus maintenance procedures.

As in Mumbai, the DTC has no real choice in the selection of buses as the only suppliers in India, Tata and Leyland, offer the same CNG power train with a Cummins B series electronically controlled engine and Allison automatic transmission. In the depot visited, the majority of buses were quite new (< 2years old) and the Cummins engines were running very reliably with few failures.

Depot staff inspect the tires, brakes and engine oil/coolant levels every morning, and note fuel fill levels and odometer. Tire pressure is checked only by “feel”. ICF is not sure if daily check related data are entered into the data base but fuel fill and odometer data are reported daily. The depot manager stated that there had been zero oil additions between service intervals and only minimal coolant additions. Overall reliability was such that bus availability was 96% to 98% with about 2 or 3 buses in service on a given day. Given the fact that the buses were very new, this is not surprising. The problems typically reported were inability to start due to electrical problems (low battery or electrical short) or non-availability due to body damage from accidents.

All service is conducted by on site manufacturer staff, and the buses are scheduled for major service every 9000 km (docking inspection), when all fluids are changed and there is an engine, transmission and brake inspection. The DTC provided us with the inspection sheet for these inspections that required a 42 point check of the drive-train, fuel system, body and electrical systems. (The 42 point check was useful to develop a specific fuel economy procedure for the

Guidance Note). At 36,000 km the bus is subjected to "pit maintenance" and additional checks above those conducted every 9000km are carried out on the water pump, alternator and drive pulleys; the cylinder head valve clearance is checked and spark plugs replaced. Since the engine is electronically controlled, it has on-board diagnostics and any diagnostic light is checked immediately. Most buses had accumulated less than 200,000 km and there was no data on major repairs or overhauls.

Depot level mechanics were questioned by ICF on types of maintenance occurring frequently. They confirmed that the engines were quite reliable and typical engine related diagnostics were usually related to electrical components or sensor failures. They also confirmed that all service was based solely on manufacturer recommended intervals and service procedures for each diagnostic code was strictly followed and enforced by manufacturer supervisory staff. They were unable to cite any instances of buses being examined for low fuel economy, but suggested that this would be solved by examining for friction in the drive-train (brakes not disengaging fully or un-lubricated bearings and joints), transmission gear shift problem or an engine misfire problem. The air-gas mixer is a unit that is calibrated in the central repair facility and not checked at the depot repair facility.

DTC collects detailed bus travel, fuel consumption and repair data on each bus every operating day but do not utilize the detailed data for rescheduling maintenance events since maintenance issues are contracted out. They do not use commercial fleet management software but have developed in house programs to analyze data. There is a daily performance report that ICF obtained a printout for, and it shows the actual travel per day, passengers, earnings, and earning per kilometer, but fuel economy was not in that report. The depot manager confirmed that the focus was on earnings per km., and buses with low earnings per km. resulted in special attention to see if any funds were being diverted. The depot manager was also able to print a report with fuel economy. The report showed very significant variations in fuel economy for buses of the same type, with buses reporting 2.5 km/kg to 3.5 km/kg of natural gas, and two buses reporting 2.35 km/kg, almost 20% below the average and 35% below the best buses. When ICF inquired if these low fuel economy buses received special attention, it was apparent that this was not part of the operating procedure.

ICF also visited the operations management of DTC, and due to the subcontracting of maintenance, the management position is only to ensure that maintenance and repair are carried out according to the agreement and bus availability is high. Management confirmed that the maintenance agreement did **not** have any requirement on fuel economy performance of the buses.

The management does monitor depot average fuel economy and low fuel economy depots are sent letters requiring them to investigate. However, the depot manager stated that low fuel economy was typically blamed on route specific issues like obstruction from political demonstrations (frequent in Delhi) or construction related traffic problems, but rarely resulted in detailed bus investigations. Since buses are quite new, the depot managers' explanation may be true in many instances. However, management confirmed that no incentives were provided to employees for fuel economy performance but depots were rewarded for bus availability and earnings per km. performance as well as safety performance.

Driver training is provided to all drivers and the operations managers confirmed that both safety and fuel efficient driving were emphasized but did not have details on the program length or whether the program has been evaluated. Drivers are periodically sent for retraining but the selection procedures were unclear, as the depot manager suggested he often sent good drivers for retraining as a day off from the routine, rather than the bad drivers to maximize fuel economy.

A1.2.3 Julio Simoes Bus Company- Sao Paulo Urban

Julio Simões is a Logistics Company that owns an urban bus company. The Company also owns buses for chartering. Julio Simoes is located in Mogi das Cruzes, in the State of Sao Paulo, Brazil. The Company owns urban buses that operate in six different cities near Sao Paulo in the State of Sao Paulo. Julio Simoes also have vehicles that operate in intercity bus lines (from the city of Mogi das Cruzes to the city of Sao Paulo). The Company did not inform ICF on the exact size of their fleet (number of buses) although they have about 600 buses.

The company operates mostly Scania or Mercedes buses with six cylinder diesel engines as well as some small VW buses for 18 passengers with four cylinder engines. All engines are electronically controlled Euro 3 certification engines and the buses have manual transmissions. The larger buses are utilized for about 90,000 to 100,000 km year while the smaller buses average about 70,000 km/year. The company employs an unusual strategy of selling the buses after 4 years so that the fleet is always very new, to reduce maintenance costs and maximize fuel economy. Buses were resold to smaller operators around Brazil. Bus selection was based on cost of ownership where the resale value of the bus was a major contributor based on the market expectation of bus durability. The company also focused on fuel economy as they were carbon footprint sensitive, which is also very unusual among bus companies, and the fuel economy was based on prior experience with the make.

Maintenance requirements are warranty driven and include the following:

- a visual inspection every day to ensure no damage, leaks or tire problems,
- a minor service where fluids are inspected and oil changed, and fuel lines and brakes inspected and repaired as required every 5000 km,
- a major service every 30,000 km where engine and transmission components are inspected and repaired as required,
- about 20% of its fleet receives major service every month and an additional 3 percent receives service based on breakdowns or accidents.

In general the engines do not have any significant issues requiring engine rebuild or injection pump overhaul as the buses are sold by the time they have 400,000 km of service. Simoes also confirmed that even the injection nozzles rarely received service over the 4 year period of ownership. Most of the causes of breakdowns were due to electrical faults or failure to restart, although they have had trouble with older transmissions and clutch failures on a less frequent basis.

Much like Mumbai and Delhi, data is collected on all major repair actions on each bus and daily fuel fill and travel, but data is not collected on minor service items like oil and coolant top-up. Data quality assurance was conducted and data analysis is currently limited and based on a in-house program, but Simoes has been testing commercial software to improve maintenance and reduce costs. They report favorable results with commercial maintenance software and are planning to switch all operations to this software by 2011. The software does report daily fuel economy by bus and route and Simoes is currently investigating whether a maintenance program for low fuel economy buses would be useful given the new fleet. They plan on investigating 1) increased drive train friction from brakes or un-lubricated bearings 2) gear box and clutch issues, which has been a source of problems for them and 3) engine related problems on air intake and injection nozzles.

The company only employs trained mechanics and also sends them for additional training at the bus manufacturer sponsored training programs. The company follows manufacturer guidelines generally but occasionally may add additional maintenance for components that they have experienced trouble with. Mechanics are re-trained whenever technology changes are introduced in the fleet. All mechanic QA/QC appears to be done at the depot level by the chief mechanic, but it was not clear if an external company-wide audit team is used.

Driver training is standard practice for all new drivers and Simoes management believed that the training programs were relative standard across the industry in Brazil, emphasizing both safety and fuel efficiency. Local depot managers recognize poor drivers based on daily reports on fuel economy but this does not appear to be a standardized practice across all depots but a local management initiative, with poor drivers being retrained or warned. Historically, they have not rewarded drivers for fuel efficiency but Simoes management has had a significant change recently, where they are emphasizing the carbon footprint of the company. This has resulted in senior management directives on fuel economy and the bus company managers are now evaluating a reward scheme on fuel economy based on the data results from the new software. Simoes is considering rewarding drivers and depot managers on the basis of fuel economy while historically, rewards were only for safety. ICF believes that this is a classic example of how management focus and granular data can enable new initiatives on fuel economy to be enabled in the company.

A1.2.4 Bel Tour Bus Company – Rio Suburban

Bel Tour is a small bus company located in suburban Rio de Janeiro that operates suburban and regional bus service with a fleet of 51 large buses and 20 small buses. The large buses are all Scania buses with mechanical fuel injection and have an average age of 7 years. The small buses are VW and are relatively new with an average age of 7 years. The buses (large and small) average 95,000 km/ year. Being a small operation, all buses are housed and serviced out of one depot and the maintenance and operations manager knows all the mechanics and drivers personally. Bel Tour always orders Scania buses because they have had a good experience with them and their mechanics are trained on Scania technology. The spare parts inventory is also a major consideration. The manager recognized that there may be some fuel economy benefit possible by shopping other brands but the structural change needed to adopt another brand would be over- whelming burden for a small company. Bus are scrapped using a cost of ownership model where each bus is evaluated each year to check if the cost of repairs and remaining life are lower than procuring a new bus. Hence, there is no fixed life but a condition dependent approach where some buses in good shape are retained longer than others.

Bus maintenance is based strictly on manufacturer recommended intervals as Bel Tour is too small to have any R&D plan to develop its own procedures. It has only six mechanics and who have all attended the Scania sponsored training and the VW training, with the chief mechanic overseeing the work of others. Due to the small size, the manager believed that informal oversight worked very well as it soon became clear if any mechanic was implementing sub-standard repairs. Hence, the company does not employ formal repair QA/QC procedures but achieves its goal of good maintenance.

The maintenance plan mirrors those at other companies interviewed. There is a daily check done by the garage assistants and drivers on fluid levels, engine smoke, tire pressure and oil leaks. Minor maintenance is carried out at 5000 km intervals and major maintenance at 40,000 km intervals. All of the checks are as per Scania's manual, and are followed carefully to ensure warranty coverage. The maintenance facility is not capable of carrying out major maintenance like injection pump calibration and these are outsourced from the Scania dealer. The head manager interviewed by ICF actually conducts the surprise audits himself on the daily checks and reprimands drivers if he finds they have been lax in their checking. He also works closely with the chief mechanic to ensure that mechanics work is audited on a random basis.

Data collection is almost completely manual and does not include small daily maintenance items like fluid top up but includes daily fuel fill and travel. They do not use any commercial fleet management software. ICF examined some printouts from their own software and found it reported only simple monthly averages on fuel economy as well as breakdown and repair rates by bus, but not be route or driver. Interestingly, the manager claimed that fuel economy was very important to the company but could not identify specific actions for fuel efficiency. He believed that good maintenance practices automatically gave rise to good fuel economy,

Drivers were trained by a commercial organization that offered such training, and the manager stated that he informally monitored driver specific fuel economy. He was well aware of who the best and worst drivers were and often requested the worst drivers to obtain additional training or risk being fired. On the other hand, he had tried rewarding the best drivers with bonuses based on his monitoring but he said he had to stop this because it caused a lot of resentment among drivers. The drivers believed that certain routes and buses conferred an advantage to some drivers, and his informal method of awarding drivers was unconvincing to them.

The Bel Tour interview shows the limitations and benefits of a small company, and the informal approach to fuel economy. A smart manager in this situation already knows what data analysis will show in a larger company just from observation, but changes are more difficult to implement without adequate data and analysis backup.

A1.2.5 Beijing Pubic Transport Holdings, Ltd. (BPT)

Beijing Pubic Transport Holdings, Ltd. (BPT) is a state-owned-enterprise which deals mainly with the operation of ground public transportation. This company consists of 29 subordinate units, namely 14 branch companies, 11 share-holding subsidiaries and 4 affiliated institutions, with a staff strength of 106,309 people. BPT is the market leader in Beijing which manages 90%

of routes (from route 1 to route 899) in Beijing. By the end of 2007, BPT had been operating 25,368 vehicles and managing 823 route lines. In order to improve the air quality of Beijing, 13996 green buses used clean fuels were put into use, of which 3752 consume CNG. Buses are nominally retained for 8 years by law, although the turnover is more frequent in recent years due to a desire to move to a low emissions fleet. They provided a summary of all the bus types operating in Beijing and all buses now have EU3 certification. It is interesting to note that the Cummins B- series gas engine is used in Beijing and is the only available engine in India for CNG power. There are significant restrictions on what buses can be purchased so it appears that the purchase decision does not involve fuel economy.

Maintenance is conducted by a separate company within the group that specializes in the maintenance function. The company provides both emergency repairs and normal repairs but routine maintenance (standard checks for oil, coolant, tires, etc.) appears to be done at the depot by the bus company staff. Local depot staff also may take care of minor repairs, although ICF was unable to ascertain how repairs are classified as major.

Apparently, a unique feature of this approach is that the maintenance company intervenes only when there is a malfunction or a repair that falls outside of the expertise of depot staff. The approach is to maintain only on failure for major parts, like the transmission, injection pump and nozzles. The bus maintenance branch has a city-wide first-aid repair network with GPS, GIS systems, smart dispatch platform and wireless voice communication system with bus drivers, ensuring quick and 24-hour “first-aid” repair for buses that breakdown in the field. The maintenance organization sees this rapid response capability as a key element of the “repair-on-failure” approach.

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Mechanics employed have professional certification and get trained by the company every year. There are chief mechanics, usually selected on the basis of extensive work experience, to check the repair quality by means of direct checks. BPT has a Senior Technical Training School as an affiliated institution, which train mechanics for the maintenance company. Mechanics are required to attend a re-training and update course every year, and the maintenance logs also track mechanic performance. Since all major maintenance is centralized, there is no depot specific independent audit, although mechanics at the central facility are audited by a team of senior mechanics.

BPT has a sophisticated data acquisition and maintenance system that is highly automated and tracks all maintenance, fuel fill and oil addition and also includes data from daily checks and oil/coolant top up. Depot managers are provided statistics on their bus performance and availability, but fuel economy was not listed specifically as a variable provided to them. Fuel economy of newer buses were stated to vary between 2.5 to 3.3 km/L. Senior management reviews monthly statistics on breakdown rate, percent of buses in service and safety statistics but ICF could not confirm if fuel economy statistics are reviewed by them. As with other large bus companies, management stated that fuel economy was important, but the only specific maintenance action that they could cite was the pulling of very low fuel economy buses for repair by central maintenance. Subjectively, management indicated that this was not a very frequent occurrence and would occur with a few buses every month, but no detailed statistics were provided. Mechanics and depot managers were not rewarded on the basis of fuel efficiency.

Driver training was required by governmental regulation and they confirmed that training was for safety and fuel efficient driving. Drivers were re-trained periodically (but our contact at BPT was unfamiliar with the specific requirements). In addition BPT staff stated that drivers were rewarded on the basis of **both** safety and fuel efficiency, and drivers who did poorly on these metrics were first fined and then later terminated if their performance continued to be poor. Details on the percent of drivers rewarded and the specific criteria were not provided to us. However, BPT stated that management had done enough data analysis to set up **fuel economy**

ranges for every route in the city. Drivers exceeding the range were rewarded and those below the range were actually fined.

In summary, BPT was willing to provide only general data on the interview but specific data were not made available. The main features of the BPT maintenance scheme are the relatively unique repair-on-failure system backed up with a sophisticated data acquisition and management system that allowed real time tracking of buses and on line availability of its maintenance history. This allowed mechanics to respond rapidly to any break down in the field. The system is also aided by the government requirement to operate buses that are less than 8 years old, so that actual major breakdown on the road is a relatively infrequent occurrence.

A1.2.6 Beijing Xiang Long (BXL) Bus Company

Beijing Xiang Long Bus Co. Ltd., founded in 1999, is a non-state-owned enterprise that consists of 6 branch companies, managing more than 20 routes and 400 buses with a staff of 3600 people. Most of the buses in the company are diesel powered, with automatic transmission and EU III emission standard. In February 2003, Xiang Long applied for the ISO9001-2001 international maintenance quality standard and received an attestation that its program met the standard.

BXL operates under the same government constraints as BPT in that they must operate buses less than 8 years old and the recent “green” push in Beijing has resulted in buying newer buses that all meet the EU III emissions standard. Like BPT, BXL also operates Cummins engine powered buses among others. Buses are usually sold after the 7th year of operation to operators outside the Beijing Metropolitan area where the 8 year old limit does not apply. Given the regulatory regime, BXL said that fuel economy was not a factor in the bus purchase decision.

The BXL bus maintenance program is developed according to national and local standards. The national standard *Specification for the inspection and maintenance of motor vehicle (GB/T18344-2001)*[27] has defined the items of basic maintenance and complete maintenance. As for buses in Xiang Long, minor maintenance is done at 1,000km intervals, and major service is required every 12,000km, which corresponds to, on average, the buses being inspected in detail once every 55 or 60 days. If the bus fails this inspection, it usually sent to the central facility for a mechanic to conduct the required repair. The types of failures vary by season with electrical problems happening through the year. In summer, overheating is a common failure while in winter, hose and belt failures are most common.

BXL hires both trained and untrained mechanics, with the untrained fraction serving as assistants or helpers. 80% of the mechanics in the company are well trained and certified. All employees get periodic training every three or four years by the company at a central training facility, and assistants can receive training there and move up to the mechanics position. There is a separate inspection and audit department that is in charge of evaluating the mechanics' performance and they conduct periodic and random checks for quality assurance. Bonuses or rewards are given to mechanics for passing the QA checks on a regular basis.

BXL had a somewhat unusual data collection system that did not include variables like oil and coolant addition but was focused on fuel efficiency, with the fuel fill and travel data being input daily. Apparently, other variables were still recorded manually at the depot in hard copy only and the depot manager examined the written logs to spot unusual patterns in coolant and oil consumption or in recurrent failures.

Fuel efficiency is apparently a major concern of management and they have set up a special program focused on fuel economy. The company places great emphasis on fuel consumption in operation. An Energy-Saving Group has been established by the company to monitor bus fuel efficiency and provide improved maintenance schemes and advise on technology retrofit as needed. Separately, a key component is analysis of driver performance through data analysis on the fuel economy database. First, there is a daily inspection of fuel consumption and the results are entered into a database, analyzed and reported to the manager. Second, in the data analysis process, fuel economy comparisons are always made between different drivers on the same route, and different routes for the same driver to disentangle driver and route effects. Third, the group has set up a fuel efficiency baseline and range based on route and bus type and an incentive or penalty is provided for bus drivers based on their performance relative to the baseline/range. The fuel cost drivers have saved is rewarded to them while the exceeded cost is recouped from their salary. This was the only instance of a comprehensive statistical analysis of fuel economy data that was explicitly identified in our interviews (although BPT may also be conducting such detailed analysis).

Given these detailed data analysis for rewarding drivers, BXL also has a strong driver training program for safety and fuel efficiency. Both BPT and BXL use government sponsored driver training programs and the managers believe that the program content has been standardized to follow international best practices. As with most other organizations, low fuel economy drivers are warned and retrained, or discharged if their performance continues to be poor.

Although BXL is a relatively small company, it is unusual in its fuel economy focus and commitment by management to create a special group devoted to this topic.

A1.2.7 Washington Metropolitan Area Transit Authority (WMATA)

WMATA serves the entire metropolitan area of Washington that covers several counties in different states with 1482 buses in mid-2010. 461 of these buses are CNG powered while the rest are diesel, although 253 0f these buses are the new diesel- electric hybrids with an additional 147 scheduled for delivery. Buses are retained for a minimum of 15 years but the actual replacement and new bus purchase cycle is very budget cycle dependent. Like its counterparts the world over, WMATA bus purchase decisions are driven by regulatory needs and the senior executive in charge of operations stated that they often had no choice in suppliers – for example, there is only one competitive diesel-electric hybrid bus supplier that bids on the WMATA purchase orders. However, one key difference that ICF noted relative to other companies interviewed was the very detailed specification sheet for the bus that is internally developed and WMATA is able to customize the buses to some degree to meet its local needs. Many of the specification are for the body durability and passenger access, but even the drive-train issues are tackled- for example, WMATA requests a specific radiator and cooling capacity to meet local hot weather needs. This approach has been very successful in reducing maintenance needs over the years.

