Toolkit for Integrating Non-Dedicated Vehicles in Paratransit Service

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 121

Toolkit for Integrating Non-Dedicated Vehicles in Paratransit Service

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), Transportation 2000, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

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Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

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FOREWORD

By Gwen Chisholm Smith
Staff Officer
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TCRP Report 121: Toolkit for Integrating Non-Dedicated Vehicles in Paratransit Service is a toolkit that can be used by transportation managers to determine the appropriate split between dedicated and non-dedicated paratransit services to increase cost-effectiveness and meet peak demand needs. This report includes a Non-Dedicated Vehicle Optimization (NDV) Model and User Manual. The NDV Model is spreadsheet-based and may be used by paratransit system managers and planners to assist with making decisions regarding appropriate service ratios for specific conditions and environments. In addition to the toolkit, a Case Study Report and an Interim Report (which includes an analysis of factors that influence the mix of dedicated and non-dedicated paratransit service) are available for download from the project's website.

Many demand-responsive paratransit agencies in urban, suburban, and rural areas deliver services to their customers through a combination of dedicated and non-dedicated service. Providers of dedicated service use vehicles that commonly are owned internally by the lead agencies and are used exclusively for serving their customers. Often non-dedicated service is delivered by external service providers (e.g., taxi companies or community transit agencies) to increase cost-effectiveness, cover peak-period demand, and provide flexibility in meeting customer needs.

The main advantage of operating dedicated service is that the lead agency more completely controls the delivery of service. When compared with non-dedicated services, dedicated services may be more reliable because there is increased control of drivers, more stringent control of vehicle maintenance and replacement schedules, and consistent customer service and operating policies.

The main advantage of using a combined service structure that includes both dedicated and non-dedicated services is its cost-effectiveness in dealing with the inherent daily and seasonal fluctuations of demand. By purchasing supplementary non-dedicated services from a third party to cover peak overflow trips or low-demand periods, fewer dedicated vehicles are needed.

Currently, decisions on the ratio between the amount of dedicated versus non-dedicated service are mostly made by transportation managers on the basis of their experience and judgment. This report includes tools that may be used to assist transportation managers in deciding the appropriate ratio between dedicated and non-dedicated service in a systematic and comprehensive manner.

Under TCRP Project B-30, "Optimal Split of Dedicated and Non-Dedicated Service for Demand-Responsive Paratransit," the research team conducted a literature review related to current practices and planning for paratransit service options and operating and capital costs of paratransit services. Also, the researchers conducted case studies and documented how decisions are made regarding the ratio of dedicated to non-dedicated services. Based on the information gathered, an Excel-based optimization model was developed to help the practitioner identify the optimal split of dedicated to non-dedicated services in order to help improve the cost efficiency of a paratransit system for specific service conditions and environments. This NDV model allows for "what-if" analysis of various service structures for specific service conditions and environments. The software for this model is available for download from the TRB project website.

CONTENTS

PREFACE

The focus of TCRP Project B-30 was to produce a “toolkit” that would assist paratransit operators and planners in the integrated use of non-dedicated service to improve the cost efficiency of their paratransit service.

The Toolkit has three sections:

- Section 1—Phase I Research. This section describes the research goal, methodology, and findings of the initial research.
- Section 2—Phase II Research: Key Findings from Case Studies. This section summarizes the key findings from nine case studies.
- Section 3—NDV Optimization Model—User Manual. Based in part on the findings from the initial and case study research, an Excel-based optimization model was developed to guide practitioners with optimizing the split between dedicated and non-dedicated paratransit service. Additionally, the model also helps guide the practitioner in suggesting the run structure of the dedicated portion of the fleet at that optimal point. The software may be downloaded from the TRB website. The user manual walks the practitioner through using the model.

In addition to this toolkit, two technical reports are available for download from the TRB project website. The Case Study Report includes the full case studies summarized in Section 2. The Interim Report includes an analysis of factors that influence the mix of dedicated and non-dedicated service, the effect of non-dedicated service on community mobility, how using non-dedicated vehicles helps in achieving zero denials in ADA Paratransit, and how Medicaid and human services transportation requirements affect the service mix.

SECTION 1

Phase I Research

Research Goal

The goal of this research was to identify how some transit agencies have used non-dedicated service delivery mechanisms to improve the cost efficiency of their paratransit services, while maintaining desired or required levels of service quality. A major part of this research was to explore how various factors influence the particular service mix of dedicated and non-dedicated service for a given system and to produce a tool that will assist organizations in determining the optimal service mix for them

Dedicated versus Non-Dedicated Service

Before proceeding, it is appropriate to first define what is commonly understood as dedicated service and non-dedicated service. These definitions are provided below. In addition, a glossary of terms for the paratransit practitioner is presented in Appendix A.

- **Dedicated Service**—This is an operation where the vehicles are dedicated exclusively to the transportation of customers of a transportation program (or coordinated set of programs) during a specified period of time. The trips scheduled or dispatched to dedicated paratransit vehicles are typically controlled by one entity—the responsible organization, its call center or broker contractor, or its operations contractor (for that system or a specific service area).
- **Non-Dedicated Service**—This is an operation where the vehicles used to provide paratransit service do not provide transportation exclusively for the customers of a particular transportation program (or coordinated set of programs); hence, these vehicles are also used to transport other passengers. The most common example is a taxicab operation that can be called on to serve a particular trip or a set of trips from a transportation program, but is otherwise free to serve general public trips (dispatched from the base office or flagged from the street) or trips from another contract. Another nuance of the definition is where the non-dedicated service provider has the option of co-mingling trips from different, unrelated contracts on the same vehicle at the same time. An entire transportation program can be based on non-dedicated service. Alternatively, it can augment a dedicated service in an integrated fashion or a supplementary fashion, as described below:
- **Integrated Non-Dedicated Service**—This is a service where trips to be served are booked via a central source (e.g., responsible organization, its call center or broker contractor, or its dedicated operations contractor) for the program at large or for a service region, and where the trips are either scheduled onto dedicated vehicles or are assigned to a provider of non-dedicated service for dispatching to specific drivers/vehicles. Thus, ultimately, it is the program or carrier staff that decides the vehicle or the carrier to which the trip is scheduled or assigned. Sometimes, an operations contractor can provide both dedicated and non-dedicated service.

- **Supplementary Non-Dedicated Service**—This is an auxiliary service that may cater to the same set of (certified/eligible) riders as the dedicated service; however, the riders either directly contact the non-dedicated service provider or are empowered to choose from the central booking staff the auxiliary service option (and sometimes the specific non-dedicated provider as well). The most common example is a taxi subsidy program.

The study focused more on integrated non-dedicated service and on systems that use non-dedicated service in its entirety and less so on supplementary non-dedicated service.

Background

To serve their current paratransit demand more efficiently, some transit agencies have implemented policies and practices to improve the productivity of their dedicated fleet in order to increase the cost efficiency of the system. Examples of such policies and practices include

- Shortening the number of days in advance that a rider may place a reservation;
- Implementing harsher no-show penalties (to reduce no-shows and late cancellations);
- Implementing trip-time negotiation and/or limiting the number of trip requests per time slot (to spread the peak demand);
- Overbooking and filling gaps in the schedule from late cancellations with unassigned trips;
- Encouraging more pro-active dispatching; and
- Altering or fine-tuning the methods for paying, penalizing, and rewarding service contractors, especially where contractors are responsible for scheduling.

Much less attention has been directed to the service delivery structure itself and in particular to the structure of dedicated runs and the mix of dedicated and non-dedicated service and their effect on cost efficiency.

In establishing or refining a service delivery design, paratransit managers and practitioners should be looking at the mix of dedicated and non-dedicated service and how that mix can be modified to minimize the overall cost per trip (or cost per passenger-mile) while meeting or exceeding service quality standards. This is not easy and often takes months, if not years, of experimentation to identify just the right service mix. A review of the industry indicates systems predominantly dedicated, systems predominantly non-dedicated, and systems that have different splits. In many of these cases, management has figured out the service mix that makes sense for their system, based largely on the weight that each places on service quality versus service efficiency, as well as other factors such as the availability and comparative cost and quality of non-dedicated service providers.

This process begins with gaining a basic understanding of the spatial and temporal characteristics of demand. Armed with this information, it should be then possible to develop a systemwide or zone-based dedicated run structure that results in

- Good spatial coverage of the peak-demand periods;
- Minimization of over-supply of service in low-demand areas and periods; and
- Minimization of pullout and pull-in deadheading.

Once the dedicated vehicle runs have been optimized, the strategic use of carriers operating non-dedicated vehicles can be used to

- Cover the peak overflow trips;
- Serve trips in low-demand periods and areas;
- Serve long, out-of-the-way trips that are not ridesharable and that would otherwise adversely affect the productivity of the dedicated fleet;
- Better handle special events or seasonal fluctuations; and

- Improve the match between the demand curve and the dedicated run structure, and, by doing so, improve cost efficiency.

This split between dedicated and non-dedicated vehicle service is a delicate one and is highly dependent on the characteristics of the trips. For example, a service that has a relatively condensed service area (with shorter trips and common trip patterns) will undoubtedly benefit from a high percentage of dedicated service. In contrast, a more regional service (with longer less "ridesharable" trips and more diverse trip patterns) would probably benefit from a higher percentage of non-dedicated service.

The "acid test" lies in the productivity of the dedicated fleet and the systemwide unit costs (per passenger trip and per passenger-mile), noting again that cost per trip is a more appropriate measurement for systems where the trips are more homogeneous, and cost per passenger-mile is a more appropriate measurement for systems where the trips are more diverse. With a goal of sizing the supply of the dedicated vehicles so that each vehicle is productive, the task of the scheduling and dispatch staff is to identify when it makes financial sense to add a new dedicated vehicle run (or extend an existing run) in order to cover trips in a specific time period or to expand spatial coverage of the dedicated fleet versus when it makes sense to continue serving those "other" trips with non-dedicated vehicles. This is not a one-time analysis but an ongoing task.

Until now, there has been little guidance in this area. This research project was designed, by way of a national survey and several case studies, to demonstrate how different transit agencies have used non-dedicated service in an integrated fashion to help improve the cost efficiency (and service quality) of their overall paratransit system.

The other core product of this research effort is an easy-to-use automated optimizer-based planning application into which a transportation manager will input local data and characteristics of his/her service and information on the availability and characteristics of non-dedicated vehicles in his/her community/region. This application generates specific guidance to the user, detailing how, when, and the degree to which non-dedicated vehicle services can be integrated with the dedicated fleet, as well as an estimate of the benefits that would result. A user manual for this tool (the NDV Optimization Model) is presented in Section 3. The software itself can be downloaded from the TRB website. The automated tool also provides assistance in shaping the run structure of dedicated vehicles.

Summary of Initial Research

The initial research phase of the project consisted of a literature review and survey. The literature review provided insights into the use and benefits of non-dedicated service in paratransit operations, based on earlier research studies and results provided by transit agencies as their paratransit programs evolved.

The survey was intended to gain insight into the how's and why's of the use of non-dedicated service from a cross-section of organizations representing different geographic areas, different demographic settings, and different types of paratransit services. The 31 responding organizations reflected a wide geographic representation. The respondents also reflected a good mix of service area environments which were categorized into metropolitan, suburban, small urban, and rural areas.

Survey Results

One survey finding was that systems that make the most use of non-dedicated vehicles tend to be in small urban areas. Nine of the 15 systems (60%) that provide service in such environments use non-dedicated operations for at least 50% of their passenger trips. This is twice the rate of the other service environments. In contrast, systems in suburban and rural areas tended to use non-dedicated vehicles for a relatively small portion of their total service—less than 15% of their passenger trips, while systems in metropolitan areas were most likely to employ a moderate use of non-dedicated service—15% to 50% of all trips.

Not surprisingly, taxis were the prevalent type of non-dedicated service used. Seven out of every eight respondents used taxis. The predominant use of non-dedicated service is for peak overflow trips and other trips that could not be efficiently scheduled onto the dedicated fleet. The extent of non-dedicated service ranges from a very small portion of a paratransit operation up to 100% of the service.

Although the predominant payment structure for dedicated vehicle contractors is a rate per revenue vehicle hour (over half of the systems reported paying for dedicated service by the vehicle hour), non-dedicated service is mostly purchased by trip mileage—based either on the taxi meter or on vehicle miles with passengers on board. Taxi meter fares are almost universally based on the combination of a price per pickup (often called a flag drop) and a price per mile. Given that so many of the respondents use taxis (88% of the respondents), it was not surprising that the most common payment structure corresponds to the existing rate structure (for taxis) already in use.

Non-dedicated vehicle operations appear to be somewhat more productive than dedicated vehicle operations, registering approximately 7% to 19% more passengers per revenue vehicle mile. However, this may be an artifact of how revenue vehicle miles are measured in non-dedicated vehicle operations, typically only when a passenger is in the vehicle. In contrast, in dedicated vehicle operations, revenue vehicle miles are generated whenever the vehicle is in service, even if no passenger is on board, with deadhead miles contributing to as much as 50% of the total revenue miles. Therefore, this comparison of productivity may not be useful.

Another finding was that non-dedicated vehicle operations have significantly lower costs per passenger trip than do dedicated vehicle services—approximately \$14.00 to \$16.00 per trip compared to \$23.00 to \$24.00 per trip. However, it is important not to overlook that this difference may be at least partially attributable to the difference in capital and operating costs (most of the vehicles used by non-dedicated providers are sedans and minivans), overhead, and trip length.

Trip length can provide a glimpse into a transit agency's use of non-dedicated service. Some transit agencies consider the use of non-dedicated providers as an "out-of-pocket" expense. These agencies will tend to shift the shorter trips to the providers (especially if the rate is distance based) in order to minimize out-of-pocket costs. This is one reason why the trip lengths and cost per trip for non-dedicated service (versus dedicated service) are lower. However, in taking this approach, these same transit agencies may be unintentionally increasing the overall cost per trip for the entire system because, as shorter trips are taken away from the dedicated service, the productivity (and cost efficiency) of the dedicated fleet decreases. Indeed, some of the case study systems that have taken the opposite approach point to resulting improvements in cost efficiency.

The survey also identified the underlying reasons why non-dedicated service is used. Based on the survey response, responsiveness and cost efficiency were tied as the number one advantage.

There was very little difference in the perception of problems between systems that make substantial use of non-dedicated vehicles and those that use them in a more limited fashion. Those at either end of the spectrum were most likely to cite issues with contract compliance (compared to those with moderately low or moderately high use of dedicated vehicles), and the systems with moderately low usage—15% to 50% of all trips—were most likely to cite problems with the lack of accessible vehicles: 50% compared to 23% overall. But in other respects, there was consensus on the problems that existed and their perceived severity.

Factors Affecting the Use of Non-Dedicated Service

The survey revealed that the following demand and supply characteristics of the paratransit service affect the decision to use non-dedicated vehicles:

- The temporal characteristics of daily demand,
- The spatial characteristics of demand,
- Expected fluctuations in demand,
- Unexpected increases in demand, and
- Unexpected decrease in supply.

Temporal Characteristics—The demand profiles of many paratransit systems typically have a pronounced peak in the morning, and a more elongated peak in the afternoon, with demand slowly tapering out into the evening, overnight, and early morning hours. Some systems also have a mini-peak around the noon hour.

A few strategies (e.g., staggered runs combined with partial or split shifts) can be used to develop a run structure that closely mirrors the demand profile, bearing in mind that driver work rules that limit the length and structure of shifts can sometimes pose an obstacle to this. Recognizing the prevalence of this traditional demand profile, the use of contracted, non-dedicated service provides an additional tool to (1) generally improve the temporal match between the supply and demand for service; (2) accommodate the peak overflow trips; and (3) serve trips during the low-demand off-peak hours.

If the sole or dominant portion of the service is provided with a dedicated fleet (as is the case with most paratransit systems in the United States and Canada), it behooves the paratransit manager, as a good steward of the program, to maximize the productivity of the dedicated fleet in order to be as cost efficient as possible while otherwise meeting established service standards. The general idea is to remove—or not add—unproductive dedicated service. Among our survey respondents, 69% reported that they were able to do this by using non-dedicated service.

Spatial Characteristics—Dedicated vehicles are often an expensive way to serve long out-of-the-way trips. Serving long trips that do not fit into common trip patterns will therefore adversely affect the productivity of the dedicated fleet, lowering its productivity and cost efficiency. In contrast, the use of a non-dedicated vehicle is a comparatively cost-efficient way to serve such a trip. First, the dedicated vehicle can be reserved for more productive service. Second, the cost of serving such trips with non-dedicated vehicles may be less expensive than pulling out an additional dedicated run for a minimum number of hours (typically at least 4 hours, and often as much as 8 hours) or extending a run and factoring in overtime. Thus, a spatial demand pattern that is quite dispersed and that does not fall into spatial (and temporal) patterns conducive to grouping trips may suggest a service delivery mix that relies on non-dedicated service.

Expected Fluctuations in Demand—Special events and/or seasonal fluctuations can outstrip the capacity of a dedicated fleet. Use of non-dedicated service presents a way to handle these short-term spikes in demand. From the survey, 21% of the respondents indicated that they used non-dedicated service providers to accommodate spikes in demand caused by special events or seasonal fluctuations.

Unexpected Increases in Demand—In general, it is difficult to quickly expand a dedicated fleet to meet an unexpected or sudden increase in demand. (Such sudden demand changes may result from a policy change, expansion of the service area, changes in operating days or hours, and/or an influx of new riders from a new sponsor.) In many systems, it may not be possible to rapidly increase the fleet size, the number of drivers, or even the number of vehicle hours of existing dedicated service to accommodate a sudden, rapid increase in demand. It typically takes months to order new vehicles or even acquire leasable vehicles that meet program requirements. In addition, the transportation provider must recruit, hire, and train new drivers, which may be particularly difficult in environments already experiencing driver shortages.

In circumstances such as these, the use of non-dedicated service can be a useful transitional strategy until additional vehicles can be secured and/or until new drivers can be recruited, hired, and trained for the dedicated fleet.

The use of non-dedicated service can also be used for measuring when the number and types of trips carried on non-dedicated vehicles reaches a critical mass that could yield a productive and efficient dedicated run, thereby justifying an expansion of the dedicated fleet.

Unexpected Decrease in Supply—The use of non-dedicated service can also provide an "insurance policy" in case of unexpected service disruptions due to work stoppages by unions or a sudden and unexpected shortage of drivers that lasts for several months.

Problems and Obstacles in Using Non-Dedicated Service

The most prevalent problem among the survey respondents was the amount of oversight required to ensure that non-dedicated service providers complied with contractual obligations associated with driver training, drug and alcohol testing, preventive maintenance programs, complaint investigation/resolution, reporting requirements, and record-keeping. The general problem was the lack of staff to properly perform contract oversight.

The second most-cited obstacle was that the prospective/existing non-dedicated service provider(s) lacked accessible vehicles and so the use of the provider(s) was limited to ambulatory trips. Solutions to overcome this obstacle include providing, leasing, or even loaning accessible vehicles to the non-dedicated service provider(s).

The third most-cited reason for not using non-dedicated service was the perception that the service quality and reliability of the non-dedicated service is substandard or poorer than the service provided by the in-house or dedicated service contractor(s). The service quality issues most commonly mentioned were the poor quality of customer service, lack of professionalism exhibited by the non-dedicated service drivers, and poorer on-time performance.

The other most commonly cited obstacles included the scarcity of non-dedicated providers and the unavailability—or the lack of excess capacity—of existing providers during peak demand times. This was particularly the case among the nine respondents who served small urban areas, the five respondents who served rural areas, and the six respondents who served both small urban and rural areas.

In many rural communities and regions, there is not enough demand to support taxis and other non-dedicated providers. Thus, if there is any public transportation at all in these communities, it is likely to be demand-responsive service, with origins in human services transportation and operated with dedicated vehicles.

Other Issues from the Survey Concerning the Use of Non-Dedicated Providers

FTA Drug and Alcohol Testing—The FTA first published drug and alcohol testing rules in February 1994 and then in 2001 revised, updated, and consolidated the rules into one. This regulation applies to any contractor who performs safety-sensitive functions (stands in the shoes) for a covered transit agency. Non-dedicated transportation providers that stand in the shoes of covered transit agencies must comply with the FTA regulation, even if their involvement is limited or incidental. The preamble to the updated regulation clarifies applicability to non-dedicated taxicab operators. The regulation applies to taxicab operators when the transit provider enters into a contract (written or otherwise) with one or more entities to provide taxi service as part of the public transit service. Drug and alcohol testing rules do not apply to taxicab operators when service is provided where patrons are allowed to choose the taxicab companies that will provide the services. Thus, if the transit system, broker, etc., assigns trips to non-dedicated service providers, they are covered by the rule. If customers choose between service providers without direction or control of the transit agency, the non-dedicated service provider is exempt.

Insurance Requirements—In the taxi and livery industry, the insurance requirements are either regulated by the municipality or fall under a state minimum. Either way, it is rare when the insurance levels are equal to the required levels for most ADA, municipal-based, or human services agency paratransit service, and if a lower insured vehicle is used, it places the purchasing organization at risk. Moreover, with insurance costs increasing rapidly in the last several years, the higher insurance requirements of ADA paratransit programs, some municipal dial-a-ride programs, and some human services agency transportation programs have precluded program participation for many taxi and livery operators, i.e., the higher costs of insurance cannot be recovered through the transit agency program revenues.

Regulatory Environment—The regulatory environment can also affect the usefulness of non-dedicated providers and especially taxis. Taxis are usually regulated by municipalities. This may cause difficulty with respect to their usefulness when a regional program is larger than the area in which the taxi may pick up trips. Some municipalities, such as Santa Clara County in California, have taxi regulations that include requirements for drug testing, insurance, driver hiring (driver record and criminal history checks), driver training, and the condition of the vehicle. In the case of Santa Clara County, these taxi requirements were as stringent as those required by the Santa Clara Valley Transportation Authority's broker (Outreach) for its primary contractor. Hence, these requirements have together paved the way for incorporation of taxis as non-dedicated providers in the ADA paratransit service.

Case Study Research

Nine case study systems were selected for examination in a detailed manner, as well as to collect additional data that would be used to ground the planning tool. The four primary criteria used to select the nine case studies were as follows:

- The lead agency was a transit agency or municipality responsible for public transportation.
- The paratransit service of the lead agency employs a mix of dedicated and non-dedicated vehicles in an integrated fashion, meaning that some entity is determining whether each trip or trip type is to be (1) scheduled to a dedicated vehicle (or assigned to a dedicated service provider) or (2) assigned to a non-dedicated service provider.
- In their survey response, the system cited improved productivity, a better match of capacity to demand, and/or overall cost-efficiency as major advantages of using non-dedicated vehicles.
- The system had the data to support its belief in the advantages of non-dedicated vehicle operations and was willing to share the data and participate in the project as a case study.

For systems meeting these criteria, additional selection criteria included

- Systems in various geographic regions;
- Systems that operated in major metropolitan areas versus small cities or rural areas;

Table 1. Overview of case studies.