The maintenance plan is very similar to those followed by other organizations with daily checks of fuel/oil/coolant and a visual check of bus condition, 10 to 14 day checks of transmission fluids and axle and driveshaft lubrication, and the heating, ventilation and air conditioning (HVAC) system, belts, hoses and hydraulic system, and service according to manufacturer specified interval which vary a little by manufacturer and fuel type but is typically done every 6000 miles which corresponds to about 8 weeks of use, and major service at 24,000 miles. A detailed maintenance log for diesel buses was provided to us to illustrate the types of service at each interval. Buses typically log 35,000 to 45,000 miles per year and a major bus rebuild is done at 300,000 to 350,000 miles (~ 8 years). Over this period, WMATA stated that engine failures are usually quite rare and most of the problems are typically electrical or hydraulic system related. With individual models, like the first generation CNG systems, there were unique and unusual problems like cylinder head cracking, and this is apparently typical for new generation technologies with the new hybrid buses displaying its own unique problems. WMATA emphasized that a significant advancement is their program to tailor the maintenance schedule to the types of breakdowns being experienced. The manufacturer recommendations for service serve as a starting point but are modified and updated every year to over-maintain those systems with the most frequent failures. The adaptive maintenance plan has resulted in a significant cost and breakdown rate reduction. The changes have been facilitated by good data collection and a commercial data management program called “Fleetwatch”. They also mentioned the engine oil analysis program done bi-annually a good measure to indicate longer range wear and durability issues and this program has been an integral part of improving the life of the engines in service.

Data collection is becoming more automated over time although many maintenance items continue to be recorded by hand, like oil fill and coolant fill, bit the data system appears to have a very complete record of performance and maintenance history. The Fleetwatch commercial data analysis software does an automatic data QA/QC check and has approved ranges for all parameters input the system. Parameters falling outside the ranges are flagged everyday in an ‘exception report’ and depot staff follow up and correct most of the data errors immediately. The exception report also triggers flags on buses where oil consumption is too high or fuel consumption is too high. However, the fuel consumption flag is not based on route and bus age and design specific parameters but has relatively wide ranges of data acceptance so that only very low fuel economy buses are flagged. Although management did not have the data, ICF had the impression that this type of flag occurs very infrequently like once or twice a month.

The data system also signals when buses are due for maintenance and provides a work order with a list of all inspection and service items for each bus pulled in for maintenance. This ensures all service is conducted at the right time and is an important component of warranty enforcement. The system also provides listings of frequent component failures, or frequent re-repair requirements to spot trends in component failure and erroneous repairs. WMATA believes that the data analysis system is also a key to improved maintenance.

Mechanics who are hired must have AST certification which requires a five year training program and there are different grades of mechanics rated ‘D for entry level to “AA” for the master mechanics. Jobs are assigned by complexity of repair and entry level mechanics first work with master mechanics before moving up the ladder. Mechanics’ work is checked by supervisors and supervisors’ work is checked by the chief mechanic at each depot. All mechanics receive annual training where new procedures and new technologies are introduced and covered. WMATA has instituted a series of procedures that they recommended to us as being the core principles of good quality repairs:

- all diagnostic and repair functions have written “ standard operating procedures” (SOP) and checking metrics that the mechanics can access on line on the “Maximo” software system.

- mechanics at all depots are expected to use the SOP and are trained in the specific practices and tools to be used, and must sign off on all the repairs that are done by them.
- failures after repair are tracked back to the mechanic who has signed off and then rechecked.
- depot supervisors check mechanics' work after re-repair against the SOP to ensure strict adherence to the SOP. Mechanics failing to follow the SOP frequently are subject to disciplinary action.
- a company-wide independent QA/QC team audits all depots to ensure that SOP are implemented in the same way across the entire company's operations.

This level of standardization has led to significant improvements in the quality of work and has allowed mechanics to transfer to different depots with no difficulty since the tools and practices are identical. WMATA also reviews which repairs should be done in house and which should be out-sourced; at present, the diesel fuel injection pump and CNG gas-air mixer calibration and repair are outsourced to company dealers.

Management appears focused on maintenance and uses indicators of bus availability and average miles between failures as indicators of maintenance quality, but fuel economy was not in the picture. Even in the case of miles between failures, WMATA used only internal benchmarks and did not have any benchmarking against other nearby cities like Philadelphia; one report from WMATA showed wide variances in the miles between failures between US East Coast cities but this was explained as resulting from different methodologies by different cities used to compute this value. No benchmarking or goal setting has been done for fuel economy even though management is aware that fuel costs are a large fraction of variable costs, at almost 30%. (The 11% figure cited in the introduction includes fixed costs). Management appears to be trying to improve fuel economy through the introduction of new technology, as the new diesel hybrid buses are averaging 5.60 MPG as against 3.47 MPG for diesel buses and 3.15 MPGE for CNG buses.

In summary, WMATA has implemented many innovative ideas for standardizing maintenance and repair quality, but the actions are focused on improving bus reliability and availability for service. To the extent the same actions improve fuel economy, the benefits are transferred, but there is no specific action plan for improving fuel economy.

A1.2.8 Centre Area Transportation Authority (CATA), State College, PA

CATA is a small transit bus operation in a midsize city in Pennsylvania, USA. It has a fleet of 61 buses of different sizes (40, 35 and 30 foot length) with the vast majority powered by the Detroit Series 50 G natural gas engine (4 older buses use the now discontinued Deere engine). The city had made a decision to switch to natural gas power about 10 years ago, and CATA simply purchased the only available option in the 2000 to 2005 period which was the Detroit Diesel 50G engine. Hence, fuel economy considerations never entered into bus purchase. Buses are kept in the fleet for about 12 years, although more recently, bus retirement and new bus purchase is tied to the financial condition of the company rather than any specific number of years.

All operations are from a single depot so all maintenance is centralized at this location. The larger buses are operated about 5000 miles per month, while the 30 foot buses are operated only about 3000 miles per month so that the frequency of inspection varies in time. As is common in the industry, there are daily checks of tire condition, coolant, oil and fuel levels. Service intervals strictly follow manufacturer recommendations with minor service occurring every 6000 miles and major checks of the engine and transmission at 24,000 mile intervals. CATA has very limited manpower capability to conduct any original research into specialized maintenance needs and have not tried to adjust maintenance schedules to better suit local conditions. The 50G engine has been quite reliable in service so they have no specific reason to change maintenance.

The number of mechanics is very small (~5) and the chief mechanic is personally familiar with their work. Hence, repair QA by the chief mechanic occurs at an informal level and is not very data driven. Mechanics have been trained by the bus suppliers and retraining occurs when new technologies or repair processes are introduced, which occurs on an infrequent basis, roughly every 3 to 4 years. CATA hires trained mechanics and due to the relatively static nature of the fleet, does not see much value in annual retraining. Repair procedures are standardized and closely follow manufacturer recommendations, and the operations chief was happy with the state of the fleet.

Due to the small scale of operations, data collection is primarily manual and only the fuel fill and major maintenance data are kept in the data base. Operations do not appear to be data driven but more schedule driven, and our subjective impression was that the data and statistics reported do not play a significant role in the strategy for maintenance. In addition, the data base does not contain data on driver specific performance. Overall statistics on safety and miles between failures are reported but there is virtually no reporting of fuel economy.

Driver training is done separately from the maintenance department and the manager ICF interviewed was less familiar with the driver training program, but was aware that the program covered both fuel efficiency and safety. There is some periodic re-training but ICF was not able to obtain information on the frequency. As noted, the agency does not track driver fuel efficiency data and was therefore unable to examine issues with low fuel economy drivers.

The use of relatively new CNG buses combined with the low price for gas may be one of the reasons that CATA management has not focused on fuel economy. The maintenance manager ICF interviewed did not recall any instances in recent years when the senior management requested fuel economy data or had expressed concerns about increasing the fuel economy. Based on monthly reports on fuel economy, he estimated that the 40 foot buses averaged 2.75 MPGE, which is significantly lower than the WMATA buses of the same size (which are at 3.15 MPGE or about 15% better) and ICF expect that congestion is much greater in Washington than in State College so that the results should show some advantage for State College. It was also obvious that fuel economy had not been benchmarked against other locations.

Since there is not much emphasis on fuel economy, there are no specific employee rewards for fuel economy, and the rewards are structured towards safety and reliability. In summary, CATA is similar to the other small company interviewed (Bel Tour) where the small size allows managerial competence to substitute for sophisticated data collection and analysis. Managers and supervisors are personally familiar with the crew and have a good feel for who is doing a good job. However, the lack of data and analysis also shows the limitations like CATA lack of focus on fuel economy,

ANNEX 2

CASE STUDY: DOW CHEMICAL COMPANY

Adapted with permission from the Pew Center for Global Climate Change Publications

A.2.1 Energy Efficiency Strategy Overview

Energy is a small cost for most companies—the 48 respondents to the Pew survey reported energy costs averaging less than 5 percent of revenues. For Dow Chemical, about half of every dollar the company spends goes toward energy, mostly in the form of natural gas and natural gas liquids, which are the energy feedstock for the company. Not all of that energy is used to power Dow's operations; in fact, two-thirds of the energy molecules Dow buys are used as feedstock, transformed via chemical processes into myriad products. That still leaves 30 percent of Dow's costs as energy to run its plants, making it one of the world's most energy-intensive companies. Dow's energy intensive nature, coupled with its continuous-processing, 24-7 operating mode, makes its energy efficiency strategy somewhat different than some of the other companies studied in this report that use relatively moderate amounts of energy. While certain aspects of Dow's strategy are more applicable to other energy-intensive companies, many elements hold relevance for a broad range of companies. These elements include Dow's efforts to organize an effective program, set up a detailed reporting system, and gain cooperation across business units to meet ambitious energy savings goals.

Energy is so big it constitutes its own business unit at Dow. The energy business sells electricity, steam, and natural gas to other business units. It is also a major player in world, national, and state energy markets, selling as well as buying energy on a wholesale basis. At the Freeport Texas site, Dow operates some 1,000 Megawatts of electricity generation, as much as the largest utility power-plants. When energy is such a huge part of production costs, reducing the energy needed to make a pound of product is a matter of competitive survival. It's not surprising then that Dow was among the first companies to set quantitative, measured energy savings goals. In 1995, the company set a goal of cutting energy use per pound of product 20 percent by 2005. Dow beat that goal, realizing 22 percent savings as of 2005. But from 2002 to 2007, Dow's energy bill rose from $8 billion to $27 billion as natural gas prices skyrocketed. While these price effects offset the energy intensity improvement, Dow saved almost $8 billion compared to the energy bills it would have paid without the efficiency strategy.

Against the backdrop of sustained high energy prices, in 2006 CEO Andrew Liveris raised the bar, increasing the goal by pledging to slice another 25 percent off the energy needed to make a pound of product. Dow's energy efficiency goal is represented in British Thermal Units (BTUs) per pound of product produced, so natural gas used as feedstock (which does not emit greenhouse gases in the production process) is not included as part of the goal. However, Dow is exploring ways of becoming more efficient in its use of feedstock primarily due to cost concerns. Figure 1┐ illustrates the company's goal and progress to date. 2009 usage shows an increase in energy per pound, largely because the economic slowdown has cut production, and energy use cannot be reduced in proportion, but as the economy recovers Dow expects energy intensity to go down again.

The way in which the 2015 energy goal was announced illustrates Dow's commitment to energy efficiency. Rather than simply issuing a press release from headquarters in Midland, MI, Liveris spoke at a special event in Washington, DC, delivering a speech, largely unscripted, that showed a detailed understanding of the numbers and the technologies involved. Dow's extra effort and the CEO's personal and visible involvement indicate that this is a high priority for the company. And the energy savings commitment, with the company's other sustainability goals are measured and reported on the Dow website on an ongoing basis. The Dow home page includes "Sustainability" as a top-level menu title so visitors are able to easily track the company's progress toward meeting its goals.

A.2.2 Energy Efficiency and Dow's Climate Strategy

Because energy use is such a major factor in Dow's operations, energy efficiency and GHG reductions are closely linked. Accordingly, the company's 2015 sustainability goals include a 2.5 percent per year reduction in GHG intensity per pound of product. This closely tracks the ten-year, 25 percent energy savings goal. Figure .2 illustrates the GHG intensity goal. As with energy, recent data show an uptick in GHG intensity caused by the economic slowdown in production.

Internal Operations

Dow's business units are broken out by product type, even as their operations are highly interconnected: Olefins, Chlorine, etc. Energy is such a large part of Dow's operations that it is structured as its own business unit. The energy business owns and operates about 10 percent of all of Dow's assets, making it the second-largest business unit behind the Olefins business, followed closely by the Chlorine business. The Energy Efficiency and Conservation (EE&C) program leadership team operates from the energy business, engaging some 40 roles overall, about 26 leads in the various business units, plus 14 site leaders, and some individuals at larger individual

[1] Figures are at the end of Annex A2

plants. Most EE&C members work on a number of issues including energy; energy might take up all their time some days and little or none on others. The amount of time spent on energy is driven partly by the EE&C team's regular meeting and reporting cycles, and partly by specific actions undertaken at given plants or sites in response to operational changes or project investments.

How the EE&C Program Operates

A note on Dow's terminology for its operating units helps in understanding the EE&C operation. Because of the large scale of Dow's manufacturing, and the many different chemical products involved, its manufacturing centers are termed "sites," within which it operates several individual "plants." A plant is typically defined by its product; so a site might hold an olefin plant, a chlorine plant, a power plant, and others. The Texas site, for example, contains some 75 individual plants of the 328 total U.S. plants Dow operates.

Since 95 percent of Dow's energy use flows through its 14 largest sites, the 14 site leaders play an important role, especially when it comes to energy efficiency opportunities that cut across different plants. For example, all the major sites have extensive steam systems with miles of piping; at the Texas site, one pipe moves steam four miles from the power-plant to a remote production plant. Steam systems need regular maintenance, especially for steam traps, the valve like devices that remove condensed steam from the line while keeping the live steam flowing. A site EE&C lead will typically develop a site-wide steam trap maintenance contract; plants can opt out, but typically don't because of the cost-efficiency of the larger contract and the operating efficiency benefits. Site leaders also play an important role in the company culture, building relationships with plant operators, providing them help and information, and leaning on them as needed to achieve energy goals.

As in most of the successful energy efficiency programs examined by Pew, energy efficiency team members faced challenges in gaining the active cooperation of production plant operators and other site-based staff. Getting participation in the company's data reporting system was not as big a challenge, in that Dow already possessed in most cases the metering and billing information, based on the way the energy business is structured. The company had long used a centralized reporting system, and was able to build the new energy reporting elements into it. More detailed monitoring systems and data reporting occur within each business unit and each operating plant. The energy metrics thus act as a high-level indicator with centralized information; finer-grained information is kept decentralized at individual business units and sites. Since the energy business is a functional unit like others in Dow, it has had the core data it needs to track performance at a high level; setting aggressive energy performance targets motivated business unit and plant site staff to look harder at their finer-grained operating data to look for ways to meet the targets.

But Dow shares with other companies the challenge of persuading production managers to consider changes in operating practices and technologies. Production staff are focused on product quality, production volume, and reliability of equipment and systems. Energy improvements, be they changes in operating or maintenance procedures or new technologies, pose potential risks to these ironclad principles. Dow addresses the potential conflicting interests of the energy team and the production plants partly through its Tech Centers. Each business unit has a Tech Center, with experts on its particular production technology, and with one or more EE&C experts.

These Tech Centers each have a director reporting to the business leadership. As a result, the Tech Centers create focused teams that not only develop technology and operating solutions, they also build trust relationships that help the EE&C team gain the cooperation of product staff. The involvement of Tech Center staff in developing, testing, verifying, and then instituting new practices and technologies is key in this respect, as is the highly interactive nature of the EE&C team. Regular conference calls, webinars, email exchanges, and site visits build trust and help spread technical information. Dow's EE&C team is part of the larger Dow Sustainability Team, as illustrated in Figure 3. EE&C includes team members from each business unit, and each large site. Having an EE&C team member at each large site allows for coordinated and collaborative efforts among the many plants operated by different business units within a given site.

Drilling deeper into the EE&C structure, Figure 4 shows how EE&C works within a given business unit. Each business's EE&C team leader is sponsored by the respective business Tech Center Leader. The team leader works with people at the individual plants in the business. For example, each olefin plant has a person assigned to work with the olefin plant's EE&C team leader. The Tech Center's role is to provide engineering and technology support for the business, developing new specifications for production equipment and ancillary equipment, and working with plant operators to advance and sustain operating practices.

A.2.3 Data Collection and Reporting: The Global Asset Utilization Reporting System

A key element of Dow's EE&C program is the energy data collecting, reporting, and accountability system built around the company's Global Asset Utilization Reporting (GAUR) system. GAUR collects energy data from the numerous metering and sub-metering points at each plant, aggregates them up to a total BTU number, and reports the BTU total along with pounds of product per plant. A typical GAUR report consists of rows for each reporting facility, and includes its energy use, production, and energy use per pound of product. The columns show this information by quarter and year, allowing quick visual comparison of performance over time. Plant operators, business unit leaders, EE&C staff and corporate staff all have access to this information.

Developing the calculations needed to produce the BTU totals in GAUR was not simple. A longtime Dow engineer painstakingly developed methods to convert the various flows of energy commodities, and intermediate energy flows in Dow's complicated operations, to a standardized set of BTU equivalents (calculating GHG equivalents added another layer of computational complexity). Dow uses lots of primary (raw) energy, but also converts it into intermediate forms like steam and electricity. Accounting for the conversion and distribution losses, and the energy content of various energy streams as they are delivered to each plant, involves complex calculations, which led Dow to institute a formal, documented procedure to ensure consistency and quality of information across the company.

Because natural gas is the dominant source in Dow's energy purchases, all energy forms consumed are translated to equivalent BTUs of natural gas and adjusted to reflect real-world efficiencies and losses associated with energy conversion. This method allows staff across the company to use a common currency, in terms of how much natural gas has been or would have to be used to produce the energy consumed at a given plant. GAUR reports roll up to business unit and corporate levels, and form the basis of the energy and production numbers in quarterly sustainability reports, which are posted on the Dow website. But GAUR numbers are also used to produce internal reports with much more detail. In addition to the basic energy and production numbers, the internal reports assess actual vs. target performance, discuss issues that explain performance numbers, and suggest action items to correct any sub-par performance levels. These reports go to business unit leadership as well as to plant operators and site leaders, and often become the focus of extended discussions and follow-up actions.

A.2.4 How Dow Achieves Energy Savings

Dow achieves its energy savings goals somewhat differently than other companies. While all of the case study companies focus on low-cost operating improvements, Dow is much more capital-intensive, and less labor-intensive, than most. Dow plant operators rely on the continuous flow of data they get on energy and other performance indicators to determine whether their operations are on track. This may occasionally include operating adjustments or maintenance actions, but most big efficiency improvements come from process technology changes. For example, Dow's Light Hydrocarbon (LHC)-7 plant at the Freeport Texas site won a 2008 American Chemistry

Council (ACC) Responsible Care® Energy Efficiency Award in 2009 for replacement and upgrade of its ethylene furnace capacity. Dow replaced the existing 10 furnaces with five new, larger state-of-the-art furnaces with significantly higher energy efficiency. Interestingly, this investment was initiated for compliance with NOx emissions regulations, but the additional benefits in energy savings, yield improvements, corporate sustainability, and extended lifetime of the facility made the business case very strong. This investment has improved LHC-7 plant energy efficiency by more than 10 percent, producing energy savings of over 2,000,000 MMBTU/yr, equivalent to the annual electricity use of more than 17,000 homes, and cutting CO2 emissions by 105,000 metric tons annually.

Across the Atlantic in Antwerp, Belgium, Dow and its partner BASF in 2009 opened the world's first commercial-scale propylene oxide (PO) plant based on the innovative hydrogen peroxide to propylene oxide (HPPO) technology the two companies jointly developed. Producing up to 300,000 metric tons of PO per year for the polyurethane industry, the new Antwerp plant reduces energy use by 35 percent and wastewater by up to 80 percent.

A.2.5 Finding the Funding for Energy Projects

While these projects represent major efficiency gains and provide several streams of business benefits, the capital for such projects is hard to come by, even for a large company like Dow, and especially in the current economic downturn. Dow's capital budget must serve many priorities, and meeting energy goals is just one of them. Dow applies various financial criteria to project investment opportunities; including discounted cash flow, net present value, and internal rate of return. Business units use their own analysis and prioritization methods, driven by competitive forces and the norms of their businesses. In many cases, investments that are seen as critical to maintaining or improving competitiveness are moved to the fore; this forces the EE&C team to make a broader business case for energy-related investments, documenting the co-benefits in competitiveness terms. For example, a given efficiency investment might not meet a simple payback criterion; but if it keeps the company competitive in a specific market and avoids the loss of a specific customer or a certain share of the market, such considerations can help justify the investment.

In one sense, energy has long been a key issue for Dow, so energy efficiency competes relatively well when the numbers are compelling. Dow expects to ultimately factor in carbon price expectations in assessing energy projects. But because it does not expect carbon prices to appear in energy markets for several years, except in Europe, carbon prices only have a material effect on larger capital projects, and these tend to be major process changes that involve more than energy as driving forces. Dow does have facilities that are regulated under the European Union's Emissions Trading System. The carbon price created by the trading system is an added cost that Dow incorporates into the evaluation of energy efficiency projects.

A.2.6 Pursuing Operational Improvements vs. Capital Investments

The challenge of raising capital for efficiency investments turns the focus back to operating improvements. Dow works hard at this on an ongoing basis, but EE&C team members also know that the sheer scale of energy and product flows in a continuous processing environment limits the relative impact of operating changes. Using the engineering talent in the Tech Centers and other EE&C team members, Dow sometimes uses Pinch analysis, a methodology evolved in industrial circles in the last three decades. The Pinch method is designed to minimize energy consumption in chemical processes by calculating technically feasible energy targets, and then achieving them by optimizing heat recovery systems, energy supply methods and process operating conditions. In a Pinch analysis, process data is typically represented as a set of energy flows as a function of heat load against temperature. These data are combined for all the energy flows in the plant to give composite curves, one for hot flow and one for cold flow. The point of closest approach between the hot and cold composite curves is called the pinch temperature or pinch point. By finding this point, various heat recovery or transfer solutions can be developed.

Dow engineers constantly use their creativity combined with the variety of energy and material streams in their plants to find new efficiency ideas. For example, at the Texas site, hydrogen occurs as a byproduct in one process. EE&C staff have experimented with blending this available hydrogen with natural gas fuel in their power turbines, taking the mix up to the limits that the turbines will tolerate. For its efforts, the EE&C team also seeks outside input to find new ways to save energy. It maintains a panel of outside energy and environmental experts to provide technical and strategic input. Dow also participates in national programs like the U.S. Department of Energy's (DOE) Save Energy Now program to review its large US-based facilities.

A.2.7 Conclusions

Dow is one of the few companies that has not only set and met a 10-year efficiency target, but has gone on to set another, more aggressive 10-year target. This "in it for the long haul" demonstration of commitment is one of the hallmarks of a successful sustainability program. Dow has also set and met its goals in a manufacturing environment where energy has long been a critical factor of production, so the company had been paying attention to energy issues since Herbert Dow pioneered bulk chemical manufacturing a century ago. This means energy savings were not as easily found as they might be in companies where energy has only recently become an issue. Dow has made effective use of its energy efficiency team from its energy business unit, reaching across business units and functional lines to create teams of experts and local site leaders to keep the efficiency program moving forward.

Key lessons learned from Dow's energy efficiency successes, include the importance of:

• Corporate leadership commitment. In Dow's case, the CEO has made a very clear and public commitment to achieving the company's energy savings goals.

• Building the appropriate organizational structure to institutionalize and lead the program. This includes cross-functional teams with clear lines of accountability.

• Robust measurement, tracking, and reporting systems so that management can monitor progress and identify potential problems.

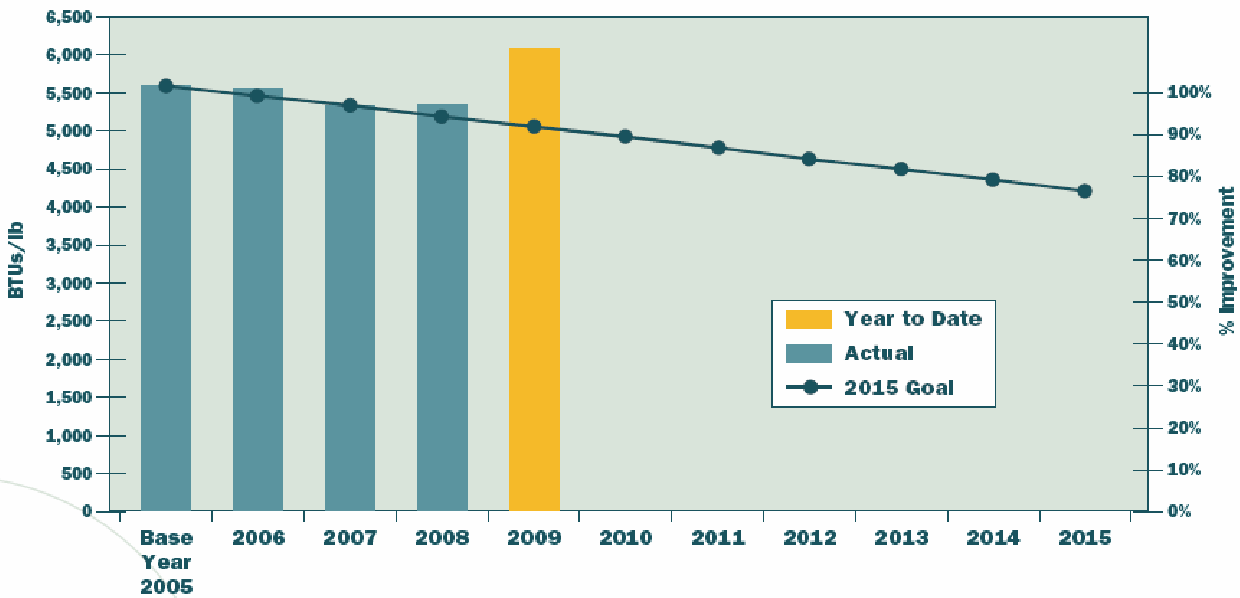
• Establishing clear goals and objectives, and then revising them over time as the initial targets are met.

• Communicating the importance of energy efficiency as a core company value to both internal and external stakeholders.

• Recognizing success by rewarding employees and business units for energy saving innovations.

Figure 1

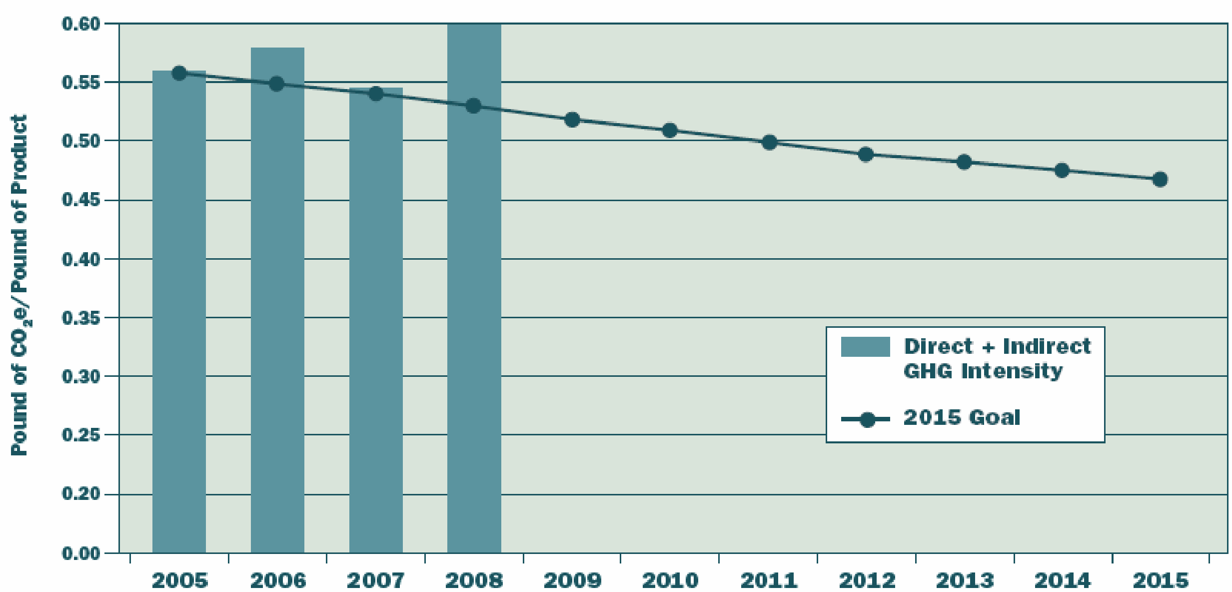
Dow's **Energy Intensity** Performance 2005-2015



Recreated based on image provided courtesy of Dow (2009).

Figure 2

Dow's **GHG Intensity** Performance 2005-2015



Recreated based on image provided courtesy of Dow (2009).

Figure 3

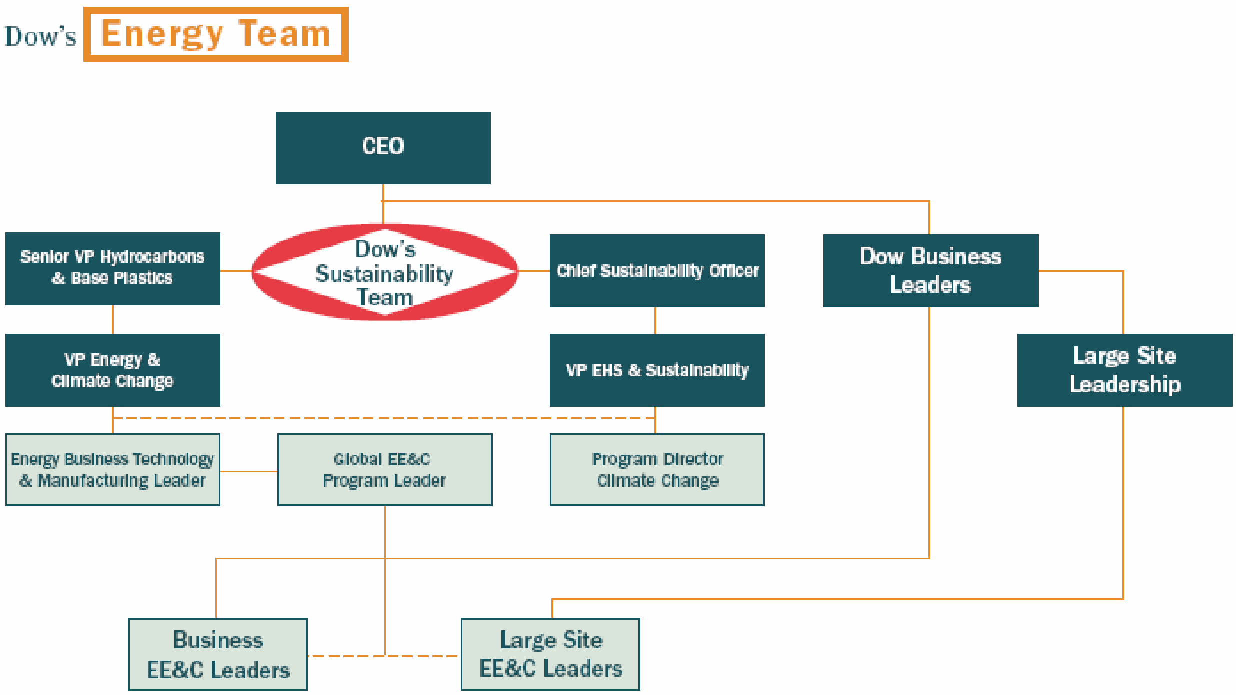


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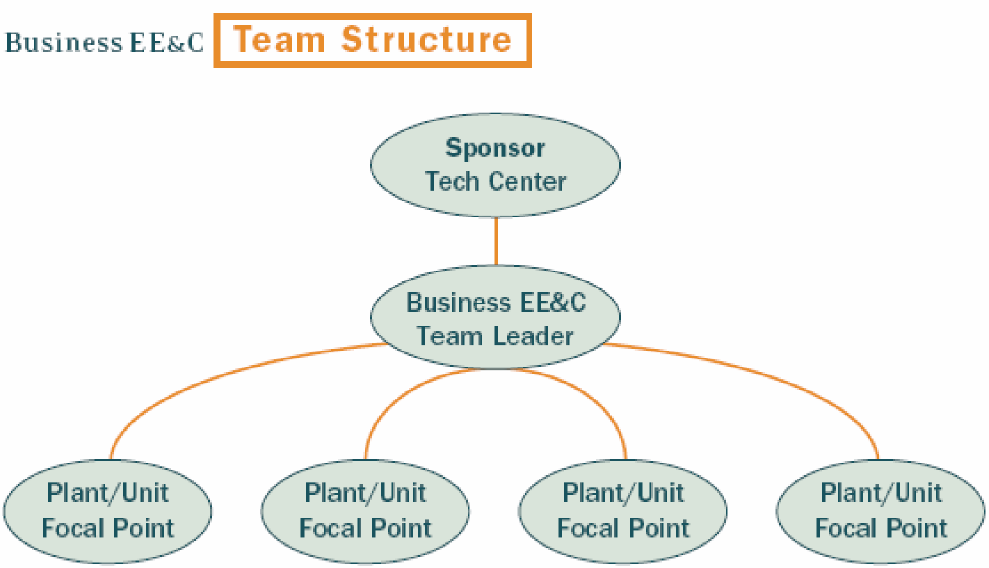
Figure 4



Recreated based on image provided courtesy of Dow (2009).

ANNEX 3

CASE STUDY: TOYOTA MOTOR MANUFACTURING

Adapted with permission from the Pew Center for Global Climate Change Publications

A.3.1 Toyota-TMMK—Internal Operations

On a wall in an open bay in the middle of the Toyota Motor Manufacturing Kentucky (TMMK) plant hangs a mockup of a NASCAR racetrack. On a Wednesday morning in July, some 40 people gather in front of the magnetic track-board, from TMMK President Steve St. Angelo to the site's Energy Management Organization (EMO) lead, Roger Wallin, to shop captains and other team members. This meeting marks the start of the 2009 "Race for the Greenest." Roger places the tiny cars in order on the track-board, based on the points they earned in the previous month and year to date from energy, water, compressed air, and steam efficiency. Now in its third year, this friendly competition not only gets good attendance, it appears to be getting results. TMMK beat the Toyota goal of using less than 6.3 million British Thermal Units (BTUs) per vehicle produced, having driven its usage down below six million.

The Race for the Greenest competition epitomizes Toyota's energy efficiency strategy. Energy is a key performance indicator that is measured and reported regularly, and the process engages the whole organization, from senior management to individual shop staff. But beyond the mechanics of the process, energy performance is part of the company's culture. There's a certain amount of fun that is palpable in these monthly gatherings: so it's not just about numbers, it's about how people see themselves, what they take pride in, what they hold to be important. Imposing new requirements on employees in an organization is not something that is always embraced with open arms; but at Toyota, the Race for the Greenest reveals a culture that is not only about performance by the numbers, but also about engaging people's pride and ingenuity for collective gain.

A.3.2 The Energy Management Organization

Energy as a formal performance indicator was first measured in Toyota North American operations in 1996, around the time that the Toyota Motor Engineering and Manufacturing North America (TEMA) corporate structure was formalized. In 2000, Toyota used over 9 Million BTUs per vehicle produced. The 6.3 million BTU target represents about a 30 percent improvement. Originally set in 2002 to be achieved in 2011, TEMA was close to realizing its goal in 2007, as shown in Figure 1. Since then, production slowdowns driven by the global recession have caused the per-vehicle number to creep up, as some energy uses cannot be throttled back in proportion to production. To illustrate the production slowdowns, in 2007, TMMK made over 500,000 vehicles; in 2009, it expects to make about 366,000. "Race for the Greenest" also shows a critical link in the Toyota EMO—between the facilities staff and the production teams. In a large manufacturing organization like Toyota, facilities is a service organization to the product units; it provides them the electricity, compressed air, steam, chilled water, natural gas and other services they need to produce quality products. But the facilities team does not own, and is careful not to dictate, how the product units or "shops" run their operations. The production shops—assembly, paint, welding, stamping, etc.—have two primary mandates: (1) product quality and (2) production volume. Shop captains don't easily embrace ideas that might put either of these goals at risk. They need to be shown that meeting the energy and other Key Performance Indicators (KPIs) will help them, not hinder them, in meeting their quality and production goals.

The EMO has found that one way to overcome production shops' reluctance is through the use of pilot projects. EMO will commission one small project in one plant, document its success, and then engage the production staff in sharing their experience with others in the company. Peers from other shops and other plants inherently bring a greater comfort level to their counterparts than do facilities staff seeking to advance the EMO goals.

Figure 2 charts the EMO's relationships in North America, from the President of TEMA to the individual production shops at each TEMA facility. The term "Kaizen" in this figure refers both to Toyota's overall Kaizen philosophy (see footnote below) and to the practical application of the term as a database of efficiency technology information.[2]

Figure 3 elaborates on the EMO's several roles in supporting the various elements of the energy program. Reporting to and receiving support from senior management, the EMO focuses on the six internal activities on the left side of the figure, from KPIs to target-setting. It also maintains the three more outward-facing activities on the right side—creating visually-interesting reports for senior management, benchmarking performance against competitors and third party programs, and pursuing awards and recognition, both inside the organization and with third-party programs like ENERGY STAR.

[2] The Japanese term *kaizen* means "improvement." Within Toyota, it describes a philosophy as well as specific practices aimed at continuous improvement in manufacturing, business in general, and even life overall. In the workplace, kaizen typically refers to activities that continually improve any or all functions of a business, from manufacturing to management and from senior management to shop-floor workers. By improving and standardizing various practices, technologies, and processes, kaizen aims above all to eliminate waste.

A.3.3 Importance of Data in Continuous Improvement (Kaizen)

Like other successful energy management programs, Toyota's EMO maintains a monthly/quarterly/annual data collection and reporting system, and an accountability system that operates at all levels, from individual shops to senior executives. What sets large manufacturers like TMMK apart from the average company, however, is the added levels of data monitoring they apply to their operations. TMMK staffer Bill Pulliam manages the plant's Enterprise Building Integrator (EBI) software, through which he can monitor up to 30,000 data points in the 1,300-acre complex. EBI enables him to look deeply into HVAC units, individual shop equipment, and other operations. EBI can generate very detailed reports, with data measured down to one-minute intervals or less, for individual units or shops, so shop captains can diagnose issues as needed. Shop captains pay attention to this information because they must meet specific KPI targets, and if their weekly or monthly reports deviate from those targets, they will often follow up with facilities staff for data and assistance. The NASCAR racetrack imagery in "Race for the Greenest" also shows how TMMK has adapted the Toyota kaizen philosophy in its own uniquely American way. As a practical tool, kaizens are specific proposals, entered into standard forms and loaded into an enterprise-wide database. Individuals are encouraged to develop and submit kaizen ideas into this system, and the database is available to Toyota worldwide to share these innovations throughout the company. Ultimately, it is the sum of Kaizen ideas developed in each facility that drives future goal setting. Both operations changes, and capital investment recommendations, are summed and translated into energy use and cost per vehicle, and the summed potential savings are applied to future years' energy savings targets (see the Pew project web site[3] for examples of Toyota's Kaizen reports).

A.3.4 Development of Specific Strategies

Facilities staff works as hard as production shops to drive down energy usage and costs. Historically, they focused on running utility plants, in separate buildings from production units, and piping steam, compressed air, and chilled water to the various shops through miles of pipes. Staff and equipment systems were physically and organizationally somewhat distant from production. But as the company's energy goals per vehicle pushed both facilities and production staff to rethink their ways, this pattern changed. Facilities staff began finding ways to bring energy supplies closer to production units. Rather than generating steam in a bank of huge

[3] http://www.pewclimate.org/energy-efficiency.

boilers, and piping high pressure steam for long distances, with all the attendant losses at each step of this process, facilities staff began placing smaller, hot water boilers at production unit locations. This saves energy first by allowing lower temperature and pressure in the system, second by eliminating the step-down losses from running high-pressure steam through pressure reducing valves to serve process loads, and third by eliminating the thermal losses from long pipe runs across the plant. At TMMK, facilities staff has reduced central boiler needs from six units to two, and plan to shut down these remaining units soon.