Agency	Location	Population	Area (sq. miles)	Population Density	Types of Non-Dedicated vehicles		% Non-dedicated	Passenger Trips
					Taxicabs	Other		
Large Metropolitan Areas								
Arlington Co. DOT / STAR	Arlington, VA	186,000	26	7,150	Y		76%	110,000
Pomona Valley TA / Get About	La Verne, CA	250,000	60	4,165	Y	Y	18%	107,000
Nashville MTA / AccessRide	Nashville. TN	570,000	502	1,135	Y	Y	15%	212,000
Calgary Transit / Access Calgary	Calgary, AB	951,000	279	3,410	Y		19%	825,000
Volusia County / Votran Gold Service	S. Daytona, FL	443,000	1103	400	Y	Y	37%	325,000
Small Urban and Rural								
Indiana County Transit Authority / Indigo	Indiana, PA	90,000	829	110		Y	31%	77,000
Merrimack Valley RTA / EZ Trans	Haverhill, MA	330,000	276	1,195		Y	9%	59,000
Ottawa County Transportation Agency	Port Clinton, OH	41,000	255	160	Y		6%	58,000
Link Transit / Link Plus	Wenatchee, WA	44,000	200	220	Y	Y	5%	85,000

- Systems that had varying program sizes and characteristics;
- Systems that employed different mixes of dedicated and non-dedicated service; and
- Systems that also/alternatively retained different types of non-dedicated service providers other than taxis.

Five case studies in major metropolitan areas and four case studies in small cities and rural areas were conducted. An overview of the case studies is presented in Table 1. A summary of findings for each case study is found in Section 2.

SECTION 2

Phase II Research: Key Findings from Case Studies

The full results of the case studies are presented in the separate Case Study Report available on the TRB website. The following case study summaries are intended to highlight the key elements of the dedicated and non-dedicated operations for each agency and the results that they have been able to achieve in terms of increased productivity of the dedicated fleet and decreased cost per trip. When available, the summaries include information about customer satisfaction with the dedicated and non-dedicated services provided.

Arlington County, VA (Agency: County DOT; Program: STAR)

Arlington County is located across the Potomac River from Washington, DC. At the urging of its ADA paratransit-eligible residents, Arlington County in 1999 set up a service, called STAR, to provide these residents with a non-ADA alternative to WMATA's MetroAccess ADA paratransit service. To be eligible for STAR, a person must be a resident of Arlington County and have already been certified as ADA paratransit eligible by MetroAccess. Reservations are taken by the County's call center contractor and are either scheduled onto 10 dedicated vehicles operated by two contractors (Diamond—6 vehicles, and Answers, Inc.—6 vehicles), or assigned to Red Top Taxi for dispatching onto non-dedicated taxicabs (including regular and accessible taxicabs).

One of the interesting aspects of this program is that most trips are served by Red Top Taxi. For example, of the 108,809 trips in FY 05 (Jul-Jun), 82,750 trips (including 66,659 ambulatory trips and 16,091 wheelchair trips) or 76% of all trips were assigned to the non-dedicated service provider. This is the highest percentage of non-dedicated trips among all of the case studies, and they were all carried by a taxi operator. In Arlington County, Red Top had the resources to accommodate this volume of trips with 20 accessible taxis and 304 regular taxis (sedans). They also continue to invest in additional regular and accessible resources to match the growing demand. Moreover, Red Top's management believes in providing nothing less than highly trained drivers. Indeed, this philosophy appears to be attracting business from transit agencies.

The County achieves a considerable cost savings due to a service mix with a high percentage of non-dedicated trips carried by Red Top, since their cost per trip in FY 2005 ($20.50) was 37% less than Diamond ($32.46) and 21% lower than Answers ($25.96). It should also be noted that Red Top, with their 20 accessible taxis, transported 74% of all wheelchair trips during FY 2005, virtually the same percentage as the overall rate for all trips.

Despite the availability of 7 accessible vehicles in the dedicated fleet and 20 accessible taxis, there are an increasing number of times when there is insufficient wheelchair trip capacity during the peak periods. This is partly due to the need for Red Top to serve the transportation needs of other organizations, even though they give the highest priority to STAR customers. The

County is exploring the possibility of adding three new accessible taxi certificates and/or adding one or more dedicated vehicle runs operated by accessible vehicles.

The County has also achieved cost savings as a result of implementing STAR as an alternative to WMATA's MetroAccess service. In FY 2005, the service cost per trip on STAR was approximately $27.00 across the different carriers, while the fully loaded cost per trip (including the call center and county administrative costs) amounted to about $28.30. Without STAR, the County would have been paying $35.00 for each ADA trip that an Arlington resident took on Metro Access. Using this as a range and the total number of trips made by eligible customers (108,809) in FY 2005, the County saved between $729,000 and $870,000 by having its own service. These cost savings are directly attributable to the very large proportion of trips carried by the non-dedicated provider.

To gauge customer satisfaction with service quality, the County commissioned a customer satisfaction survey that was conducted by WB&A Market Research in September 2004. One hundred fifty (150) riders were interviewed, of which 14% used wheelchairs. The results of the survey were positive. Overall, 94% of the respondents were satisfied, giving scores of 8-10 out of 10. Half of these (46%) gave the service a score of 10. When split between the major functions, 92% of those surveyed gave high satisfaction marks for call center customer service, and 96% for service delivery. The two most prominent reasons for the impressive satisfaction levels were the drivers (friendly, helpful, safe), and the on-time performance.

The riders on the Advisory Committee had similar feedback, especially noting that both the drivers and call center staff demonstrated particular sensitivity to the needs of individuals and that STAR as a whole was a "critical to allowing them to lead more independent lives and to be a part of the fabric of society." The only shortcomings mentioned by these riders were a shortage of wheelchair service during the peak periods and on Sundays.

Also contributing to driver satisfaction with the program where the $2.00 and $5.00 driver "tips" that the County pays to Red Top for each ambulatory and wheelchair STAR trip. Because of this extra incentive, drivers are more willing to accept a STAR trip, which ultimately results in better on-time performance.

The Arlington STAR program is a highly successful example of the effect that non-dedicated providers can have on both the cost and quality of paratransit service. It is also somewhat unusual in that most metropolitan area paratransit services do not make such extensive use of non-dedicated providers. Based on the survey results, paratransit services in metro areas typically made moderate use of non-dedicated service (from 15% to 50% of trips), while 76% of STAR trips were on non-dedicated vehicles. Much of the credit for the success of STAR has to be attributed to the fact that Red Top is a taxi company that has the resources and management capability to provide high-quality transportation at a competitive price.

La Verne, CA
(Agency: Pomona Valley Transportation Authority; Program Name: Get About)

PVTA, in Los Angeles County, operates a four-city (Claremont, La Verne, Pomona and San Dimas) paratransit system for those who are elderly or have disabilities. PVTA carried approximately 107,000 passengers in FY 2005. PVTA's primary operations contractor (Laidlaw) receives all trip requests (generally 1 day in advance and subscription, and some same-day service on a space-available basis) and schedules about 82% of these trips onto the 18 (18-passenger) dedicated accessible vehicles that it operates. The balance (18%) of the trips is then assigned to the on-demand non-dedicated provider (Diversified Paratransit Services, Inc. (DPI)) which operates taxi service in the area under the name Paul's Yellow Cab). Assignment is based primarily on scheduling and efficiency criteria.

PVTA contracts directly with Laidlaw and with Paul's Yellow Cab (DPI). Because Laidlaw has productivity standards to meet, it will naturally select the trips based on scheduling efficiencies. Paul's Yellow Cab uses a mix of cabs and accessible minivans. The major use of the non-dedicated service provider is to cover trips at peak periods as well as trips at the edges of the service area which would otherwise consume a large amount of time on the dedicated vehicles causing on-time and ride time issues. Given that a few of the cabs are accessible low-floor minivans, cabs are effective in serving isolated rides, particularly for those in mobility devices. The cabs are also effective in covering the start and end of the day when demand does not justify pulling out a large number of dedicated vehicles.

Although most trips are referred to the taxi company a day in advance, the dedicated contractor is allowed to refer trips to the cab company as little as 45 minutes prior to the pickup time. This permits the contractor to overbook on the dedicated service and hence have more trips available to plug gaps that emerge from late cancellations.

PVTA began using taxicabs for part of Get About service in 1996. It was hoped that having the dedicated vehicle contractor assign some trips to taxis would improve overall productivity and also address certain persistent service problems. At that time there was very little demand for Get About from San Dimas or La Verne. On-demand trips from these cities were often picked up late because most service tended to be concentrated in Pomona and all vehicles were in use at peak periods. In addition there was a problem serving will-call return trips in all parts of the service area. PVTA calculated that, if dedicated vehicle productivity could be increased from around 3.8 to 4.3 passengers per revenue vehicle hour, then the increase in cost efficiency would pay for an increased level of trip making in San Dimas using taxicabs.

Laidlaw's contract with DPI requires that trips be allocated to the cab provider and states that

> *"The goal of the trip allocation is to optimize cost effectiveness, while maintaining a maximum access to the service of riders in mobility devices and residing in outlying areas."*

The PVTA-Laidlaw contract originally set a target of assigning no more than 1,700 trips per month to the cab provider and specified that a penalty applies if more than 1,850 trips are assigned to the cab provider in any calendar month. For the 2005-06 Fiscal Year, the limit is described as 60 trips per day. Previously more trips had been assigned to taxicabs as implied by the contract provision.

Laidlaw is paid for Get About service using a fixed rate per month plus a rate per revenue vehicle hour, plus a fuel price escalator. The contract also specifies that Laidlaw must achieve passenger productivity of at least 4.3 passengers per revenue vehicle hour. If productivity drops below that, PVTA will pay only for those revenue hours that would have been needed to carry the actual patronage if productivity had been 4.3. In other words PVTA pays a fixed amount per passenger equal to revenue hours divided by 4.3. These provisions were negotiated at a time when Laidlaw was actually achieving about 4.0 passengers per hour, with the understanding that better use of taxicabs would enable Laidlaw to meet the target. This arrangement gives Laidlaw a very strong incentive to create efficient driver schedules and to assign to taxicabs any trips that would reduce productivity.

The service statistics for FY 2005 show that the dedicated fleet has achieved a productivity of 3.92 passengers per hour resulting in a cost per trip of $12.65. For the same period, the cost per taxi trip was $17.56, and the average taxi trip was 6.9 miles while the dedicated trips were averaging 2.9 miles. The PVTA contracting arrangement is apparently achieving the desired cost-saving effect of having the taxis carrying the longer trips since they operate at a much lower cost per mile ($2.56) than the dedicated fleet ($4.31). PVTA management believes that while the productivity goal of 4.3 passengers per hour has not been achieved, the current productivity (3.9) would be much lower without the use of non-dedicated taxis. This is based on the measured improvement in productivity (approximately 8%) that occurred when PVTA initiated the use of taxis in 1996.

There was no specific information regarding customer satisfaction with the service; however, after some customers indicated a preference for taxicabs, PVTA added language to the Get About brochure to say: "Get About service is provided using vans, minivans, and cabs. Because of limitations both in terms of funding and vehicle availability, Get About cannot accept requests for specific types of vehicles (for example cabs or minivans)." It was also noted that a small minority of passengers had indicated a preference for the dedicated vehicles.

Nashville, TN
(Agency: Nashville Metropolitan Transit Authority; Program: AccessRide)

AccessRide is the MTA's ADA complementary paratransit service. AccessRide provides a higher level of service than many other ADA paratransit services, in that (1) drivers provide door-to-door service, as opposed to curb-to-curb service, and (2) service is provided to trips going to/from origins and destinations within 1-1/2 miles corridors, as opposed to ¾-mile corridors. The latter policy effectively means that the AccessRide service area extends to the entire Davidson County, noting that only about 8% of the trips go to/from areas beyond the ¾-mile corridor.

Up until recently, AccessRide consisted of two components: an in-house dedicated fleet consisting of 51 vehicles (41 accessible), and a non-dedicated service provided by American Taxi. During FY 2005, 79% of the 212,282 completed trips were on the dedicated vehicles and 21% on the non-dedicated vehicles.

Since then, the MTA has added two new non-dedicated service providers, Johnson Transportation and All City Transportation, while also enlarging the in-house fleet operate by the MTA. With these changes, the service mix has changed to 85% dedicated/15% non-dedicated on weekdays, and an 88%/12% split on weekends.

The general strategy in assigning trips to All City and Johnson is to first schedule trips to maximize the productivity of the MTA-operated AccessRide fleet, then assign trips to Johnson Transportation and then All City, with the remaining trips assigned to American Music City Cab. With shorter trips tending to be scheduled onto the AccessRide vehicles (to maximize the productivity), it is not surprising that the average length of trips assigned to the overflow contractors are longer than the average length of trips scheduled onto the AccessRide vehicles. Using revenue miles per trip as a surrogate for trip length, the average weekday trip lengths calculated for June 15-21, 2005, were 7.4 miles for trips scheduled to the MTA-operated AccessRide vehicles, compared to 14.8 miles and 12.3 miles for trips assigned to Johnson Transportation and All City Transportation, respectively.

As mentioned above, the MTA assigns all the "leftover" trips to American Music City Cab and uses this taxi resource as a "second tier" resource for back-up service. Based on the analysis of data from June 15-21, 2005, data, an average of 38 trips or 5% of the total trips on weekdays, and 12 trips or 8% of the trips on an average weekend day were assigned to taxis.

The MTA purposely overbooks by approximately 10%, knowing that most of these trips will be placed into gaps in scheduled runs that are created by next-day cancellations, with the remainder assigned to non-dedicated providers. This overbooking strategy has a positive effect on the productivity of the dedicated fleet, and on the overall cost-efficiency of the system. The productivity of the dedicated fleet for June 2005 was 2.37 trips per revenue hour. This reflects a 21% improvement in productivity over the preceding June. Based on FY 2005 data, the cost per trip on the dedicated fleet was $19.53.

The MTA has found that the use of non-dedicated vehicles works well as a barometer for dedicated fleet expansion. In other words, rather than expend capital monies needlessly on new vehicles that might or might not be used, the MTA waits until there is a critical mass of trips on overflow providers that could yield a productive, dedicated run. At that point, the fleet is expanded.

Six riders were interviewed during the site visits. All six used AccessRide frequently, were familiar with all four providers (including the MTA), and were active in the disability community. All gave high marks to the service quality provided by the MTA and its overflow subcontractors. Interestingly, when quizzed on specific elements such as timeliness, there was no difference in the provider ratings. Several of the riders mentioned that the overflow carriers exhibited perhaps even more flexibility in catering to customer needs and appeared to be more successful in communicating with their drivers than with the MTA drivers. Specifically, the riders mentioned that cancellations do not always get to the MTA drivers. At the same time, there was a consensus that the MTA vehicles (and particularly the inside of the vehicles) were cleaner. In addition, several of the riders had the impression that taxi drivers were not as well trained as the MTA drivers and the drivers of the other two overflow contractors (all of which receive the same training).

Calgary, AB
(Agency: Calgary Transit; Program: Access Calgary)

Access Calgary is a shared-ride, door-to-door transportation service provided within the city limits of Calgary. Access Calgary is responsible for eligibility certification, reservations, scheduling, and delivering trip manifests to three service providers. Access Calgary is also responsible for controlling the daily operation and monitoring the service quality and contract compliance of the providers. The latter includes conducting customer satisfaction surveys and monitoring on-time performance.

Service delivery is provided by a non-profit operator, Calgary Handi-Bus Association, and two taxi companies, Checker Transportation Group, and Associated Taxi. In addition, Access Calgary also contracts with Calgary Handi-Bus to provide transportation for pre-school children and manages a user-side subsidy taxi program, available to customers of Access Calgary.

Calgary Handi-Bus has a dedicated fleet of 121 accessible vehicles operating on a run structure consisting of approximately 100 runs each weekday. The supply of vehicles is designed to meet the peak demands for service by employing a substantial number of drivers on split shifts.

Associated Taxi has a fleet of 382 taxis and 15 accessible taxis. However, Access Calgary only makes use of 5 of these accessible minivans—for dedicated service only. Access Calgary schedulers will send over driver manifests for these dedicated runs, and the drivers will essentially drive these runs as is.

Checker Transportation Group has a fleet of 108 non-accessible taxis (70 sedans and 38 vans). On any given day, roughly 89 taxis are providing Access Calgary service, and of these, approximately 40 vehicles (or 45%) would be considered to be dedicated as they work "full-time" for Access Calgary, while the others (55%) serve a mixture of Access Calgary trips and other trips and, hence, are non-dedicated.

Checker does not track how many trips were served by its dedicated versus non-dedicated taxis; therefore, it was assumed that each dedicated vehicle serves twice as many trips as the non-dedicated vehicles. Using this estimate, along with the ridership figures for Calgary Handi-Bus and Associated Taxi, the overall dedicated/non-dedicated service mix was calculated to be 81%/19%.

The origins of Access Calgary provide an interesting perspective on the development of the service mix. Calgary Handi-Bus is a private, not-for-profit organization with its origins stemming from an effort involving Easter Seals, the Shriners, the United Way, and the City of Calgary's Community and Social Development Department. Calgary Handi-Bus began service in the late 1970s providing door-to-door, shared-ride transportation service for Calgary residents who had physical and/or cognitive disabilities that prevented them from using public transit "with safety and dignity."

The City's Community and Social Development Department also began a Frail and Elderly Taxi Subsidy Program, which evolved into the Special Needs Taxi (SNT) subsidy program, available to lower income residents with special needs.

In 1997, the City commissioned a review of transportation services for people with disabilities in Calgary because the City realized (1) it could not keep up financially with the dramatic growth in each program's ridership; (2) with the general population aging, the demand would only grow; (3) the cost of service was increasing at a disproportional rate; and (4) Calgary Transit was becoming increasingly accessible. In short, the study recommended a consolidation of the two separate services.

Access Calgary was established as a division of Calgary Transit in 2002, and, in concert with the study's recommendations, the reservations, scheduling, and dispatch staff at Calgary Handi-Bus was shifted to the newly created service.

The City of Calgary found that merging customers from two separate systems into one program and using dedicated and non-dedicated service providers to provide shared-ride service has allowed the overall delivery of service for people with disabilities to be more efficient and to optimize the use of existing resources, thereby enabling more service to more customers.

Access Calgary reports that the main advantages of using the taxi companies for both dedicated and non-dedicated service are (1) the lower labor costs and (2) the flexibility they have in adjusting the needed number of vehicles or start/end times to better match the demand. They also state that the use of the taxi providers has caused Calgary Handi-Bus to be more responsive to Access Calgary's requirements in terms of consistency in providing manpower, vehicles, and adjusting driver shifts to better match the demand profile.

Access Calgary acknowledges the key role that non-dedicated service plays in maximizing the productivity of the dedicated fleets. Given that Access Calgary has a "fixed" commitment of revenue hours to Calgary Handi-Bus, Access Calgary schedulers make sure that any gaps in Handi-Bus schedules resulting from late cancellations are filled, even if they have to recall trips that had already been assigned to the non-dedicated providers.

Without this commitment to Handi-Bus, Access Calgary could balance the productivity of the dedicated fleet against the cost savings associated with increasing the percentage of non-dedicated trips in the service mix. Using the cost data for FY 2004, the cost per trip on Checker Taxi (the only non-dedicated provider, estimated to provide 42% of its trips on a non-dedicated basis) was 22.54% ($13.15 US) lower than Handi-Bus ($42 US). The addition of accessible vehicles as non-dedicated resources could have a further positive effect on systemwide cost efficiency.

Calgary Transit conducts an annual telephone survey to assess customer satisfaction with Access Calgary services. The types of issues examined in the 2004 survey included

- Frequency and use of Access Calgary services,
- Service expectations and performance ratings,
- Customer satisfaction with key issues,
- Use of various telephone services, and
- Expectations for future initiatives for Access Calgary.

A total of 400 telephone interviews were conducted with Access Calgary customers using a random sampling technique to draw names from the customer database.

The results from the survey showed that the vast majority (87%) of Handi-Bus customers considered the service to be excellent (49%) or good (38%). The specific service attributes that respondents were most likely to agree with included

- Drivers are nice.
- Vehicles are clean.
- Drivers provide help to and from the vehicle.

As part of the case study, four riders were interviewed during the site visits. All four used Access Calgary frequently and were familiar with all three providers. In general, all gave high marks to the service quality of Calgary Handi-Bus, noting especially that the drivers were well-trained, also adding that the "full-time" drivers of the taxi companies were well-trained as well. Shortcomings of the systems included some drivers having trouble with securement equipment and communicating in English, drivers talking on their cell phones (for personal calls) while driving, and the rough ride of the accessible vehicles.

Volusia County, FL (Agency: Votran; Program: Votran Gold Service)

Volusia County is on Florida's Atlantic coast and includes the Daytona Beach metropolitan area. The county's land area has 1,103 square miles. In 2000, the county had a population of 443,343. However, this population is unevenly spread, with heavily populated areas between I-95 and the coast, and along I-4 (which connects Daytona Beach with Orlando), with the rest of the county being very rural.

Votran Gold Service is Votran's door-to-door shared-ride paratransit service. Votran Gold Service is provided to the following individuals:

- Persons with disabilities who are certified as **ADA paratransit eligible**. ADA trips are limited to trips with origins and destinations within the ¾-mile transit route corridors, where and when fixed-route transit is provided.
- Persons with disabilities who qualify under Florida's **Transportation Disadvantaged** (TD) program. TD trips are for persons who reside within Volusia County but outside the ADA paratransit service area (i.e., they aren't eligible for ADA paratransit service).
- Volusia County residents who are Medicaid recipients and who are deemed eligible for paratransit service. Eligible trips are for **Medicaid-sponsored non-emergency medical transportation** only. Some destinations for authorized trips are out-of-county. Some trips also require stretcher service.
- **Senior transportation** sponsored by the Volusia County Council on Aging, as well as **other human services agency contract transportation**. Sponsored senior transportation currently includes transportation associated with Foster Grandparent programs and nutrition/dining programs.

Votran Gold Service consists of three components: (1) a dedicated fleet operated by Votran; (2) a set of eight contractors operating non-dedicated vehicles; and (3) two taxi companies. Overall, the service mix between dedicated and non-dedicated service was 63%/37% in FY 2005. In order to improve cost efficiency, Votran is modifying this split so that it is closer to half and half.

Votran tries to assign trips to the eight contractors based on the location/service area and in such a way that maximizes the cost efficiency of the entire system. Indeed, it is generally true that Votran uses its contractors to serve trips in the outlying regions of the county and trips that would otherwise adversely affect the productivity of the in-house fleet.

Votran purposely overbooks by approximately 10%, knowing that most of these trips will be placed into gaps in scheduled runs created by next-day cancellations, with the remainder assigned to non-dedicated providers. This overbooking strategy has a positive effect on the productivity of the dedicated fleet and on the overall cost-efficiency of the system. Indeed, Votran has estimated that the productivity of the dedicated fleet would be reduced from 2.1 to 1.9 trips per hour if they did not employ this strategy. Overbooking has been employed by Votran since the onset of Votran Gold Service.

Votran also has purchase orders with two taxi companies, both based in Daytona Beach. Between the two, these taxi companies get assigned about 30 ambulatory trips per weekday. These include ADA, TD, Medicaid, and senior/agency trips. These taxi companies are used to accommodate peak overflow trips, provide back-up service (in case a vehicle operated by Votran or one of the contractors is running late, has broken down, or is involved in an accident), or serve a trip that adversely affects the productivity of the Votran fleet or cannot fit onto a contractor run.

The current productivity of the dedicated fleet is approximately 2.1 trips per hour. Votran staff undertook an analysis that concluded that this productivity would decrease to 1.4 trips per hour with an all dedicated fleet, also noting that the current fleet would have to be enlarged. As a result, it was estimated that the unit cost of ambulatory trips currently served by the contractors would increase from $14.26 per trip to approximately $21 per trip, while the unit cost of wheelchair trips currently served by the contractors would increase from $22.52 per trip to about $27.00 per trip.

Two riders were interviewed during the site visits. These two riders, however, also represented numerous other riders. One is a Rehabilitation Supervisor for the Florida Department of Education's Division of Blind Services (and is herself blind). The second rider sits on the Transportation Disadvantaged Local Coordinating Board (which is a subcommittee of the Volusia County MPO and is also the president of Handicapped Adults of Volusia County. Both riders not only drew from their own experiences riding Votran Gold Service, but also could speak of the experiences of their clients and constituents.

There was a clear and rather interesting pattern. Of the three components of the system, in-house, contractor, and taxi, the riders indicated that Votran's in-house service was clearly the best in terms of customer satisfaction. Interestingly, taxi service was not that far behind, recognizing that currently this consists of ambulatory service only. Surprisingly, there was a significant drop off in the customer satisfaction of the contracted service. According to the informal poll taken by the two rider representatives, there was no one carrier that was clearly superior or inferior. One of the reasons that this is surprising is that Votran has worked with the contractors to ensure that drivers receive the same training and are subject to the same drug and alcohol testing, and vehicles must be maintained to the same standards. Meanwhile, the training received by taxi drivers does not compare. And yet, the taxi service is considered to be of higher quality than the contractor service.

Indiana, PA
(Agency: Indiana County Transit Authority, Program: IndiGO)

IndiGO is a public transportation agency that provides a family of transportation services designed to meet the mobility needs of the residents of Indiana County. In addition to a small (7-route) fixed-route system and a fixed-route/route deviation service, there are several paratransit and shared-ride options for residents with special needs. The ADA Paratransit service had 78 persons registered in 2005, with approximately 8 one-way ADA trips provided in the average week. These trips are scheduled in with the Senior Shared-Ride Program, funded by the Pennsylvania State Lottery and available to persons 65 years of age or older for trips to senior centers, shopping centers, and medical appointments. IndiGO also provides Job Access and Reverse Commute (JARC) transportation services on dedicated vehicles and is also responsible for the Medical Assistance Transportation Program (MATP), the Medicaid non-emergency medical transportation service in Indiana County.

IndiGO's paratransit services are served in three different ways: (1) IndiGO's dedicated fleet; (2) dedicated fleets operated by contractors; and (3) non-dedicated fleets operated by contractors. The dedicated fleets are used to operate the public transit service, ADA complementary paratransit service, and most of the Shared Ride program service. The non-dedicated service providers are used to provide the MATP service.

In the past, the Shared Ride program was provided through a contract with a service provider that used non-dedicated vehicles. In an effort to control the quality of service, IndiGO decided to lease six vehicles and one spare on a lease arrangement to Stewart Bus Lines(SBL). These vehicles are dedicated to the operation of the Shared Ride program and are leased from IndiGO to SBL for their exclusive use with the Shared Ride program. Occasionally, an ADA complementary paratransit passenger or MATP passenger is transported on the Shared Ride program, but no other non-IndiGO trips are transported on these vehicles.

IndiGO currently has four private for-profit contractors operating non-dedicated vehicles that provide approximately 90% of the non-emergency medical transportation under MATP. These carriers are Stewart Bus Line, Inc., Pittsburgh North Air-Ride (PNAR), Citizen's Ambulance Service, and Med-Van Transport. The SBL division that operates the MATP service is separate and distinct from the division that operates the shared-ride and ADA complementary Paratransit services.

During FY 2004 the combined Shared Ride, ADA, and MATP service carried 60,149 total passenger trips. The service mix between dedicated and non-dedicated service is 69% dedicated and 31% non-dedicated.

By contracting with four carriers, IndiGO has the flexibility to shift trips among carriers, depending on the capabilities and quality of service of each provider, thereby creating an ongoing competitive environment. If one carrier cannot perform, IndiGO can move trips to another carrier, thus maintaining a fluid, but stable service delivery system. The challenge is to maintain a competitive environment that will keep the costs low and maintain service quality, but will also provide sufficient volumes of trips for each carrier to sustain their ongoing participation in a market with limited demand for service.

Public transit systems that purchase service from small rural private operators often are the sustaining force of a company that would not otherwise be able to exist. By sustaining the company with a stable revenue source, companies often can serve other agencies and individuals that would not otherwise have service. This relationship is beneficial for the transit system, service provider, and purchasing agencies and individuals, as well as the community-at-large. Even though the public transit system may not receive any direct benefit by using subcontractors with non-dedicated vehicles, the intangible benefits to a community are significant.

IndiGO conducted a customer service survey on the Shared Ride service in the spring of 2005. Respondents were very pleased with the service and provided positive feedback. IndiGO management staff speculated that most people do not distinguish between the service directly operated by IndiGO and that contracted out and that they do not perceive any difference in quality.

Haverhill, Massachusetts (Agency: Merrimack Valley Regional Transit Authority; Program: Special Transportation Services)

Special Transportation Services (STS) offer curb-to-curb ADA paratransit service, non-ADA service to senior citizens and those with disabilities, general public service along two former fixed-route services, general public service/senior citizen service through contracts with five communities, and some business commuter service. The STS service area covers the same 276 square miles of the overall MVRTA area, but the subcontracted service providers, Assist Transportation and the non-dedicated service provider, Andover Livery, operate within a much smaller geographic area.

STS has a fleet of 19 accessible paratransit vehicles equipped with MDT and AVL systems. STS assigns 16 to their primary turnkey contractor, First Transit, and three to First Transit's subcontractor, Assist Transportation, which provides ADA and senior paratransit services in the town of Methuen. All 19 vehicles are operated on a dedicated basis.

First Transit schedules about 91% of the 61,000+ annual STS trips onto the dedicated vehicles as efficiently as possible. The remaining 9% of the trips are assigned to a livery operator, Andover Livery. Non-dedicated vehicles are primarily used to serve trips that do not fit on the dedicated vehicles, peak overflow trips, and in a back-up role serving trips for passengers whose appointments run late. Andover Livery is responsible for vehicle operation, maintenance, operating facility, vehicles, fuel, and insurance. Both Assist Transportation and Andover Livery get reimbursed based on zonal rate.

Although STS service has expanded since its introduction in 2002, the mix between dedicated and non-dedicated service has not changed significantly since then: 53,143 one-way passenger trips were provided in FY 2005 by the dedicated fleet, with an additional 5,574 trips on the non-dedicated vehicles, amounting to 9% of total service provided by the non-dedicated provider.

The productivity of the dedicated fleet in FY 2005 was 2.4 trips per hour, and the cost per trip was $19.92. The zone rate for the non-dedicated provider starts at $10.50 for Zone 1 and goes up to $28.00 for inter-zonal trips. Most of the non-dedicated trips are at the Zone 1 rate, because Zone 1 covers the major towns in the STS area.

STS has not recently conducted customer satisfaction surveys, but the paratransit manager reports that this activity should occur within the current fiscal year. The number of complaints handled per year was not provided, but the STC manager reported that there are few and these are handled by her when they arise. Customer satisfaction appears to be high overall for all services.

Ottawa County, OH
(Agency: Ottawa County Transportation Agency; Program: OCTA)

OCTA is a public transportation agency that provides curb-to-curb demand response transportation service to all residents of Ottawa County. The service is also available to all County visitors, including tourists to the Put-In-Bay area along Lake Erie. Door-to-door service is provided upon request to meet specialized needs. Reservations for service within the County are required, with a minimum of 24 hours notice. Out-of-county trip reservations are requested one week in advance. Same-day requests are accommodated only if the schedule permits or there is a trip cancellation.

In 2005, OCTA merged its Mental Retardation Developmental Disabilities (MRDD) transportation service with the public transit service. The MRDD service includes flex routes for day rehabilitation and sheltered workshop trips and demand response trips for community-based service.

The OCTA service consists of two types of services provided by an OCTA directly operated dedicated fleet and one contractor operating non-dedicated vehicles. The OCTA fleet consists of 16 accessible vans used for in-County and out-of-county demand response service and four accessible buses used primarily for MRDD sheltered workshop trips.

The contractor, Linda's Dependable Transportation Service, Inc., is a taxi company which is used to provide late evening trips (after 8:00 pm) and additional capacity within the City of Port Clinton when OCTA has a capacity limitation or personnel shortage. Overall, the service mix is 94% dedicated and 6% non-dedicated. The contractor rarely provides service outside the City due to the perceived cost of the long-distance trip and the limited budget for purchased transportation.

Linda's standard rates are significantly lower than OCTA's unit costs. For example, Linda's contract rate outside of the County is $1.60 per mile, whereas, the OCTA fully allocated rate is $1.81 per mile, a savings of nearly 12%, noting that the contractor can use the vehicles for other purposes and to fill in runs with other agency and general public customer demands. OCTA is thus able to purchase service at a trip cost lower than they would be able to provide if they operated the service directly.

OCTA's use of the contractor is limited by the total purchase of service contract amount ($20,000). This artificial cap has resulted in limited use of the contractor, especially near the end of the year when the cap is approached. Historically, the dispatcher has tried to assign as many trips as possible within the budget cap. Given the lower per mile charge, the contractor would be the most likely choice for long trips that are difficult and expensive for OCTA to provide directly. However, because these trips would be more costly because of their length and would consume the limited budget faster, they are instead assigned to OCTA with a higher per mile cost. This practice results in a much higher overall cost to the system.

The additional volume of trips associated with the OCTA service is sufficient to provide system stability for Linda's by covering system overhead cost, especially during the winter months when demand for services from private customers is low. The OCTA contract thus enables the contractor to be viable throughout the year so that it is available to provide a much-needed service during the tourist season. The tourist population and business community benefit greatly from the taxi service. Thus, the public/private partnership provides intangible benefits to the County as a whole.

OCTA has not conducted any customer service surveys to determine satisfaction with the service. Consequently, comparisons cannot be made between the directly operated and contracted service. However, passengers interviewed appear to be very appreciative of the service and there are few complaints.

Wenatchee, WA
(Agency: Link Transit; Program: Link Plus)

Link Transit is the public transportation operator in Wenatchee, Washington, and the surrounding area in Chelan and Douglas Counties. Wenatchee is almost exactly in the center of Washington State. The service area has a population of roughly 44,000 people, of whom about three-fourths live in the twin cities of Wenatchee and East Wenatchee on opposite sides of the Columbia River.

Two of several outlying communities served by Link Transit have figured prominently in the agency's use of non-dedicated vehicles. Leavenworth is a community of about 2,100 located 23 miles west of Wenatchee. Leavenworth is a base for mountain-oriented sports; by developing itself as a Bavarian village it has attracted a substantial tourist trade. Chelan, about 40 miles north of Wenatchee on the shore of Lake Chelan, has a year-round population of about 3,500. The area attracts a high volume of tourism oriented to the lake during the summer months. An Indian casino in the lakeshore community of Manson, 8 miles from Chelan, is also a significant draw.

Link Plus service, Link Transit's ADA paratransit service, is provided principally by transit agency staff that take reservations, prepare schedules, dispatch rides, and operate and maintain the fleet of 30 accessible vehicles. In addition there are two small contracts with non-profit agencies and agreements with four non-dedicated providers.

The four non-dedicated providers primarily serve inter-community trips between several outlying communities and the central area of Wenatchee and East Wenatchee. These trips are very expensive to serve using Link Plus dedicated vehicles; opportunities for trip sharing are often limited.

Overall, 5.1% of trips in FY 2004 were carried on non-dedicated vehicles. However, these trips accounted for 19% of revenue vehicle miles because the non-dedicated vehicles are mostly used for inter-community trips.

Within its core service area, Link is able to group trips very effectively. By comparison, for long inter-community trips such grouping opportunities are less common, and long deadheads are sometimes unavoidable. Although exact dollar savings are not known, it clear that it is much less expensive to serve long inter-community trips with non-dedicated providers than with Link's own vehicles. Trips carried by non-dedicated providers were 16 miles long on average in 2004 and cost about $17 or roughly $1.07 per mile. By comparison, the typical directly provided Link Plus trip was about 4 miles long and had a direct operating cost (excluding allocated agency cost for administration, planning, or marketing) of about $15 per trip. Link Plus's direct operating cost per revenue vehicle mile in 2004 was approximately $3.80.

Link Transit has experimented with innovations designed to maintain service levels for people with disabilities in the face of extreme budget pressure resulting from the loss of a major portion of its operating funding. Some of these innovations are non-ADA service intended to increase the overall efficiency of Link's services for people with disabilities. For trips to and from outlying areas, Link has used taxis and Medicaid van providers and has limited pickup times in order to concentrate these trips at particular times. This is a principal innovation of interest to this research, since it uses non-dedicated vehicles integrated with the use of dedicated vehicles.

Link Transit has also experimented with flexible service in two of these same outlying areas and developed fixed-routes in its central service area designed to allow older people and people with disabilities to meet many of their needs without needing to rely on paratransit. Link has contracted with two non-profit organizations to provide service to clients of specific programs at very favorable rates. Last, as of July 2005, Link was developing a taxi scrip program to provide ADA paratransit in one outlying community.

The principal motivation of Link's innovations was to reduce Link Plus's operating cost per trip, which was one of the highest in Washington State. These high costs stem, at least in part, from the fact that paratransit and fixed-route drivers are paid the same at Link and from the fact that Link Transit and Link Plus serve some very long trips. Pressure to cut costs also came from the passage of Initiative 695 in November 1999 which repealed the state motor vehicle excise tax that had provided about half of Link Transit's budget. The agency cut fixed-route transit service, but this did not reduce paratransit demand. The agency also began charging a fare. However, the $.50 basic fare is quite low and is the same for fixed-route and paratransit.

Link Transit currently limits its use of non-dedicated vehicles due to budget considerations and a need to make productive use of its available driver runs. All of the non-dedicated providers indicated that they could provide more Link Plus service. All of them operate small fleets. Clearly they could handle additional occasional trips. All were willing to add vehicles to their fleets if they could be sure of some consistent level of trips from Link Plus. Link Plus service does not appear to pay well enough to support additional vehicles and drivers on its own, but could be combined with other business to be viable.

From the perspective of people with disabilities, the most positive aspect of Link Transit's innovations has been the preservation of service in outlying communities. For example, a rider who takes trips within Leavenworth was happy with service provided by the non-dedicated vans and liked the smaller vehicles. This rider did not like using the prior trolley route-deviation service and noted the difficulty the driver had maintaining a schedule. Two riders in Chelan get taxi rides within town on days that Lake Chelan Community Hospital does not operate bus service under contract to Link. Both riders found that the arrangement worked fine and noted that Link Plus no longer sent its own vehicle for trips within Chelan since the trolley began providing deviation service. One rider was interviewed who regularly travels into Wenatchee on a non-dedicated vehicle. This rider was not pleased with the limitation of pickup times that was introduced in March 2005, which limits the times he can get to medical appointments, but felt that otherwise non-dedicated vehicles provide service just as good as Link's own vehicles.

SECTION 3

NDV Optimization Model—User Manual

I. Introduction

The Non-Dedicated Vehicle Optimization Model (NDV Model) is a spreadsheet-based computer model that enables paratransit system managers and planners to evaluate the feasible uses of non-dedicated vehicle fleets—most typically taxicab operations—as a component of their overall paratransit service delivery system. (The software is available for download from the TRB project website.) The NDV Model is intended to assist paratransit managers and planners in answering the following key questions about the potential and/or actual use of non-dedicated vehicles in their service delivery system.

1. Is it cost-effective to use non-dedicated vehicles (NDVs) as part of the service delivery system?
2. What roles are most appropriate for NDVs?
   a. Peak service augmentation to level out the dedicated vehicle (DV) run structure
   b. Handling longer trips that would otherwise reduce the productivity of dedicated vehicle operations
   c. Providing service during evenings and other low-demand periods
3. What is the likely magnitude of cost impacts associated with using NDVs compared to using only a dedicated vehicle fleet—or compared to a system's current mix of dedicated vehicles and non-dedicated vehicles?
4. How will the cost impacts of different strategies for using NDVs be affected by different near-term cost and utilization levels for dedicated and non-dedicated vehicle operations?
5. Given the DV cost and operating environment, and the cost and availability of NDV service, what is the optimal split of trips assigned to DVs versus NDVs, i.e., what "service mix" results in minimizing the overall cost per trip?

The NDV Model is implemented in an Excel spreadsheet format and programmed in a combination of Visual Basic for Applications (VBA) and Excel's built-in capabilities. The NDV Model relies on two component models.

- A driver/vehicle run optimization model (developed as part of this project) that determines the most cost-efficient vehicle run schedule for dedicated vehicles for a given passenger demand pattern in a service area;
- An analytic model of demand responsive transportation (DRT) capacity and quality of service (referred to hereafter as "the DRT analytic model") developed by Liping Fu of Waterloo University and incorporated into the overall optimization approach of the NDV Model.

The NDV Model systematically searches for and determines the mix of DV and NDV service that minimizes the total cost of DRT service provided. In doing so, it uses an optimized DV run structure—which is based on an optimized driver shift schedule—and constraints on both the NDV and DV services that reflect fleet size and other business and policy constraints. For example, a typical constraint is that many or all wheelchair trips will need to be provided by the DV fleet due to the absence—or limited number—of wheelchair-accessible vehicles in the NDV fleet. The NDV Model allocates passenger trips to NDVs—subject to constraints on fleet and vehicle type availability—whenever doing so yields a more cost-efficient solution than having these trips transported on DVs. This most typically occurs for peak period trips, trips during low density times of the day, or long trips. The overall result is a minimum cost DRT service delivery system.

II. The Optimization Models

Model Descriptions

The tool includes three different versions of the optimization model, which are described briefly below. In each case, the optimization model seeks to find the solution that minimizes the total cost of serving the specified level of passenger demand, subject to the constraints imposed by the model structure and by user-specified parameters.

The overall modeling approach enables a realistic supply and cost of DV and NDV service to be generated to meet the user-specified demand levels for an actual DRT system. The DRT analytic model has been tested against several real-life DRT operations and generates results for required fleet size and system productivity that are reasonably consistent with the actual situation. Hence the model-generated DV requirements are likely to be realistic approximations in most cases.

In addition, the driver/vehicle run optimization model embeds realistic constraints on driver shifts—such as user-defined limitations on part-time drivers—that are enforced in developing the necessary supply of vehicle service during the day. These constraints ensure that the real-life driver scheduling practices, as well as any scheduling inefficiencies associated with serving demand that features peaks and valleys during the day, are reflected in the model result.

With respect to NDV supply, the model incorporates constraints on the amount of service that can be provided by NDVs based on the user-defined limitations on the number of total—and wheelchair-accessible—vehicles available to the DRT service. The use of existing DV and NDV cost levels per unit of service (vehicle hours in the case of DVs and vehicle miles or passenger trips in the case of NDVs)—both of which can be modified by the user to reflect future or changed conditions—ensure that the costs of the supply of service are also realistic.

The three optimization models have the following characteristics:

1. **Core Model—Peak Run Leveling**

   This model, which is used as well by the other two models, seeks to minimize service costs by reducing DV peaking through the use of NDVs at certain times during the day. Leveling out the vehicle run structure tends to minimize driver scheduling inefficiency and hence provides more cost-effective service than a highly peaked DV run structure. The Peak Run Leveling model evaluates all combinations of DVs and NDVs starting with a base number of DVs specified by the use, and then systematically increasing the number of DVs. Each level of DV peaking is one iteration of the optimization model, during which appropriate numbers of passenger trips are allocated to DVs or NDVs in accordance with the level of allowed DV peaking—but also subject to capacity and policy constraints specified by system data and the user on how many trips and what type of trips are allocated to NDVs. By determining the optimum solution at each point in the entire range of peaking possibilities, the Core Model thus finds the overall optimum solution for DV peak leveling.

2. **Evening Diversion Model**

   This model builds on the Core (Peak Run Leveling) Model by taking the further step of diverting as many trips as feasible from DVs to NDVs during evening hours and other low-demand periods of service. In the limiting case, all passenger trips during the evening period are handled by NDVs—if input data and user-specified parameters indicate there are sufficient accessible vehicles to make this a feasible option. Otherwise, the diversion is limited by practical constraints, such as the need for wheelchair trips to be transported on accessible vehicles that may only be available in the fleet of the DV provider—and hence require some baseline level of service by the DV fleet during evening hours.

3. **Trip Length Diversion Model**

   This model determines the optimal use of NDVs in two phases. It first optimizes the distribution of trips among DVs and NDVs based on trip length (since longer trips tend to reduce DV productivity) by finding a solution that minimizes overall DRT service costs through this approach. As with the other models, the solution is subject to constraints on NDV trip allocation due to the possibility that NDV providers may have little or no access to accessible vehicles. (The model approximates the impact of trip length on fleet productivity by using a modified version of the DRT analytic model.) This solution is then used as the starting point for the Peak Run Leveling model for those trips allocated to the DV service. The overall result of applying the Trip Length Diversion model is to both allocate longer trips to NDVs and to reduce DV service peaking. However, it is not necessarily the case that this will produce an overall lower cost solution than peak run leveling optimization by itself.

Description of the Core Model Computational Process

The following description explains how the Core Model operates:

1. The user enters data onto Excel worksheets that describe the temporal demand profile (number of trips in each half-hour period), current use of dedicated vehicles (DVs) and non-dedicated vehicles (NDVs), the availability of wheelchair accessible and non-wheelchair accessible NDVs, constraints on DV driver shifts, and unit operating costs of DVs and NDVs.
2. The user can specify limits on the following categories of DV driver shifts: 4-hour shifts for part-time workers, 5-hour shifts for part-time workers, total part-time workers for all 4-hour to 6-hour shifts, 8-hour regular shifts, 8-hour split shifts, 9-hour regular shifts, 10-hour regular shifts, and 10-hour split shifts for full-time workers.
3. The user enters factors that specify a "Baseline" demand level that will always be carried with DVs. Typically, this Baseline demand level will have essentially no peaking, so it is defined as having a "Peaking Ratio" of 1.0.
4. The model begins by assuming that all trips above the Baseline demand level will be carried by NDVs, to the extent that NDV capacity is available. Wheelchair-accessible NDV capacity can be specified separately. If appropriate, the user can specify that no wheelchair-accessible NDVs are available.
5. Using the DRT analytic model, the optimization model calculates the number of DVs needed in each half hour to accommodate the Baseline demand level plus any additional trips that cannot be carried on NDVs due to limited availability or accessible vehicle limitations.
6. The model uses the built-in Excel Solver to create an optimal set of DV driver shifts—essentially equivalent to vehicle runs—that (a) respect labor constraints specified by the user and (b) ensure that the number of DVs required to handle the passenger trip demand is available in each half hour period. It then calculates the total daily operating cost for DVs and NDVs.
7. The model then repeats Steps 4 through 6, at each iteration increasing the number of trips assigned to DVs. This number of DV trips is the product of the Peaking Ratio—for that iteration—and the Baseline demand level. At each iteration, the Peaking Ratio (which initially has a value of 1.0 as specified in Step 3) is increased by increments of 0.1. Based on the DV level of demand calculated for that iteration for each time period, the model then generates the DV requirements in each half-hour period, determines the optimal driver shifts/vehicle runs to

meet these requirements, and calculates the resulting total operating cost of DVs and NDVs. This iterative process (typically requiring 10 to 30 iterations of the model) continues until eventually all trips are carried on DVs.