The other way that TMMK reduces steam demand is through reducing heating loads, and through heat recovery, in the paint shop operations. The easiest step was to experiment with elimination of the first water rinse tank through which the auto bodies pass to remove surface dirt. After being satisfied that unheated water worked just as well for this step, the next target was heat recovery. The paint shops are the biggest energy users in the plant partly because they must incinerate exhaust air to burn off the hydrocarbons and other residues of the painting process. This produces 640-degree air; by applying heat exchangers, TMMK staff was able to recover a large fraction of this heat and pump it back into the steam loop. This first reduced loads on the boiler system and made localized hot water units more efficient.

But the most overlooked energy use at Toyota, as is the case in many manufacturing operations, was compressed air. Steam boilers, cooling systems, electric motors, and sometimes lighting have typically received the greatest focus in most efficiency programs. This has changed as efficiency programs look harder into all aspects of plant operations. Such examinations quickly show that compressed air runs many of the assembly and other production tools, keeping electricity and fuels away from critical production steps, where a spark or a gas leak could be a health and safety risk, not to mention the risk of stopping the production line. TMMK generates compressed air at the central utilities plant through a bank of huge compressors. Facilities staff save energy by replacing compressors as funds and opportunities permit. Their most recent Atlas-Copco compressor saves 25 percent or more energy than its predecessor, paying for itself well within the company's three-year payback guideline. But it is also quieter and maintains pressure more reliably than earlier generations.

The view from the utilities plant compressor control booth shows another way that TMMK saves compressed air energy. As the first shift goes to lunch at 11:30 a.m., the compressor load drops like a rock, falling 40 percent in a matter of minutes. In the past, this would not have happened; but facilities worked with production staff on a shutdown routine that takes air tools offline during lunches, breaks, nights, and weekends. The practice in the past had been to leave tools on, partly because shop-level staff were not aware of the energy needed to keep the system pressurized even when tools were not in active use, and partly because there was a perception of performance risk in shutting off and restarting tools. Facilities staff worked with shop captains to show them the energy impacts of leaving tools on, and to reassure workers that the reliability of the tools would not be compromised and that restart times would not be a problem. In addition, production crews and facilities staff alike watch religiously for air leaks, the Achilles heel of compressed air systems. Leaks are inspected and repaired regularly, and it is the KPI reporting system that allows staff to see when compressor energy use is drifting up, triggering a deeper look.

A.3.5 Employee Involvement

TMMK's management of compressed air energy use is emblematic of the way Toyota implements its energy efficiency strategy company-wide. One of the most effective methods the EMO uses to drive operational improvements in plants is to conduct unannounced "Treasure Hunts" that seek low-cost efficiency opportunities. A departure from the "energy audit" terminology of traditional energy management, "Treasure Hunts" connotes opportunity, with a hint of fun, as distinct from the compliance-based implications of the word "audit." In a typical Toyota Treasure Hunt, a team of energy experts from other facilities visits a plant, with their presence known in advance only to senior managers. The Hunt typically starts on a Sunday, and focuses primarily on finding equipment that is left on and other operational improvements. The team then observes the first shift on Monday, compares its practices with the second Monday shift, prepares a report, and presents it to plant leadership and shop captains on Tuesday. Because the Treasure Hunt team is composed of Toyota peers, its findings tend to bear weight, and with senior management hearing the recommendations, they tend to get implemented. The final report is reviewed by the plant, action items are prioritized, and then the kaizens are scheduled for implementation based on resources. These activities are then followed up, confirmed and best practices are shared with other plants.

While the EMO's day to day work is intensely focused on running existing equipment at peak efficiency, eliminating waste, and looking for individual Kaizen opportunities, the company also has a larger vision. The Toyota plant of the future will be a zero-emission facility. The intent is to minimize emissions at all plants. Current energy efficiency activities are shown in the green boxes, along with broader carbon emissions strategies like buying carbon offsets or sequestering carbon. Moving "down the road" toward the Ultimate Eco Factory, Toyota envisions designing advanced energy efficiency with supply strategies like onsite renewable energy and combined heat and power (or cogeneration) systems. If the company can drive down its energy needs to a minimum, purchase or generate non-emitting energy supplies, and use other strategies to offset any remaining carbon emissions, it can reach the goal of a zero-emission factory.

A.3.6 Conclusions

Toyota has developed one of the world's most thorough and integrated energy efficiency strategies, building on its cultural as well as technical assets. Culturally, the Kaizen philosophy helped engage individuals across many levels of management and many functional units in the common cause of driving down energy waste. This application of individual responsibility in service of collective goals has helped the program establish itself within the organization quickly, and increased the likelihood of sustained success. As people take ownership of the goals and the practices needed to reach them, the efficiency strategy becomes part of the company culture. Technically, Toyota's strong engineering talent was able to tap its physical assets to support the strategy. Toyota plants have very fine-grained data monitoring and reporting systems that enable staff to pinpoint performance issues down to individual shop and equipment levels. Years of engineering experience have produced Kaizen project information in the company database, making its technical knowledge available across the organization. And the company's "Treasure Hunt" practice of bringing in experts from peer facilities to examine improvement options at other plants keeps plant staff on their toes, and increases the credibility of the findings, coming as they do from Toyota peers. The success that flows from these efforts is recognized and reinforced regularly at the highest levels, as evidenced by the plant president coming to monthly Race for the Greenest festivities.

Key lessons learned from Toyota's energy efficiency successes include:

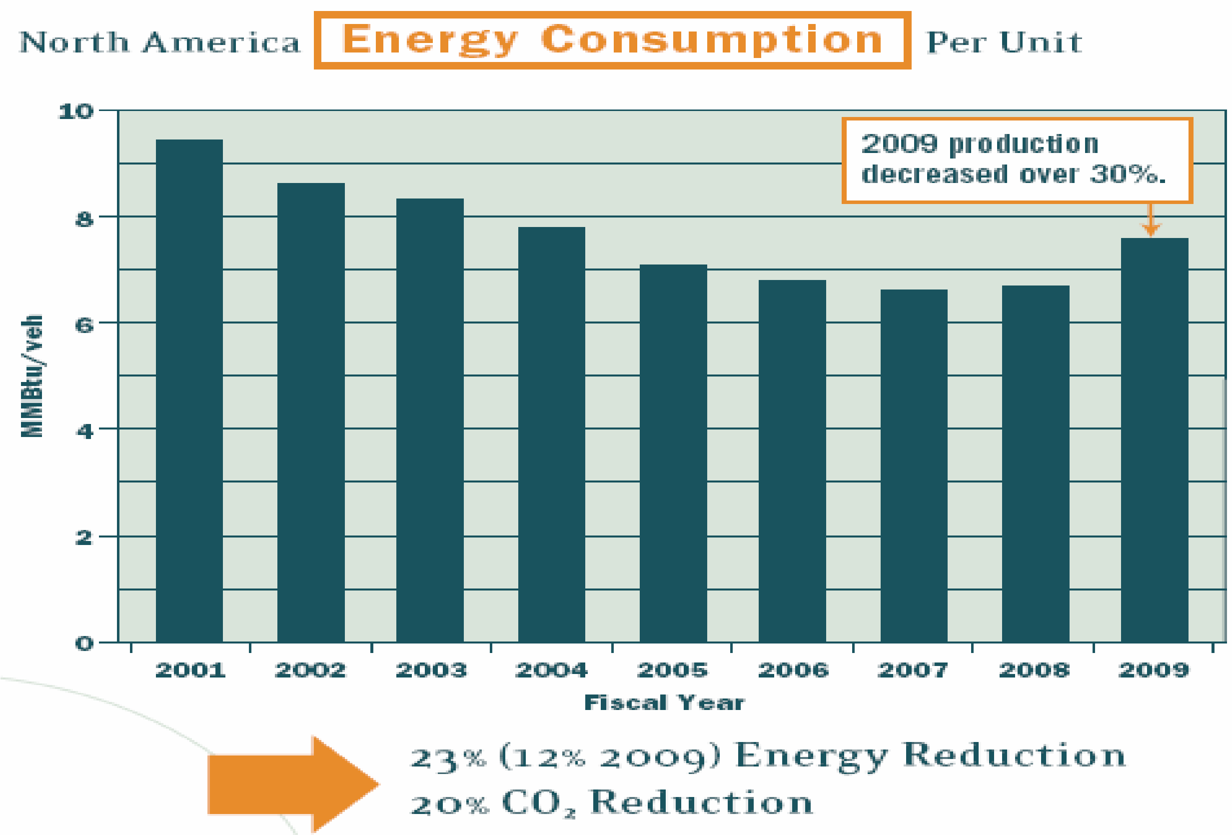
• **Work hard to make your Kaizen permanent**. Temporary improvements are of limited value. Remove old methods, equipments, and processes after improved versions are developed.

• **Look at new technologies and try to build them into the design and production process**. Pilot projects can be helpful in demonstrating success and overcoming resistance from production staff and others more focused on product quality and volume.

• **You can never report too much information**. At the same time, it is important to recognize that different company officials will require different types of information. A deluge of data can be costly and cumbersome to sift through, especially for senior managers with limited amounts of time on their hands. Toyota goes to great lengths to gather and report vast amounts of data, but equally important is the effort the company puts into rolling this data up into more streamlined reports that senior management can easily digest and act upon.

• **Awards and recognition—both internal and external—are important**. These have the effect of motivating facility staff to go beyond strict compliance with environmental laws and regulations and instead, reach for a higher level of energy efficiency and sustainability.

Figure 1



Recreated based on image provided courtesy of Toyota (2009).

Figure 2

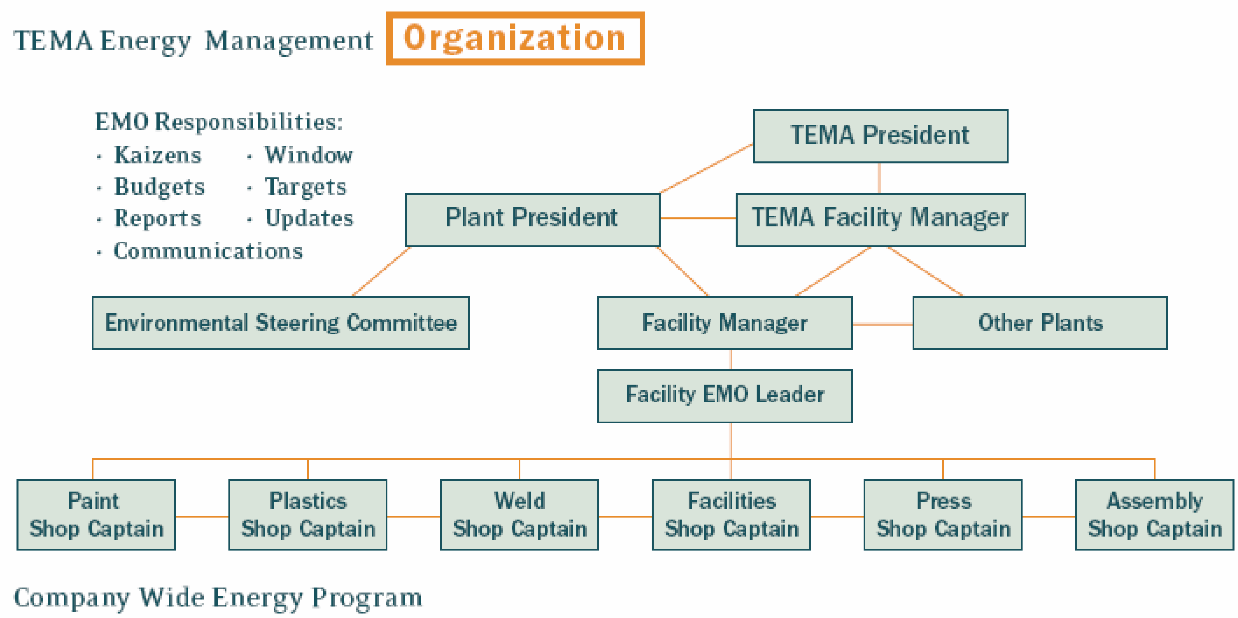


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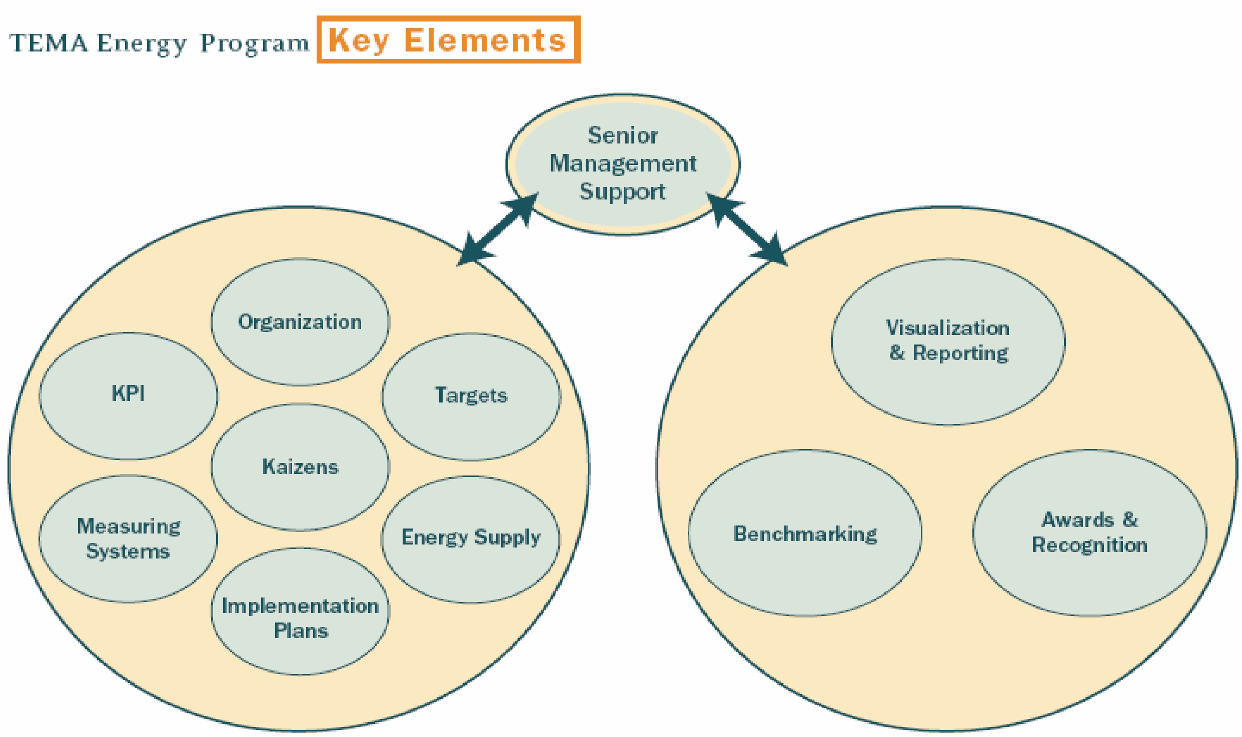
Figure 3



Recreated based on image provided courtesy of Toyota (2009).

ANNEX 4

CASE STUDY: ST. LOUIS METRO TRANSIT VEHICLE MAINTENANCE DIVISION

A.4.1 OVERVIEW

The City of St. Louis was facing a number of problems in its Metro system (bus and rail) in late 2002. The rolling stock was declining in operability and desirability from their in-service date of introduction to the end-of-life point when they were scrapped. Due to the municipal financial situation, new bus purchases were being curtailed, and major investments had to be made on older buses to bring them up to specification even as they were approaching the end of their useful life. Since bus purchases had been on a "when money is available" schedule, the cycle of investments in older buses created large swings in annual maintenance costs between fiscal years. The maintenance level of effort had little or no co-ordination with the stock capital investment cycle.

The maintenance network also had a number of problems. The metro area had three depot level repair garages, and they each employed different business models. The garages differed significantly in the ratio of mechanics to buses and mechanics to operating miles. The Central garage where major repairs were made was heavily backed up and about 15% of the bus fleet was awaiting repair. Bus turnaround time was an unsustainable level of 117 days. Due to the pattern of investing in maintenance late in a buses' life, the scrap fleet had many drive-train components that had less than 35,000 miles of use. Hence Metro St. Louis urgently needed a new approach and senior management developed a comprehensive new business plan to address the problems.

A.4.2 BUSINESS CONCEPT

Recognizing the heavy overload on the Central facility that performed major overhauls of the buses, management created a concept where the single major overhaul at 400,000 miles with several intermediate smaller scale actions to prevent bus deterioration. Comprehensive body repairs were scheduled every 100,000 miles along with minor drive train overhauls. Small scale rebuilds of the engine including recalibration of the diesel injection pump and cleaning of nozzles occurred every 200,000 miles with the transmission also receiving extensive maintenance. More intensive maintenance was also programmed at the annual maintenance point which corresponded to about 50,000 miles of use. The business plan refocused on pre-failure overhauls on components rather than wait for breakdowns before maintenance.

The business plan also set up one year and three year goals that had clear specific targets and timelines. The first year goals were

- Achieve departmental consensus on pre-programmed maintenance activities.
- Audit manufacturer suggested maintenance plan against consensus plan developed
- Develop standard work procedures for all routine maintenance activities
- Determine mechanics abilities in each garage to complete the maintenance activities properly

The three year goals were to rework the existing inspection program to better support the programmed maintenance, and to implement bus “service writers” who tracked all the problems on an incoming bus at the depot and central facilities and ensured that each one was addressed before the bus left the garage.

A.4.3 IMPLEMENTATION PLAN

Senior management convened operations staff and lead mechanics to develop the pre-programmed maintenance plan and evaluate mechanics and also paid considerable attention to data analysis and facility support. The Metro system invested in fleet maintenance software to create an automated inter-departmental interface that automatically generated pre-notification of impending maintenance activity to all concerned departments and generated the work orders for each bus. Parts departments were also pre-notified to reduce reliance on last minute parts acquisition (which had historically been overused) and followed standardized parts inventory procedures. In addition, the automatically generated parts list reduced mechanic trips to the storeroom window.

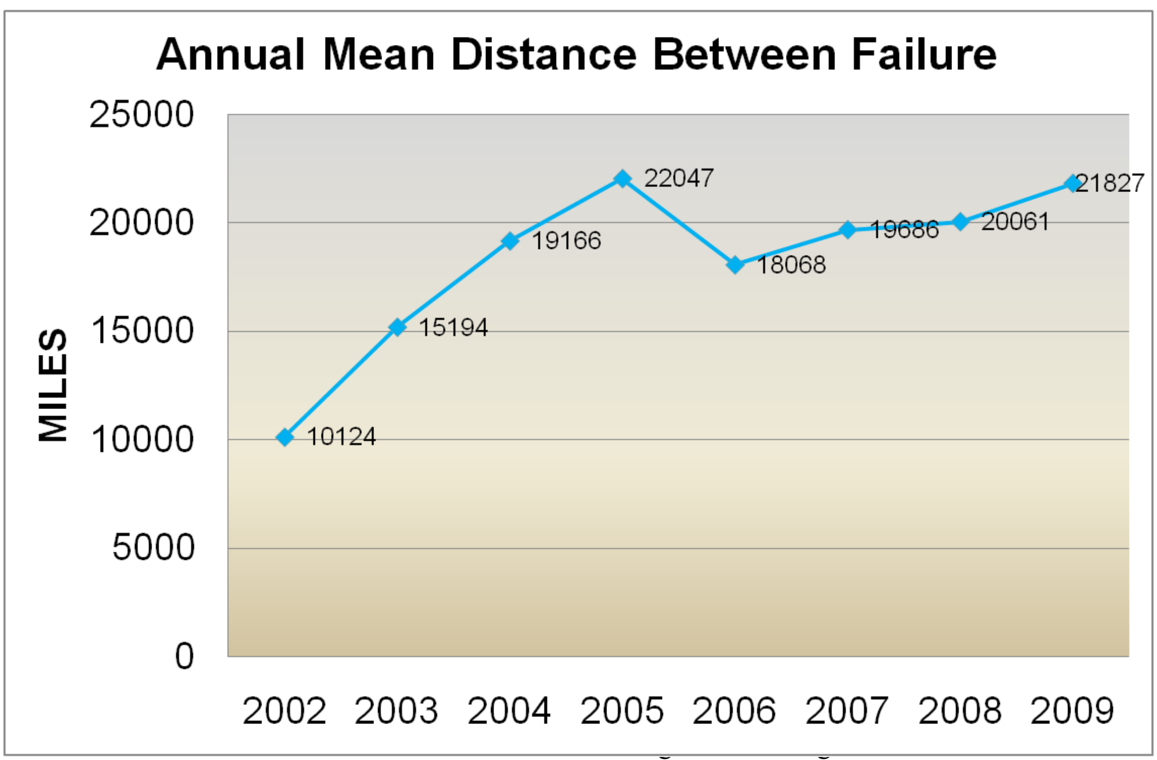
The garages were also carefully evaluated for their capabilities and the “choke points” in the system where items like hoists and dynamometers being out of service would result in a major maintenance back-up. The Metro also invested in portable diagnostic and test equipment for field maintenance. All mechanics were retrained according to the newly developed procedures, and chief mechanics spent a greater amount of time in the QA/QC functions than previously.