8. The model then examines the operating costs for each iteration and identifies the point at which the total cost (DV plus NDV operating costs) is minimized. This point constitutes the "optimal service mix" or optimal split of DV and NDV service.

Core Model Computational Process Illustrated

This process is illustrated by Figures 1 through 4 using data from the paratransit system in Calgary. Based on actual experience, it was determined that NDVs could carry at most 125 passenger trips per 30-minute period. Figure 1 shows the daily demand pattern in half-hour periods. The Baseline demand level (Peaking Ratio = 1.0) was set at 62 trips per half hour, meaning

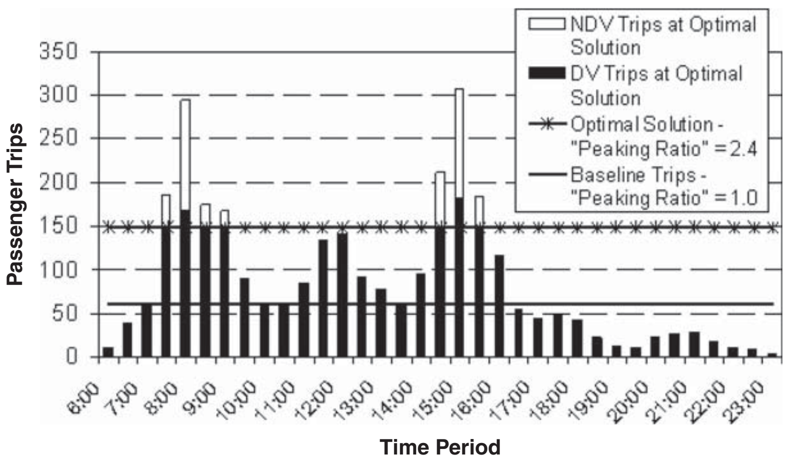


Figure 1. Optimum cost DV vs. NDV passenger allocation.

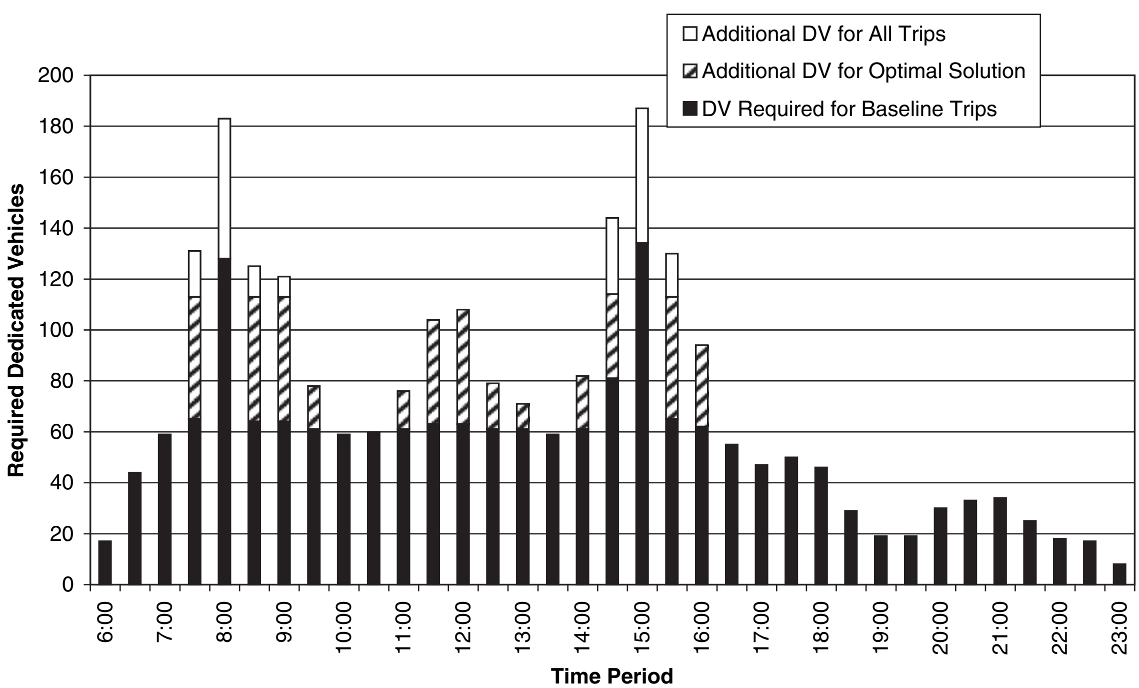


Figure 2. Required dedicated vehicles by time period.

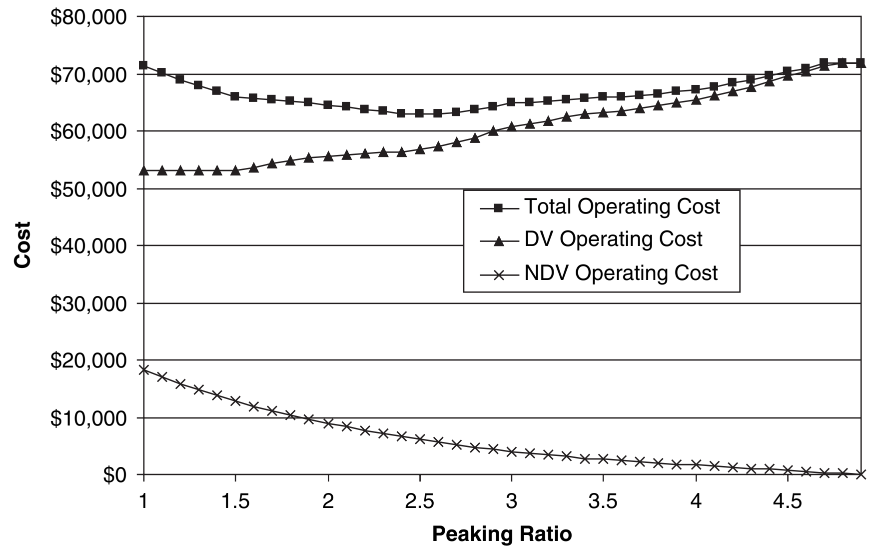


Figure 3. Operating costs vs. "Peaking Ratio."

the model begins by trying to assign all trips above this level to NDVs. This level was chosen to represent minimum conceivable use of DVs.

As the model increases the Peaking Ratio, the "cutoff line" of trips allocated to DV service gradually increases. At each incremental step, the model determines the cost to carry all trips below each setting of the line using DVs. As shown in the example in Figure 1, the lowest cost occurs at Peaking Ratio = 2.4, corresponding to 149 trips per half hour on DVs. This point is represented in Figure 1 by the horizontal line with stars on it.

In Figure 2, the black bars represent the DV requirements to carry the Baseline demand. There is a spike in the number of DVs in use at 8:00 AM and at 3:00 PM (15:00), even though the model attempted to use DVs only for the baseline demand. This results from the fact that total demand in these two periods far exceeds the amount that can be accommodated on NDVs, so that additional trips beyond the baseline level have to be assigned to DVs.

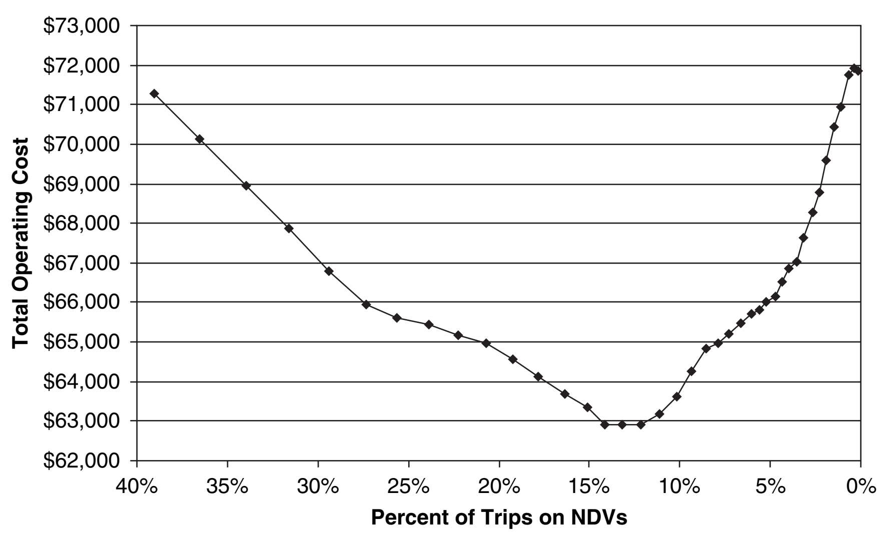


Figure 4. Cost and percent of trips on NDVs.

As shown in Figure 2, the optimal service mix requires the baseline number of dedicated vehicles (shown as black bars) plus additional vehicles (shown as diagonal hatch bars). Figure 2 also shows how many additional DVs are needed if no NDVs are available (white bars).

Figure 3 shows the calculated operating cost for DVs, NDVs, and both combined over the whole range of Peaking Ratios. At Peaking Ratio = 1.0 (all trips over 62 per half hour on NDVs to the extent permitted by NDV capacity), DV cost is minimized and NDV cost is at its highest. As the Peaking Ratio is increased, DV cost increases and NDV decreases. At the far right, with Peaking Ratio = 4.9, all trips are on DVs and NDV cost falls to zero while DV cost is at its highest. The graph shows that total of the two costs is at its lowest level at Peaking Ratio = 2.4, which is the optimal level of use of NDVs.

Figure 4 shows the equivalent data expressed using the percentage of trips carried on NDVs. At Peaking Ratio = 1.0, 39% of trips are carried on NDVs, and at Peaking Ratio = 4.9, no trips are carried on NDVs. At Peaking Ratio = 2.4, which minimizes cost, 14% of trips are on NDVs.

Computational Procedures for Other Versions of the Optimization Model

The computational procedures for the other two versions of the optimization model are variations on that of the Core Model.

For the Evening Diversion Model, the same procedure is followed except that beginning at the time period that the user has specified as the start of the evening, all passenger trips are placed on NDVs, subject to NDV capacity and accessible vehicle constraints. If the NDV provider(s) do not have accessible vehicles, then all wheelchair trips during evening time periods are transported on DVs. All ambulatory trips are allocated to NDVs (assuming adequate NDV capacity) during the evening time periods. Otherwise, the same iterative calculation procedure beginning with a Peaking Ratio of 1.0 is utilized. Because there are few or no DV vehicle runs during the evening hours for this model, the optimized driver shift/vehicle run schedule will tend to be different than for the Peak Run Leveling model.

In the Trip Length Model, there is an initial optimization of trips between DVs and NDVs based on allocating trips from different trip length categories—subject to accessible vehicle and user-defined constraints—so as to produce a minimum cost result. For example, perhaps 80% of total trips would be allocated to DVs by the initial optimization, and the NDV trips would be concentrated among the longer trips. The second optimization procedure—using the Peak Leveling model—then uses this overall demand level for DVs as its starting point for the Baseline demand level. In this example, that would mean that the Baseline demand level would be 80% of that used by the Core Model. This (reduced) Baseline demand level is then multiplied by the initial Peaking Ratio of 1.0 for the first iteration of the Core Model calculation procedure that produces the optimized driver shift/vehicle run structure. The Peaking Ratio is then increased by 0.1 and the iterative procedure of generating optimized driver shift/vehicle run structures continues until, in the final iteration, all trips are assigned to DVs.

During the process of optimizing the driver shift/vehicle run structure, the trips initially allocated to the NDVs are held out of the optimization calculations. However, these NDV trips are then added to the trips assigned to the NDVs by the Peak Run Leveling optimization at the conclusion of each iteration of that optimization process. Each batch of NDV trips is separately costed, since they have different average trip lengths. This overall result is then used for each successive value of Peaking Ratio. After the results have been generated for the entire range of Peaking Ratios, the minimum total DV-NDV cost solution is identified in the same fashion as the original Peak Run Leveling model.

III. Working with the NDV Model

This User Guide focuses on the following aspects of using the NDV Model.

- Installing the model on your computer,
- Data requirements for the model,
- Inputting data into the spreadsheet,
- Obtaining results from the model,
- Viewing and saving model results, and
- Parameter adjustment and sensitivity analysis.

This section explains how to install the software on your computer; subsequent sections cover the other specified topics.

Installing the Spreadsheet Model

The system requirements for the NDV Model are as follows:

- Operating System: Windows 2000 or higher
- Microsoft Office/Excel Version: Office 97 or higher; Excel 97 or higher
- Computer Memory: 128 MB or higher (256 MB or higher desirable)
- CPU: No specific requirements, performance directly a function of CPU speed

The NDV Model is distributed as an Excel workbook file (with the .xls file suffix). The CD contains two versions of the workbook file, one that includes a complete set of test data and another that contains no data and which you will use to enter your organization's data. Installation begins by copying these files to a directory on your computer's hard drive.

After the workbook files have been copied to the hard drive, it is typically necessary to activate or modify certain Excel features in order for the model to run properly. To do so, follow these instructions:

1. Start Excel
2. From within Excel, select Tools -> Add-Ins. Excel displays the Add-Ins dialog box. Scroll down the list of Add-Ins and check the one named Solver Add-In. Click OK. This will make the built in Excel Solver available to the NDV Model, which is necessary in order for it to execute.
3. If Solver is not available on your computer, you will be asked if you want to install it. If this occurs, you will need your Office or Excel CD, but this only applies to versions of Office or Excel that are several years old.
4. After activating Solver, make sure that Macros can run, because the model requires the use of Macros. To do so, complete the following step.
5. Select Tools -> Macro -> Security. Excel displays the choice of security levels for Macros. Check either Medium or Low. Click OK.
   a. The next step is to load the workbook file containing the model. Depending on the Macro security level you have selected previously, you may have one more action to do each time you open the model file, as explained in Step 9 below.
6. From File -> Open, select the file NDV_Model_Testdata.xls from the directory where you initially copied it and click Open.
7. If you have set Macro security at Low, the file should open and place you on the home screen (Main Page) of the model.
8. If you have set Macro security at Medium, Excel will inform you that the worksheet file contains Macros and ask you whether you want to enable or disable them. Select the choice "Enable Macros" from the dialog box. Note that you will be prompted for this every time that

you load the model, so you may wish to reconsider your choice of Macro security level if this is excessively annoying.

9. Try to run the model. From the Main screen, select Optimize. This will transfer control to the Optimization page. On that page, click on the Optimize button in the Peak Run Leveling column of the spreadsheet.
10. The model should begin a calculation cycle, indicated by the appearance of an hourglass and messages and numbers in small font flashing across the bottom left area of the screen. It may take two or three minutes (or even more) for the model to complete the calculation cycle. When it is finished, the hourglass will disappear. The numbers on the spreadsheet will not change since you simply ran the optimization with the existing data and parameters of the model.
11. If the model runs without error, you have successfully modified Excel's settings so they will support the model.

After you have followed these procedures and verified that your Excel will now work with the model, close the spreadsheet that contains the model, but not Excel itself.

Now load the file NDV_Model_New.xls using the Excel File -> Open menu item. This spreadsheet file is the model with no data. You are now ready to begin entering your system's data into the model.

IV. Data Requirements for the Model

The NDV Model requires a significant amount of data in order to properly execute. In general, all of the data elements should be readily available from annual/quarterly operating and financial reports or from routinely used operational data. In addition, there are several optional data elements that the user is encouraged to provide but for which default values are available in the absence of user-input data. The required and optional data elements are specified below.

A. Required Data Elements

Service Supplied

1. Total DRT System
   - Maximum available vehicles
   - Revenue vehicle hours—annual
   - Total vehicle hours—annual
   - Revenue Vehicle Miles—annual
   - Total Vehicle Miles—annual
2. Dedicated Vehicle Fleet
   - Total vehicles
   - Wheelchair accessible vehicles
   - Weekday peak vehicles operated
   - Weekday peak accessible vehicles
3. Non-Dedicated Vehicle Fleet(s)
   - Maximum number of vehicles available for use by DRT program
   - Maximum number of vehicles available for use by DRT program during peak period (as defined locally)
   - Maximum number of wheelchair accessible vehicles available for use by DRT program (total and during peak period)
4. Dedicated Vehicle Driver/Vehicle Run Schedule
   - For each driver/vehicle run for a typical day, data required is driver report time, vehicle pullout time, deadhead time (inbound/outbound), vehicle pull-in time, driver sign-out time, and any scheduled driver breaks (for lunch period or split shifts)

- Alternatively, the user can provide summary driver/vehicle run data for a typical day in which the number of vehicles in service at each time point during the day is entered in the spreadsheet and the total number of driver hours for the day is specified

DRT System (Dedicated Vehicle) Driver Compensation Arrangements

- Driver wage rates and benefit rates, by type of shift—full-time, part-time, straight shift, split shift

Operating Costs

1. Total DRT System
   - Total operating cost—annual
   - Administration (non-provider) cost—annual—optional, but highly desirable for cost calculation purposes
2. Dedicated vehicle operational costs
   - Variable cost per revenue vehicle hour—derivable but requires user judgment
   - Driver incremental cost per hour—derivable but requires user judgment
3. Non-dedicated vehicle costs for DRT system
   - Cost per trip or cost per pick up and cost per mile and cost per wait hour—NDV service provider compensation rates

Passenger Trip Demand Data

- Passengers—annual
- Weekday trips per day—average
- Weekday passengers per day—average
- Passengers per trip—average
- Percent wheelchair trips
- Passenger trips by 30-minute period for typical day or all five weekdays
- Passenger trip length distribution (specified in 2-mile or less increments)

Service Area Characteristics

- Service area size (square miles)
- Effective service area size (square miles—estimates will suffice)
- Vehicle average speed when traveling (excluding pickup and dropoff time)
- Excess ride time standard—policy for system
- Time window for pickup time estimate (minutes)—policy for system
- Average dwell time ambulatory trips (estimates will suffice)
- Average dwell time wheelchair trips (estimates will suffice)

B. Optional Data Elements

These data elements are desirable, but, in some cases, default values can be substituted—as indicated below—if actual data are not available.

Non-Dedicated Vehicle Operational Data

- Maximum achievable passenger trips/Vehicle Service Hour (VSH)—user estimate of maximum level of vehicle productivity that can be achieved by NDV service, potentially necessary to determine amount of NDV capacity available, default value is provided.

Dedicated Vehicle Operational Data

- Peak vehicle productivity (passengers per VSH)—desirable for verification purposes
- 10-hour demand density (passenger trips generated per square mile per hour)—desirable for verification purposes
- Peak demand density—desirable for verification purposes

C. Derivable Data Elements

The model uses other data elements that can be derived from required data, assuming data are available, and for which the spreadsheet contains calculated fields designed to generate such data. The derivable data elements include items such as cost per passenger trip and trips per vehicle service hour.

V. Entering Data into the Model

A. General Instructions

On the main page of the NDV Model spreadsheet, the user selects Input Data to enter data into the model. Figure 5 shows that making this selection causes a pop-up form to appear which enables the user to select one of five different types of data entry:

- DRT System Data
- Dedicated Vehicle Data
- Non-Dedicated Vehicle Data
- Passenger Trip Demand Data
- Driver Shift/Vehicle Run Data

Another type of data is entered by selecting the Set Baseline Factors button. This causes a pop-up window to display that contains several data entry choices used for initial calculation or service selection purposes. This is shown in Figure 6.

To begin entering data into the model, select the Input Data button and then select the DRT System Data radio button and press OK.

Following these steps will cause the worksheet shown in Figure 7 to appear. The cells in this and the other data input worksheets are color-coded to indicate the nature of the data to be entered into each cell.

If a cell is light yellow this indicates that it contains required data. The model will not work properly without such data. In a few cases, the required data have default values based on derived

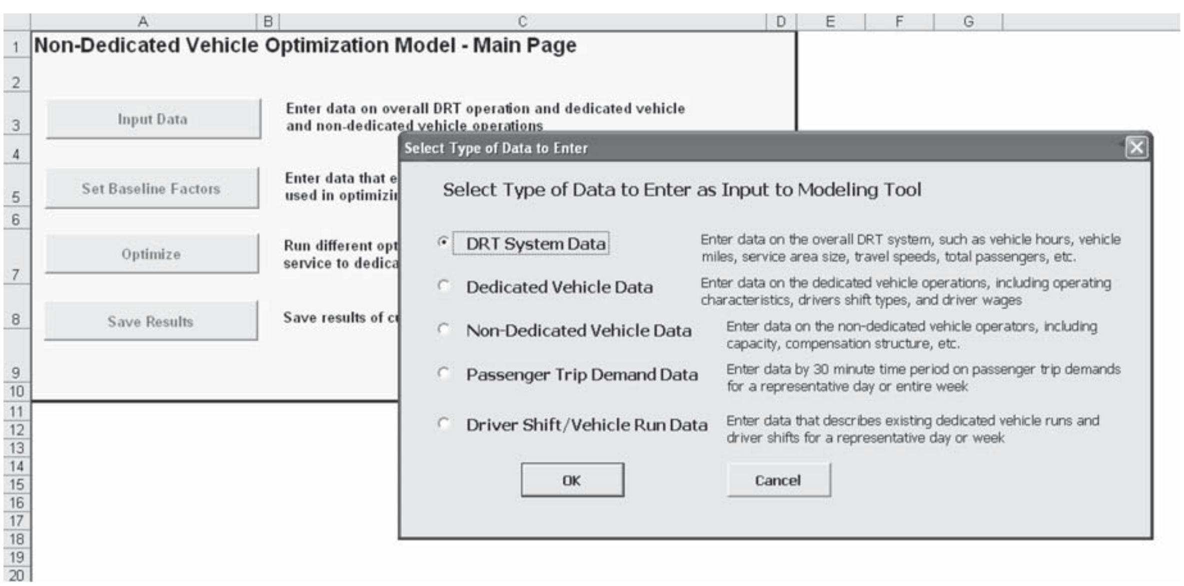


Figure 5. Data entry form selection from main page.