The program also had several risks. If the maintenance plan was flawed due to incorrect assumptions on component life cycle, or if some components that fail had been omitted, then the new business plan could deliver no improvements in cost or reliability. A separate plan to monitor and address risks was developed, and the system monitored the number of service delays, the number of breakdowns in the field and the number of customer complaints. They also instituted a component specific mean-time-between-failure measure to benchmark the performance against expectations.

The key issues that management had to face was to resist the temptation to show quick reductions in maintenance costs in the short term, and study the system response over 3 to 4 years to update and modify the plan as required. Also, due to the different levels of staffing at different locations, personnel had to be moved around to "right size" human assets at each location. Finally, management realized that the supervisory staff did not have the analysis skills and this had to be developed over time.

A.4.4 RESULTS

The program was instituted in 2003 and Metro St. Louis was able to document the improvements over time. They increased mean time between failures and reduced maintenance costs per operating mile. Customer complaints also dropped sharply over a four year period, and bus waiting time for repairs as reduced dramatically with greatly improved scheduling. The figure below shows the Metro experience with mean distance between on-road breakdowns which doubled between 2002 (baseline) and 2005. The reduction in 2006 and the relatively modest growth thereafter is due to the introduction of less reliable CNG buses in 2006 and their increased presence thereafter.



training on different equipment to more "systems" training. Existing staff had more time and skills to analyze failures and spot failure trends in advance of their becoming endemic problems. The standardized work procedures have made it easy to move mechanics between garages as they can find the same tools and procedures in use everywhere.

Metro St. Louis current state that the oldest buses have annual mileage just 10 percent below average, and large savings in parts costs have been realized. In addition, there are no more “campaigns” to improve maintenance that simply exhort mechanics to work harder without providing the system backup required to achieve the improvement.

Derived from the Metro St. Louis presentation at the FTA State of Good Repair Roundtable, July 2009

ANNEX 5

CASE STUDY: MAKING FLEET AND TRANSIT OPERATIONS MORE EFFICIENT IN EDMONTON

A.5.1 OVERVIEW

Fuel Sense is a four-hour training program on fuel efficiency practices that combines practical and classroom training to realize fuel efficiency gains in the City of Edmonton's fleet and transit operations. The program instructs drivers to operate vehicles for maximum fuel efficiency while considering operational needs. Participating drivers learn techniques such as reducing idling time and planning more efficient routes. A computerized fuel dispensing system tracks the fuel usage of individual drivers to allow Fuel Sense to measure results at regular intervals.

Fuel Sense targets municipal employees who log the highest fuel consumption in City vehicles. To date, 800 municipal operators have been trained in Fuel Sense with the group averaging a 12% efficiency gain. To date, Fuel Sense has successfully reduced annual fuel consumption by over 10%, or by over 200,000 liters a year. This translates into an estimated reduction in GHG emissions of 310 tons in annual fleet operations.

A.5.2 COMMUNITY CONTEXT

The City of Edmonton owns and operates a large fleet of vehicles for municipal operations, including light and heavy duty trucks, cars and buses for Edmonton Transit. Edmonton Transit's fleet alone includes over 700 diesel buses and 26 non-diesel community buses.

Edmonton's city operations represent only a small proportion (approximately 3 to 4%) of GHG emissions from within the municipal boundaries, but they do provide a target over which the City has control and can demonstrate leadership by example. Municipal and transit fleet operations account for 20% emissions from city operations.

To achieve operational savings and reduce the overall environmental impact of fleet operations, the City began exploring methods of modifying driver practices and implementing training programs beginning in 1999. At the time, the City's Fleet Safety section provided a variety of staff driver training programs, but none that focused on the combination of defensive and fuel-efficient driving techniques.

A.5.3 POLICY CONTEXT

The City of Edmonton is an active partner in FCM's Partners for Climate Protection program, a national GHG reduction program that seeks to achieve a 20% GHG emissions reduction in partner municipal operations by 2008.As part of their commitment to this program, City Council approved both an Environmental Strategic Plan and a Corporate Greenhouse Gas Plan in 1999. Both promoted proactive corporate initiatives to reduce GHG emissions, in particular those from City operations including the municipal fleet.

In response to these plans, Edmonton's Asset Management and Public Works Department and its Fleet Safety section developed the Fuel Sense program to help improve the efficiency of the City fleet vehicles operations by modifying driver practices through a driver education training program.

"The City Council encourages initiatives that are working to constructively preserve the environment," say Bryan Payne, Edmonton's Supervisor of Fleet Safety and one of the principal architects behind the fuel sense program.

A.5.4 RATIONALE AND OBJECTIVES

The development of Edmonton's Fuel Sense program was created in response to the City's commitment to reduce corporate greenhouse gas (GHG) emissions and its desire to reduce fleet operations costs, particularly fuel expenses.

As a member of the Federation of Canadian Municipalities (FCM), the City of Edmonton is committed to the organization's Sustainable Communities program and is a founding member of FCM's Partners for Climate Protection campaign. As part of the commitment to this campaign, City Council approved a GHG reduction plan that seeks to reduce emissions from municipal operations by 20% by 2008.

In combination with the environmental imperative, the City of Edmonton was affected by increasing fuel costs. In 2000 alone, the City of Edmonton experienced a 40% increase in fuel prices. With that trend expected to continue, a major budget deficit was predicted for city vehicle operations.

The program's objectives include:

- Achieving a 5-10% reduction in the overall corporate fuel usage
- Maintaining fuel cost reductions through reduced consumption
- Reducing community-wide GHG emissions
- Training one thousand of the highest fuel-user drivers working for the City of Edmonton in fuel-efficient driving techniques
- Attaining 100% support and participation from the senior management team, department management teams and all targeted drivers

In addition to these shorter-term objectives, several longer-term objectives and goals were developed, including:

- To develop partnerships with like-minded organizations and groups, such as the Alberta Motor Association and other municipalities
- To expand the program to include all drivers of city-owned vehicles
- To promote the program to all City residents as an opportunity to address high fuel costs and reduce automobile-related air emissions

A.5.5 ACTIONS

Fuel Sense is a fuel efficiency training program for fleet operations drivers that combines practical and classroom training to realize fuel efficiency gains. The training program is included as part of regular municipal fleet driver training programs and in Edmonton Transit's driver training programs. Fuel Sense teaches each participant basic driving techniques that help achieve a vehicle's maximum fuel efficiency. The program focuses on driver skill development and works to eliminate habits that lead to poor energy consumption and excessive GHG emissions, such as excessive idling and variable speed driving.

The Fuel Sense Program was first operated as a 10-month pilot program beginning in October 2000. After hiring an instructor to oversee the project, the next task was the identification of those municipal employees that did the most driving in their jobs. Initially, approximately 1,000 corporate employees were identified as drivers logging the highest fuel consumption in city vehicles and were targeted for Fuel Sense training. These potential participants were then invited to take part in the voluntary training program.

In the Fuel Sense program, drivers attend a four-hour training session that includes two hours of classroom instruction and two hours of on-road instruction on a special closed street course. The student instructor ratio is purposefully kept low at 4 students per instructor per class. In the classroom session, employees learn about:

- The impact GHGs have on the environment and the global climate;
- The potential cost savings associated with efficient driving techniques; and
- The correlation between speed, revolutions per minute (RPM) and fuel efficiency and excessive idling.

During the on-road instruction employees test their knowledge and practices on a special 10-kilometre closed street course designed to recreate actual city driving conditions. A pre-test establishes a benchmark of performance for each driver who then completes the course with the trainer, this time receiving instructions from the trainer. Individualized coaching is provided where necessary.

The vehicles used on the street course are equipped with on-board computers, one of which captures RPM and speed information. "There is a direct correlation between that and fuel efficiency," says Payne. "Drivers who maintain a consistent RPM tend to be more productive than those that are on and off the throttle constantly." A second computer is connected to a fuel flow gauge to permit the trainer to compare fuel consumption for each driver before and after training. The trainer is also able to monitor day-to-day fuel consumption for different drivers using the City's computerized fuel dispensing system that tracks the fuel usage of individual drivers.

So far, feedback on the program has been very positive, with 95% of drivers rating the training as excellent. As reported in a FCM/CH2MHILL review of the program, “for many drivers, using efficient driving techniques is a much more relaxed way to cover their routes.” Mr. Payne agrees with the observation. “It proves that there's always something new to learn,” he says, adding, “The best drivers always realize the impact they potentially have behind the wheel and never fail for a second to remember that safe driving is important.”

The lessons learned by drivers also appear to be sticking. Drivers retested a year after completing their initial training boast an average improvement over their first scores of 1.5%. Although this improvement may seem minimal, it not only demonstrates an excellent retention rate amongst drivers, but also translates into significant fuel savings when extrapolated over the entire fleet.

A.5.6 RESULTS

The Fuel Sense program quickly achieved most of its objectives after only its first year of operation. A more comprehensive review conducted in June 2004 confirmed the following results:

- Over 1200 drivers trained
- 350 tons (estimated) of GHG emissions avoided annually
- Fuel volumes consumed per kilometer dropped overall by approximately 5.5%, or a gain in fuel efficiency of 1.8 liters/100 km
- Driver fuel consumption savings of up to 15%, regardless of the type of vehicle

As more drivers are trained in Fuel Sense principles, it is estimated that annual fuel cost savings could well be over half a million dollars.

In 2002, the Fuel Sense program received an FCM-CH2M HILL Sustainable Community Award. In 2004 the Edmonton Transit Fuel Sense program was incorporated into the in-house Defensive Driving course and qualifies for a Provincial certificate of completion.

A.5.7 PARTICIPANTS

Fuel Sense has been delivered to both Edmonton Transit and drivers from the City of Edmonton through an interdepartmental partnership with the City's Fleet Safety division and Edmonton Transit.

To date, requests for information have been received from municipal and provincial governments across Canada, the Alberta Trucking Association and the Alberta Motor

A.5.8 RESOURCES

Fuel Sense training is considered as a supplement to the normal driver training courses that all City operations employees undergo. As a result, all program costs were absorbed by the Fleet Safety section. The Fuel Sense program's first-year start-up costs were $60,000. Annual program related costs are estimated at $45,000.
"There was another fuel price increase [in 2004]," says Bryan Payne, Edmonton's supervisor of fleet safety, "and we were able to deflect a large percentage of the increase through the savings of the drivers."

A.5.9 LESSONS LEARNED

One of the key lessons learned in Fuel Smart was how easily the entire process can be transferred to other types of operations. Bryan Payne, Edmonton's Fleet Safety Supervisor, believes that the success of Fuel Sense rests on its practicality. "The program is based on simple techniques," he says, "but it was bringing it together in a synergistic manner that makes the program a success. The bottom line is achievable by anyone."

Other lessons learned include:

- **Communicate results regularly.** Communicating results regularly to driver and Council is important. Drivers benefit from follow-up communication and are motivated to continue their lessons if they are kept appraised of the results. Council, on the other hand, needs to be kept informed of program efficacy and efficiency to support the growth of the program and its applications in new areas. Mobile Equipment Services maintain a voice on the City's environmental steering committee.

- **Coordinate training sessions with community events and seasonal workloads.** Although most of the training occurred without a hitch, program coordinators did have to reschedule some re-testing in respect of higher seasonal workloads during the spring and summer months. Originally, driver re-testing occurred three months after initial training. It now takes place one year after to allow greater flexibility in scheduling the re-test, to better test driver retention and to help sustain staff commitment to the program.

Initial implementation of Fuel Sense for Edmonton Transit also experienced some delays while a "best practices" study determined the most effective way to introduce the program to Transit operators.

A.5.10 NEXT STEPS

Given the success of the Fuel Sense program, the City of Edmonton and Edmonton Transit are seeking to gradually expand the program into other fleet operations areas.

Currently the City has partnered with Natural Resources Canada, Office of Energy Efficiency, together with other stakeholders have developed an urban transit fuel-efficiency training program based partly on Fuel Sense. In addition, the program may be expanded to in the following ways:

- Using Fuel Sense as a model for a "train the trainer" program for private companies with significant fleet operations and which already have a driver training program in place, but are also concerned about fuel costs and the effect on the environment.
- Developing of a multimedia component of the Fuel Sense program to increase accessibility beyond the normal channels of delivery, e.g. E-Learning.

Finally, the monitoring and identification of high potential candidates for Fuel Sense training is gradually being enhanced through the installation of on-board vehicle technology that measures day-to-day fuel consumption, driving habits and routes. "Part of our commitment is to reinvest in on-board technology," says Mr. Payne. "We're working towards a one-system communication tool and have recently introduced GPS/AVL technology into our Fleet Management practices. Under this program idling is analyzed and operating practices are examined and modified whenever.

Adapted from Transport Canada, Case Study 24, Case Studies in Transportation, Urban Transportation Showcase Program

ANNEX 6

CAPABILITIES OF FLEET MAINTENANCE SOFTWARE

There are a wide range of options for fleet managers to consider when choosing fleet software. They range from basic software that managers can use to enter information about their fleets to more expansive software that can determine if new parts need to be ordered. There do not appear to be any clear favorites amongst fleet managers and fleet magazines report favorable reviews of preventive maintenance software, citing ease of use and functionality of the programs. Below are three examples of maintenance software with different levels of capabilities compile from the websites listed below. The three examples are to provide an illustration of fleet software capabilities, but the examples should not be construed as recommendation to use this particular brand of software

A.6.1 FLEET MAINTENANCE PRO BY INNOVATIVE MAINTENANCE SYSTEMS

http://www.mtcpro.com/index.htm

This software tracks an unlimited number of vehicles/equipment, starting from general fleet details such as vehicle number license number, Serial number, purchase information, etc. It also tracks user-defined fields for equipment facts (i.e., Oil Type). The software capabilities include ability to:

- Categorize the fleet by location, department, and type.
- Track preventive maintenance and repairs.
- Automatically calculate and inform when maintenance is due by automatically highlighting equipment due for service.
- Schedule preventative maintenance notifications by date, mileage, kilometers, and/or hours.
- Provide detailed maintenance history and costing.
- Specify search, filter, and sorting criteria for your reports.
- Track registration, MVI, emissions, and user defined renewals.
- Track employee data, driver licensing, renewals, and certifications.
- Provide fuel transaction history, economy, and costs statistics.
- Vendor database for servicing, inventory, and fueling.
- Track and monitor equipment usage.
- Include built-in data backup and restore capability.

- Export to numerous formats (ASCII, Excel, PDF, + more)

A.6.2 FLEET MAINTENANCE SOFTWARE BY TATEMS (http://tatems.com/)

This software is intermediate in complexity and level of automation required. All records can be previewed or printed, and the program keeps a detailed record of vehicle inspections completed and shows each item inspected for a bus and schedules the next inspection and notifies of upcoming inspections prior to due date. It also has a record of lubrications performed and schedules the next lubrication based on time, miles or hours of operation. Information can be stored on one computer and accessed from any computer on network.

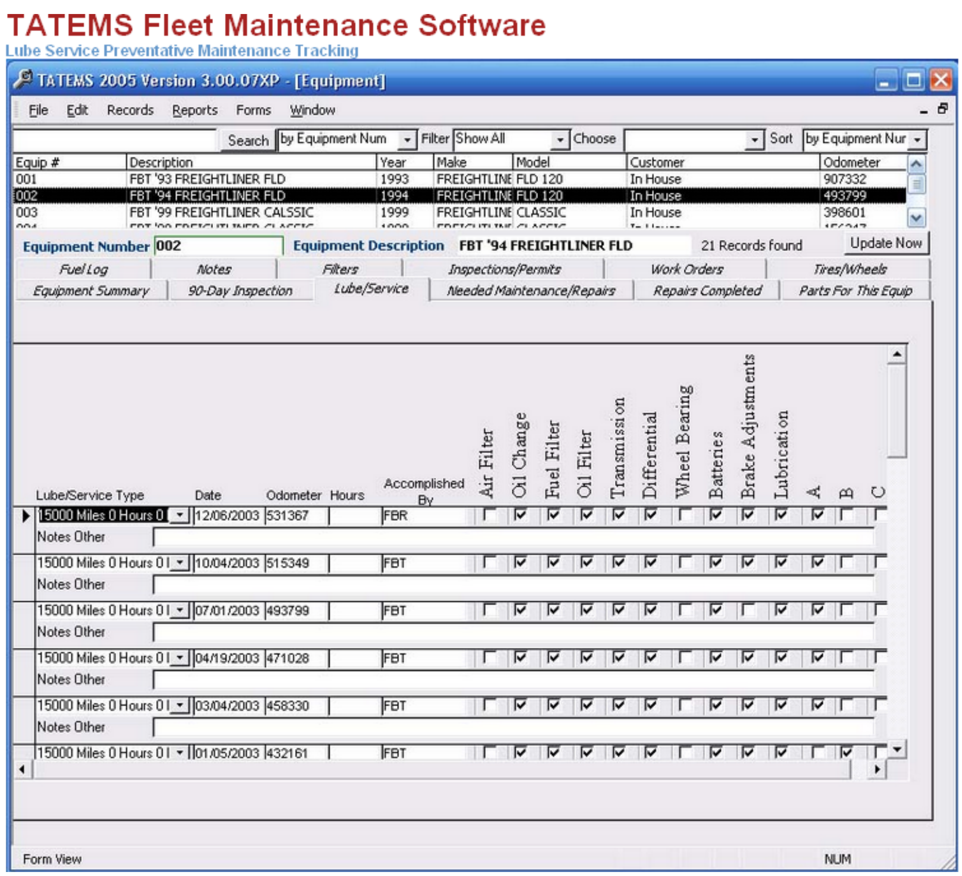


Figure 1: Screenshot of Tatems Fleet Maintenance Software

Typical tracking capabilities include

- miles/km within a State/Province
- which driver was driving which equipment
- Common parts on a piece of equipment
- Filters used on a piece of equipment
- Tires and Wheels used on a piece of equipment

- Permits issued expiration dates+ Reminders
- Registration renewals + Reminders
- Fuel usage by shift/day
- Last and Next Maintenance Report lists a summary of each unit's equipment number, VIN number, license number, year, model, last lubrication, next lubrication and the month in which registration is due.
- History of repairs and cost for each repair. Displays all the repairs done on each piece of equipment.

A.6.3 COLLECTIVE-FLEET SOFTWARE BY COLLECTIVE DATA

http://www.collectivedata.com/index.html

This software is typical of more comprehensive maintenance systems programs and it has sections to track parts, keep notes, fuel logs including fuel cost per mile, and filters for each piece of equipment. The listing below shows the wide range of capabilities available.

Vehicles & Equipment

- Schedule, track & report on an unlimited number of pieces of equipment
- Location/department information with complete history
- Total expenditures, including: Work Orders, Fuel, Registration, Expense, and Accidents
- Fuel type and usage
- Meter tracking
- Purchase & release information
- Equipment details (user-defined)
- Condition
- Driver/equipment relation
- Tire log
- Warranty tracking
- Registration (user-defined and scheduled)

Scheduling

- Preventative maintenance and inspection scheduling/notification
- Warranty scheduling/notification on equipment, tires, work orders, parts, and expenses
- License/certification scheduling & for all employees
- Equipment registration scheduling/notification for all equipment

Work Orders

- Track all work completed on each piece of equipment
- Automatically create work orders from task lists
- Automatic notification of warranty, if available, for that piece of equipment or part.
- Track all inventoried/non-inventoried parts used on pm services, inspections, external work, and/or repairs. Automatically adjusts parts inventory quantity on hand
- Track all labor to include mechanic, rate and hours worked. Mechanic efficiency reporting also available.
- Include parts & labor in/out of preventative maintenance services, inspections, external work and/or repairs.

Trip Log

- Track all trips with drivers, details and fuel usage
- Track each state and the mileage driven

Fuel Log

- Track inventoried/non-inventoried fuels and fluids
- Track all fuel usage and efficiency for each piece of equipment
- Track fuel type
- Track fuel taxes

Tire Log

- Purchase information
- Location within service/out of service
- Warranty scheduling/notification

Parts Management

- Track all inventory/non-inventory parts to include costs, quantity on hand, re-order point, etc.
- Completely integrated with work orders for automatic deductions of quantity on hand
- Purchase orders, receive items, and receive items one time with automatic additions of quantity on hand
- Inventory adjustments/transfers between warehouses
- Track and recoup more warranty dollars on parts
- View historical information on parts

Vendors

- Unlimited vendors grouped by user-defined vendor types
- User-defined services for each vendor

Employee Management

- Complete employee records
- Task scheduling
- Total expenditures including: license/certification, expenses, and traffic violations
- License/certification scheduling & notification for all employees
- Driver/equipment relation with complete history
- Upload employee image and documents
- Evaluations
- Labor tracking

Traffic Violations

- Track all driver's violations including cost and user-defined-ticket type

Accidents/Claims

- Track all details on each accident/claim
- Track damages on equipment, other's equipment, and any properties
- Track all injured persons, witnesses, police officers, and towing companies
- Track complete narrative, and upload images/documents

Reports

- Stock reports
- Export report data to Excel or other spreadsheet applications
- Report editors provide virtually unlimited report configurations

Expense Log

- Track all expenses for employees, equipment and general expenses
- Group each expense by a multi-level category
- Indicate if expense is tax deductible or reimbursable

Loan/Loan Payments

- Track all loan information with specific equipment relations
- Track all loan payments

Insurance

- Track all insurance information with specific equipment and loan relations
- Track all insurance payments

Email Notification

Receive emails for services, inspections, registrations, warranties

ANNEX 7

DRIVER TRAINING PROGRAMS FOR FUEL EFFICIENCY

Reducing fuel consumption through bus driver behavior is an important step that can be achieved through training. Fleets ranging from public transit to private trucks have used training to teach their drivers to operate their vehicles in a manner that will cut costs and fuel use. Most will emphasize idle reduction but there are other useful techniques while the buses are being driven such as slower accelerations and avoiding stop at red lights. In addition, software can be used to monitor driver behavior and this accountability can reduce fuel consumption by 15%.[4] Below are three examples of how different programs educate their drivers, with two programs sponsored by governments. The examples were compiled form the websites listed below.

A.7.1 Enviance: Driving Change (https://www.drivingchange.org/home.aspx)

Using a small device installed in each vehicle, Driving Change monitors key operating parameters of vehicles and driving behaviors and translates them to CO_2 emissions.

- Vehicle on/off
- Miles traveled
- Idling
- Fast starts
- Hard breaking
- Driving over 60 MPH
- Fuel consumption

Vehicle and emissions data are then transmitted to a secure website where it is analyzed and graphed to produce individual results in the form of simple to use dashboards, or online performance reports, so that corporate personnel, supervisors and individual drivers can track the success of the reduction strategies your organization employs and reduce CO_2 emissions and fuel costs simultaneously.

A.7.2 The Illinois State Board of Education

The Illinois School Bus Driver Training Curriculum Section on Fuel Efficiency starts with an introduction on the driver effect on fuel efficiency and then covers the following steps as instructions to the driver:

1. Pre-trip

   Give particular attention to the daily walk-around inspection.

[4] http://www.assetworks.com/fuelfocus

a. Not only does this check give the driver an opportunity to identify important safety concerns, but a thorough inspection will help to prescribe preventative maintenance needs.
b. A well-tuned and well-maintained engine and properly inflated tires will support your fuel conservation efforts.

2. Start Your Engine

The steps you take in starting the engine can be important for the wear and life of the engine.

a. Don't pump the accelerator pedal more than once or twice if you have a carbureted fuel delivery system.
b. Don't crank the starter more than 15 seconds at any one time. These habits not only waste fuel, but can damage the vehicle. If the engine doesn't start after a total of 30 seconds, wait for a minute or so before trying again.
c. Racing the engine and/or allowing the engine to idle for an extended period of time in an attempt to warm the engine in any weather serves no useful purpose. This simply wastes fuel. It may be necessary to allow a diesel engine to warm up longer than a gasoline engine, but you should always guard against excessive idling.
d. Begin your route shortly after you start your engine. Diesels need to be raced to kick the alternator in or it will burn up on the alternator. (BUT ONLY for a short time.)

3. Beginning Your Route

You will save fuel by the way you shift gears.

a. To move your vehicle, rest your foot on the accelerator pedal and press slightly. Do not push the pedal to the floor. If your vehicle is equipped with an automatic transmission, accelerate easily to the slowest speed at which the transmission first shifts to the next higher gear smoothly. Accelerate to let the next smooth upshift occur as you move along.
b. When using a manual transmission, start in low gear and accelerate to a speed where an up shift can be easily executed without lugging. Increase the speed of the vehicle slowly each time you shift to the next higher and more fuel-efficient gear.
c. You should become familiar with the feel of the vehicle and the sound of the engine. Eventually you will know when a change in gear should occur.

4. Highway Driving

   Because of its size, a bus sits above the normal flow of traffic. This is a definite advantage you should use, along with your mirror system, to position your vehicle in the flow of traffic for maximum fuel efficiency and minimum use of the brakes.

   a. Practicing the four-second following maneuver will reduce braking (You are following too close to the vehicle in front of you if you are within four seconds of that vehicle.). Constant braking and speeding up is a waste of fuel. Once you reach a speed that feels most comfortable in relationship to traffic movement maintain a steady speed. The legal speed limit for a school bus is the same as that for an automobile. Traveling somewhere between 40 and 50 miles per hour is the safest and most fuel-efficient highway speed, however;
   b. When approaching a curve or any situation that requires a substantial speed reduction or stop, lift your foot from the accelerator early enough to reduce your vehicle speed in a smooth and easy manner.

5. Route Driving

   Keep your stops to a minimum.

   a. You are required to let students off the school bus only at their assigned stops. While this practice is designed to provide the highest level of protection possible for you and your passengers, restricting additional stops will also save fuel. DO NOT change routes or pickups without authorization from the proper school official.
   b. Stay alert on your route. If you are required to idle for an excessive period of time, shut off the engine until you are ready to move again.

A.7.3 UK Department of Transport Driver Training Program

The Fuel Efficient Truck Drivers' Handbook provides the following driving tips

1) Factors Affecting Your Fuel Consumption

   Some factors affecting fuel consumption are outside your control but it is helpful to understand their effects so you can begin to measure your MPG effectively and set a benchmark for yourself.

   Experienced and professional drivers can work hard to reduce the impact of these negative factors on fuel economy. There are simple steps you can take that will increase your vehicles' MPG no matter what vehicle you drive, how congested the roads are and regardless of the weather conditions.

a) The Vehicle

The vehicle you are given to drive has a significant influence on fuel performance in any operation including:

i) Type and specification
ii) Age
iii) Condition
iv) Equipment and load

b) Traffic Conditions

Road type and traffic conditions have significant effects on fuel use. The more you have to change gear, brake or accelerate, the more fuel will be used. Variations in traffic congestion can also create differing performance results even though the route is the same.

c) Weather

Vehicle performance in the winter months can be as much as 10% poorer than in the summer months. Winter conditions can mean greater use of auxiliary equipment such as fog lights, screen de-misters, etc, the change from 'summer grade' diesel fuel to 'winter grade' can also contribute to a difference in consumption of around 3%.

2) How To Reduce Your Fuel Consumption

a) LOOKING AHEAD: Every time you drop down a gear, fuel consumption increases. Forward planning helps to reduce excessive gear changes. Use your visibility advantage provided by the high seating position in a truck. Keeping a vehicle moving, even at walking pace, requires considerably less fuel use than moving a vehicle from a standstill.

FACT! By planning well ahead and keeping the vehicle moving, gear changes will be reduced and fuel will be saved.

b) HAZARDS: Awareness is essential to road safety. It also enables early selection of the gear and speed appropriate for the situation. The result is a safe and economical drive. Using the correct gear, engine speed and position for any given situation also results in a more environmentally friendly operation. FACT! Use of information gained through observation gives more time to plan ahead and systematically avoid hazards.

c) SPEEDING: Speeding is dangerous. It puts your life and the lives of other road users at risk as well as jeopardizing your driving license. In addition, due to the importance of road speed in aerodynamic efficiency, speeding will have negative effects on fuel economy due to increased aerodynamic drag. Excessive speeding can also put extra stress on the engine and transmission system. FACT! Fuel is directly proportional to the speed your truck is travelling. A 22% reduction in fuel consumption can be achieved simply by reducing your speed from 56 to 50 MPH

d) MOMENTUM: The speed gathered under power can be used to ascend and descend hills on undulating roads without the use of the accelerator. On electronically controlled vehicles, when the foot is taken off the accelerator, fuel stops entering the combustion chamber. The vehicle is still moving, but using no fuel.

FACT! Using the momentum of the vehicle will save fuel.

e) CRUISE CONTROL: If you have cruise control, it will help to optimize the electronic control system's ability to deliver the appropriate amount of fuel for any given situation, thus improving fuel efficiency. Remember, cruise control doesn't have eyes!

FACT! To maximize fuel economy, cruise control should be used whenever safe and appropriate.

f) CLUTCH CONTROL: Engaging and disengaging the clutch twice will halve the life of friction surfaces. This technique is only necessary for crash gear boxes. Double-declutching will simply increase clutch wear.

FACT! Double-declutching is not necessary on synchromesh gearboxes. It increases clutch wear and wastes fuel.

g) SKIP GEARS OR USE BLOCK CHANGES: Even when a vehicle is fully laden, it is not normally necessary to use every gear. The quicker you move up the gearbox to top gear, the more fuel you will save. As a rough rule of thumb, every time you change up a gear you improve fuel consumption by somewhere between 10% and 30%. Reducing the number of gear changes saves time and energy.

FACT! The fewer the gear changes, the less the physical activity needed and the more fuel efficient the operation.

h) AVOID UNNECESSARY BRAKING: When the footbrake is used the road speed that has been lost has to be made up by using the accelerator, thereby burning fuel. If it becomes necessary to change down a gear or half gear then even more fuel is used. The load is also more likely to shift under heavy braking. FACT! Harsh braking uses more fuel and requires an increase in the number of gear changes that you will subsequently have to make.

i) EXHAUST BRAKE: By using the exhaust brake system instead of the footbrake, brake lining life is extended. When the exhaust brake is applied, fuel delivery to the combustion chamber is halted. The vehicle is driven forward by its own momentum, so there is no need for fuel to be burnt.

FACT! Use of the exhaust brake will contribute to smoother decreases in speed, increase the lifespan of brake linings and save fuel.

j) MOTORWAYS AND DUAL CARRIAGEWAYS: Optimum use of motorways and dual carriageways will result in a safer, more consistent and more economical drive. Wear and tear on the engine and running gear will be reduced and the vehicle will be able to run at its most economical rate.

FACT! Use of constant speeds on motorways and dual carriageways will enable full use of cruise control, leading to less gear changes.

k) MANAGE YOUR IDLE TIME: Engine idling wastes fuel and money and increases emissions. Turn off your engine when you do not need it on or you have been stationary in traffic for any period of time. Also think before you turn on your engine to warm your cab. .FACT! A typical 420hp heavy-duty truck engine consumes fuel at the rate of around two liters an hour when left idling and stationary.

l) LOW REVS, LOW NOISE, LOW EMISSIONS: Lower revs give higher levels of fuel economy. The use of appropriate horsepower engines (to avoid engine strain) and computer controlled engine management systems reduces noise levels and assists in maximizing fuel economy.

FACT! Quiet operations produce less air pollution.

m) ADJUSTABLE AERODYNAMICS: Many articulated tractor units have adjustable roof mounted air deflectors. The roof mounted air deflector should be adjusted to guide airflow over the highest point at the front of the trailer or load. As a rule of thumb, remember that for every ten centimetres of the front of the trailer exposed to airflow, the fuel consumption will worsen by 0.1 MPG.

FACT! Vehicles that travel at high speeds and have a large frontal area will use less fuel if fitted with correctly adjusted aerodynamic body styling equipment.

n) HEIGHT OF THE LOAD: Minimizing the height of the load will save fuel by reducing the drag of the vehicle. This is particularly relevant when using a flat-bodied vehicle or trailer. Knowing how to load your vehicle is central to your fuel performance. Sheeting a load or an empty tipper body can save fuel because it reduces aerodynamic drag.

FACT! The height of a trailer or load should be kept to a minimum to reduce aerodynamic drag.

o) POSITIONING THE LOAD: The load should be positioned to reduce aerodynamic drag but care should be taken not to overload any axles on the vehicle or trailer. Varying the load on each axle can impact fuel consumption.

FACT! The positioning of a load, particularly on a flat trailer, can influence fuel consumption.

p) OVERFILLING OF THE FUEL TANK: Fuel expands when it is hot. It can be heated by both the sun and by fuel returned from the engine or fuel system. If you fill the fuel tank to the brim, then when the fuel expands, its only way of escape is via the breather vent. Diesel spillages are a hazard to other road users, in particular motorcyclists. FACT! Overfilling the fuel tank allows fuel to leak through the breather.
q) TYRES: Under inflated tires will reduce MPG and increase wear, thereby reducing tire life and increasing running costs. FACT! Correctly inflated tires offer less resistance on the road, improve fuel economy, give greater stability and reduce the risk of accidents.
r) VEHICLE TECHNOLOGY: Vehicle technology advances rapidly. Read the vehicle's handbook to ensure you are fully up-to-date with the systems installed. Telematics can also be a useful tool to help improve operational efficiency. FACT! Technologies will only assist in fuel economy and safe and efficient operation if you are fully familiar with your vehicle's systems.
s) And finally…
    i) Be ready to learn, no matter how experienced you are
    ii) Know your average MPG for the vehicle you drive
    iii) Read your vehicle's handbook
    iv) Park up in a way that will avoid early-morning
    v) maneuvering with a cold engine - this wastes fuel

ANNEX 8

REPAIR PROCEDURES FOR TATA AND LEYLAND BUSES USED BY THE APSRTC

A.8.1.Activities of Schedule-I Maintenance

1. Arrest leakages of water, fuel, oils including ATF oil for power steering, brake fluid for TATA and top up as per the need.
2. Tightening of all bolts and nuts of wheels, Axle shafts and PP shaft mounting etc.,
3. Checking of road springs and their mountings with due attention to U-Clamps.
4. Attention of RG by Mechanics and other artisans based on the log sheet complaints.
5. Identification of RG connected to Electrical, Coach and Upholstery by the Schedule-I Mechanic. Recording the RG in the register shall be done by Shift Supervisor. The Shift Supervisor shall allot the RG to the concerned artisans.
6. Check of tire pressure by tapping daily has to be done by Schedule-I Mechanic. Check & adjust the Tire inflation pressures with gauge twice in a week for all the vehicles.
7. Check the tread depth of tires and replace tires as per by RG mechanic.
8. Drain the condensate from the Air Tank (other than those fitted with Air Dryer)
9. Drain the water from fuel-water separator

Tyre Inflation Chart

TYPE	CROSS PLY (NYLON)				RADIAL			
	FRONT		REAR		FRONT		REAR	
	Kg/cm^2	PSI	Kg/cm^2	PSI	Kg/cm^2	PSI	Kg/cm^2	PSI
Long Wheelbase 9.00 - 20 - 14PR	5.95	85	5.30	75	8.10	115	7.00	100
Small Wheelbase 9.00 - 20 - 14PR	4.90	70	4.90	70	7.40	105	7.00	100
Meghdoot - N/AC 10.00 R 20 - 16PR					8.45	120	7.40	105
Meghdoot - AC 10.00 R 20 - 16PR					8.45	120	7.75	110
Volvo 295/80 R 22.5					8.10	115	8.45	120
CNG 10.00 R 20 - 16PR					8.10	115	5.65	80

A.8.2 Activities off Schedule-II Maintenance

1. Clean the Air cleaner and replenish oil. Replace the gaskets/ seals if necessary.

2. Carry out brake test and steering test. Attend to the defects if any in the steering 1. Lubricate all points as per the lubrication chart

3. Clean breathers of Engine, G/Box, R/Axle. Clean the feed pump strainer, and refit. Check oil level in FIP, G/Box, R/Axle, Steering Box, Power Steering reservoir, Brake fluid and clutch fluid and top up if necessary. For the Vehicles with dual air brakes, hand brake functioning has to be checked and attend if necessary.

4. Check road spring holding down bolts, spring brackets, shackles and shackle pins for proper tightness. Attend if necessary

5. Check for excess play in front and rear hubs and attend if necessary. Check and adjust if necessary the clutch pedal free play and brake pedal free play.

6. Check the tightness of the steering foundation bolts and fuel tank mountings and attend if necessary.

7. All mechanical irregularities causing rapid tire wear such as mis-matching, brake binding, misalignment etc., as pointed out by the Tire Mechanic shall be attended to.

8. Identification & reporting of all defects/damage in the electrical system and coach work with due attention to upholstery, seat frames, seat cushions, doors, glasses etc., to the shift supervisor

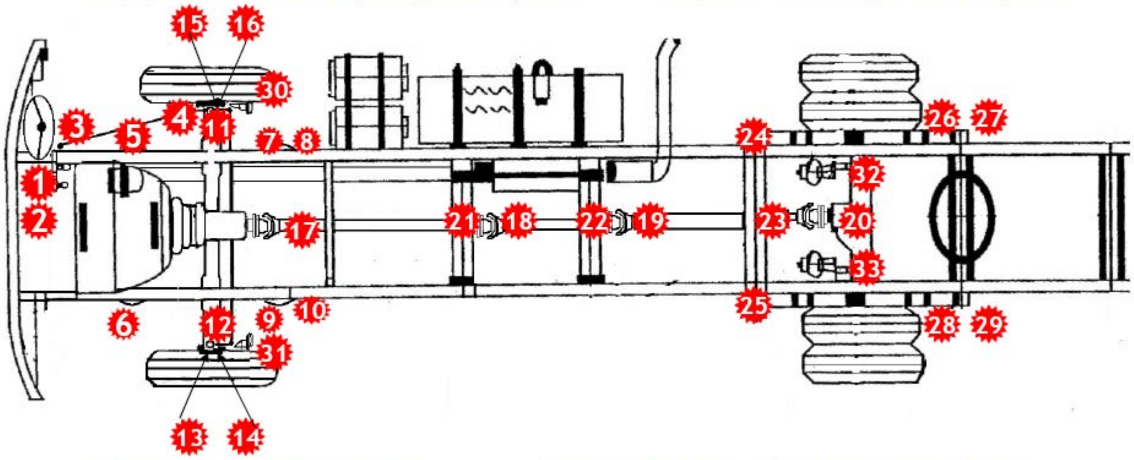
9. Carry out battery maintenance.

10. Check proper functioning of all gauges in the instrument panel and attend if necessary.

11. Check water pump bearing play and attend if necessary. Check the condition of fan belt and attend if necessary (Other than Cummins Engine). Check and tighten alternator foundation bolts if necessary.