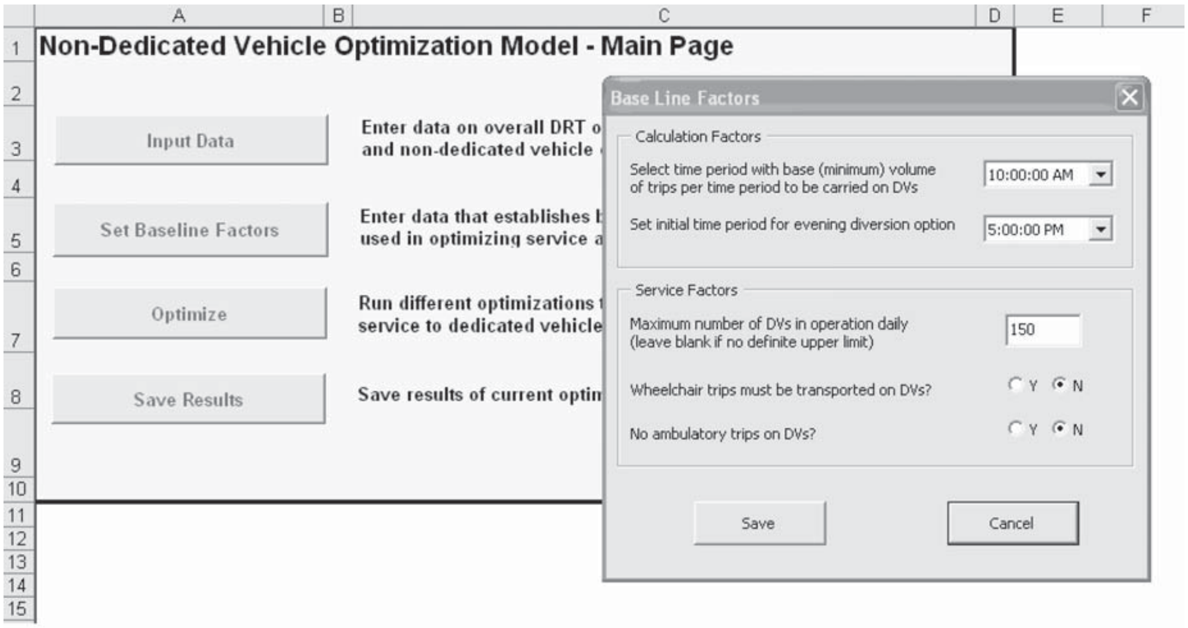
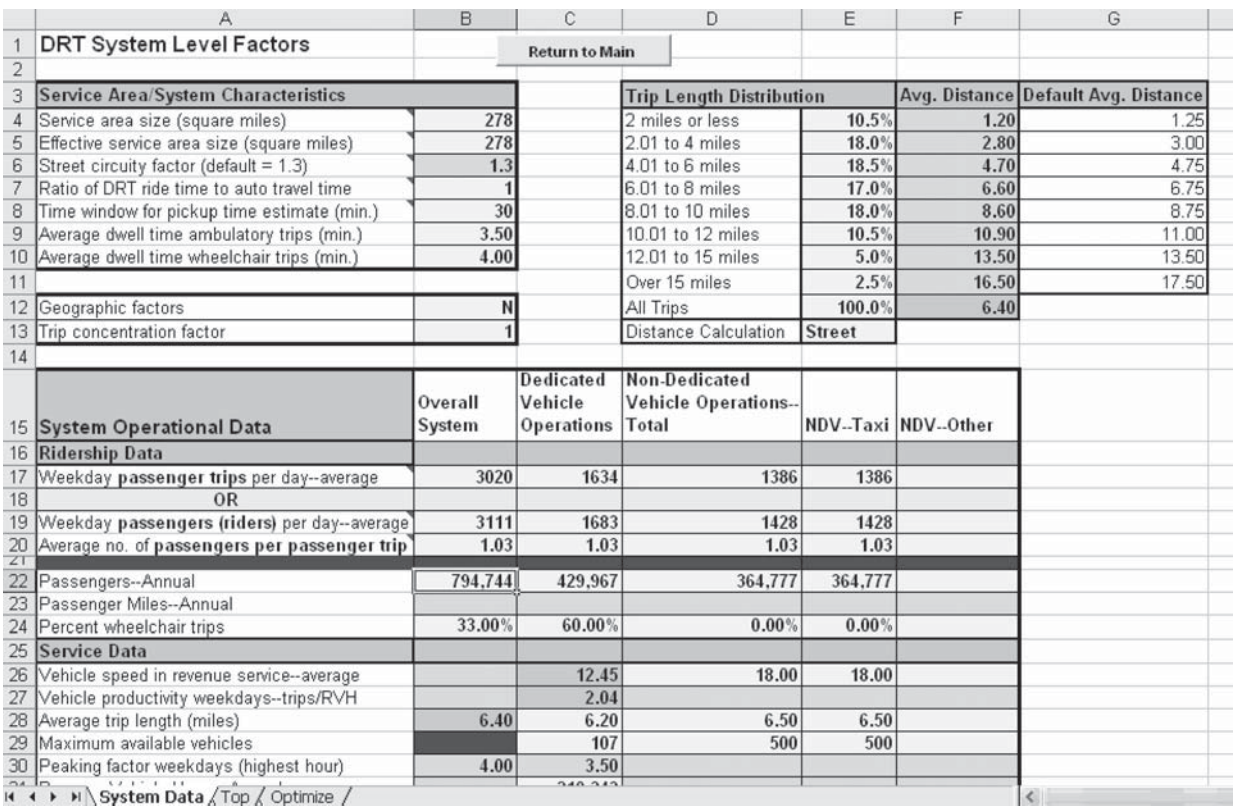


Figure 6. Base line factors data entry form.



DRT System Level Factors

Return to Main

Service Area/System Characteristics	
Service area size (square miles)	278
Effective service area size (square miles)	278
Street circuity factor (default = 1.3)	1.3
Ratio of DRT ride time to auto travel time	1
Time window for pickup time estimate (min.)	30
Average dwell time ambulatory trips (min.)	3.50
Average dwell time wheelchair trips (min.)	4.00
Geographic factors	N
Trip concentration factor	1

Trip Length Distribution		Avg. Distance	Default Avg. Distance
2 miles or less	10.5%	1.20	1.25
2.01 to 4 miles	18.0%	2.80	3.00
4.01 to 6 miles	18.5%	4.70	4.75
6.01 to 8 miles	17.0%	6.60	6.75
8.01 to 10 miles	18.0%	8.60	8.75
10.01 to 12 miles	10.5%	10.90	11.00
12.01 to 15 miles	5.0%	13.50	13.50
Over 15 miles	2.5%	16.50	17.50
All Trips	100.0%	6.40	
Distance Calculation	Street		

System Operational Data	Overall System	Dedicated Vehicle Operations	Non-Dedicated Vehicle Operations--Total	NDV--Taxi	NDV--Other
Ridership Data					
Weekday **passenger trips** per day--average	3020	1634	1386	1386	
OR					
Weekday **passengers (riders)** per day--average	3111	1683	1428	1428	
Average no. of **passengers per passenger trip**	1.03	1.03	1.03	1.03	
Passengers--Annual	794,744	429,967	364,777	364,777	
Passenger Miles--Annual					
Percent wheelchair trips	33.00%	60.00%	0.00%	0.00%	
Service Data					
Vehicle speed in revenue service--average		12.45	18.00	18.00	
Vehicle productivity weekdays--trips/RVH		2.04			
Average trip length (miles)	6.40	6.20	6.50	6.50	
Maximum available vehicles		107	500	500	
Peaking factor weekdays (highest hour)	4.00	3.50			

System Data / Top / Optimize

Figure 7. DRT system factors data entry worksheet.

data or a model-defined value (explained in the following section). In such cases, an adjacent field contains the default value but this will be ignored if the user enters a value into the yellow data cell.

Tan cells contain optional data, which, in some cases, will have default values that can be used. If default data are available for this field, such data will be next to the tan cell in a cell with a white background if the data are model-defined. If the default value is based on derived data (explained below), the data will be in a cell with a light blue background. Default data values cannot be changed by the user. If the default value is not considered appropriate, users must enter their own data values in the tan optional data cell, or the model will use the default.

Light blue cells contain derived data calculated from a formula that uses other cells in this or another data entry worksheet. In such cases, the user will not be able to enter any data in the spreadsheet cell because it will be protected against data entry.

B. Instructions for the DRT System Data Entry Worksheet

Figure 7 shows the DRT System Factors Data Entry worksheet. Each cell is color coded to reflect whether a data element is required or optional.

In addition, the small red triangle seen in the upper right corner of some of the cells indicates a Help comment viewable when the cursor is placed on that cell. These Help comments apply to the data to be entered in the cell to the right of the data field name/descriptor.

On this worksheet, most of the data can be sourced directly from an annual operating report. In addition, several calculated data values derive their results from other annual operating data items on the spreadsheet.

It is extremely important for the user to separate the overall system operating data into dedicated vehicle and non-dedicated vehicle components and to enter the data into the required fields for the separate service delivery elements. Without such separate DV and NDV data, the model will not work.

The trip length distribution data are essential, even if they must be estimated. Ideally, passenger trip lengths will be direct origin to destination distances (street distance). If airline distance is used instead, the user must indicate this in the cell below the trip distance matrix. In that case, the street circuity factor (default value of 1.3) will be used to estimate street distances from the trip length distribution.

Data entry for the following service area characteristics values merits additional discussion:

- **Service area size**—This is the total size of the service area in square miles. When significant portions of the service area are not populated or otherwise represent unserved territory (e.g., parkland or open space), then the value for this field will not be representative of the true size of the area to be served. In such cases, the value for the effective service area size field (below) must be estimated as precisely as possible.
- **Effective service area size**—The service area size is a key value in the DRT analytic model (the model originally developed by Liping Fu at Waterloo University) to predict the necessary supply of DRT vehicles for a given level of demand; therefore, this value must be reasonably accurate. Accordingly, the model uses the effective service area size field in its calculations, not the total service area size. Effective service area size is an estimate of the size of the service area that trips actually begin or end in—It can often be estimated to reasonable accuracy by plotting trips for a representative week.

- **Street circuity factor**—This factor, which has a default value of 1.3, is used to convert airline distance to street distance if the former is used as the basis for trip length distribution data. If the street network is a perfect grid, the street circuity factor is approximately 1.4. Any value between 1.3 and 1.4 is likely to be realistic.
- **Excess ride time standard**—The excess ride time standard is a measure of the level of service of the DRT operation. Excess ride time is defined as follows: DRT ride time minus automobile travel time divided by automobile travel time. Automobile travel times can be estimated based on distance and average automobile travel speed, typically 15 to 25 MPH in urban/suburban areas for the types of trips served by DRT services. An excess ride time value of 1.0 means that the average trip on a DRT vehicle will take twice as long as the automobile travel time (due to intervening pickups or dropoffs on the DRT service). The excess ride time value is a key factor used in the DRT analytic model and affects the predicted productivity of the DRT system significantly.
- **Time window for pickup time estimate**—This is another measure used in the DRT analytic model, expressed in number of minutes, of DRT system level of service. This value represents the time window for a trip pickup that a reservations agent provides to the DRT passenger at point of reservation. A typical 20- or 30-minute time window means that the passenger is advised by the reservation agent that a vehicle will arrive within 20 or 30 minutes of the agreed-on pickup time.
- **Average dwell time for ambulatory trips**—This is the average amount of time (expressed in minutes) that the DRT vehicle spends waiting at both the pickup and dropoff points of a passenger's trip. To provide a reasonably accurate estimate of this value, it is typically necessary to collect data for a single day or more. The DRT analytic model uses this value, defined as the sum of the pickup and dropoff dwell times for the typical trip by ambulatory passengers (those who are able-bodied or not in a wheelchair or using some other device that requires a special passenger loading process).
- **Average dwell time for wheelchair trips**—This is the value of the average total dwell time restricted to passengers using wheelchairs. Separate values of dwell time for different passenger types are used in the DRT analytic model because there can be a substantial difference between such dwell time values. Because dwell time reduces the amount of time during an hour that is available to the DRT fleet to actually travel to pickup and dropoff locations, dwell time has a measurable effect on system productivity.

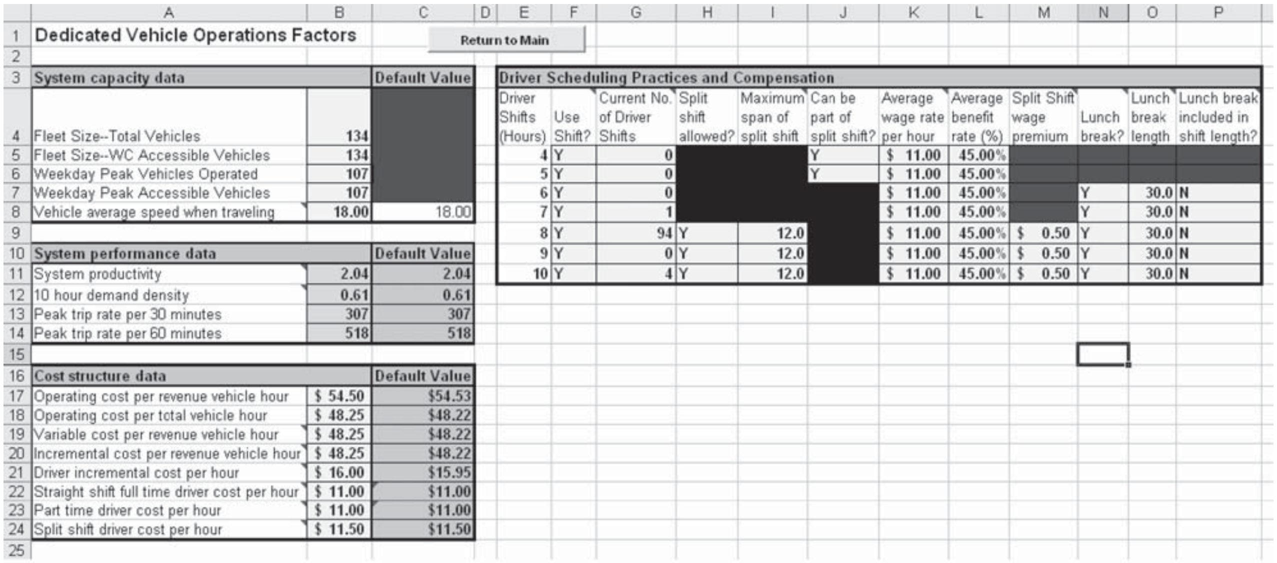
C. Instructions for the Dedicated Vehicle Data Entry Worksheet

Figure 8 shows the Dedicated Vehicle Data Entry worksheet. With the exception of driver shift and wage data, most of the data for dedicated vehicle operations are obtained from the DRT System worksheet.

The System Level Data section contains one required data element that merits additional discussion, namely Vehicle Speed When Traveling. This can be calculated from driver trip sheets for a representative sample of vehicle runs, using the travel distance and travel time between stops. This is a key data input to the DRT analytic model, so it is essential that it be reasonably accurate. If the value entered varies significantly from the true value, the DRT analytic model will substantially over- or under-estimate the number of dedicated DRT vehicles necessary to serve a particular level of passenger demand.

The Cost Structure Data section contains eight different measures of cost, all of which have default values derived from other data used in the model. The cell rollover Help box provides the definitions of each of these data elements.

It is strongly recommended that the user NOT simply use the default values provided in every case, because some cost measures, such as incremental or variable cost per revenue vehicle hour,



Dedicated Vehicle Operations Factors

Return to Main

System capacity data		Default Value
Fleet Size--Total Vehicles	134	
Fleet Size--WC Accessible Vehicles	134	
Weekday Peak Vehicles Operated	107	
Weekday Peak Accessible Vehicles	107	
Vehicle average speed when traveling	18.00	18.00

System performance data		Default Value
System productivity	2.04	2.04
10 hour demand density	0.61	0.61
Peak trip rate per 30 minutes	307	307
Peak trip rate per 60 minutes	518	518

Cost structure data		Default Value
Operating cost per revenue vehicle hour	$ 54.50	$54.53
Operating cost per total vehicle hour	$ 48.25	$48.22
Variable cost per revenue vehicle hour	$ 48.25	$48.22
Incremental cost per revenue vehicle hour	$ 48.25	$48.22
Driver incremental cost per hour	$ 16.00	$15.95
Straight shift full time driver cost per hour	$ 11.00	$11.00
Part time driver cost per hour	$ 11.00	$11.00
Split shift driver cost per hour	$ 11.50	$11.50

Driver Scheduling Practices and Compensation

Driver Shifts (Hours)	Use Shift?	Current No. of Driver Shifts	Split shift allowed?	Maximum span of split shift	Can be part of split shift?	Average wage rate per hour	Average benefit rate (%)	Split Shift wage premium	Lunch break?	Lunch break length	Lunch break included in shift length?
4	Y	0			Y	$ 11.00	45.00%				
5	Y	0			Y	$ 11.00	45.00%				
6	Y	0				$ 11.00	45.00%		Y	30.0	N
7	Y	1				$ 11.00	45.00%		Y	30.0	N
8	Y	94	Y	12.0		$ 11.00	45.00%	$ 0.50	Y	30.0	N
9	Y	0	Y	12.0		$ 11.00	45.00%	$ 0.50	Y	30.0	N
10	Y	4	Y	12.0		$ 11.00	45.00%	$ 0.50	Y	30.0	N

Figure 8. Dedicated vehicle data entry worksheet.

require judgment. If the user does not enter a value in the required cell, the default value adjacent to that cell is used in the model instead.

The Driver Scheduling Practices and Compensation section should be fully completed if possible. If a particular length of shift is not used, that should be indicated and, in such cases, no other data should be entered for that shift type. The model uses these data to generate default values for driver costs for the different types of shifts and to set certain initial values. However, when running the optimizations, the user has full control over what types of driver shifts can be used and limitations on the number of different types of shifts via adjustable parameters accessible on the Optimization page of the tool.

D. Instructions for the Non-Dedicated Vehicle Data Entry Worksheet

The Non-Dedicated Vehicle Data Entry worksheet is shown in Figure 9. A relatively small number of data elements are on this worksheet. The data elements separated by the OR row are not both required, but an entry is required for one of these two data elements. Almost all of the cells on this worksheet contain a rollover Help box that describes the nature of the data to be entered.

The Provider Compensation Structure section of this worksheet is used to generate the cost of providing service in non-dedicated vehicles. It is assumed, based on prevailing practice, that non-dedicated vehicle service providers will seek to be compensated either on a per passenger trip basis or on the basis of a charge for each trip pickup and for each mile traveled while transporting one or more passengers. For taxi providers, these compensation rates are often identical to the taximeter rates for "flag drop," fare per unit of distance, and waiting time cost.

E. Instructions for the Passenger Trip Volume Data Entry Worksheet

Figure 10 shows the Passenger Trip Volume Data Entry worksheet. On this data entry worksheet, the user must enter in the Avg. Weekday column a single value of passenger trip volumes/demand for each 30-minute period of the day or enter values for each time period for the different days of the week. The values to be entered are the TOTAL passenger trip volumes/demand for the time period, irrespective of whether they are transported on dedicated vehicles or non-dedicated vehicles.

	A	B	C	D	E	F	G	H
1	Non-Dedicated Vehicle Operations Factors							
2		Return to Main						
3	Fleet Capacity Data							
4	Taxicab Non-Dedicated Vehicles	Input Value	Default					
5	Current number of NDV trips per day for DRT program	750						
6	Maximum Number of Taxis Available as DRT NDVs at any time period between 8 AM and 5 PM	150						
7	Number of Taxis Available as DRT NDVs at Peak Period (1-2 hour peak period)	125						
8	Maximum Number of Wheelchair Accessible Vehicles Available as DRT NDVs at any time period	10						
9	Number of Wheelchair Accessible Vehicles Available as DRT NDVs at Peak Period	10						
10	Estimated Maximum Number of Passenger Trips that Taxi Operator can Transport at Peak Hour	300						
11	OR	OR						
12	Maximum Achievable Trips/VSH	2.20	2.25					
13	Non-Taxi Non-Dedicated Vehicle Fleets							
14	Current number of NDV trips per day for DRT program							
15	Available Fleet Size for Service Area							
16	Number of Wheelchair Accessible Vehicles							
17	Maximum Number of Vehicles Available as DRT NDVs							
18	Number of Vehicles Available as DRT NDVs at Peak Period							
19	Maximum Achievable Trips/VSH		2.25					
20								
21	Provider Compensation Structure							
22	Type of Non-Dedicated Service Provider	Pickup Cost	Cost/Mile	Wait Time Cost/Hour	OR	Cost/Trip		Actual Avg. Cost Per Trip
23	Taxicab Operations	$2.15	$2.00	$30.00	OR			$15.15
24	Non-Taxi Non-Dedicated Vehicles				OR			

Figure 9. Non-dedicated vehicle data entry worksheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Passenger Trip Volume Demand Data--Overall System									Return to Main					
2						Calculate Avg. Daily Volume									
3	Time Period	Start Time	End Time	Avg. Weekday	OR	Monday	Tuesday	Wednesday	Thursday	Friday		Saturday	Sunday		Evening
4	1	5:00	5:29	0											
5	2	5:30	5:59	0											
6	3	6:00	6:29	10											
7	4	6:30	6:59	40											
8	5	7:00	7:29	60											
9	6	7:30	7:59	125											
10	7	8:00	8:29	180											
11	8	8:30	8:59	130											
12	9	9:00	9:29	120											
13	10	9:30	9:59	90											
14	11	10:00	10:29	60											
15	12	10:30	10:59	60											
16	13	11:00	11:29	80											
17	14	11:30	11:59	110											
18	15	12:00	12:29	115											
19	16	12:30	12:59	80											
20	17	13:00	13:29	70											
21	18	13:30	13:59	70											
22	19	14:00	14:29	85											
23	20	14:30	14:59	150											
24	21	15:00	15:29	190											
25	22	15:30	15:59	135											
26	23	16:00	16:29	95											
27	24	16:30	16:59	55											
28	25	17:00	17:29	45											45
29	26	17:30	17:59	45											45
30	27	18:00	18:29	40											40
31	28	18:30	18:59	20											20

PassTrips-Tot / Top

Figure 10. Passenger trip volume data entry worksheet.

The user may wish to enter data values for the Evening column separately, even though the values will appear to be redundant since they include some of the same time periods as the Avg. Weekday column. This allows the user to assess the effect of modified demand levels for just the evening time periods if this is relevant to operational strategies being considered.

The volume/demand data needed for this worksheet can usually be generated via daily trip manifests or as output from an automated paratransit scheduling software system. If average passenger trip volumes by time point are available for all 7 days of the week, they can be entered in the spreadsheet rather than data for a single representative weekday. However, this level of detail is not truly necessary, since the model will only operate on a single day of demand/volume data—either the representative weekday or an average of the 5 weekdays. (A weekly average will be calculated if at least two daily columns are filled in—data for all 5 days are not necessary.)

If the user wishes to enter trip volume data for several weekdays, the average weekday value can be computed and transferred to the Avg. Weekday column by selecting the Calculate Avg. Daily Volume button. Users can then enter data directly into the Avg. Weekday column and overwrite the calculated average values if they wish.