Greasing Points – TATA

1 & 2 - Pedal Shaft Bushes
3 & 4 - Draglink ends
5 & 6 - Front Spring Brackets
7,8,9,10 - Front spring rear pins
17,18,19,20 - UJ Crosses
21,22 - CJ Bearings
23 - PP shaft slip joint
24,25 - Rear Sp. Front pins



11 &12 - Tierod ends
13 &14 - L/s Kingpin
15 & 16 - R/s kingpin
26,27,28,29 - R.Spring rear pins
30,31 - Front slack adjusters
32,33 - Rear slack adjusters

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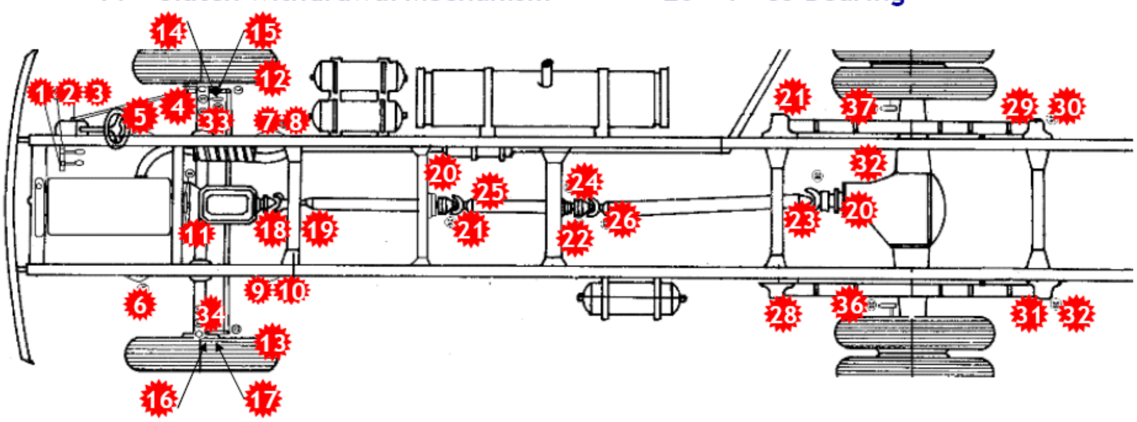
Greasing Points – LEYLAND

1 & 2 - Pedal Shaft Bushes
3 & 4 - Draglink ends
5 & 6 - Front Spring Brackets
7,8,9,10 - Front spring rear pins
11 - Clutch withdrawal Mechanism
14,15 - R/S Kingpins
16,17 - L/S Kingpins
18 - G/B UJ cross
19 - 1st PP shaft sliding yoke
20 - 1st CJ Bearing



12 &13 - Tierod ends
24 - 2nd CJ Bearing
25 & 26 - Sliding yokes
27, 28 - R. Spring front pins
29,30,31,32 - R.S rear pins
33,34 - Front slack adjusters
35,36 - Rear slack adjusters

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A.8.3 Activities of Mechanic-I in Schedule-III

1. Check for leakages of water, fuel and lubricants and rectify if necessary
2. Check oil level in Engine, top up if necessary. Check the condition of fins of Radiator, foundation of radiator and stay rods and attend if necessary. Top-up radiator with coolant, examine the radiator cap and replace if necessary.
3. Remove alternator, self-starter and re-fit after overhaul. Check fan belt tension and tightness of alternator foundation bolts and attend if necessary.
4. Check all road springs, spring holding down bolts, spring brackets and shackles, and change if necessary.
5. Check oil level in FIP, Gear Box, Steering Box, power steering reservoir, differential and clutch fluid and top-up if necessary
6. Clean Air cleaner and change the oil (other than dry type Air filters). For Dry type Air filters clean the primary filter as per the circular instructions. Check the condition of inlet hoses and FINOLEX pipe for Hino and attend if necessary.
7. Check and adjust the free play of clutch, brake and accelerator.
8. Lubricate all points as per chart
9. Check and change if necessary the damping buffers and Engine mounting pads.
10. Check water pump bearing play and attend if necessary
11. Check cylinder head tightness and adjust tappets. Check fuel injection timing by spill cut method
12. Check PP shaft center bearing and universal joints for play, change if necessary. Replace rubber dust boot. Ensure correct alignment. Check seals for Leyland vehicles.
13. Check and attend if necessary compressor oil seal leakage and compressor performance
14. Clean Air breathers of Engine, FIP, Gear Box and Rear Axle
15. Remove and refit front bumper after attending to damages if any
16. Remove and refit spare wheel carrier with spare tire after attending to damages if any
17. Ensure proper clamping of all fuel lines and rubber ferrules for injector pipes
18. Check for black smoke and attend if necessary
19. Any other item of work entrusted by Maintenance in charge

A.8.4 Activities of Mechanic-II in Schedule-III

1. Check for correct air pressure, attend if necessary, remove brake drums, check for scoring and excessive wear of liners and drums change if necessary. Drain water from Air tank. Check level of brake fluid and top-up if necessary (TATA)
2. Check steering foundation bolts and attend if necessary. Tightness of bolts of Engine cross members and brackets of metacon bushes for Leyland), Engine mounting pads (TATA) to be checked and attend if necessary
3. Check front and rear hub play and adjust if necessary. Check the condition of bearing grease.
4. Check ball joints of drag link and tie-rod ends for excess play and repair or replace if necessary.
5. Check wheel alignment and adjust if necessary
6. Check kingpins for excessive play and replace bushes if necessary, adjust kingpin end play, clean through hole of kingpin and top up oil in kingpins (Leyland)
7. Check fuel tank holding brackets and clamps for proper padding and tightness.
8. Remove and refit the rear bumper after attending to the damages if any
9. Carry out brake test. Check proper functioning of all gauges in instrument panel and attend if necessary
10. Check and attend if necessary cabin foundation bolts. Body U-clamps and anti-sag bag by coach builder

A.8.5 Activities of Mechanic-I in Schedule-IV

1. All items specified in Schedule-III maintenance for Mechanic-I
2. Replace front two springs with reconditioned springs. Check shackle pins, shackles, shackle beds of front two springs for wear and tear and replaced if necessary. Check the chassis cracks particularly near the spring beds area and inform to shift supervisor for attention. Ensure the fitment of correct size M14 bolts for spring brackets.
3. Dismantle water pump, repair and refit or replace if necessary.
4. Replace crank oil seal if necessary
5. Remove and check the injectors for correct pressure and change if necessary
6. Flush out the radiator for 370 Engines (Leyland), 692 Engines (TATA).
7. Any other items of work entrusted by Mechanical Supervisor

A.8.6 Activities of Mechanic-II in Schedule-IV

1. All items specified in Schedule-III maintenance for Mechanic-II.
2. Carry out brake test. Overhaul Air brake system with due attention to the following:
   - Air filter element
   - All brake pipes and pipe connections and ensure proper clamping
   - All brake chambers, diaphragms, brake chamber clamp rings, bolts and nuts
   - Hand brake system including all pipe connections
   - Check the functioning of all brake valves
3. Remove brake S' cam shafts, slack adjuster, needle bearings/ derlin bushes replace if necessary duly ensuring full greasing to the brake components.
4. Remove front and rear hubs, repack with grease and adjust for correct setting.
5. Check differential backlash and adjust if necessary
6. Any other items of work entrusted by Mechanical Supervisor

A.8.7 Activities of Mechanic-III in Schedule-IV

1. Remove strainer in the fuel tank and remove fuel tank complete for cleaning, attend leakages if any and refit after painting.
2. Remove clutch and Gear box, check the condition of pressure plate and driven disc, replace if necessary. Check Gear box oil leakages and attend if necessary. Lubricate spigot bearing, replace fly wheel ring gear if teeth are found damaged. Check the Hydraulic clutch system and attend if necessary. Overhaul hydraulic clutch system and replace master cylinder and slave cylinder kits on every alternate Schedule-IV service.
3. Check excess play for remote gear shift mechanism and attend if necessary. Check the selector mechanism of Gear box top cover and ensure proper functioning.
4. Replace rear two springs with reconditioned springs. Check shackle pins, shackles, shackle beds of rear two springs for wear and tear and replace if necessary. Check the chassis cracks particularly near spring beds area and inform the shift supervisor for attention. Ensure fitment of correct size M14 bolts for spring brackets.
5. Any other items of work entrusted by Mechanical Supervisor.

Oil, Filter & Coolant changes

Description of Lubricant	LEYLAND	TATA
Engine Oil Long Life CH4	36,000 for Dist 24,000 for City	36,000
Engine oil other than CH4	15,000/ 16,000	18,000
Gear Box oil Ordinary	32,000	18,000
Gear Box oil Extra Long life	40,000	72,000
Differential oil Ordinary	32,000	18,000
Differential oil Extra long life	48,000	72,000
P.Steering oil & Filter	80,000	80,000
Clutch Kits & Clutch Fluid	40,000	72,000
Coolant	75,000	3.00 lakhs (or) 2Yrs

Filter Changes

Description of Filter	LEYALND	TATA
Fuel Filter Felt	20,000	27,000
Fuel Filter Paper	30,000 & 20,000 for BS-II	36,000 & 18,000 for BS-II
Spinon Fuel filter	25,000 BS-II	18,000 TC
Fuel Strainers (Baby filters)	50,000	clean at 9,000
Dry Air Filter element Primary	72,000	72,000
Dry Air Filter element Secondary	2,16,000	2,16,000

ANNEX 9

APSRTC VALIDATION DATA

Table A9-1 Regression Analysis Based Identification of Low FE Buses and Drivers

(t-statistic over a value of 1.67 implies identification with over 90% confidence)

Location	Bus Type/ Model (number of buses) Target FE	Low FE Bus No. (t-statistic)	Baseline FE	Low FE Driver No. (t-statistic)	Base-line FE
GVPT – 2	697 CM ORD (N= 19) FE = 5.34	5935 (-2.21)	4.74	358127 (-2.04)	4.75
		-		360141 (-2.04)	4.98
		-		960967 (-2.05)	4.64
		-		960895 (-2.00)	4.57
	697 NA ORD (N=8) FE = 5.34	6665 (-2.97)	4.47	959604 (-1.05)	4.68
		4150 (-2.26)	4.74	960870 (-1.05)	4.53
		5068 (-1.97)	4.73	-	
	Cummins ORD (N=17) FE = 5.34	-		360759 (-2.28)	4.11
		-		358110 (-1.82)	4.41
		-		959524 (-1.67)	4.16
	Hino CNG ORD (N=19) FE = 4.64	5973 (-5.93)	3.37	961037 (-3.49)	4.51
		5966 (-3.99)	3.80	351222 (-1.57)	4.33
		6006 (-3.85)	3.86	357469 (-1.57)	4.46
	Hino CNG SLF (N=63) FE = 4.64	6731 (-9.73)	3.73	961060 (-2.18)	4.58
		7052 (-6.70)	4.00	960818 (-2.19)	4.64*
		6734 (-6.72)	4.12	961071 (-2.14)	4.07
		6711 (-6.04)	4.03	360130 (-2.30)	4.17
GVPT-1	697 CM ORD (N=45) FE = 5.34	3468 (-2.38)	4.25	354115 (-1.59)	4.44
		2798 (-1.54)	4.19	357378 (-1.98)	4.38
		-		360065 (-0.85)	4.53
	697 NA ORD (N=27) FE = 5.34	9782 (-7.38)	4.52	360790 (-1.73)	4.37
		1916 (-7.51)	4.51	360767 (-1.58)	5.03*
		1010 (-4.05)	4.70	360579 (-1.54)	4.64
		-		959789 (-1.40)	4.13
	Cummins ORD (N=35) FE = 5.34	9489 (-3.77)	4.73	960786 (-1.93)	4.40
		9088 (-5.30)	4.90	361055 (-2.01)	4.17
		8706 (-5.43)	4.55	960750 (-3.05)	4.95

* Driver fuel economy close to target, may have been selected by route characteristics

Table A9-1 Continued

Location	Bus Type/ Model (number of buses) Target FE	Low FE Bus No. (t-statistic)	Base FE	Low FE Driver No. (t-statistic)	Base FE
BKPT	Euro-1 ORD (N=17) FE = 5.40	1004 (-1.87)	5.01	984843 (NS)**	3.51
		993 (-2.36)	4.81	211553 (NS)**	3.92
		2032 (-1.12)	5.01	109294 (NS)**	4.23
				928127 (NS)**	4.03
	Euro-2 ORD (N=49) FE = 5.10	4821 (NS)**	4.04	202233 (-4.59)	2.81
		5721 (NS)**	4.05	984887 (-3.13)	4.30
		5111 (NS)**	4.05	984829 (-2.44)	4.01
		-		928121 (-2.05)	3.30
	Euro- 2 M-EXP (N=17) FE = 5.10	1886 (-1.92)	4.34	203287 (-1.61)	3.93
		4838 (-2.07)	4.22	982635 (-1.61)	4.85
		-		201732 (-1.51)	4.51
	Hino ORD (N=45) FE = 5.40	9300 (-2.97)	5.03*	982569 (-1.68)	3.35
		3386 (-3.17)	4.55	203793 (-1.21)	3.53
		9177 (-1.65)	3.83	271630 (-1.37)	3.33
		-		981916 (-1.33)	3.36

* Bus fuel economy close to target. **NS – not significant, T < 1

A9.2 Worksheets

Worksheet 1 for Meeting with Depot Management

Topic	Action	Result
1. Communications	Identify single point of contact at each depot for data and follow-up	Contact name, phone and email:
2. Regression Analysis	Compare low FE buses and drivers identified by ICF to APSRTC list	Add APSRTC low FE bus numbers and drivers not identified by ICF to list:
3. Communication of FE data to depot employees	Identify how FE data is provided to depot employees	List location and visibility of FE data:
4. Repair Traceability	Check if each bus repair can be traced back to mechanic	Yes/ No / Exceptions if any
5. External audit of repairs	Check if outside team will audit repairs occasionally	Yes/ No Audit result available?
6. Depot walk through	Check data procedures	Deficiencies?

Worksheet 2 for Meeting with Depot Mechanics

Tier 1 Check	Pass/ fail criterion and repair	APSTRC Compliance
1.Check tire inflation 2. Check for free rolling of wheels 3. Wheel bearing lubrication	Pressure meets specification, or add air Wheels rotated easily by hand or check brakes (see below) No grinding noise in bearings or lubricate as required.	Yes, checked with gauge Yes Yes, bearing play checked by moving tires axially and radially
4.Check fuel lines and tanks for leakage	Check for fuel drops on floor under bus (diesel) or use gas detector (CNG). Replace lines or tank as required	Yes, CNG leaks checked with soap and water (to observe bubbles)
5. Check for free play of brake pedals 6. Check gap between brake liners and drum/disc 7. Check caliper boot and wear adjuster cap 8. Check for brake retraction after pedal release	Excessive free play requires brake pedal linkage adjustment Gap must be visible or liners reinstalled Wear adjuster should not be at setting limit, or replace liner Liners move away from rotor on brake release, or else check for brake hydraulic/air line defects	Yes, free play is estimated subjectively Yes, checked if tire does not rotate freely Yes, based on driver complaint Yes, check based on applying brakes and moving tire immediately on pedal release.
9. Check lubrication of driveshaft joints, axle bearings and differential 10.Examine tightness of driveline and gearbox mounts	Lack of visible lubricant and/or noise in joints and bearings signify need for lubrication Visible driveline and gearbox vibration indicates need to tighten mounts	Yes, bearings and seals repacked on every major service Yes/ No
11. Check clutch pedal linkages 12. Check Accelerator linkages 13. Check accelerator return spring	Excessive play requires linkage adjustment Excessive play requires linkage adjustment Accelerator snaps back on release or else replace spring	Yes, based on driver complaint Yes, based on driver complaint Yes
14. Check air cleaner for clogging 15. Check exhaust pipe for blockage 16. Check on-board diagnostics if applicable 17. Check for visible smoke on snap acceleration	Visible dirt on air cleaner, replace Check for any foreign objects or broken catalyst in pipe. Electronics check for diagnostic codes indicating any failure Smoke opacity over 20% indicates engine problem, send to central maintenance facility	Yes, pressure pop-up checked Not usually unless exhaust noise is different All mechanical engines for diesel. Yes, based on visual opacity estimate

Worksheet 3 for Meeting with Depot/ Central Repair Facility Mechanics

Tier 2 Check	Pass/Fail Criterion and Repair	APSRTC Compliance
1.Check wheel alignment	Set to manufacturer specification	No*
2.Check tire camber	Set to manufacturer specification	No*
3.Check condition of clutch facings	Replace clutch facing if worn	Yes, based on driver complaint
4, Check clutch release bearing	Replace bearing if worn/ failed	Yes
5.Check Fuel Injection pump timing and maximum fuel stop	Set timing and stop to manufacturer specifications	Yes, Checked outside Yes, Checked outside
6. Check FI pump pressure	Low pressure indicates pump rebuild	Yes
7. Pull and check injectors for leakage or clogged spray holes	Asymmetric spray indicates need for injector cleaning or replacement	Yes, especially if engine is smoky
8. Check turbocharger bearings (if turbocharged)	Turbo rotor must rotate freely or else replace bearings	No, have never experienced problems
9. Check cylinder compression	Low compression requires head gasket, ring check or engine rebuild	Yes
10. Inspect cylinder head for cracks, bolt tightness	Torque head bolts to manufacturer spec., replace cracked head	Yes
11. Check piston rings if oil consumption is high	Replace worn rings	Yes
12. Check for engine coolant loss	Radiator or hose leaks should be patched.	Yes, triggered by overheating
5A. Check air-fuel mixer settings	Set to manufacturer specifications	Checked by Leyland, no malfunctions yet
6A Check gas pressure regulator	Output pressure must be within specifications or replace	Yes
7A. Check ignition wires and spark plugs for misfire	Replace broken wires and fouled spark plugs	Yes
8A. Check turbocharger bearings (if turbocharged)	Turbo rotor must rotate freely or else replace bearings	No, never experienced problems
9A. Check cylinder compression	Low compression requires head gasket, ring check or engine rebuild	Yes
10A. Inspect cylinder head for cracks, bolt tightness	Torque head bolts to manufacturer spec., replace cracked head	Yes
11A. Check piston rings if oil consumption is high	Replace worn rings	Yes
12A. Check for engine coolant loss/overheating	Radiator or hose leaks should be patched.	Yes
14. Inspect exhaust brake valve if used.	Valve not opening freely should be cleaned or replaced	No exhaust brakes in fleet.

* not part of low FE procedure, see text.

Worksheet 4 for Driver Training Interview

Key Training Elements	**Performance Criteria**	**APSRTC implementation method**
Frequency of Training	Biennial + special training for poor performance	Biennial + special training for poor performance
Classroom + On-road training	On road training for several hours are essential	Both classroom and on-road training
Avoiding unnecessary idling	Specific idle time criteria for engine shut-off required	Max Idle time specified at 2 minutes
Staying within the speed limit	Tacho-graph or other speed monitoring required	Not enforced, not an issue in the city
Maintaining engine RPM at optimum levels	Engine RPM zones by engine type for good FE to be specified	On-road training using engine sound
Accelerating and braking gently	Only subjective criteria for smooth driving employed.	Only trainer observation
Using vehicle momentum to maintain cruise speed	Only subjective criteria for smooth driving employed.	Only trainer observation
Avoiding pumping the accelerator pedal	Observable in on-road training only	Only trainer observation
Anticipating traffic to minimize hard braking and acceleration.	Observable in on-road training only	Only trainer observation
Avoiding clutch Riding	Observable in on-road training only	Only trainer observation
Feedback to drivers on performance	Post on-road training clinic recommended	Immediate sit down session with trainer after test

A.9.3 Low Fuel Economy Bus and Driver Data for APSRTC

GVPT1 –Buses

Vehicle Number	Engine Type	KMPL January	February	March	% Change
493	EURO-2 Turbo	4.25	5.22		22.82%
3468	EURO-1	4.50	4.58		1.78%
9511	EURO-2 Turbo	4.71	4.29		-8.92%
452	EURO-2 Turbo	4.74	5.21		9.92%
3829	EURO-0	4.85	4.55		-6.19%
9891	EURO-2 Turbo	4.86	4.56		-6.17%
8706	EURO-2 Turbo	4.91	4.91		0.00%
9107	EURO-2 Turbo	4.98	4.93		-1.00%
9782	EURO-0	4.99	5.18		3.81%
5272	EURO-0	5.09	5.32		4.52%
3260	EURO-1		4.14	4.40	6.28%
4417	EURO-0		4.95	4.80	-3.03%
3259	EURO-1		4.79	4.88	1.88%
9511	EURO-2 Turbo		4.27	5.01	17.33%
3482	EURO-1		4.53	5.07	11.92%
8706	EURO-2 Turbo		4.91	5.34	8.76%
4423	EURO-0		5.02	5.36	6.77%
1949	EURO-1		5.17	5.59	8.12%
8229	EURO-2 Turbo		5.23	5.60	7.07%
4955	EURO-1		4.90	5.82	18.78%

GVPT-1 Drivers

Driver Number	KMPL			KMPL		
	January	February	% Change	February	March	% Change
959788	4.32	4.42	2.31%	4.42		2.31%
958942	4.39	5.04	14.81%	5.04		14.81%
960728	4.66	4.76	2.15%	4.76		2.15%
357091	4.74	5.08	7.17%	5.08		7.17%
961084	4.76	5.06	6.30%	5.06		6.30%
961233	4.76	5.07	6.51%	5.07		6.51%
350028	4.82	5.19	7.68%	5.19		7.68%
959540	4.86	4.97	2.26%	4.97		2.26%
361504	4.93	4.98	1.01%	4.98		1.01%
960641	4.96	4.82	-2.82%	4.82		-2.82%
368360	4.99	5.15	3.21%	5.15		3.21%
350573	5.00	5.20	4.00%	5.20		4.00%
350106	5.06	5.08	0.40%	5.08		0.40%
959570	5.11	5.12	0.20%	5.12		0.20%
360765	5.17	5.26	1.74%	5.26		1.74%
960740	4.77	5.00	4.82%	5.00	4.99	-0.20%
960750	4.81	5.04	4.78%	5.04	5.32	5.56%
357230	4.82	4.98	3.32%	4.98	5.28	6.02%
361055	4.94	4.85	-1.82%	4.85	5.08	4.74%
96198	5.08	4.98	-1.97%	4.98	5.75	15.46%
368293		4.98	-5.62%	4.98	4.70	-5.62%
960647		4.37	11.90%	4.37	4.89	11.90%
361182		4.81	3.74%	4.81	4.99	3.74%
351064		4.82	3.73%	4.82	5.00	3.73%
961221		4.40	13.86%	4.40	5.01	13.86%
960832		4.88	3.48%	4.88	5.05	3.48%
357665		4.69	9.17%	4.69	5.12	9.17%
352680		5.07	1.38%	5.07	5.14	1.38%
368394		4.81	7.69%	4.81	5.18	7.69%
960576		4.54	15.20%	4.54	5.23	15.20%
361640		4.86	8.23%	4.86	5.26	8.23%
961214		4.82	9.96%	4.82	5.30	9.96%
360069		5.06	5.53%	5.06	5.34	5.53%
358107		5.21	8.06%	5.21	5.63	8.06%

GVPT2 – Buses

Vehicle Number	Engine Type	KM/KG			% Change
		January	February	March	
5958	EURO-3 CNG	3.45	3.89		12.75%
5955	EURO-3 CNG	3.72	4.25		14.25%
6380	EURO-3 CNG	3.77	3.63		-3.71%
6062	EURO-3 CNG	3.93	4.54		15.52%
6583	EURO-3 CNG	4.00	3.84		-4.00%
6018	EURO-3 CNG	4.01	4.41		9.98%
6734	EURO-3 CNG	4.12	4.52		9.71%
6017	EURO-3 CNG	4.13	3.90		-5.57%
5984	EURO-3 CNG	4.14	3.74		-9.66%
5966	EURO-3 CNG	4.19	4.47		6.68%
6380	EURO-3 CNG		3.63	3.68	1.38%
5958	EURO-3 CNG		3.87	3.92	1.29%
5972	EURO-3 CNG		3.74	4.00	6.95%
5984	EURO-3 CNG		3.74	4.00	6.95%
7051	EURO-3 CNG		3.95	4.06	2.78%
6017	EURO-3 CNG		3.90	4.27	9.49%
6738	EURO-3 CNG		4.37	4.50	2.97%
6586	EURO-3 CNG		4.24	4.53	6.84%
5982	EURO-3 CNG		3.59	4.60	28.13%
6711	EURO-3 CNG		4.38	4.86	10.96%

GVPT-2 Drivers

Driver Number	KM/KG			KM/KG		
	January	February	% Change	February	March	% Change
357836	3.45	4.60	33.33%	4.60		33.33%
960689	3.64	4.81	32.14%	4.81		32.14%
357402	3.91	4.34	11.00%	4.34		11.00%
358154	4.00	4.60	15.00%	4.60		15.00%
359956	4.15	4.52	8.92%	4.52		8.92%
960981	4.15	4.51	8.67%	4.51		8.67%
959275	4.18	4.91	17.46%	4.91		17.46%
360549	4.22	4.29	1.66%	4.29		1.66%
359992	4.25	4.86	14.35%	4.86		14.35%
360337	4.25	4.42	4.00%	4.42		4.00%
960654	4.25	4.79	12.71%	4.79		12.71%
351222	4.27	4.63	8.43%	4.63		8.43%
960897	4.28	4.03	-5.84%	4.03		-5.84%
960998	4.30	5.01	16.51%	5.01		16.51%
958920	4.32	4.86	12.50%	4.86		12.50%
960864	4.33	4.58	5.77%	4.58		5.77%
360889	4.00	4.16	4.00%	4.16	4.31	3.61%
960963	4.29	3.70	-13.75%	3.70	4.56	23.24%
358308		3.81	-0.52%	3.81	3.79	-0.52%
959604		4.06	-5.17%	4.06	3.85	-5.17%
360750		4.00	0.75%	4.00	4.03	0.75%
360169		4.12	1.70%	4.12	4.19	1.70%
360082		3.96	7.83%	3.96	4.27	7.83%
960780		3.81	14.96%	3.81	4.38	14.96%
960625		4.15	5.78%	4.15	4.39	5.78%
358140		4.05	8.64%	4.05	4.40	8.64%
357399		4.31	4.64%	4.31	4.51	4.64%
958753		4.17	8.87%	4.17	4.54	8.87%
960965		3.88	17.78%	3.88	4.57	17.78%
958965		4.10	13.66%	4.10	4.66	13.66%
360174		4.38	6.62%	4.38	4.67	6.62%
958971		4.33	8.78%	4.33	4.71	8.78%
960628		4.06	16.50%	4.06	4.73	16.50%
353608		4.32	9.95%	4.32	4.75	9.95%
357842		4.42	11.31%	4.42	4.92	11.31%

BKPT Buses

Vehicle Number	Engine Type	KMPL			% Change
		January	February	March	
10Z 8198	EURO-2 Turbo	4.22	4.55		7.82%
28Z 4806	EURO-1 and -2	4.28	4.87		13.79%
11Z 3079	EURO-1 and -2	4.29	4.98		16.08%
10Z 1723	EURO-2 Turbo	4.29	5.09		18.65%
10Z 3108	EURO-2 Turbo	4.35	4.60		5.75%
28Z 3606	EURO-1 and -2	4.37	4.78		9.38%
11Z 1942	EURO-1 and -2	4.38	4.68		6.85%
28Z 2168	EURO-1 and -2	4.44	4.68		5.41%
28Z 0252	EURO-1 and -2	4.45	4.60		3.37%
11Z 5753	EURO-1 and -2	4.45	4.73		6.29%
11Z 4909	EURO-1 and -2	4.51	5.00		10.86%
11Z 1722	EURO-2 Turbo	4.53	4.66		2.87%
10Z 3386	EURO-2 Turbo	4.55	5.25		15.38%
11Z 0993	EURO-2 Turbo	4.84	5.11		5.58%
10Z9933	EURO-1 and -2		4.63	4.20	-9.29%
11Z3108	EURO-1 and -2		4.60	4.57	-0.65%
11Z1002	EURO-1 and -2		4.65	4.63	-0.43%
10Z1567	EURO-2 Turbo		4.65	4.64	-0.22%
28Z0181	EURO-1 and -2		4.44	4.83	8.78%
11Z2373	EURO-2 Turbo		4.57	4.89	7.00%
10Z8740	EURO-2 Turbo		4.54	4.89	7.71%
10Z9217	EURO-2 Turbo		4.66	4.94	6.01%
28Z4821	EURO-1 and -2		4.51	4.99	10.64%
10Z8198	EURO-2 Turbo		4.55	5.07	11.43%
10Z5871	EURO-2 Turbo		4.68	5.08	8.55%
28Z0254	EURO-1 and -2		4.64	5.20	12.07%
11Z5721	EURO-2 Turbo		4.71	5.23	11.04%
11Z5062	EURO-2 Turbo		4.60	5.24	13.91%

BKPT- Drivers

Driver Number	KMPL		
	January	February	% Change
984707	4.59	4.56	-0.65%
650924	4.70	4.76	1.28%
214483	4.53	4.65	2.65%
984829	4.46	4.59	2.91%
088432	4.42	4.62	4.52%
103770	4.42	4.62	4.52%
209894	4.68	4.92	5.13%
980136	4.44	4.67	5.18%
206852	4.50	4.76	5.78%
206523	4.45	4.75	6.74%
650926	4.51	4.84	7.32%
095154	4.50	4.86	8.00%
206837	4.54	5.04	11.01%
214905	4.57	5.12	12.04%
271567	4.42	4.99	12.90%
211778	3.87	4.41	13.95%
100840	4.08	4.80	17.65%
980142	4.24	5.00	17.92%
112235	4.21	5.07	20.43%
107340	3.80	4.63	21.84%

A.9.4 Low Fuel Economy Bus and Driver Data for KSRTC

MYSORE –Buses

Vehicle Number		KMPL			KMPL		
	Engine Type	January	February	% Change	February	March	% Change
F7924	EURO-2	4.59	5.09	10.93%	5.09		10.93%
F7905	EURO-2	4.62	4.88	5.58%	4.88		5.58%
F7893	EURO-2	4.64	4.83	4.15%	4.83		4.15%
F7904	EURO-2	4.64	4.98	7.20%	4.98		7.20%
F7894	EURO-2	4.66	4.92	5.50%	4.92		5.50%
F7892	EURO-2	4.66	4.83	3.51%	4.83		3.51%
F3255	EURO-2	4.69	5.17	10.31%	5.17		10.31%
F3416	EURO-2	4.73	5.07	7.22%	5.07		7.22%
F3267	EURO-1	4.85	5.11	5.33%	5.11		5.33%
F3101	EURO-1	4.87	5.18	6.54%	5.18		6.54%
F3188	EURO-1	4.90	5.09	3.77%	5.09		3.77%
F1286	EURO-1	4.95	5.06	2.09%	5.06		2.09%
F3174	EURO-1	4.96	4.99	0.68%	4.99		0.68%
F3076	EURO-1	4.97	5.25	5.61%	5.25		5.61%
F7938	EURO-2	4.33	4.63	7.01%	4.63	4.85	4.75%
F7941	EURO-2	4.51	4.60	1.98%	4.60	4.81	4.57%
F3411	EURO-2	4.53	4.63	2.30%	4.63	5.08	9.72%
F3451	EURO-2	4.53	4.59	1.36%	4.59	4.68	1.96%
F3127	EURO-1	4.66	4.78	2.66%	4.78	4.96	3.77%
F7907	EURO-2	4.67	4.79	2.59%	4.79	4.98	3.97%
F8108	EURO-2	4.70	4.61	-1.84%	4.61	4.76	3.25%
F3618	EURO-2	4.71	4.77	1.37%	4.77	5.18	8.60%
F1288	EURO-1	4.72	4.82	2.09%	4.82	4.86	0.83%
F2915	EURO-1	4.72	4.59	-2.93%	4.59	4.94	7.63%
F7770	EURO-1	4.76	4.81	1.11%	4.81	5.02	4.37%
F3203	EURO-1	4.79	4.86	1.54%	4.86	5.00	2.88%
F3126	EURO-1	4.88	4.91	0.59%	4.91	5.04	2.65%
F2774	EURO-1	4.88	5.02	2.79%	5.02	5.29	5.38%
F3275	EURO-1	4.89	4.94	1.22%	4.94	5.09	3.04%
F3196	EURO-1	4.93	4.98	0.94%	4.98	5.1	2.41%
F3382	EURO-2		4.64	1.08%	4.64	4.69	1.08%
F7953	EURO-2		4.57	3.06%	4.57	4.71	3.06%
F3407	EURO-2		4.56	5.26%	4.56	4.8	5.26%
F3409	EURO-2		4.63	4.10%	4.63	4.82	4.10%
F3412	EURO-2		4.79	4.18%	4.79	4.99	4.18%
F3378	EURO-2		4.73	5.92%	4.73	5.01	5.92%

	F3683	EURO-2		4.77	5.03%	4.77	5.01	5.03%	
	F3278	EURO-1		4.88	3.69%	4.88	5.06	3.69%	
	F3450	EURO-2		4.77	6.71%	4.77	5.09	6.71%	
	F1285	EURO-1		4.95	4.04%	4.95	5.15	4.04%	
	F3139	EURO-1		4.98	3.41%	4.98	5.15	3.41%	
	F3304	EURO-2		4.75	8.42%	4.75	5.15	8.42%	
	F7773	EURO-1		5.00	4.80%	5.00	5.24	4.80%	
	F2869	EURO-1		5.00	5.00%	5.00	5.25	5.00%	

Mysore Drivers

Driver Number	KMPL			KMPL		
	January	February	% Change	February	March	% Change
1883	4.25	4.82	13.41%	4.82		13.41%
3664	4.45	4.71	5.84%	4.71		5.84%
2710	4.47	4.64	3.80%	4.64		3.80%
8511	4.49	4.90	9.13%	4.90		9.13%
2257	4.60	5.04	9.57%	5.04		9.57%
3553	4.60	5.23	13.70%	5.23		13.70%
2467	4.70	4.89	4.04%	4.89		4.04%
98	4.73	4.86	2.75%	4.86		2.75%
355	4.73	4.81	1.69%	4.81		1.69%
1807	4.32	4.45	3.01%	4.45	4.54	2.02%
1854	4.38	4.58	4.57%	4.58	4.68	2.18%
3237	4.41	4.48	1.59%	4.43	4.62	4.29%
902	4.42	4.63	4.75%	4.63	4.73	2.16%
3506	4.46	4.77	6.95%	4.46	4.58	2.69%
2734	4.52	4.56	0.88%	4.56	4.71	3.29%
14	4.60	4.80	4.35%	4.56	4.81	5.48%
221	4.62	4.63	0.22%	4.62	4.70	1.73%
5101	4.71	4.88	3.61%	4.51	4.58	1.55%
4939		4.51	2.22%	4.51	4.61	2.22%
4302		4.51	2.66%	4.51	4.63	2.66%
11282		4.48	4.02%	4.48	4.66	4.02%
7943		4.44	5.63%	4.44	4.69	5.63%
3161		4.47	5.15%	4.47	4.70	5.15%
1976		4.60	3.91%	4.60	4.78	3.91%
5191		4.52	6.86%	4.52	4.83	6.86%
3168		4.59	8.93%	4.59	5.00	8.93%
3118		4.58	9.61%	4.58	5.02	9.61%

A 9.5: World Bank/ESMAP - Bus Guidance Note Validation in APSRTC

FEEDBACK QUESTIONNAIRE AND RESPONSES

1. How important is it to have senior management be actively involved in the program to maximize fuel economy?

   It is necessary that Senior Management of the organization shall actively get involved in the program to maximize the fuel economy. Unless the senior management takes initiative, devise methods, channelize resources, develop systems for improving the systems to maximize the fuel economy it would not be practically possible to achieve positive results.

2. Is it appropriate to set a depot specific target fuel economy that will give employees a clear benchmark to aim for?

   Yes, it is appropriate to set a depot specific target fuel economy. The target shall be fixed based on the trends of fuel economy of the depot, the type of fleet mix, operational peculiarities etc.

3. Is providing the fuel economy results to drivers and mechanics a key part of involving employees?

   Yes, it is necessary to provide the fuel economy results to drivers and mechanics as they are the key persons responsible for improving efficiency. The awareness among the mechanics about fuel economy of each vehicle helps them to understand the vehicle condition better and to carry out necessary repairs. The drivers can put in efforts to improve their fuel economy if awareness about route-wise, type-wise bench marks is provided to them.

4. Does manual (written by hand) data collections provide adequate data quality or automated data collection preferred?

   Automated date collection is preferable over manual data collection. Manual data collection is laborious and mistakes are bound to occur in data recoding and compilation. At basic level, i.e., before entering the data into computer, certain manual data entry to certain extent is inevitable.

5. Are data cleaning procedures useful for improving data quality and results?

   Yes. Data cleaning procedures are useful for improving data quality and results. Elimination of aberrations gradually through properly designed data cleaning procedures will help to improve the quality of data and the end results.

6. How well does the regression method performing in identifying bus drivers and buses with low fuel economy?

   Regression method is definitely an improved technique to identify bus drivers and buses with low fuel economy. But, certain inevitable constraints limit the scope of implementing the regression method at the Depots. Analysis of data pertaining to low economy buses and drivers compared to route averages, type averages, group-wise driver averages etc., are also found giving reliable conclusions with regard to identifying low fuel economy buses/drivers.

7. Are the specified items for repair similar to or identical to the list employed internally by your mechanics?

   Yes. Most of the items specified for repair of the buses are similar to the list of items employed internally by APSRTC. APSRTC has devised the systems for improving the fuel economy of buses and drivers about three decades back and has been constantly improving the methods according to the requirements of technology.

8. How important is it to audit every mechanics work on a random basis?

   The works being performed by mechanics are being monitored and audited through various systems like physical inspection, analysis of vehicle failures, analysis of fuel performance of vehicles etc. This system has been found to be yielding positive results.

9. Is an external audit across all depots to standardize repair procedures effective in making all depots the same?

   Yes, there is a system of external audit by a senior level officer at each district level. This officer/engineer inspects the depots under his controls, checks the repair procedures being followed, corrects the wrong practices, imparts necessary skills to mechanics involving vehicle manufacturers, provides necessary assistance to depots and initiates disciplinary action against the erring employees.

10. How often should mechanics be retrained?

    Mechanics are to be trained subjecting them to refresher courses at least once in a year. Their skills and knowledge updated on the lasts technologies.

11. How important is driver training for new drivers to improve fuel economy?

    Drivers are shall be trained on the skills required for driving the latest technology vehicles, high powered engine vehicles etc. The low fuel economy drivers shall be constantly subjected to rigorous training.

12. Is the retraining of low fuel economy drivers useful in improving their performance? What do the data show?

    Yes. Retraining of low fuel economy drivers is quite useful in improving their performance. The enclosed data will prove this aspect.

13. Is the notice board listing the best and worst drivers useful in motivating drivers? How do you know that it is effective?

Yes, listing the best drivers and bad drivers and exhibiting their names in the depot at important places is found developing lot of awareness among the drivers. The best performers are getting motivated to improve upon further and the low performance drivers are willing to undergo trainings without any grousing.

14. How do drivers and mechanics like the award system for the best driver and best mechanic? Even though the award is small, do you think drivers are still motivated to win the award?

    The best mechanics and drivers are being rewarded through incentive and other awards system throughout the corporation. The best KMPL drivers of the depot are felicitated at district level and state level with merit certificates and cash awards. The family members of the best performers are also invited to witness the felicitation at District level and regional level awards functions.

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Date: 04.03.2011 **S.A.ANSAARI, CM (HRD), APSRTC**

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LIST OF ABBREVIATIONS

APSRTC	Andhra Pradesh State Road Transport Corporation
ASRTU	Association of State Road Transport Undertakings
BEST	Brihan Mumbai Electric Supply and Transport
BPT	Beijing Public Transport
BXL	Beijing Xiang Long
CATA	Central Area Transportation Authority, State College PA
CEO	Chief Executive Officer
CNG	Compressed Natural Gas
DC	District of Columbia
DTC	Delhi Transport Corporation
EE	Energy Efficiency
EECI	Energy Efficient Cities Initiative
EMO	Energy Management Organization (Toyota)
Euro- 0/1/2/3	Heavy Duty Engine Emission Certification Levels for the European Union (higher numbers indicate increasing stringency)
ESMAP	Energy Sector Management Assistance Program
FE	Fuel Economy (km/L or mpg)
FTA	Federal Transit Authority (USA)
GN	Guidance Note
GVPT-1/2	Governorpet 1 and 2 depots in Vijayawada India
Km/L	Kilometer per liter
KSRTC	Karnataka State Road Transport Corporation
MM	Maintenance Management
mpg	Miles per gallon
MTBF	Mean Time Between Failures
O&M	Operational and Maintenance
SAFED	Safe and Fuel Efficient Driving
SOP	Standard Operating Practice
TMMK	Toyota Motors Manufacturing Kentucky
TRRL	Transport and Road Research Laboratory
QA/QC	Quality Assurance/ Quality Control
WMATA	Washington Metropolitan Transportation Authority (Washington DC)
UNEP	United Nations Environment Programme