F. Instructions for the Driver and Vehicle Shifts Data Entry Worksheet

There are two alternative methods for entering driver/vehicle run data into the spreadsheet. When users select Driver Shift/Vehicle Runs for data entry, they are presented with a dialog box that requires them to select either the Calculated or Manual method of entering driver shift data. Figure 11 shows the Driver and Vehicle Shifts Data Entry worksheet with the dialog box. If users

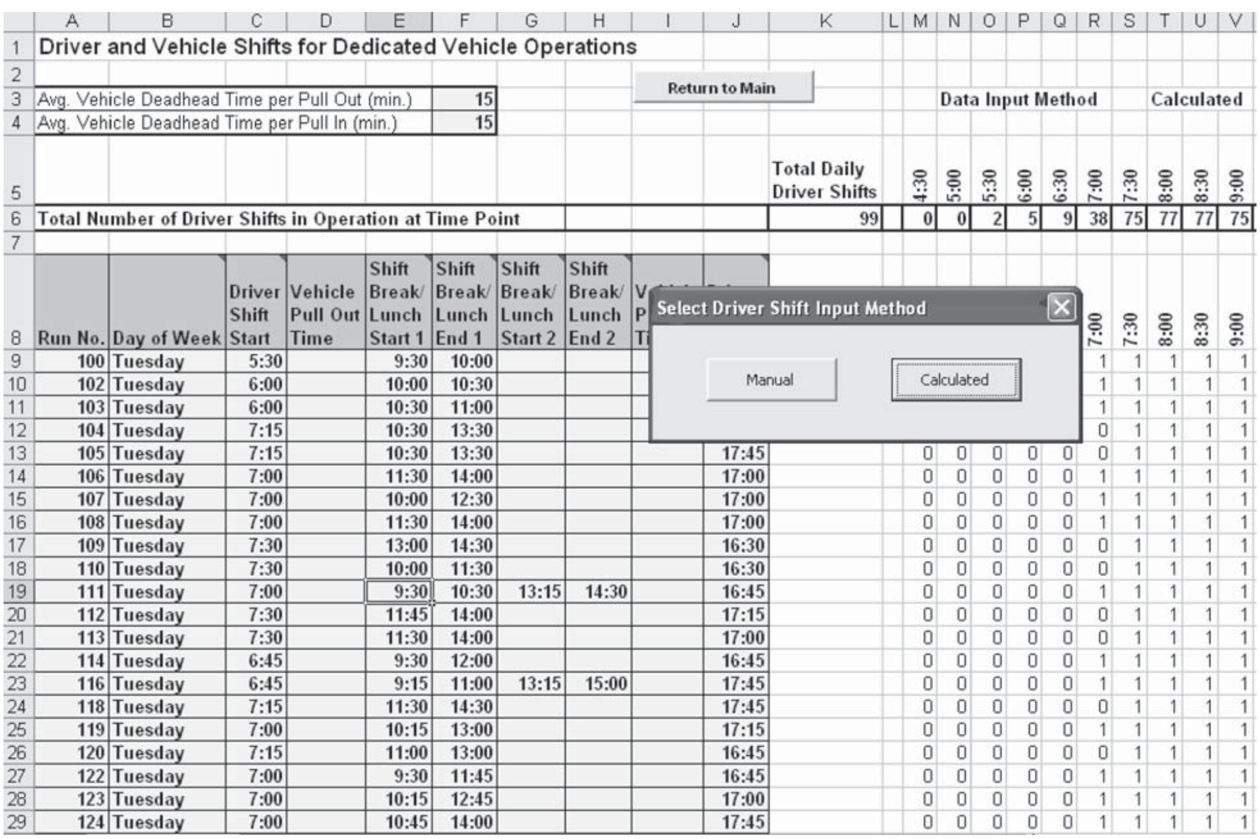


Figure 11. Driver and vehicle shifts data entry worksheet.

select the Calculated method of data entry, they enter the driver/vehicle runs for the dedicated vehicle operation for a typical day of the week into this worksheet, using the following format:

1. Run number (can be any number—for user reference purposes only)
2. Day of week (can be any day—for user reference purposes only)
3. Driver shift start time for the driver assigned to the run
4. Vehicle pullout time (leaves facility to enter operational status)
5. Start of first break in driver shift for either a scheduled lunch or the start of inactive time in a split shift—leave blank if straight shift with no scheduled lunch
6. End of first break for scheduled lunch or break due to a split shift—leave blank if straight shift with no scheduled lunch
7. Start of second break in driver shift for either a scheduled lunch or the start of inactive time in a split shift—leave blank if straight shift with no scheduled lunch or no second break in shift
8. End of second break for scheduled lunch or break due to a split shift—leave blank if straight shift with no scheduled lunch or no second break in shift
9. Vehicle pull-in time (vehicle returns to facility, no longer on road)
10. Driver shift end time

These input data are then automatically transformed by the tool into a run profile which includes data on the number of vehicles in active service at every 30-minute period from 5 AM to 11 PM. This run profile is shown on the worksheet in the Total Number of Driver Shifts in Operation at Time Point row, with a cell entry for each time period. The values represent the supply of dedicated vehicle DRT service available to serve the total passenger trip demands entered on the Passenger Trip Demand worksheet.

The alternative approach for specifying the driver run structure is the Manual data input method. If users choose the Manual option from the dialog box, they can enter data directly into the cells of the Total Number of Driver Shifts in Operation at Time Point row of the data entry worksheet. A value must be entered for each 30-minute period (the time values on the worksheet represent the start time of the period) during which vehicles are operated in revenue service. When using this method, no individual driver/vehicle run schedule data should be entered into the worksheet, only the summary values for each period.

Whichever method of data entry is selected by the user is displayed in the upper right of the worksheet, adjacent to the Return to Main button.

The worksheet will prevent the user from directly entering the driver/vehicle run summary data if the Calculated method of data entry is selected. If users wish to enter the summary data, they must select the Manual method when entering the worksheet.

If the user initially selects the Manual method and then later decides to use the Calculated method, this is a workable scenario, provided the user performs the following action. For the Calculated method to work after the Manual method has been used, it is necessary for the user to copy and paste the values of the cells from the TOTAL row of the spreadsheet (Row 259) into the corresponding columns on the Total Number of Driver Shifts in Operation at Time Point row (Row 6). This will restore the automatic calculation capabilities needed to summarize the individual driver schedule data and use it in the various procedures that use the driver shift/vehicle run data.

G. Instructions for the Set Baseline Factors Dialog Box

Selecting the Set Baseline Factors button on the main page of the tool causes a dialog box to pop up, as shown in Figure 12. There are five fields to set in this dialog box, each of which

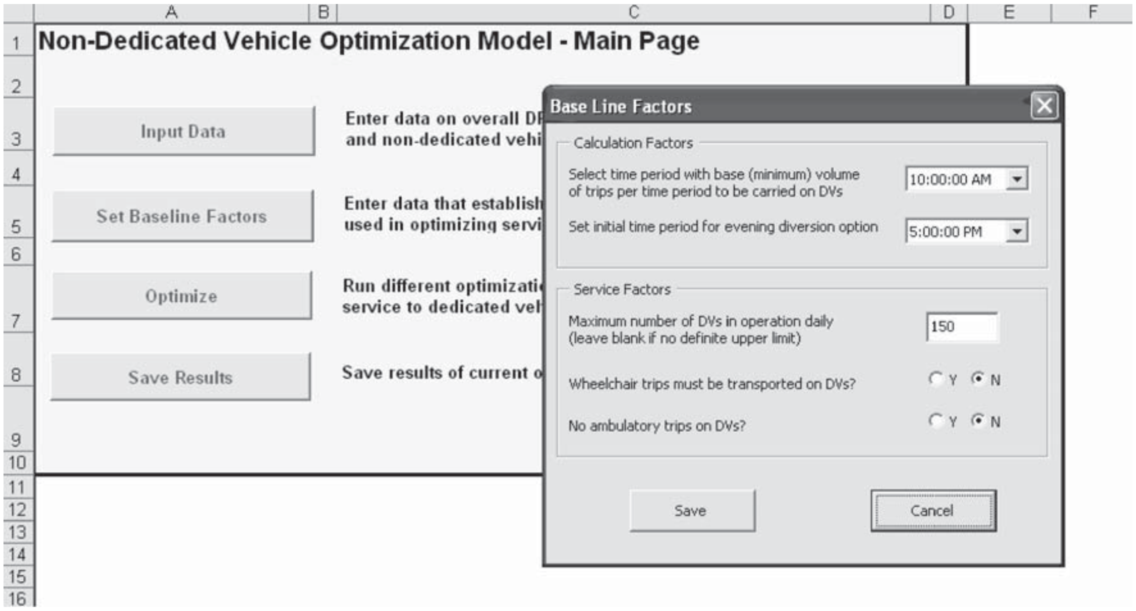


Figure 12. Set baseline factors dialog box.

enables the user to control certain parameters that affect how the model will work for a particular optimization run. These parameters can be altered frequently or left largely unchanged after they have been set initially, depending on the user's needs and preferences.

The Calculation Factors section of the dialog box enables the user to set the following two factors:

- **Time period considered the base period for service peaking**—The optimization routines in the model always include calculations of the effect of diverting "excess" passenger demand over the base period level to non-dedicated vehicles. Users are presented with a dropdown list of time periods and passenger demands—from the Passenger Trip Demand worksheet—and must select the time period that they believe best represents the "base" period for their system. This is a matter of user judgment—a mid-day period of moderate demand is likely to be a reasonable choice.
- **Time period when evening service is considered to begin**—This is the time period when the user considers evening service to begin. The choices range from 4 PM to 7 PM. The user's selection is used in the Evening Diversion optimization model that diverts all or most of passenger trips to non-dedicated vehicles during low-demand periods.

The Service Factors section of the dialog box provides the user with another set of parameters that can be adjusted to control the optimization calculations. The following three factors can be set.

- **Maximum number of dedicated vehicles**—By setting an upper bound on the number of dedicated vehicles used in the system, the user can force the optimization model to place more passenger trips on non-dedicated vehicles. This upper limit can be based on actual circumstances or could be part of a "what if" scenario. It is recommended that this field initially be left blank or set at a level somewhat higher than the current total number of dedicated vehicles, unless there is a strong policy constraint on the maximum number of dedicated vehicles that can be used.
- **Wheelchair trip restriction to dedicated vehicles**—If this checkbox is checked as "Y," then the model will restrict wheelchair trips completely to dedicated vehicles, even if the NDV provider has accessible vehicles in their fleet. Selecting "N" for this field will enable some

wheelchair trips to be placed on accessible vehicles in the NDV fleet, based on the capacity of such vehicles as specified on the NDV Data worksheet.

- **Ambulatory trip restriction to non-dedicated vehicles**—This field should be set to "Y" only if the DRT service is based entirely on non-dedicated vehicles with a supplemental service provider to handle wheelchair trip needs. This would typically be the case for a user-side subsidy taxi service in which there is another contractor whose sole role is to provide transportation for wheelchair trips. In most systems, this field should be set to "N."

VI. Optimization Model: Execution and Results

A. Model Execution Overview

After the user has input all of the necessary data and set the baseline factors for model calculations, the next step in using the tool is to actually generate model results. This process is initiated by selecting the Optimize button on the home page, which takes the user to the Optimization page of the spreadsheet, shown in Figure 13.

From the main optimization page the user can launch the optimization runs by clicking on the Find Optimum button for one of the models. Summary results are shown on this page for the current optimizations, in addition to buttons that will access three views of additional results.

As discussed previously, the tool includes three different optimization models. In each case, the model will attempt to find the solution that minimizes the total cost of serving the specified level of passenger demand, subject to the constraints imposed by the model structure and by user-specified parameters. A typical sequence of actions is to run the optimizations in the order of Peak Run Leveling, Evening Diversion, and Trip Length Diversion.

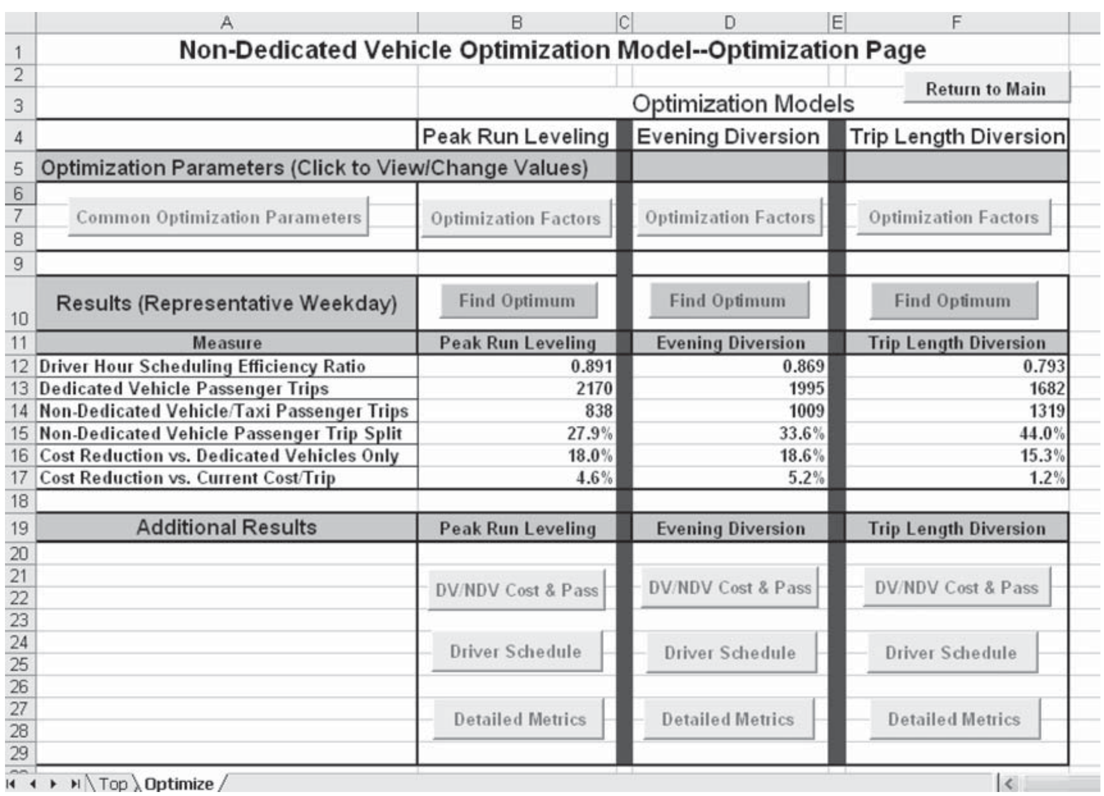


Figure 13. Main optimization page.

B. Setting Optimization Model Parameters

Before running the optimizations, the user should set or modify certain factors that control aspects of the optimization for each of the models. This is accomplished by selecting the Common Optimization Parameters button or one of the Optimization Factors buttons under the Peak Run Leveling, Evening Diversion, and Trip Length Diversion column headings and inputting or adjusting the factors that appear in the pop-up windows, as described below.

Peak Run Leveling Parameters

Figure 14 shows the pop-up window that appears when the user selects Optimization Factors under the Peak Run Leveling column of optimization models. The data entry form in this window enables the user to enter and modify several different factors affecting driver scheduling for dedicated vehicles. By specifying these factors, the user creates certain constraints on the possible solutions evaluated by the model, thereby ensuring that the optimization results are realistic vis-à-vis the local driver market and the way by which the DRT system does business. Each of these factors is discussed as follows.

- **Maximum number of part-time driver shifts per day**—This is an upper limit on the total daily number of 4-, 5-, and 6-hour driver shifts that could be feasibly used by the dedicated vehicle provider, taking into account local labor market conditions and system policies. If there is no upper limit, a value of 999 should be entered.
- **Maximum number of 4- and 5-hour driver shifts per day**—These fields enable the user to specify an upper limit on the total number of 4- and 5-hour daily driver shifts, based on the same considerations as for total part-time driver shifts. If no such shifts are feasible, a value of 0 should be entered.
- **Maximum number of 9- and 10-hour driver shifts per day**—If the dedicated vehicle provider uses shifts of more than 8 hours per day or believes it is feasible to use them, these fields enable

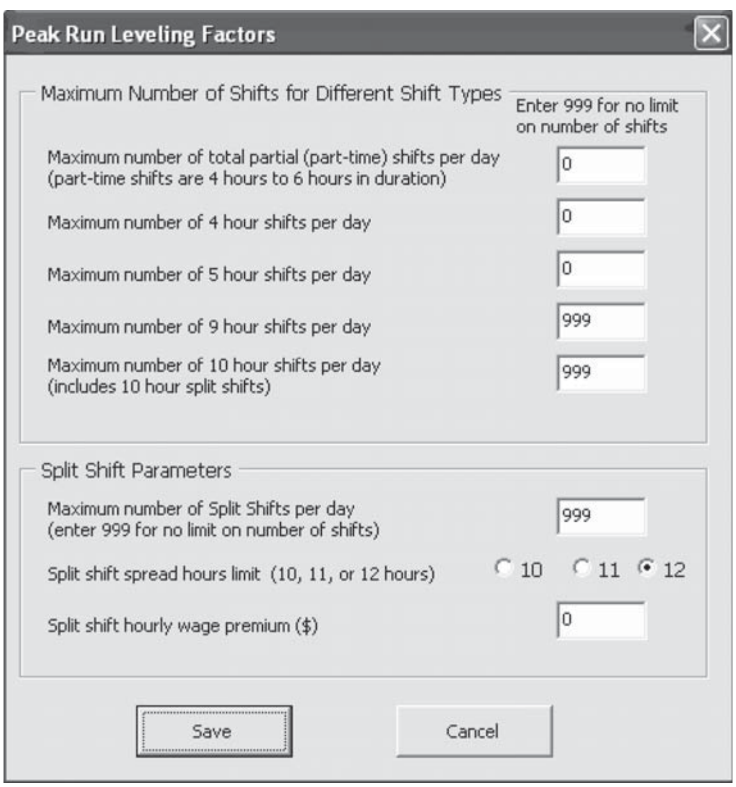


Figure 14. Peak run leveling factors.

the user to specify an upper limit on the number of such long shifts per day. The value for the 10-hour shifts per day will include 10-hour split shifts as well as 10-hour straight shifts.

- **Maximum number of split shifts per day**—If the dedicated vehicle provider uses split shifts or believes it is feasible to use them, this value is an upper limit on the number of such split shifts (counting the two portions of the shift as a single shift) per day. This includes full-time shifts of any number of working hours of 8 or more.
- **Split shift spread hours limit**—This value is the maximum amount of "spread" allowed in split shifts. The spread is the maximum duration from the beginning of the first portion of the split shift to the end of the second portion of the shift. The possible choices are 10, 11, or 12 hours via the radio button control. The smaller the split shift spread limit, the less flexibility the model has in allocating each portion of a split shift to cover the time periods when demand for drivers is greatest. A value of 12 hours—which provides the model with the most flexibility in using split shifts—is likely to be most appropriate if the user is not sure what value to enter for this parameter.
- **Split shift hourly wage premium**—In some DRT systems, it is necessary to pay a small wage premium to motivate qualified drivers to accept split shifts, since they are less desirable than straight shifts. If the dedicated vehicle provider does not need to pay such a premium, enter 0 in this field or leave it blank.

The values established for the Peak Run Leveling parameters will be used by the other types of optimizations as well. Therefore, the user must change these parameters prior to running the other types of optimizations if for some reason the same values do not apply.

Evening Diversion Parameters

Selecting the Optimization Factors button under the Evening Diversion optimization model column causes the window shown in Figure 15 to appear. The parameters that the user sets in this window each relate to some aspect of evening service and are described as follows:

- **Initial period for evening diversion**—This is the first period during which all feasible trips—consistent with other constraints specified by the user, most notably how wheelchair trips are handled—will be diverted from dedicated to non-dedicated vehicles.
- **Wheelchair trips transported on dedicated vehicles only**—The user should set this value to "Y" if the NDV service provider for evening service lacks accessible vehicles. If this value is set to "N," any accessible vehicles available to the NDV service provider will be assigned to wheelchair trips up to the capacity of such vehicles. Dedicated vehicles will be assigned to all wheelchair trips that cannot be accommodated by NDV accessible vehicles during evening hours.
- **Restrict dedicated vehicle trips to wheelchair trips only**—If dedicated vehicles are required to operate during the evening in order to handle wheelchair trips, the DRT system must determine

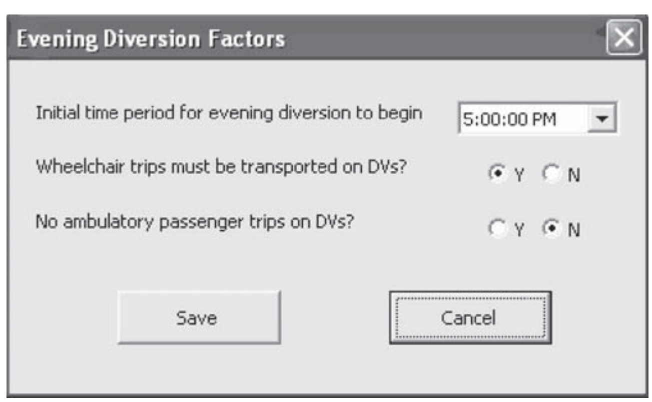


Figure 15. Evening diversion factors.

whether they should be restricted to only wheelchair trips or can be used for general purposes as well. In general, it is more cost-effective to allow the DVs to be used for all trip purposes given that a baseline level of service will be needed to accommodate the number of evening wheelchair trips.

Trip Length Diversion Parameters

Selecting the Optimization Factors button under the Trip Length Diversion column of the optimization models causes the window shown in Figure 16 to appear. The Trip Diversion optimization reflects a strategy of diverting the longer trips currently carried on DVs to NDVs. The data entry form in this window provides the user with two alternative methods (each can be used for different model runs) for determining how the trip length optimization will be performed, as described below.

The first method involves setting three parameters that will cause the model to optimally allocate trips of different lengths to DVs or NDVs to achieve a minimum cost solution prior to vehicle/run optimization.

- **Minimum percent reduction in average trip length of DV passenger trips**—This is the value the user specifies to determine the magnitude of diversion of longer trips from DVs to NDVs. A value of 20% in the context of an average trip length of 5.0 miles, for example, means that the optimization will divert a sufficient number of DV trips to NDVs to reduce the average trip length of the remaining DV trips to 4.0 miles.
- **Minimum percentage of total trips to be allocated to NDVs**—This value specifies the minimum percentage of trips that will be transported on NDVs—subject to other user-specified constraints. The optimizer will attempt to allocate at least this many trips to NDVs, consistent with the trip length constraint established by the prior parameter.
- **Maximum percentage of below average distance trips to be allocated to NDVs**—This value specifies how many "short" trips—i.e., trips with a length less than the systemwide average—will

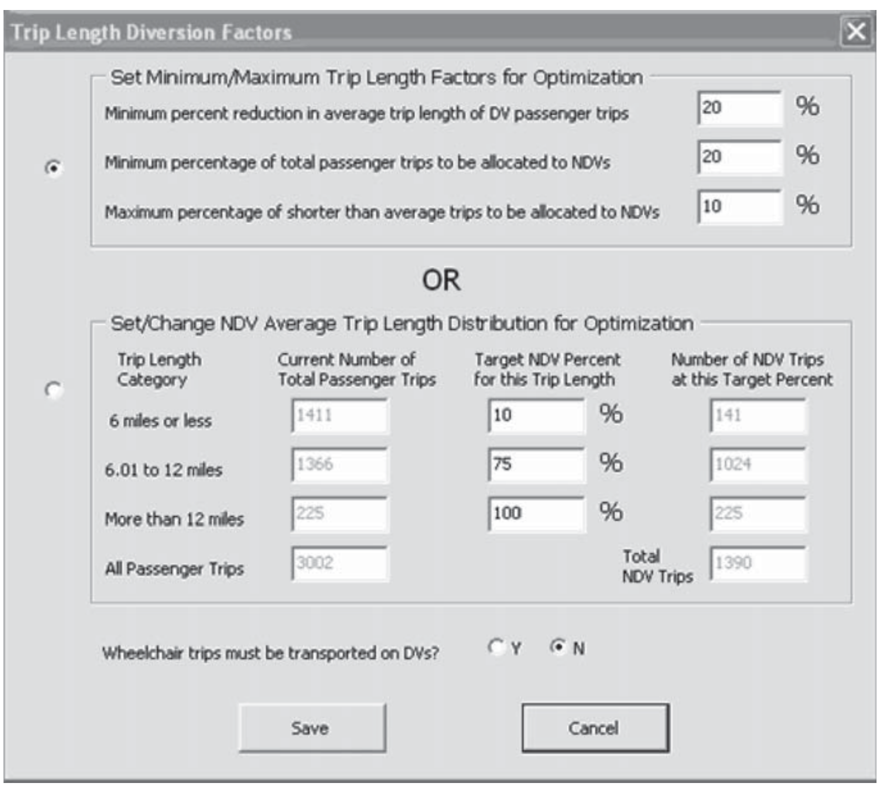


Figure 16. Trip length diversion factors.

be allocated to NDVs. It is usually appropriate to set a small value for this field, typically no more than 10% to 20%, or else the optimizer may divert many short trips in attempting to satisfy the prior two constraints.

The second method involves the user specifying in a more detailed fashion the relative allocation of DV and NDV trips for different trip length categories. For each of three trip length categories—6 miles or less, 6.01 to 12 miles, and greater than 12 miles—the user specifies the target percentage of trips to be allocated to NDVs. The optimizer treats this value as an upper limit on the number of trips to allocate to NDVs during trip length optimization; it will not assign more than this number of trips to NDVs during this initial optimization. The form shows how the target percentages translate into actual number of trips in order to aid the user in determining the appropriate values to set.

These two trip allocation approaches are mutually exclusive for any specific optimization run; that is, only the one selected by the radio button will be used. However, the user can switch back and forth from run to run as desired.

For both methods, there is also the option of changing the setting on whether wheelchair trips must be transported by dedicated vehicles. This value will already be set and including it on this form is a convenience to the user so that they can be aware of its current value and re-set it if appropriate for this optimization type.

C. Performing Optimization: Running the Models

After users have input or adjusted the parameters for whichever type of optimization they intend to run, the next step is to select the Find Optimum button for that particular optimization. This action causes the tool to invoke the optimization calculation routines and search out the best solution. During this time, user will see an hourglass and will also see numbers and messages continually updating in the leftmost portion of the bottom Excel windowpane. These indicate that the Excel optimizer is running and solving the optimization problem.

During the course of each invocation of the Excel optimizer, it is solving an integer programming problem using a technique called "branch and bound." Inherent in this technique is the possibility that it may be difficult or impossible in a limited period of computational time to determine if a feasible solution is in fact an optimum solution. In the case of the NDV Model, the optimizer is given 40 seconds to find a solution. It bears emphasizing that total model solution time can be significantly greater than 40 seconds, since—as explained previously—the optimizer is invoked iteratively as the solution routine systematically increases the peaking ratio at each solution cycle.

Important Warning

Because the optimizer may not always find a definitively optimum solution within the 40-second time limit of each optimizer solution cycle, it may "time out." When this occurs, a dialog box will appear as in Figure 17 below.

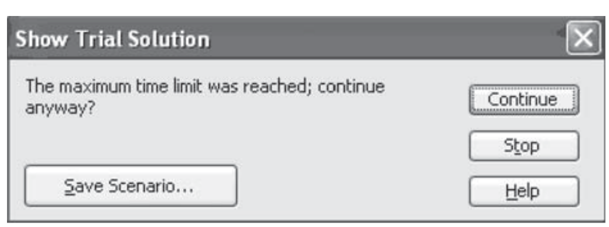


Figure 17. Show trial solution dialog box.

Do NOT choose the "Continue" option—which is the Excel default choice—unless you are prepared to either wait a long time for the optimizer to find a solution or to potentially abort Excel via Windows Task Manager—since the optimization may continue to run indefinitely if you select the Continue option. Do NOT simply hit the Enter key if this pop-up appears, because the default selection is "Continue"—which is not what you want. It is STRONGLY recommended that you select "Stop" if this pop-up dialog box appears. In virtually all cases, a feasible solution will already have been generated by Solver for the individual optimization cycle when this dialog box appears.

A solution cycle can require several minutes to complete and may require the user to stop the Solver process—as described above—on several instances during the overall solution cycle. You will know that the optimization process is completed when the hourglass disappears and you can access Excel again. At this point, the tool will have filled in the results for the Measures for the specific optimization approach selected. The user follows the same process to invoke any of the different optimization approaches.

D. Viewing and Understanding Optimization Model Results

After the user has run one or more of the optimization models for a particular set of parameters, various views of the results are available. On the Optimization page itself, several key measures are shown. These summary results include the following:

1. Optimum allocation of passenger trips to dedicated and non-dedicated vehicles.
   a. DV passenger trips
   b. NDV passenger trips
   c. Optimal NDV "split"—NDV trips as percent of total trips
2. Dedicated vehicle driver run efficiency, a value ranging from 0 to 1. (This is calculated as the number of vehicle and driver hours needed to exactly serve the demand at each 30-minute time point over the entire day divided by the number of driver hours that the optimized driver schedule produces. A value of 1.0 would indicate a perfectly efficient driver schedule, which is not achievable in practice since real driver shifts cannot be subdivided into 30-minute increments and then flexibly recombined, and vehicles cannot be taken in and out of service without deadheading.)
3. Cost impacts of the optimum strategy for using NDVs relative to two benchmarks:
   a. The cost of providing all DRT service by dedicated vehicles.
   b. The cost of the existing mix of DV and NDV service.

By examining the summary results of one or more optimizations, the user can quickly determine if changes to operating strategies or policy variables are yielding improvements in outcomes. The side-by-side comparison of the three different optimization models facilitates easy comparisons of these approaches for a given set of data and parameters. For example, if the results of the trip length diversion optimizations yield significantly smaller cost savings than one or both of the other optimization approaches, it is likely that only by changing some assumptions about how this approach would be implemented—i.e., by altering the adjustable optimization factors or other input parameters—will this strategy yield superior results.

More detailed results can be viewed by clicking on one of the three buttons below the summary results for a particular model.

Clicking on the DV/NDV Cost & Pass button for a specific model places the user on the screen shown in Figure 18, which shows the minimum cost solution at each iteration of the overall optimization cycle as well as the allocation of trips and vehicles to DVs and NDVs for the overall optimum solution. The data which generate these graphs are also shown below them in the worksheet.

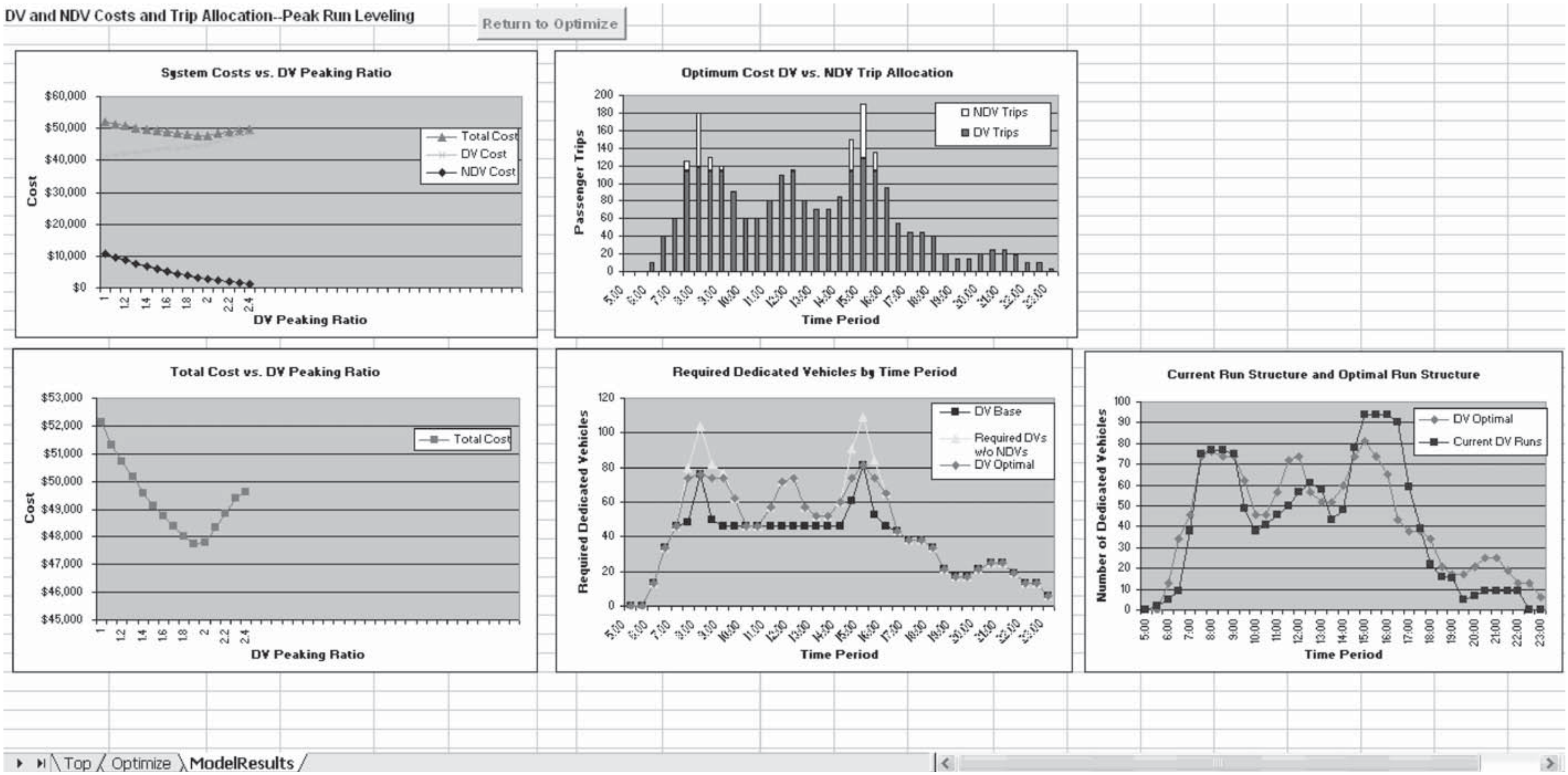


Figure 18. Optimal split solution.

The middle bottom graph on this spreadsheet page shows the different run structures—in terms of required DVs at time points during the day—necessary for the base solution, the optimal solution, and the situation where only DVs are used. The graph to the right of this compares the current run structure and the optimal run structure generated by the model.

In reviewing the model results as shown in Figure 18, users must verify that the supply, demand, and trip allocation pattern of the optimized solution is reasonably consistent with their expectations of how the DV and NDV service components would operate. If the optimized solution indicates many more NDVs or DVs than is feasible or even seemingly plausible, the solution is probably not reasonable for the actual system. In that case, users need to assess the quality of the data used by the model and/or the parameter values used in generating the optimal solution.

Clicking on the Driver Schedule button for a specific model places the user on the screen shown in Figure 19, which shows the driver shift/vehicle run schedule for the optimum solution, including when driver shifts of different types begin service. The worksheet also includes a table below the graph that contains the data graphed for the optimized driver shift schedules.

Users may find these results helpful in devising strategies to implement operating strategies that make greater use of non-dedicated vehicles. In particular, the optimized driver shift schedules indicate the pattern of shifts and shift starting times that produce a dedicated vehicle run structure that fits together with the optimized use of non-dedicated vehicles.

Users should verify that the driver shift schedules resulting from the optimization are realistic. For example, if many of the optimized driver shifts are 6 hours in duration, but the dedicated vehicle operator is currently utilizing only 8- or 9-hour driver shifts, then it is essential to determine whether the local labor market can yield sufficient numbers of qualified drivers willing to work only 30 hours per week. If not, then the model parameters must be modified to restrict the number of non-40 hour per week drivers, and the optimization re-run with these new constraints.

Clicking on the Detailed Metrics button places the user on the screen shown in Figure 20, which provides detailed metrics for the current optimum solution for each model. These more detailed results provide an additional level of information about the amount of DV and NDV service that should be provided for the optimum solution, the number of passengers allocated by the optimization model to the different services, and the costs of the optimized split of service,

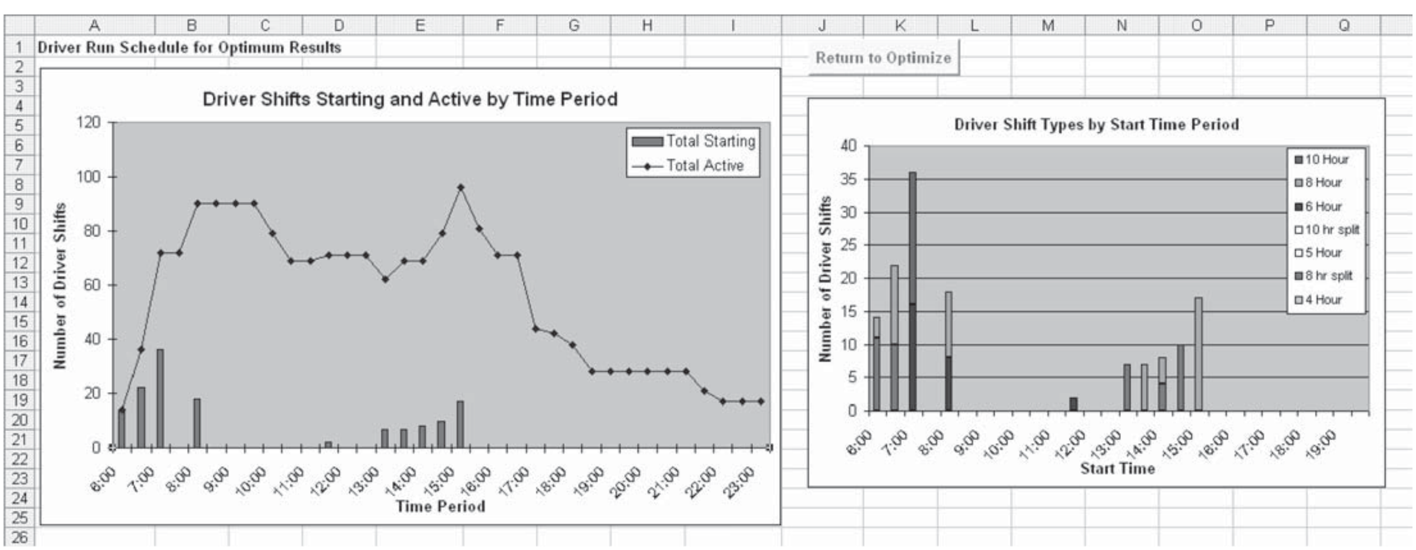


Figure 19. Dedicated run structure at optimal split solution.

Non-Dedicated Vehicle Optimization Model - Results Details

Return to Optimize

Results (Representative Weekday)

Measure	Peak Run Leveling	Evening Diversion	Trip Length Diversion
Driver Hour Scheduling Efficiency Ratio	0.916	0.901	0.882
Total DV Driver Cost	$9,570	$8,525	$8,096
Total DV Driver Hours	870.0	775.0	736.0
Total DV Vehicle Hours	920.0	817.5	790.0
DV Trips	2186	1928	1901
DV Trips per Vehicle Hour	2.38	2.36	2.41
Total DV Service Cost	$44,414	$39,444	$38,118
DV Cost per Trip	$20.32	$20.46	$20.05
DV Cost per Passenger	$19.54	$19.67	$19.28
NDV/Taxi Trips	215	473	500
NDV/Taxi Service Cost	$3,322	$7,309	$10,836
NDV/Taxi Cost per Trip	$15.45	$15.45	$21.69
NDV/Taxi Cost per Passenger	$14.72	$14.72	$20.66
NDV Passenger Trip Split	9.0%	19.7%	20.8%
Total System Service Cost	$47,737	$46,754	$48,954
System Cost per Trip	$19.88	$19.47	$20.39
System Cost per Passenger	$19.12	$18.72	$19.61
Total System Cost DV Only	$53,437	$53,437	$53,437
Cost Reduction vs. DVs Only	10.7%	12.5%	8.4%
Total System Cost Current	$57,071	$57,071	$57,061
Cost Reduction vs. Current Cost/Trip	16.4%	18.1%	14.2%

Figure 20. Detailed optimization results.

both in absolute terms and relative to both the all-DV option and the current service mix. In the example shown in Figure 20, one can conclude that, among the three models, the Evening Diversion optimization strategy (which includes the Core Model) yields the greatest reduction in cost compared to both the current service mix and the sole use of dedicated service, at an optimal split of 70% DV and 30% NDV.

E. Saving Model Results

After users have developed a set of model results that they believe merit retaining, they should save those results. This is accomplished by invoking the Save Results button on the main page of the spreadsheet and then entering a name for the file to be saved. This is shown in Figure 21. It is suggested that users develop a naming convention for the files that you save, such as "NDV-Model_Q406_DVrestrictions_1.xls". Particularly if users explore a wide range of options, they will want the file names to be descriptive enough that they can find the one wanted without having to open and examine a large number of files.

VII. Sensitivity Analysis

The model provides various ways for the user to perform sensitivity—or "what if"—analysis of the results. Although users can always change any of the basic set of data and parameters initially entered into the model to perform such "what-if" analyses, this is not the best approach. Instead, the model provides various opportunities to test adjustments to key parameters without having to change the base set of data and parameters. Among the many adjustments that users can make to the data used in the optimization model are the following:

- Tighten or loosen constraints on the driver shifts that can be used;
- Modify unit cost levels for DV and/or NDV operations;
- Change the time period used to establish the baseline passenger demand level;

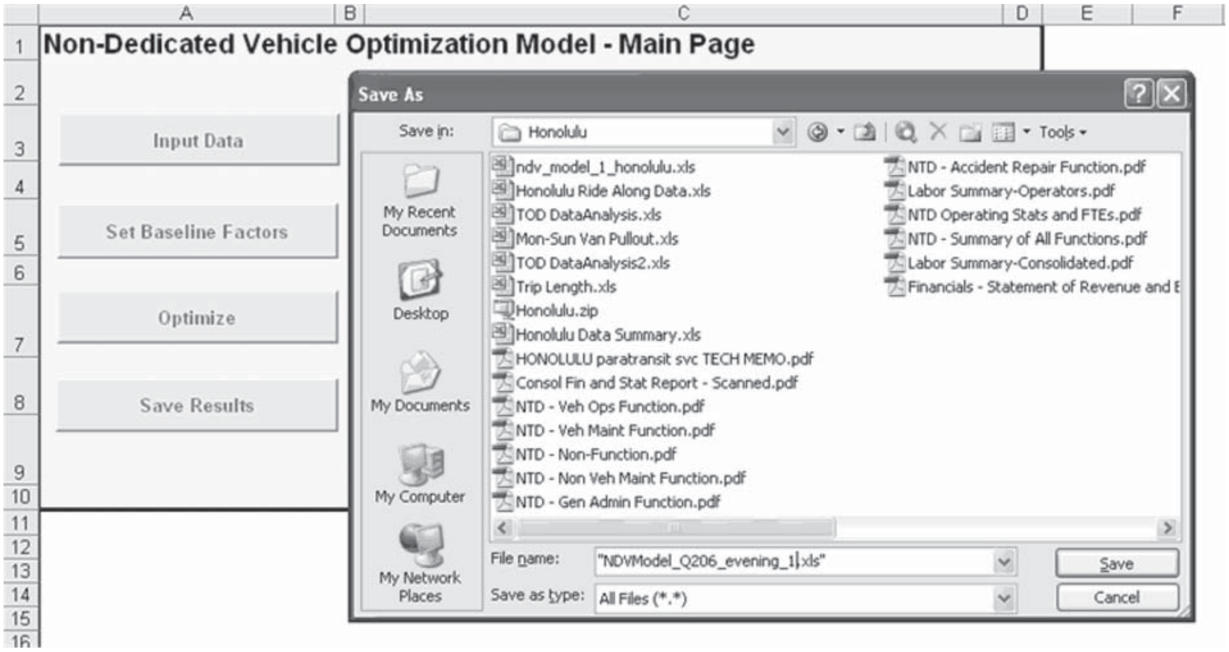


Figure 21. Saving model results to file.

- Specify the trip length distribution for the trips to be allocated to NDVs; and
- Alter policies relative to mandatory use of accessible vehicles for wheelchair trips.

Any of these actions, as well as others, is likely to affect the optimum solution. The model contains several pop-up windows with data entry forms whose purpose is to handle these data changes for the purpose of sensitivity analysis. Some of these data entry forms, such as those used to specify constraints on driver shift types or to set parameters that affect the allocation of trips between DVs and NDVs based on trip length, have previously been discussed. For example, adjusting the maximum number of allowable driver shifts of a certain shift length can significantly affect the optimum solution by increasing or decreasing the cost of DV service, thereby changing the optimal split between DV and NDV service.

Clicking on the Common Optimization Parameters button on the Optimization Page launches the pop-up window that contains many of the parameters that users will want to adjust when performing sensitivity analysis. As shown in Figure 22, this data entry form contains three tabs—for calculation factors, service split factors, and cost factors. Each tab provides a means to set or adjust parameters that control key inputs into the model, and, by doing so, to affect the results of the optimization process.

The Calculation Factors tab provides a convenient means of changing the time periods for both the base level of DVs and the start of the evening hours for the service. These are the same data elements accessible from the Baseline Factors data entry form on the Main Page of the model. They can be changed on either form. The user may wish to explore the effects of reducing the base level of trips transported on DVs, which can be done by selecting a base time period with a lower level of demand (trip volumes) than is currently in effect in the model. Since the model itself systematically increases the number of passenger trips allocated to DVs at successively higher levels of peaking ratio during an optimization cycle, it makes most sense to choose a time period with low or moderate demand level as the baseline for the minimum number of trips to be transported on DVs.

The Service Split Factors tab in the Common Optimization Factors data entry form, shown in Figure 23, provides a means for the user to adjust several factors that will affect the optimized

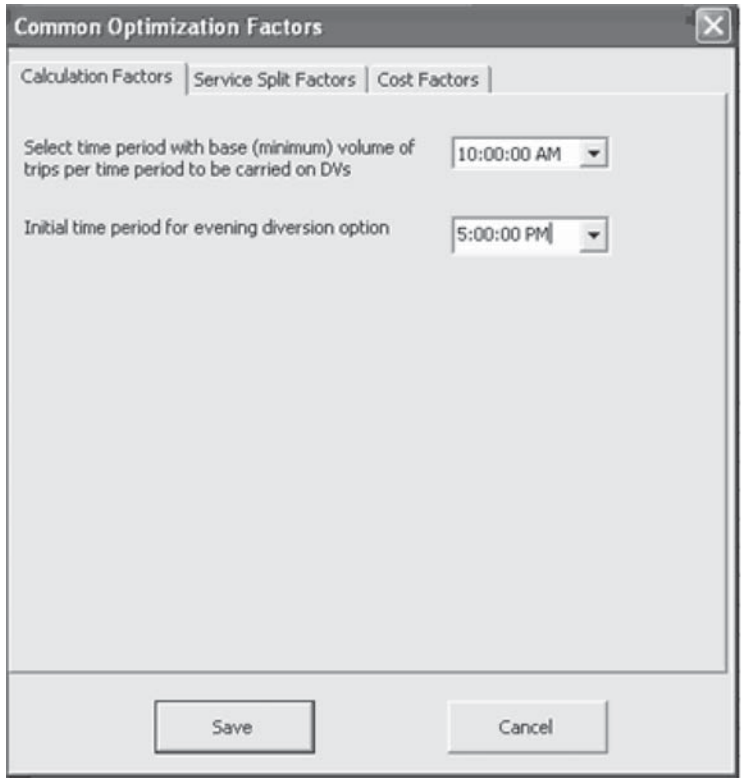


Figure 22. Sensitivity analysis input parameters—calculation factors.

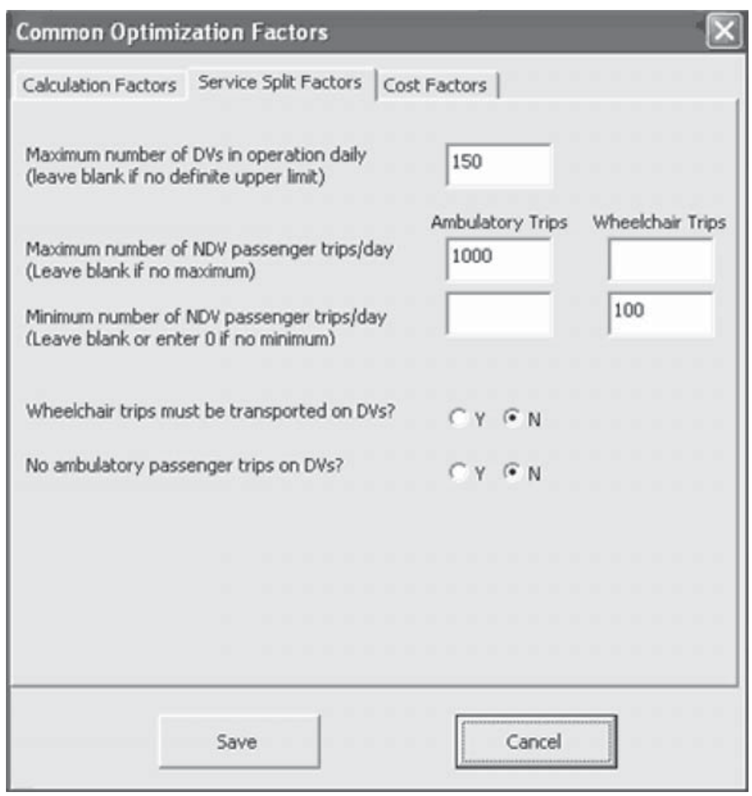


Figure 23. Sensitivity analysis input parameters—service split factors.

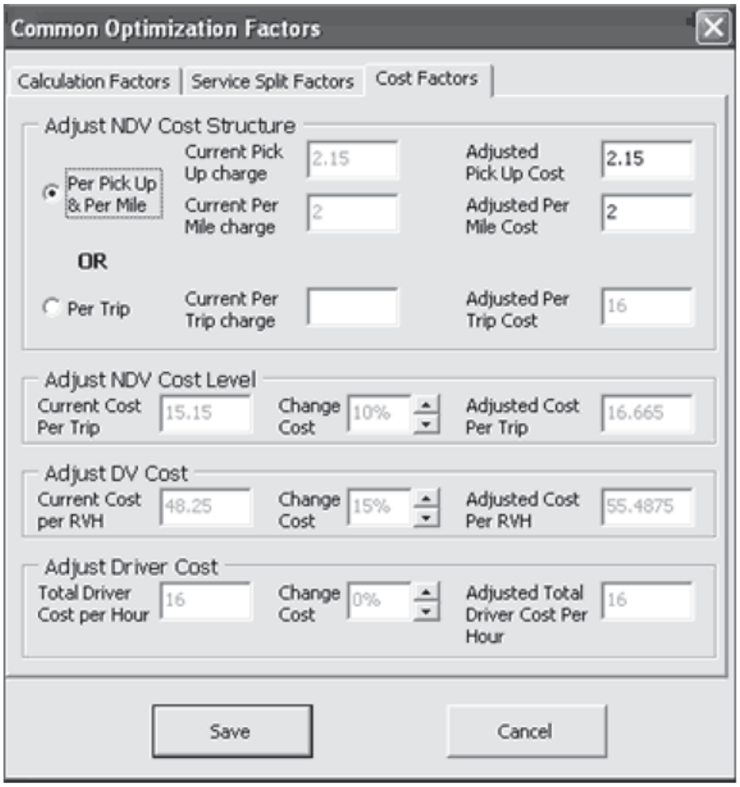


Figure 24. Sensitivity analysis input parameters—cost factors.

allocation of trips to DVs and NDVs. The user can specify the maximum number of DVs and the maximum and/or minimum number of NDV passenger trips—disaggregated by ambulatory trips and wheelchair trips. By setting a ceiling (maximum number) on NDV trips, the user can reflect contractual situations or policy preferences regarding the role of NDVs. Setting a floor (minimum number) on NDV trips may be done for similar reasons, such as a policy to only allocate overflow trips to NDVs rather than use them for many purposes.

Figure 24 shows the Cost Factors tab in the Common Optimization Factors data entry form, which provides a means for the user to adjust cost levels of DV and NDV services. The user can modify both the cost structure and the cost level of both NDV and DV services as part of any sensitivity analysis. By adjusting the NDV cost structure, the user can change from a taxi-like payment structure to a fixed price per passenger trip cost structure—and vice versa—to explore whether this has a significant effect on overall results. The user can also adjust the NDV and DV cost levels up or down using the spin buttons on the form. The new cost levels are shown, and the user can then re-run the optimizations with these new, higher or lower cost levels, in effect. Adjusting cost factors is typically a key part of any sensitivity analysis.

Changing data values in the pop-up windows shown in Figures 23 and 24 does not modify the underlying data that describe the DRT system's characteristics; it simply changes one or more input values used by the NDV Model for a specific run of the optimization model(s). The user can save the results of that optimization run if desired and then make other changes to key data values and re-run the model to assess the effects of those modifications. In this way. a wide range of NDV alternatives can be evaluated if desired.

APPENDIX A

Glossary

Abandoned calls	These are reservations calls that were put on hold (manually by an automated telephone system) and subsequently terminated by the customer. The number of abandoned calls, if tracked by a telephone MIS, can be used as a service quality measure. A high rate of abandoned calls may indicate an insufficient number of call-takers or telephone lines.
ADA	**Americans with Disabilities Act**—1991 Act that contains provisions on the acquisition of accessible vehicles by public and private entities, requirements for complementary paratransit service by public entities operating a fixed-route system, and provision of nondiscriminatory accessible transportation service.
Advance request period	The period of time (before the day of the trip) when a trip request may be placed. The ADA requires that systems provide, at a minimum, next-day service. It does not require same-day service, although many systems do provide same-day service, most on an "as available" basis and/or in response to request for **will-call returns**. The ADA formerly required a 14-day advance request period, but no longer does. As a result, many systems have shortened the advance reservation period to one week or less.
AVL	**Automatic Vehicle Location**—Computer-based vehicle tracking based on location technology, such as the global positioning system. Transmitter devices on board vehicles are used in conjunction with location technology to transmit the location of the vehicle to the radio dispatcher. In conjunction with some paratransit scheduling software and MDTs, the AVL system can be used to "location-stamp" each stop, in order to ensure that the arrival and departure time data really does pertain to the stop in question. The AVL system also is integral to systems that provide the driver with automated directions, because the system knows at any given point, where the vehicle is and in which direction it needs to go to get to the specified destination.
Brokerage	A paratransit brokerage serves as a middleman between one or more trip-sponsoring (funding) agencies and a complex service delivery network, usually involving more than one service provider. Typically, the broker enters into agreements with the funding sponsors and organizes the service delivery network. This may include contracting with the service providers. The broker may also directly perform

call-center function (such as reservations and scheduling) and, in some cases, may operate some of the service (sometimes known as a **partial or hybrid broker**). The broker may also perform or be responsible for certain functions more typically associated with the funding agencies (e.g., eligibility determination, trip ticket/scrip management, carrier/service monitoring, and carrier invoice processing).

Complementary paratransit — Specialized demand-responsive service provided for people who cannot use fixed-route transit or rail service due to a disability, meeting specific comparability requirements as established by the Americans with Disabilities Act. The service is called "complementary" because it is provided, at a minimum, where and when the fixed-route service is provided, and because it complements fixed-route service, that is, it provides additional service needed to make the entire system usable by people with disabilities.

Contract rate structure — A rate structure defines how a contracted service provider is paid for its service. Typically rate structures for paratransit include per revenue vehicle hour, per revenue vehicle mile, and per trip, or a combination thereof. Revenue vehicle hours or miles often begin with the first pickup and end at the last dropoff of a run, although they sometimes are calculated from pullout to pull-in, and, in the case of revenue hours, sometimes excludes breaks of a predetermined minimum length. It might also include a monthly fixed amount covering expenses that do not change significantly with the change in service volume, and a variable rate (per revenue vehicle hour, per revenue mile, or per trip) to cover costs that could change significantly with a change in service volume.

Cost-efficiency — Cost-efficiency for paratransit systems is usually measured in terms of cost per trip, although it can also be measured in terms of cost per mile, and for dedicated service, cost per hour. The lower the cost per trip, the more cost-efficient the system. Service productivity, typically measured in trips per hour, can serve as a surrogate measure for cost-efficiency but only for dedicated service.

Curb-to-curb service — A demand-responsive service that picks up and delivers passengers at the curb or roadside nearest their origin or destination. Passenger assistance is not provided other than for actual boarding and alighting.

Dedicated service — This is an operation where the vehicles in operation are dedicated to the transportation of customers of a transportation program (or coordinated set of programs) during a specified time. (See also **Non-Dedicate**d **Service**.)

Demand curve — A graph depicting the volume of trip requests (or trips served) during the service day.

Demand-responsive — A characteristic of transit service in which vehicles are routed according to passenger boarding and alighting requests.

Demand-responsive feeder or connector — A transit service in which vehicles operate in demand-responsive mode **within a zone, with one or more scheduled transfer points that connect** with a fixed-route network. A high percentage of ridership consists of trips to or from the transfer points.

Dial-A-Ride	A form of demand-responsive public transportation without fixed stops or fixed schedules in which vehicle routing is determined entirely in response to passenger service requests made by telephone or similar means.
Dispatching	The dispatching function is divided into Radio Dispatching and Window Dispatching. Both involve activities that happen on the day of the trip. **Radio Dispatching** is the process of monitoring vehicle operations and issuing voice instructions (via radio or cell phone) or text messaging (via MDTs) to drivers to make adjustments to a pre-planned schedule. This may involve making sure that the drivers are keeping up with their schedules, responding to no-shows, assisting drivers with incidents and emergencies, communicating late cancellations to the drivers, scheduling same-day "add-on" trips to vehicle runs and communicating these add-on trips to the drivers, switching trips from one run to another in response to vehicle running late or to vehicles that have become disabled and communicating these changes to the drivers, assisting lost drivers, responding to "Where's my ride?" calls from customers, and, where the system has MDT/AVL capabilities, ensuring that the proper pickup/dropoff times are being entered into the system, and ensuring that vehicle is in the right place. **Window Dispatching** involves assigning vehicle drivers and vehicles to scheduled vehicle runs, providing the **driver manifests** for each **vehicle run** to the assigned driver, and recording or blessing shift start and end times, and pullout and pull-in times and mileages.
Door-to-door service	A demand-responsive service that picks up passengers at the door of their place of origin and delivers them to the door of their destinations. The driver escorts or physically assists passengers between the vehicle and door of the origin or destination. Door-to-door service provides a higher level of assistance than curb-to-curb service. (Sometime used loosely as a synonym for "demand-responsive service.")
Driver manifest, trip manifest, or trip sheet	A driver manifest or trip manifest or trip sheet includes the list of trips or stops in the proper sequence for a specific vehicle run, along with needed information about the customers to be transported (e.g., name, mobility device used, and disability). The manifests also provide spaces to document actual service data that pertain to each trip and stop, and run-level summary information.
Driver wait time	The number of minutes a driver is instructed to wait for a customer after arriving at the pickup location (and within the pickup window), before calling the dispatcher to indicate a no-show and to get instructions as to whether the driver should wait longer or proceed to the next stop.
Dwell time	The time it typically takes to load or unload a passenger. Includes **Driver wait time,** use of the lift or ramp, and securement of the passenger. Computerized scheduling systems often accommodate different dwell times for ambulatory and non-ambulatory customers.

FTA	**Federal Transit Administration**
GIS	**Geographic Information System**—A system used to display service areas and other locations. GIS systems interface with automated paratransit systems to locate addresses and distances for scheduling purposes and with AVL systems to locate vehicles.
GPS	**Global Positioning System**—Technology using signals transmitted from a network of satellites in orbit to determine locations on the earth.
Hold time	The period of time that a caller is placed on hold. Some telephone systems track and differentiate between initial hold time (up until a customer first speaks with a call-taker) and total hold time. Average hold time and maximum hold time can be used as a service quality measure. A high average hold time may indicate an insufficient number of telephone lines or call-takers (or a readjustment of call-taker schedules) to better match the call volumes is warranted).
Holding run	A "bin" into which unscheduled trips can be placed, pending being scheduled.
Human services agency	A government or not-for-profit organization that provides services for essential needs such as medical care, income support, housing, education, training, and public health, typically for people requiring help due to age, disability, low income, or similar reasons.
Human services transportation	Transportation provided by or on behalf of a human services agency to bring people participating in the agency's programs or services to those programs or services.
ITS	**Intelligent Transportation Systems**—Advanced technologies applied to various aspects of transportation to enhance mobility, energy efficiency, and environmental protection.
IVR	**Interactive Voice Response**—A software application that accepts a combination of voice telephone input and touchtone keypad selection and provides appropriate responses in the form of voice, fax, callback, e-mail, or other media. IVR is usually part of a larger application that includes database access.
MDT	**Mobile Data Terminal also sometimes called MDCs or Mobile Data Computers**. These are onboard monitors/keyboards or computers that are used to communicate data between the vehicle and the dispatch office. Sometimes, also refers to an integrated onboard device that combines a mobile data terminal with a vehicle logic unit and other devices such as GPS, a communications interface, or smartcard reader. MDTs are typically used to display today's schedule (driver manifest) for that vehicle, taking the place of a paper driver manifest. Much of the information typically entered onto the driver manifest by hand (e.g., pullout and pull-in times and odometer readings, actual arrival time and departure time at each stop, the odometer reading at each stop, and break times) is instead entered into the MDT by the push of a button. The drivers can transmit codes back to the radio dispatcher, rather than by voice, for standard

communications. Also, radio dispatchers can transmit add-ons, late cancellations, and changes to the drivers via the MDTs.

Missed trip This is a trip that was scheduled to be served but was not served due to provider or driver error or adverse operational circumstances. This is not a customer **no-show**, where the customer was at fault. Some systems also include in the missed trip count trips that were served but where the vehicle arrived very late (e.g., 60+ minutes late after the negotiated pickup time or window).

Negotiated pick-up time The quoted pickup time after a customer places the trip request (versus the requested pickup time).

Non-dedicated service This is an operation where the vehicles in operation are not dedicated to the transportation of customers of a transportation program (or coordinated set of programs) and also carry other passengers. For example, a user-side subsidy taxi program. Non-dedicated service can be used in conjunction with dedicated service to meet peak demands or other situations where the use of additional dedicated vehicles may not be cost-effective or possible.

Overbooking A strategy where more trip requests are taken than can be scheduled onto dedicated vehicle runs. Trips that cannot be scheduled at the time of the reservation are placed in holding runs until they are scheduled or dispatched into holes in the schedule created by late cancellation and no-shows or are assigned to a non-dedicated service provider (if available). Accepting these trip requests is telling the customer that the trips will be served. Thus, it is generally a good idea to have a backup plan (e.g., non-dedicated service provider) in case a trip cannot be subsequently scheduled/dispatched onto the dedicated fleet.

Paratransit Most commonly used to refer to specialized demand-responsive service provided for seniors and people with disabilities, especially ADA complementary paratransit. Historically, used to refer to various shared-ride transportation services other than conventional transit service, usually using small vehicles.

Pickup window A window of time, constructed from the negotiated pickup time, in which a vehicle may arrive for a pickup and not be deemed early or late. For example, a common pickup window is +/−15 minutes from the negotiated pickup time. Some systems also have a **Dropoff Window**.

Productivity A measure of the quantity of desired results produced per unit of resources applied. In paratransit (and especially for dedicated service), productivity is commonly measured using passenger trips per hour; however, systems do not all define "passenger trips" and "hours" the same way. With some systems, trips are defined as total passenger trips, including PCAs, companions, etc. In other systems, trips are defined as just the program-eligible passengers. As the denominator for the productivity calculation, most systems use **revenue vehicle hours**. The NTD defines revenue vehicle hour as first pickup to last dropoff less breaks, whereas **total hours** also includes the breaks and the deadheading to and from the yard, and hence pullout to pull-in.

Request stop service A transit service in which vehicles operate in conventional fixed-route, fixed-schedule mode and also serve a limited number of defined stops near the route in response to passenger requests. (Request stops differ from flag stops in not being directly on the route.)

Reservations The process of receiving and booking requests for same-day, advance-reservation, and/or subscription (standing order) trips. In many systems, the staff that receive reservations also receive process cancellations and change-orders and provide general information about the system and other customer service functions.

Ride time or travel time The time a customer is on board the vehicle. Many paratransit systems have established a maximum ride time as a scheduling parameter and service quality measure.

Run structure The set of dedicated vehicle runs that are constructed so as to provide adequate capacity at various times of the service day. The run structure may include a combination of straight runs, split runs, and/or partial or part-time runs, with staggered start and end times, and accommodations for deadheading and breaks, and are generally constructed to match the demand curve. Run structures are often depicted with bar graphs for comparison with the demand curves for the same day.

RVH **Revenue Vehicle Hour**—A span of time when a vehicle is available for carrying passengers, including layover and recovery time, but excluding deadhead time to and from a vehicle storage location or break location, or between routes.

Scheduling In a demand-responsive service, the process of determining the path and schedule of vehicles in the system so that they serve the trips that have been requested. Also, the process of assigning a booked trip request to a specific vehicle run and determining in the vehicle run the scheduled (as opposed to requested) pickup time and dropoff times for the trip. In some systems, trip requests are initially scheduled onto a vehicle run immediately after the trip request is booked and while the customer is still on the phone; this is called **real-time** or **immediate** scheduling. Some of these systems also have automated **batch scheduling** capabilities, where the system schedules all trips to be scheduled as efficiently as it know how—most operations that use batch scheduling have schedulers review and further refine the schedule, as needed. In a system that permits trips to be requested on short notice, the process of scheduling may be merged with dispatching. In most systems, the scheduling process ends when the driver manifests for each vehicle run are printed. In cases where a system uses taxi contractors (or other non-dedicated service providers), the scheduling process also includes assigning trips to the non-dedicated provider for subsequent dispatching by the provider; this includes giving/sending the list of such trips to the provider.

Computerized paratransit scheduling systems typically provide computer-assisted scheduling and/or automated scheduling capabilities. Computer-assisted scheduling provides help to the scheduler, but ultimately it is the scheduler who must decide where to schedule a trip. These are often used by smaller systems and greatly increase office staff productivity as they are used to generate driver manifest and various reports. Automated scheduling systems, based on **GIS** maps of the service area that underlies the system, and based on various parameters such as average vehicle speed, allowable pickup window, dwell times, and maximum onboard travel time suggests one or more runs onto which the trip would fit and automatically inserts the trip into each run for reservation agent or scheduler blessing.

Service mix Dedicated service can be combined with non-dedicated service as an efficient response to the demand. The combination of these two different types of service is often referred to as a service mix and is often expressed as the ratio of dedicated service to non-dedicated service.

Service quality Paratransit service quality is typically measured by the following: average and maximum hold times of the reservations staff, the percentage of abandoned calls, on-time performance of service delivery and degree of lateness for the late trips, percentage of missed trips, the complaint ratio, and the complaint resolution response time.

Slack time The amount by which the time scheduled for a process exceeds the time required for its completion. In demand-responsive or flexible transit, slack time refers to time in a vehicle schedule that is available to schedule a deviation or an additional passenger stop without affecting the rest of the schedule.

Split shift A driver assignment that has two distinct pieces during a given day, with a period of non-paid, non-work in between. This is not to be confused with a straight shift with a lunch break. A split shift has two sets of starting and ending times in one day. If the two pieces are assigned to two different drivers, each piece is often referred to as a **partial** shift.

Standing order or subscription trip Standing Orders and Subscription Trips (one in the same) are typically defined as trips of a specific customer that recur in regular pattern (e.g., at least once a week and that go to and from the same origin and destination at the same times). This might include a daily work trip, a senior nutrition trip, or a Monday/Wednesday/Friday dialysis trip, for example. They involve a one-time request and hence are booked automatically after the one-time request is processed. Customers call again only to cancel or to arrange a temporary suspension.

With automated scheduling systems, standing orders are scheduled onto runs in templates for each day of the week. When the template is used to create the schedule for a specific date, all the standing order trips scheduled into runs in the template are copied into the respective runs for that date (unless there is a customer or trip suspension). This is done before the rest of scheduling process begins.

If an ADA paratransit system is capacity-constrained (noting that under the current no-denial requirement, there should be no capacity constraints), then the system, by law, is limited to having standing orders represent no more than 50% of the trips served at any time of day. However, if there is no capacity constraint, then this regulation is moot, and there is no such limit.

Straight shift trip A driver assignment that has one starting time and one ending time in a given day. In the paratransit industry, a trip is usually synonymous with a "passenger trip" which is a movement of a passenger from origin to destination.

Trip time negotiation The process in reservations of negotiating an alternative pickup to the one requested in order to create a more efficient schedule or to be able to accommodate the trip request. For ADA paratransit systems, negotiated trip times that are more than 60 minutes before or after the requested pickup time constitute denials, regardless of whether the customer agrees to the offered pickup time or not.

Turnkey contract This is a contract to provide all operational functions, including reservations, scheduling, dispatching, operations, and maintenance. It can also include the provision of an operations/maintenance facility, paratransit scheduling software (and hardware), and/or vehicles. It seldom includes, but can include, the eligibility determination function.

Vehicle run A vehicle run or tour is the piece of work that a driver performs between pullout and pull-in. Trip requests are scheduled onto specific vehicle runs. Holding runs, usually organized by time of day, are used as a temporary place to store unscheduled trip requests in some computer systems.

Will-call return trips These are round-trip requests that are booked with an unspecified return pickup time. Some systems permit will-call return trips for medical appointments and dialysis trips, where there is wide fluctuation (beyond the control of the customer) as to when the customer will be ready to go home. So, instead of scheduling the return trip pickup time, the return is left open. When the customer is ready to be picked up, the customer calls and the dispatcher "live-dispatches" the trip to a vehicle, much like a taxi dispatcher.

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation