

HSIPR Best Practices: Overview

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1 General Introduction

Background and purpose of this report

Federal involvement in the development of intercity passenger rail has historically been quite limited. This has changed considerably in the past several years, beginning with the passage of important legislation such as the Passenger Rail Investment and Improvement Act (PRIIA) and the Rail Safety Improvement Act (RSIA) in 2008, and continuing with President Obama's announcement of a High-Speed Rail Vision in April 2009. Federal funding is now available for the development of high-speed and intercity passenger rail (HSIPR), including an initial \$8 billion in grant funds made available under the American Recovery and Reinvestment Act (ARRA), as well as other passenger rail development funds made available under the federal budget and PRIIA.

This new emphasis on passenger rail development highlights the need for objective analytical methods for planning and evaluating proposed rail projects. In the highway and transit sectors, methods that can be used for these purposes have been created and refined over many years, and there is now a reasonably broad consensus on best practices. In contrast, there has not yet been a comparable development of planning and evaluation methods applicable to HSIPR projects.

To be sure, the Federal Railroad Administration (FRA) has released and is continuing to release documents that provide increasingly detailed guidance¹ to project proponents about its grant application, selection and evaluation procedures. These documents describe how the FRA's decision about a proposed rail project integrates a wide range of considerations ranging from very high-level issues such as national industrial development and regional equity, to relatively specific technical factors such as project ridership, revenue, benefits and costs.

Given the relatively undeveloped state of intercity passenger rail planning methodology, however, it is possible that proponents of different projects may prepare their predictions of ridership, revenue, benefits and costs using different and perhaps incompatible approaches, making it difficult for agencies such as the FRA to evaluate, compare and prioritize the various projects on a consistent basis.

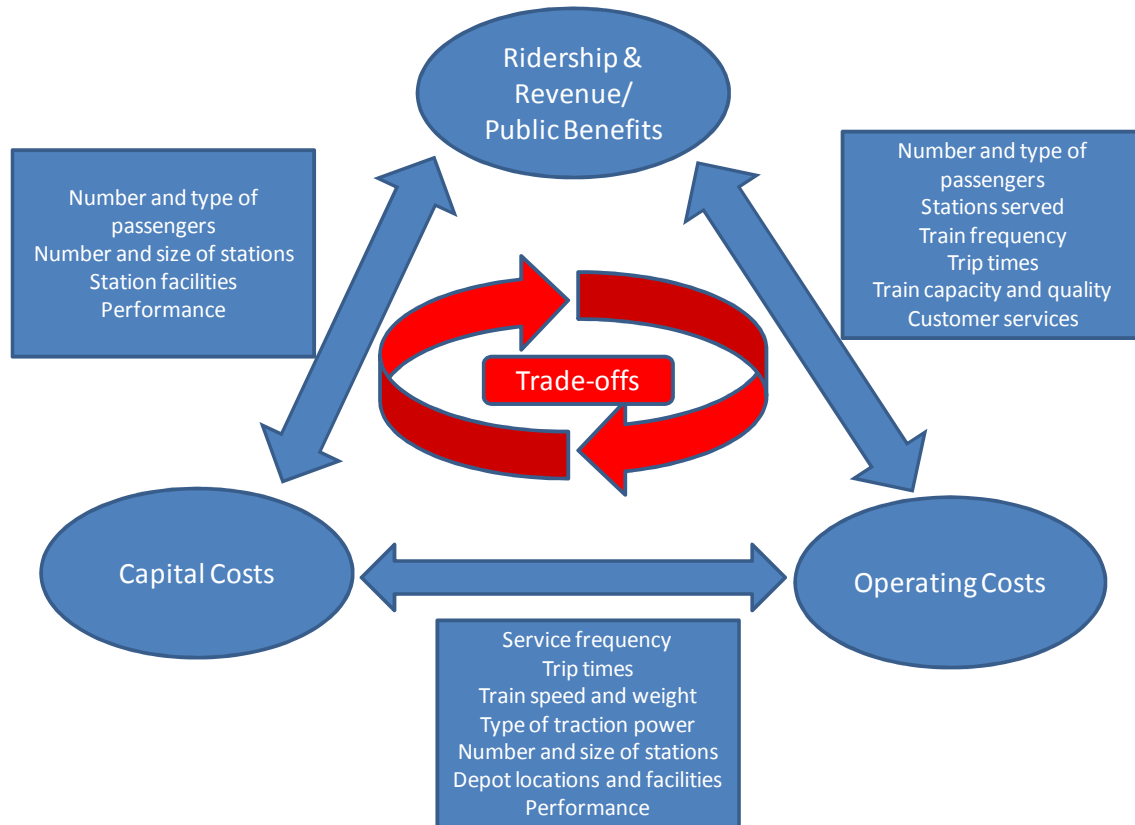
To address this situation, this report presents and discusses at a high level current state-of-practice methods in three specific areas of HSIPR planning methodology: ridership and revenue forecasting; operating cost estimation; and public benefits evaluation. Although the report does not refer specifically to elements of the evolving FRA guidance, information on these three areas will inevitably be important inputs to any decision about a rail project. In this sense, it is hoped that the report will be a useful high level contribution to the FRA's ongoing development of appropriate planning methods.

¹ At the time of this writing, the most recent guidance was included in Federal Register/Vol. 75, No 126./ Thursday, July 1, 2010/Notices.

Relationships between the study areas

Figure 1-1 illustrates the relationships between the three study areas and the influence of HSIPR project and service characteristics on them.

FIGURE 1-1. RELATIONSHIP BETWEEN RIDERSHIP, REVENUE, BENEFITS AND COSTS



It is clear that a consistent project definition should be used in preparing HSIPR capital and operating costs estimates, ridership and revenue forecasts, and public benefits assessment. This definition should also be consistent with the assumptions regarding the quality of passenger experience. However, it is not uncommon for discrepancies between the project definition and/or service quality assumptions used in the different study areas to be inadvertently introduced as a study advances. For example, initial ridership forecasts may reveal that the initially assumed service frequency does not provide sufficient seating capacity. Service frequencies may then be updated in the ridership study (potentially leading to even more ridership) but, because of communications lapses, not in the operating cost estimates.

Organization of the report

This document describes in general terms the methods currently used for ridership and revenue forecasting, operating cost estimation and public benefits assessment, and it highlights the main issues that must be considered when applying them. It is addressed to non-technical readers.

A number of similar considerations structure the discussion of the different areas including:

- The analysis approach itself;
- Study stages and their effects on choice of method;
- Established approaches and those that are still evolving;
- First- and second-order effects on analysis results; and
- Common errors and pitfalls that HSIPR study reviewers should be alert for.

The following paragraphs provide a general introduction to these issues, and the subsequent discussion within each area reveals their influence on decisions about approach and method.

Study stages

A project rarely proceeds in a strictly linear fashion from a vague concept to a detailed engineering and service design. Rather, during the course of study different possible concepts are suggested, analyzed, assessed and rejected or refined, in an iterative process that progressively improves the definition and quality of the considered options until one or a very few project designs remain for consideration, and one is ultimately chosen for implementation.

Progressively more detailed and accurate approaches for forecasting, cost estimation and benefits evaluation are appropriate as the project moves through this process of refinement. These different approaches involve tradeoffs between the level of study effort (time and resource implications, data requirements, analysis detail) and the resulting level of accuracy of study results (specificity of conclusions, associated uncertainty and risk).

It is useful to designate notional stages along this process by specific names. Although there is no universal definition of different study stages, for convenience of discussion this report will consider three generally representative stages in the development of a HSIPR project:

- **Preliminary:** approximate estimates are developed relatively quickly, with a low level of effort, and without requiring a detailed description of project characteristics. The analysis might typically be done to screen a number of possible roughly-defined alternatives, or to quickly assess the likely feasibility of a candidate project;
- **Intermediate:** some appropriate balancing of accuracy, project data requirements and level of effort is attempted. Here the analysis would typically focus on investigating the feasibility of a limited number of alternatives defined in some detail; and
- **Final:** accuracy of results is paramount. Extensive collection of original data is generally required. Project characteristics must be known in detail. Significant effort and time are required. The analysis would typically be conducted to finalize a project's documentation for submittal to approval and funding organizations.

It should be emphasized that a given study may combine elements from these different stages, and that a particular project may not progress steadily from one of these stages to the next. Nonetheless this distinction captures real differences in appropriate methodology at different points in project development. In the discussion of each study area, the approaches, data sources and methods appropriate to each study stage will be identified and distinguished.

For operating cost estimation, a **commercial closeout stage** has also been defined. This resembles a final stage estimate except that the inputs used to prepare the estimate correspond to the actual contractual terms, conditions and input costs of a service ready to be implemented. Estimates of this

accuracy might for example be required by a commercial entity's board of directors before giving final agreement to enter into a contract to provide the service.

Established and evolving approaches

Some methods and approaches are well established in each of the three study areas, and there is fairly broad consensus among practitioners about the use of these in HSIPR studies. However, other methods and approaches are still evolving, and there may be controversies or debates among practitioners about their use. The discussion of each area will focus on established approaches, but also identify emerging methods as appropriate.

First- and second-order effects

In each of the three study areas (ridership and revenue forecasting, operating costs and public benefits), there will be some elements - methods, data sources, variables, model components, model parameters etc. - that have the largest effects on the results, while the effects of other elements are more minor. The discussion of each area will distinguish (where possible) the elements that have first- from those that have second-order effects.

Common errors and pitfalls

HSIPR studies are subject to errors and pitfalls in different elements of the three study areas. HSIPR study reviewers should be aware of the common errors and alert to their possible presence. The discussion identifies some of these, and more generally advises reviewers on points to verify or examine in detail in studies performed at different stages.

Relationship to economic cost-benefit analysis

The study areas considered here - ridership and revenue forecasting, operating cost estimation and public benefits evaluation - relate directly to standard methods used for the economic evaluation of transportation projects. While the FRA's grant evaluation and selection methods integrate a wide range of factors in addition to purely economic ones, the economic value of a HSIPR project is an important factor in decisions about it.

Cost-benefit analysis² (CBA) provides a well-established framework for organizing the analysis of a project's impacts over time as part of an economic evaluation. CBA looks in depth at the costs and benefits of a project, expressing them in monetary values so that its overall impact can be quantified. Economic cost-benefit analysis considers a project's net impacts on society, which generally go beyond its purely financial costs and benefits; for example, it may incorporate factors such as time savings and environmental impacts, appropriately monetized, in the assessment. Intrinsically non-quantifiable measures (such as the policy, strategy, management and delivery factors considered by the FRA in evaluating HSIPR grant applications) may be important components of a more general decision process but are difficult to incorporate within a pure CBA framework.

Cost-benefit analysis does not consider transportation impacts in absolute terms; rather it considers a *build* (project) situation and a specified *no-build* situation, with the project benefits and costs defined from a comparison of the two. It is common to define the no-build situation as the set of "committed"

² It is not the intent here to provide a complete treatment of cost-benefit analysis, but only to discuss it in sufficient detail to furnish a context for the analysis in this report of ridership and revenue, operating costs and public benefits.

(i.e. officially approved) future network improvements, or as the minimum set of improvements needed to avoid significant deterioration of travel conditions in the future, but other definitions are possible. The no-build situation used in a study needs to be agreed with its sponsors, reviewers and audience early in the study process. Forecasts of ridership and other impacts must be prepared for both the no-build and build situations in order for the project benefits and costs to be computed.

For a benefit or cost to be included in an economic CBA, it must be quantifiable, monetizable, not duplicative and not a transfer. It must be quantifiable in order to attach a monetary value to them. Even when a benefit or cost item is not traded in a market and therefore is not directly valued in monetary terms, methods frequently exist to convert it into equivalent monetary values. Each item should be captured once and only once, and should not overlap with other items. Conventional CBA ensures this by only counting direct impacts on transportation users and operators, plus changes in externalities imposed on others. This means, for instance, that impacts such as land value changes are not accounted for, as they are simply manifestations of already-included direct impacts such as travel cost changes. Lastly, transfers between different groups (e.g. taxes) do not represent a utilization of society's resources, and therefore are not included in a CBA.

Costs accounted for in the economic CBA of a rail project include its capital, operating and maintenance costs. *Capital costs* include all the upfront costs of a project including for design and construction, right-of-way acquisition, rolling stock acquisition, etc. Capacity expansion and major rehabilitation are also generally considered to be capital cost components. Capital costs are highly specific to the particular details of an individual project, and will not be considered further in this report. Operating and maintenance costs (referred to generically here as *operating costs*) are those incurred to operate the rolling stock; maintain the rolling stock, way and systems; operate stations and other facilities; provide ancillary services such as parking; and manage the system. The level of ridership directly affects some of the operating cost items (e.g. train operations, passenger services).

Direct benefits typically accounted for in a rail project CBA are derived from the impacts of the project on transportation system users and operators, and from its externalities. User benefits include travel cost, time and related service improvements experienced by HSIPR users. Diversions to rail by users of other modes (e.g. air and auto) may reduce congestion on those modes, providing benefits for their users. Service improvements and/or congestion reductions must be quantified and expressed in monetary units. Rail project externalities may include impacts on the environment, travel safety, and others, and these must also be quantified and monetized. Ridership forecasts are inputs for the calculation of many of these benefit items.

Project costs and benefits are determined for each year (or other meaningful time interval) of an *evaluation period* that must be decided on as part of the CBA. Capital costs may be spread over a number of years, again in a way that is project-specific. Ridership and revenue, operating and maintenance costs and public benefits - which, as shown in Figure 1-1, are all inter-related - are generally computed for a year-long period, with the calculation typically done for a few representative years and then interpolated or extrapolated over the other years of the evaluation period.

For a variety of reasons, the economic value of a given project cost or benefit depends on when it occurs, even if inflation is not considered. This leads to the concept of present value, the equivalent value in a reference year of a monetary amount at some other time. Calculation of the *present values* of project costs and benefits in different years involves a *discount rate* that must also be decided on as part of the CBA.

The overall time stream of annual costs and benefits over the evaluation period can then be summarized through various indicators that can be used to assess and compare projects. Each indicator has its strengths and weaknesses and the choice of the appropriate indicator will depend on the policy and funding context. Commonly-used indicators include:

- **Net Present Value (NPV):** NPV is simply the algebraic sum of all the present values of benefits and costs. Over the evaluation period, a project with a positive NPV will deliver to society benefits that are greater than its costs. The NPV is a simple indicator that can be used to select between mutually-exclusive projects if the desire is to select the one that maximizes social benefits. It may not be helpful if there are constraints on available funds, as it does not recognize the efficiency with which money is spent.
- **Benefit Cost Ratio (BCR):** The BCR is the ratio of present value of project benefits to the present value of its costs (PVB/PVC). A BCR above 1 indicates a project whose benefits exceed its costs. Like the NPV, the BCR does not explicitly recognize limitations on funding availability, and can therefore result in an inefficient allocation.
- **Internal Rate of Return (IRR):** The IRR is the discount rate that makes the net present value of a project's benefits and costs equal to zero. From a social perspective, the IRR is the discount rate at which the present value of project benefits equals the present value of project costs.

Although the IRR may be considered a more intuitive summary of a project performance, the indicators based on present value are generally preferable from a technical perspective.

The length of the evaluation period and discount rate strongly affect the values of these measures, so projects should usually be compared in CBA using consistent evaluation periods and discount rates.

2 Ridership and revenue

Ridership and revenue forecasting process

The end product of a passenger rail ridership forecasting effort is the number of trips that are expected to use the proposed rail service. This will include trips that are diverted from a prior mode (e.g. auto, air, bus, rail) to the proposed service; and new rail trips that only occur as a result of the introduction of the service and that would otherwise not be made. This report refers to these two types of trip as *diverted trips* (or *rail diversions*) and *induced trips*, respectively.

As a first step in HSIPR demand forecasting, the study area needs to be defined. The study area is the catchment area from which the trips on the HSIPR mode are generated. The whole study area is further divided into a set of non-overlapping sub-areas called zones, which are considered to be the origins and destinations of trips. Depending on the study requirements, zones may be of different sizes and be represented at various levels of detail (e.g. census tracts, ZIP codes, counties etc.).

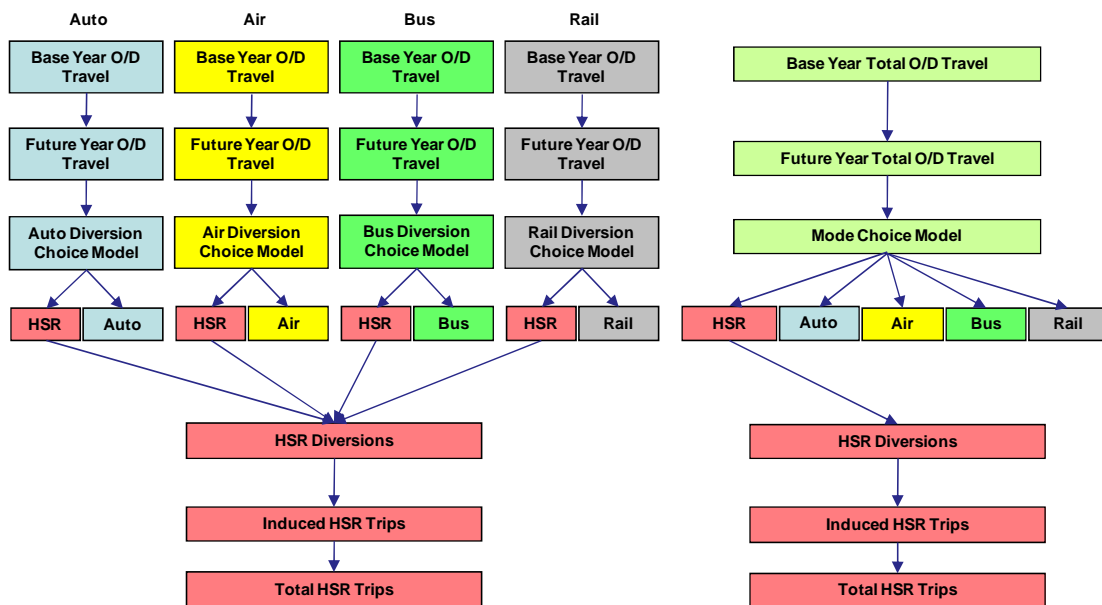
Diverted HSIPR trips

As HSIPR systems are primarily intercity services, ridership and revenue forecasting for these systems tend to follow approaches and methods used in intercity travel demand forecasting. Two main approaches (as shown in Figure 2-1) are typically applied to estimate HSIPR diversions. Both approaches require an estimate of travel patterns and volumes in the study area, represented in the form of a trip table that provides travel volume by origin-destination (OD) pair. For each OD pair, the approaches then apply a model of travelers' mode choice behavior to predict the number of trips on the rail and other modes.

In the first approach (which is called *diversion choice modeling* in this report), HSIPR diversions are predicted by calculating how many trips will divert to HSIPR from each prior mode of travel. This approach requires trip tables for each prior mode, and a diversion choice model that predicts travelers' shifts from each individual prior mode to rail as a function of relative modal service characteristics and other factors. This approach recognizes that individuals who have chosen to travel on different modes may respond differently when confronted with the option to use a new rail service. It is based on the premise that travelers' choice of mode in the absence of HSIPR service or HSIPR improvements provides information about how they value the attributes of one mode relative to other modes.

In the second approach (called simply *choice modeling* in this report), the volume of trips (apart from induced trips) on each available mode (including the new rail service) is calculated in one step based on relative modal service characteristics and other factors. The model represents travelers' choices from among all available modes, based on their respective service characteristics and other factors. The approach requires a table of all trips regardless of mode, and a choice model that forecasts the volume of trips on each mode, without consideration of prior travel choices.

FIGURE 2-1. APPROACHES USED FOR THE CALCULATION OF HSIPR DIVERSIONS



Approach 1: Based on mode specific individual trip tables Approach 2: Based on total combined trip table

As noted, both of these approaches require some estimate of trips by OD pair. The accuracy of HSIPR ridership forecasts depends heavily on the accuracy of the estimate of these potentially divertible trips. Some sources are available to establish trip tables for current and historical travel on existing modes. The US Department of Transportation maintains databases of air travel that furnish good information on airport-to-airport travel volumes, but these volumes generally need to be disaggregated to finer geographic levels for planning purposes. Similarly, Amtrak has detailed station pair data for all its trains, but the same disaggregation issue arises here. Preparation of auto trip tables poses the biggest challenges. There is currently no standard source of information about intercity auto trip making in US that is sufficiently detailed to be used in project-level forecasting. Various estimation techniques combined with some combination of new data collection (depending on available resources) and/or existing information are typically used to prepare auto trip tables.

In both approaches, HSIPR diversions are calculated for a base year and a number of future years, so trip tables are required for each of these years. This is typically done by growing current year trip tables. Various methods are available to calculate growth rates, typically relying on the socio-economic and demographic characteristics of the study area as well as individual origins and destinations in the base and future years.

Both approaches calculate travel shares for the new HSIPR mode for the base and future years. Diversion choice models separately calculate these shares for travelers on each existing mode, while choice models calculate them for all travelers combined. Both models require a variety of information types to calculate these shares. These include:

- Representation of the service characteristics of each main mode (the new HSIPR mode and other existing modes including air, auto, bus and rail) and any relevant mode used to access and leave the main modes (e.g. automobile, public transit or taxi cab). The service provided

by these travel options is represented in terms of the corresponding travel time, access/egress time, wait time, travel costs (including fares, auto fuel costs and operating costs) and others. Auto mode characteristics may be calculated using network models that accurately represent the road networks in the study area and the levels of congestion on them; or from maps or other similar methods for earlier stage studies. Characteristics of bus and other transit modes are obtained from published and projected schedules and fares. Characteristics of the HSIPR mode are sometimes extracted from detailed train simulation outputs or calculated more simply from proposed operating characteristics (speed, acceleration, deceleration profile, curvature of tracks etc.) and planned fares. These characteristics would be developed at increasing levels of accuracy as the study stages progress from preliminary to final.

- Information on travelers' choices or preferences in hypothetical tradeoff scenarios involving the new HSIPR mode and the existing modes. This information is collected through surveys of potential rail users. Great care is needed to prepare and conduct these surveys, as biased responses by respondents may ultimately lead to highly erroneous ridership and revenue forecasts. The survey should present a realistic representation of an actual choice situation (the choice between the HSIPR mode and the respondents' current mode for diversion modeling, the choice among all available modes including HSIPR for choice modeling).
- Study area socio-economic characteristics and other relevant factors.

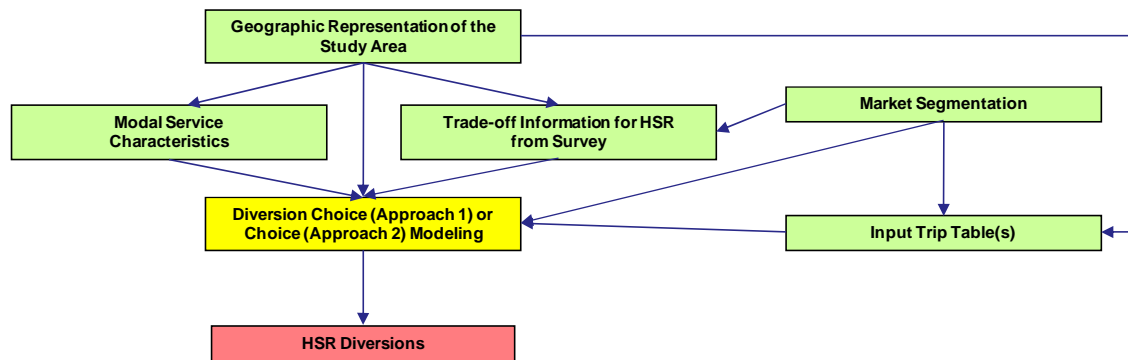
To develop and apply the mode choice models, the travel population is typically divided into segments corresponding to groups of travelers with distinct characteristics that may affect their response to a new HSIPR mode. Travelers belonging to each of these segments are assumed to have similar travel behavior. Business and non-business travelers are normally treated as distinct segments. For some rail projects (those serving major entertainment destinations such as Orlando or Las Vegas), tourism can be an important segment that may need to be separately modeled.

The auto travel market generally needs to be segmented into three groups: (1) those who require a vehicle at their final destination ("destination-captive"); (2) those who do not ("non-captive"); and (3) those who need to make intermediate stops during their trip ("en route-captive"). The likelihood of diverting from auto to HSIPR for intercity travel will be very different for the three groups. Empirical work suggests that many auto travelers are in fact captive.

Another important market that needs special treatment is air travel. Distinction between true end-to-end (OD) and connecting air trips is important. In most cases, the true OD trips are the candidates for diversion to HSIPR but connecting trips are not diversion eligible. The availability of HSIPR service to an airport may attract airport access and egress trips as a separate market segment, and in a region with multiple airports may also affect airport choice and routing decisions. The mode choice models are applied separately to different market segments and the diverted HSIPR trips for all the segments are combined to obtain the total HSIPR diversions.

Figure 2-2 below shows the different elements of HSIPR demand forecasting and their inter-relationships as described above.

FIGURE 2-2. DIFFERENT ELEMENTS OF THE HSIPR DIVERSION CALCULATION PROCESS



Induced HSIPR trips

Induced travel refers to trips that only occur as a result of a transportation improvement, and that were not made prior to the improvement. The number of induced HSIPR trips can be calculated in various ways: as a percentage of the HSIPR diversions; from survey responses; from demand elasticities relating a percentage change in demand to a corresponding change in travel time, costs or other measure of travel conditions. Induced demand can also be calculated as a percentage of the HSIPR demand and is generally a small fraction of the total HSIPR ridership.

Total HSIPR ridership and revenue

Diverted and induced HSIPR trips are added to produce the total HSIPR ridership for each OD pair and for the whole system. The HSIPR fare revenue produced by a particular alternative is calculated for each OD pair from this ridership forecast and the corresponding HSIPR fare. Detailed forecasting studies may consider multiple fare classes (e.g. premium vs. regular service) for which the calculation should be repeated. The sum of the fares generated by each OD pair and fare class (if applicable) constitutes the total HSIPR fare revenue. Of course, the forecast levels of diverted and induced trips themselves depend on the assumed fares, so in general multiple model runs will be required to investigate the relationship between fare revenue and fare policy and levels.

Computational support

Computational facilities to support HSIPR ridership and revenue forecasts are available from a number of software platforms. Some studies apply commercial off the shelf transportation network modeling software (originally developed for urban transportation demand forecasting) for most or all of the modeling steps. Most commercial network modeling packages allow users to define and automate a sequence of processing steps so that they can be carried out with minimal intervention by analysts. Other studies rely primarily on spreadsheet or other similar generic calculation tools. Even with this approach, network modeling software may be used to extract network data (e.g. travel times and costs) which are then used as inputs to the forecasting process.

Ridership and revenue forecasting for different study stages

In terms of ridership and revenue forecasting, the different study stages (preliminary, intermediate and final) generally lead to different levels of detail in the representation of travel geography (zone system) and the transportation system (modal service characteristics), and to different possible ridership forecasting approaches and methods. The study stage thus has implications on:

- The nature and level of detail of the input requirements;
- The ways in which input data are collected;
- The approaches and methods used for ridership and revenue forecasting; and
- The resulting level of ridership and revenue forecasting effort, accuracy and risk.

As noted before, the distinction between different study stages is to some extent artificial, as a particular study may involve approaches and methods from different stages, and a project does not necessarily transition successively from preliminary through to final stage studies. Nonetheless, this distinction is a useful basis for organizing the discussion of different approaches and methods in use.

Preliminary studies

Preliminary studies are commonly quick turnaround activities where the emphasis is to develop approximate results relatively quickly and with relatively low study effort. Collection of new primary data is generally beyond the scope of these studies, so they tend to rely on already-available sources to produce approximate ridership and revenue estimates. The limited timeline, scope and budget for these kinds of studies do not allow the development from scratch of customized travel demand models: the models used are usually developed elsewhere and are applied with relatively limited adaptation. Travel demand forecasting methods that can be quickly applied to multiple alternatives (e.g. requiring only a coarse representation of project characteristics and other data) are preferable for these studies.

Final studies

These studies emphasize accuracy of results and depth of analysis. They generally require significant effort, time and resources. Detailed information on traveler characteristics and on service characteristics of the HSIPR and its competing modes is needed. Final stage studies almost invariably involve original data collection, particularly regarding traveler behavior; this is used to develop or update suitable travel demand models in the project area.

Final stage studies may in some cases be considered equivalent to investment grade studies that support public (Railroad Rehabilitation & Improvement Financing [RRIF], municipal bonds) or private project financing. There are no formal rules that define the inputs to investment grade forecasts: they are characterized by their outputs. The forecasts must be adequately robust for investors to rely on. As such they must be seen to be comprehensive and based on a good understanding both of the project and of forecasting techniques. Investment grade forecasts are often peer reviewed. The revenue forecasts should clearly reflect key risks associated with the forecasts. The ideal investment grade forecast would:

- Have available recently observed data for all key components;
- Be based on parameters specific to the project, not imported from other studies;
- Not rely on third party models and data, unless these were thoroughly reviewed and checked as to their validity and applicability to the project; and
- Clearly identify and explain key risks and quantify their impact.

Intermediate studies

These studies tend to be defined in terms of their similarities and differences with respect to preliminary or final stage studies, rather than in terms of their intrinsic characteristics. The approaches and methods used in intermediate stage studies are often drawn from both preliminary and final studies as an attempt is made to find a reasonable compromise between data requirements, study

effort and accuracy of results. For example, these studies may use models transferred from other geographic areas but include limited original data collection to adapt the model parameters for more accurate representation of the study context.

Established and evolving approaches

The modeling steps for ridership and revenue forecasting described earlier constitute established approaches that are followed in most HSIPR studies. There is a reasonably broad consensus among practitioners about the use of these modeling steps, although of course different practitioners may prefer different approaches when multiple options are available. However, some approaches in ridership modeling are emerging or still evolving, and these are discussed below.

HSR ridership forecasting is likely to involve explicit modeling of diversion from several modes but this is not necessarily the case for conventional intercity rail, where a regression analysis (demand as a function of a series of factors including service characteristics like travel time, travel cost, frequency etc.; demographic characteristics like population, employment etc.) may suffice. This approach is commonly applied in the UK, where extensive data on conventional rail ridership are available. In the US such methods are less common because of the paucity of historical ridership data and a lack of experience with the approach. Most likely regression methods are not suitable as a basis for a complex forecasting exercise, especially for HSR, but they may provide useful cross-checks of forecasts developed by other means.

Modeling of fare policy is likely to be a challenging element in any HSIPR forecasting effort. It is common for multi-modal models to simplify the fare element in a variety of ways. Such simplifications can have impacts on model outputs when a range of fares is available, and when discounts are available. Representing complex fare policies, such as those prevalent on airlines, requires detailed data at an OD level, while modeling traveler response to such policies necessitates detailed demand segmentation. Yield management, where prices can be varied in response to emerging demand, presents further issues. At a more micro level, travelers may have choices between ticket types with different price implications, such as season tickets, carnets or single trip tickets. Methods for modeling fare policies at such a detailed level are still being researched, and are not commonly seen even in final stage HSIPR studies in the US.

Travel time reliability is becoming increasingly recognized as an important trip attribute, but methodology for analyzing this phenomenon is not well advanced. In highway forecasting, the evidence suggests that some travelers value some measures of time reliability more than time itself. In a multi-modal forecasting context, different modes may need different approaches. The challenge is to gather and analyze robust data on current reliability levels and travelers' responses to them, then to forecast the likely reliability of a new service and its effects on travel demand. Claims of large HSR ridership due to the mode's reliability should be carefully examined.

A similar issue, predominantly affecting air travel, is the increasing inconvenience of security measures, which affect the time taken to pass through an airport and the perceived attractiveness of using air. While the former can be added to the time element of air travel (this is frequently done in current studies), the latter is typically reflected through differential values of time or mode constants. These can be difficult to establish robustly, and surveys may be required to supplement model development.

First- and second-order effects

First-order effects

Forecasts of HSIPR ridership are directly derived from base and future year trip tables, so the accuracy of these trip tables directly influences the accuracy of the predicted rail volumes. Diversions from auto are the main source of short- to medium-distance HSIPR trips, and diversions from air are the main source of medium- to long-distance HSIPR trips. Travel on both of these modes should be estimated accurately; however, given typically large volumes of intercity auto trips, errors in this trip table in particular can translate into significant errors in predicted HSIPR ridership and revenue, even though rail diversions from auto may be relatively small in percentage terms.

Rail ridership forecasts in future years are derived from future year trip tables which, in turn, depend significantly on the methods used to establish and grow the trip tables from the base year to the future. Ridership and revenue numbers could vary significantly depending on these.

Travel time and cost are the two most important variables that affect the attractiveness of HSIPR compared to alternative modes. As a result, model parameters for these variables have first order impacts on HSIPR forecasts. In many cases, the ratio of these parameters (also known as the *value of time*) can be assessed against prevailing local wage rates by market segments.

Some mode choice models have a hierarchical or nested structure that attempts to reflect how similarly (or not) different modes are perceived by travelers. For example, HSIPR is likely to be perceived as having more similarities with other common carrier modes (air, conventional rail and intercity bus) than with autos. The hierarchical structure and associated coefficients in these models can significantly affect HSIPR forecasts.

Second-order effects

Both diversion and choice models typically include an important set of parameters called mode-specific constants that account for the effects of modal attributes that are otherwise not represented in the models. As such, if applied properly their impacts on the demand forecasts should not be significant. However, because they represent fixed adjustments, erroneous values (especially large values) of mode-specific constants can sometimes distort model predictions.

Induced demand estimates, if calculated properly, should also be a small percentage of the total HSIPR ridership and hence constitute a second-order effect. Studies with substantial values for induced demand point to potential problems with the induced demand calculation.

Common errors and pitfalls

Preliminary studies

Preliminary stage HSIPR ridership and revenue forecasting involves many tradeoffs that result from the need on the one hand for an approach that can be developed relatively quickly and then applied to a potentially substantial number of alternatives, and on the other hand for sufficient accuracy in the forecasting outputs to guide decisions about subsequent stages of project development. Forecasting work at this stage may sometimes involve more judgment and intuition than is typically called for in intermediate or final stage work.

Base year trip table development is challenging at this stage of study because of the general inadequacy of data on intercity automobile travel (air and conventional rail trip tables present less of a problem in this regard, as these are more commonly available from operators or public agencies).

Reviewers of a preliminary stage study should closely examine the approach used to develop the auto trip table and be prepared to challenge its reasonableness if necessary.

The mode choice models used in a preliminary stage study are typically transferred from other studies and have coefficients that are assumed to be valid (“asserted”) rather than statistically estimated from local data. As such, the reasonableness of the model for the intended study area should be carefully scrutinized. A preliminary stage study should make some attempt to adapt a transferred model to local conditions through recognition of local socio-economic factors (e.g. the local wage rate affecting model values of time) or transportation conditions; absence of such adaptation efforts could be a warning to reviewers.

Intermediate studies

Compared to preliminary stage studies, intermediate stage HSIPR ridership and revenue forecasting should increase the incorporation of study area context and project-specific factors, while at the same time preserving a relatively efficient forecasting work stream that can be applied to investigate a number of project alternatives. Reviewers should judge how effectively a particular study addresses and trades off these contrasting objectives, and assess the quality of the ridership and revenue forecast inputs that support the selection of a preferred alternative (or small group of alternatives) that will be advanced to final stage study.

To begin with, reviewers should particularly focus on the design, execution and analysis of the primary data collection effort (especially including travel surveys) that is normally involved in intermediate stage studies. While detailed review of such efforts is a task for subject matter experts, non-specialist reviewers should judge whether the major market segments and trip purposes have been adequately sampled, if the survey instruments avoid the use of language or graphics that might bias responses, and if survey questions relate reasonably to the ordinary travel experience of respondents and avoid far-fetched and ill-defined hypotheticals.

Some effort should be made in an intermediate stage study to prepare base year trip tables (particularly for the automobile mode) from primary data sources such as counts, surveys or anonymous vehicle or mobile phone tracking. Publicly-available data on trips by non-automobile modes should be used for this study stage, as well as any other relevant and reliable datasets (e.g. trip table estimates from prior studies). Reviewers will need to assess the reasonableness of the trip table results obtained, as much as the specifics of the data collection and processing methods. Examination of trip table values at the level of large geographic aggregations (e.g. city-to-city rather than TAZ-to-TAZ) can be useful for this purpose.

Mode choice models used in an intermediate stage study may be developed from a combination of econometric analysis of travel survey results, and results transferred from other studies (for example, for less important market segments). Reviewers should judge the reasonableness of the models by, among other things, examining the implied values of time (and comparing this to local information on incomes and wage rates) and the cost or time equivalents of any mode-specific constants³.

An intermediate stage HSIPR study should consider issues regarding access/egress to/from HSIPR stations in some detail, so as to develop accurate values for access/egress levels of service (e.g. travel

³ Mode specific constants are used in mode choice models to represent the average effect of all factors that influence the mode choice but are not included in the model.

time and cost, transfer time and penalty, etc.). Reviewers should examine the assumptions made about future year access/egress characteristics, particularly the relative values for rail and air, and particularly if substantial improvements are assumed. Reviewers should also check that the levels of service of competing modes (e.g. automobile and air) are sensible and reflect prevailing values, as obtained for example from online trip planners or similar tools.

Final studies

Reviewers of final stage HSIPR ridership and revenue forecasting studies should expect to have sufficient documentation of the model development and application effort to allow a full understanding of the process. In general, reviewers should be alert to anything that suggests that the accuracy and level of detail of the study have been compromised through insufficient representation of travel demand and supply conditions in the project service area, inadequate data collection, facile assumptions, and/or improper methodology. A final stage study should provide insight into the robustness of the study results, including quantitative measures of the variability of forecasts under changes in input values or model assumptions.

Base year trip table preparation - particularly for automobile trips - should be based on primary data collection of some sort, unless readily-available data provide sufficient detail and reliability. Even when such data collection is carried out, reviewers of a final stage study should closely examine the approach used to process the collected auto data and be prepared to challenge its reasonableness - methodology for this purpose is still evolving and has not yet been standardized.

Future year trip tables should be developed in part based on anticipated socio-economic growth in the project service area. Factors used for this purpose should be justified to the extent possible using area-specific data - for example, time series analyses of historical growth in travel by mode vs. the considered socio-economic factors.

Mode choice models used in a final stage study should normally be estimated from original primary data, notably in the form of Stated Preference (SP) surveys⁴ of potential HSIPR project users. While the detailed review of an SP survey design requires in-depth technical knowledge, non-specialist reviewers should be alert to common errors including inadequate control of the respondent recruitment process (e.g. recruitment of an unrepresentative “convenience” sample), and survey questions that, by their wording or graphical presentation, tend to encourage a particular response. Typically, respondents should be required to choose between modal alternatives having service characteristics that require a tradeoff decision (e.g. between travel time and cost), without one alternative strictly dominating all others. The choice situations represented in an SP survey should be patterned after actual trips made by the respondent, and not represent a completely fictitious situation to which the correspondent cannot readily relate.

Similarly, detailed review of the econometric analysis used to develop mode choice models from the collected data requires technical knowledge. However, non-specialist reviewers can assess the care with which the collected data have been checked and corrected, and can form an opinion about the reasonableness of the estimated models - for example, the implied values of time for different market segments and trip purposes, the equivalent monetary (or time) value of mode specific constants, and

⁴ As the HSIPR mode in many cases does not exist in the no-build situation, travelers’ modal preferences and tradeoffs between modal attributes are analyzed by asking about choices in hypothetical situations involving the HSIPR mode. These are known as Stated Preference (SP) surveys.

the like. Reviewers should expect to find a discussion of these topics in the forecasting methodology documentation.

Lack of an explicit network-based representation of the modal alternatives and their service characteristics is not necessarily an error but, if such representation is not used, reviewers should closely examine the study methodology and assumptions made regarding future year levels of service by mode. This is particularly so if the study expects the HSIPR project to produce decongestion benefits on highway, air or rail facilities.

Common to all stages

Review of the induced demand results is similar in all stages of study. Methodology in this regard has not been standardized, so a review should focus on the overall reasonableness and soundness of the approach, and verify that the predicted amount of induced travel is not excessive: a forecast of induced travel that is greater than (say) 10% of diverted travel should be examined closely.

3 Public benefits

Public benefits assessment process

The purpose of assessing a transportation project's public benefits is to accurately understand the contribution of the project to societal welfare or well-being. By public benefits we mean the outcomes that accrue to the general public, including from the mobility, economic, social, cultural or environmental aspects of a project.

A project's benefits assessment depends heavily (but not exclusively) on its ridership and revenue forecasts, and the implications that these have regarding project impacts on travelers and the general population. The outputs of a public benefits assessment provide a key input to the project appraisal, whether this takes the form of a cost benefit analysis (CBA), cost-effectiveness assessment, multi-criteria analysis or less structured decision process.

Assessment generally involves two distinct steps: quantification of project impacts followed by valuation (i.e. conversion to a monetary value) of those impacts. As noted, the quantification of many impacts derives from the outputs of the project ridership and revenue forecasting.

In order to express the different impacts in a common unit of measure and facilitate a comparison with project costs, the value of each benefit is determined by converting it into monetary terms whenever possible. Appropriate assumptions for valuations are normally available from official guidance and other existing relevant studies, but for major projects there may be scope for undertaking project specific work to identify the most appropriate values for the study.

HSIPR project public benefits fall into four broad categories:

- User benefits;
- Non-user benefits;
- Financial impacts; and
- Wider economic benefits and a variety of indirect economic impacts.

User benefits

User benefits include savings in travel cost and time, with a distinction frequently made between various time components (access/egress time, wait time and in-vehicle time). HSIPR studies sometimes account for additional aspects of the traveler experience, such as crowding, comfort and travel time reliability. Non-monetary trip attributes are converted to equivalent monetary values using factors that may be developed from traveler survey data or obtained from standard guidance. Each of these items is assessed relative to current travel choices, and represent benefits for a trip that changes to HSIPR from a prior mode. The total benefit for an item is computed by multiplying the per trip benefit by the corresponding number of trips. Benefits to new trips that are made because of the availability of HSIPR service are computed using a related procedure. The total user benefit produced by a HSIPR project is the sum of the benefits for all of these items. User benefits are typically the largest component of overall HSIPR project economic benefits.

Non-user benefits

However, a HSIPR project can provide benefits to non-users (travelers on other modes and the public at large) as well. Benefits to other modes (auto and/or air) occur if the volume of travelers who divert to

HSIPR from these modes is sufficiently large to reduce congestion levels. (This may not be common on highways, because intercity roads from which diversions might occur typically have low congestion to begin with, whereas congested urban roads carry such high volumes that diversions to HSIPR are a negligible fraction of the total.) Impacts on airport congestion depend closely on how the affected air carriers respond to competition from HSIPR. Non-user benefits can also include externalities such as changes in environmental impacts (air quality, greenhouse gas emissions, noise, and the viewscape around the project), changes in travel safety (as travelers divert between modes with different crash rates and severities), and those resulting from having a travel option available for use at times when ordinarily-used modes are unavailable. Some of these benefits can be monetized using survey results or standard values; others can only be represented in a more indicative way.

Financial impacts

The financial impacts of a HSIPR project may fall on the project operator as well as on operators of priced transportation modes that compete with it (e.g. toll roads or airlines). Diversions of travel between these modes can be translated into equivalent revenue changes. Changes in travel on different modes may also affect government tax revenues, and some forms of public benefits assessment would take this into account.

Wider economic impacts and indirect impacts

HSIPR projects may produce a range of indirect impacts that are simply different manifestations of their user benefits. Increased land values, for example, are generally a result of improved travel times and both should not be counted as project benefits. It may be of interest to document such indirect impacts, as long as care is taken to avoid double counting in project benefits assessment.

A HSIPR project that reduces the level and/or rate of growth of congestion on other modes may allow otherwise-necessary capacity improvement projects for those modes to be avoided or deferred, and this effect may be claimed as a benefit (cost reduction) of the HSIPR project. However, eliminating or deferring capacity improvements also reduce benefits to users of the other modes, and this must also be considered. Because of the complexity and uncertainty of these interactions, the impacts of a project on investment needs of other modes are frequently not considered in evaluation.

HSIPR projects may also lead to job creation, improved business productivity and impacts on factor prices which, in some cases, may go beyond the underlying user benefits and constitute additional “wider” economic impacts. Incorporation of these benefits is not yet standard in US practice, so evidence for their importance in a HSIPR project will need to be provided.

Public benefits assessment for different study stages

A public benefits assessment of a HSIPR project should strive to account for all anticipated significant benefits. As the project study progresses, the assessment of each benefit should become more sophisticated and the outputs more robust.

At the preliminary stage of development of a HSIPR project, its public benefits should be outlined to allow the project sponsor, stakeholder or funding authority to gauge their likely magnitude, using evidence from other projects where necessary. Any “show-stoppers” (e.g. large environmental disbenefits) should also be identified.

At the intermediate stage, a considerable amount of work should have been done, with corresponding level ridership forecasts completed and a detailed project specification developed; this allows the benefit quantification to be project specific. However, at this stage the valuation methods may still

rely on benchmarked assumptions because locally calculated outputs may not be available. Nonetheless, all relevant benefits should be included, using estimates and assumptions if required.

At the final stage, the project specification should be finalized and all benefit quantifications should be project specific and supported by detailed network and demand modeling. The valuation of these benefits should be based on locally-applicable data.

Established and evolving approaches

There are a number of impacts that are not typically included in all public benefit analysis although they may be important for a particular project. These items tend to be omitted because sufficient research and evidence about them is still not available, or the costs of quantifying them are disproportionate to the magnitude of the benefits. They can include:

- **Travel quality:** This benefit may be important as a HSIPR project may increase travel comfort, reliability and facilities compared to existing transportation services. However, evidence is weak regarding travelers' valuation of different aspects and levels of travel quality.
- **Option values:** This is the benefit to travelers of having the option to use HSIPR (for example as a "backup" mode when the habitual mode is unavailable), even if they never actually use the service. Again, evidence on valuation of option values is limited.
- **Wider economic impacts:** These are a set of economic benefits associated with transportation improvements that conventional appraisal fails to capture. They include improved business productivity, and job creation impacts other than those directly associated with constructing and operating the HSIPR project.
- **Indirect economic impacts:** These are benefits that may be important on a regional or local level especially in depressed locations, but are transfers and not additional to conventionally measured public benefits. However, they may still be of interest to decision makers and some of these are currently incorporated in the FRA guidance. They include changes in land values, employment levels etc. resulting from direct project user and non-user benefits.
- **Second round impacts:** A HSIPR investment that reduces the level or growth of demand on another mode may eliminate or defer the need for capacity investments in that other mode. This could be counted as a HSIPR benefit, but then the assessment must also count the reduction in benefits to users of the other mode that the investment would have produced.

In assessing the benefits of a particular HSIPR project, it is worth considering whether such impacts are likely to be important. At the least, the FRA or other project proponents should reserve the right to require or make a more detailed assessment of any of these impacts.

First- and second-order effects

Critical factors that can influence the results of a benefits assessment include:

- **Values used to monetize impacts:** Differences in the equivalent monetary values of time or of other impacts (e.g. pollutant emissions) will directly affect the magnitude of the benefits included in the assessment. In particular, given that time savings typically represent a large portion of total benefits, a change in the value of time can cause a large change in overall benefits. Where possible, the values used to monetize impacts should be project specific; if these are not available, then industry standard values should be used. Consistent values should be used when comparing projects to ensure consistency in evaluation.

- Assumptions made for demand forecasts:** Many HSIPR project benefits are calculated using information from the demand forecasts. These forecasts, in many cases, are based on high level assumptions that must be properly documented to evaluate the validity of the benefits assessment. Examples of such high level assumptions might include, among other things, trip purpose splits, auto captivity splits and demand projections beyond model horizon years.

First-order effects

The specific benefits that are most important in project evaluation may vary by project and will also depend on policy and project objectives. However the following benefit types generally have first order impacts when undertaking public benefits assessments of HSIPR projects:

- User travel time and cost savings:** Considering all components of a trip (access/egress, wait, transfer and in-vehicle). These cost or time benefits typically account for the largest portion of the benefits from HSIPR projects.
- Safety/accidents:** These are the benefits from a reduction in crashes and their costs. HSIPR projects have an excellent safety record and will often reduce total crash occurrences because of diversions from other modes.
- Revenues:** In addition to the benefits to transport users, the operators of HSIPR service will receive benefits in the form of revenues, while operators of other infrastructure (e.g. toll road operators) may lose revenues.

Second-order effects

Other potential benefits may be considered when assessing a HSIPR project, although in some circumstances they may be hard to quantify or only have a small impact on assessment results. Such benefits include:

- Decongestion:** This refers to the time and operating cost savings that accrue to users of other modes as people divert from that mode to HSIPR. For example a HSIPR project may lead to a reduction in airport delays and road traffic congestion.
- Environment:** Environmental benefits may include landscape impacts and pollutant or greenhouse gas emissions from a project. Evaluation of the latter requires a life-cycle assessment in order to capture emissions from infrastructure construction, rolling stock manufacturer and power generation.

Table 3-1 below categorizes different benefit items as first and second order.

TABLE 3-1. PUBLIC BENEFIT ASSESSMENT FIRST- AND SECOND-ORDER EFFECTS

Importance Level	Type of Benefit	Benefit
First-order effects	User Benefits	Generalized Trip Costs or Times
	Non-user Benefits	Safety/Accidents
	Financial Impacts	Private Providers
Public Providers		
Second-order effects	Non-user Benefits	Decongestion
		Environment

Common errors and pitfalls

Preliminary studies

Because project-specific data is frequently lacking, preliminary stage assessments often rely heavily on professional judgment about the nature and magnitude of significant impacts, and about their monetization. This can cause both objective errors as well as a subjective upward bias in estimated benefits. Study reviewers should examine the reasonableness of the (many) assumptions that must be made for this stage of project assessment.

The reliance on evidence from previous studies may also cause a failure to recognize the full range of impacts of a particular scheme. The impacts of HSR investments on, in particular, the environment, tend to be very project specific and it is important that such impacts are not discounted purely based on lack of significance in previous studies.

It is likely that the values of time used to monetize time savings will be obtained from government guidance or from other studies. The values used should be carefully reviewed as regards their relevance and applicability to the project study area.

Intermediate studies

Intermediate stage assessments typically entail a mixture of general professional judgment with data and values developed specifically for the project(s) under consideration.

Reliance in the benefits assessment on professional judgment regarding the nature, magnitude and quantification of significant project impacts should be carefully scrutinized. Assessments would be expected to provide analyses of the sensitivity of results and conclusions to the specific assumptions made, and situations where key conclusions of the assessment depend critically on such assumptions would be of concern.

Assessments at this stage may include some consideration and quantification of benefits associated with level of service attributes other than travel time and cost. The impact quantification and monetization methods used for such attributes should be examined and judged as to their reasonableness and consistency with accepted approaches.

Final studies

The caveats mentioned for preliminary and intermediate stages of study continue to apply at the final stage. However, at this stage there should be minimal reliance on generic guidance or assumptions that are not substantiated by reference to project-specific conditions.

Reviewers should pay particular attention to the quality of traveler surveys used to develop the models used in the forecasting task. Model coefficients imply values relevant to benefits assessments (such as values of time) that should be checked for their reasonableness to the project context.

Incorporation of extensions to conventional benefits measures will need to be fully justified, and the specific evaluation methods and values used will need to be reviewed as to their overall validity and specific applicability to the project. In a final stage assessment, for example, the decision to include wider economic benefits should be explained in full, with reference to specific aspects of the local economy that substantiate their incorporation. Similarly, inclusion of second-round impacts (avoidance or deferral of other infrastructure investments) will need to demonstrate a careful analysis of changes in the magnitude and timing of both costs and benefits of these other investments. As always,

reviewers should be alert to possible situations of benefits double-counting, for example via consideration of indirect impacts.

Complex studies can entail complex methods for valuing time and cost savings. It is essential that the methods applied for undertaking the assessment of public benefits are explained in detail, allowing for a review of their accuracy and robustness.

Common to all stages

One of the most common errors in HSIPR studies is for the different components of the study to base their analyses and conclusions on differing project definitions. The operating cost analysis, for example, might assume one service frequency while the ridership forecasts and/or benefits assessment assume a different frequency. Even if a study begins with a consistent project definition, it is easy for such divergence to occur as initial concepts are revised and refined, especially when work progresses at a quick pace and involves multiple groups having less than perfect communications.

Another potential source of error is the use of inconsistent units of account when quantifying different benefits. A choice must be made to measure benefits in terms either of resource costs or of market prices. At issue is the handling of taxes and other transfer payments and price distortions that do not reflect the true cost to society of consuming an economic resource. Evaluation approaches based on resource costs simply remove the transfer payments from unit cost and benefit values (vehicle operating costs per mile are net of fuel tax, for example) and conduct the analysis using these modified values. Evaluation approaches based on market prices also separate the transfer payment components of all unit benefits and costs, but explicitly track such payments (showing changes in government fuel tax receipts resulting from less auto use, for example). The former is more commonly used in the US, whereas the latter allows a more detailed analysis of the tax revenue implications of transportation project impacts. Once the choice has been made, all benefits and costs should be expressed in the same unit.

Double counting of benefits is another very common error that reviewers should be alert to the possibility of at all stages of study. Intermediate and final stage studies may incorporate extensions to standard benefits assessments (such as wider economic benefits, indirect impacts and others) that can make it easy for such errors to be committed. For example, in the current stage of knowledge about wider economic benefits in the US, the burden of proof is normally on the assessment study team to show that consideration of these factors does not constitute double-counting. Caution must be applied when reviewing such claims, and clear demonstration and expert review of their robustness are required before they are included as a benefit.

4 Operating costs

Operating cost estimation process

The end product of an operating cost forecast is an estimate of the annual cost of providing a HSIPR service between two or more stations. Every HSIPR service will incur cost in at least six distinct areas, irrespective of the type and scale of the service being provided. The six principal areas of cost are illustrated in Figure 4-1.

FIGURE 4-1. HSIPR OPERATING COST COMPONENTS



The first step in forecasting operating costs is to understand the outputs of the HSIPR service being proposed and how it will be delivered. The outputs of the HSIPR should be documented in the form of a railroad and train service specification, sometimes referred to as an “output specification”.

Train service outputs

The HSIPR timetable will define the number of train services per day, trip times and destinations served. Operating costs are broadly proportional to the number of services running each day, the total distance operated by trains and the time taken to make each trip. Trip time is driven by a combination of the speed and acceleration characteristics of the train and the number of en route station stops.

A good output specification will also define the type of train which will operate, times of start and close of service and differences in service level across the day (for example, longer trains on some peak services) and across the week (for example, lower numbers of trains at weekends).

The ridership forecasting study will identify the potential customers of the service and allow the quality of facilities provided at stations and on board the trains to be defined. These can have large cost implications.

Delivery structure

The contractual structure through which the HSIPR services will be delivered also has a major impact. The general assumption is that a single entity will have responsibility for providing and operating all aspects of the service shown in Figure 4-1. However, there are variants of this standard model that can obscure where costs are being incurred.

For example, in the above diagram, there is no cost element for train purchase because generally these are treated as a capital cost. However, if the trains are leased or financing is required to purchase them, then the annual payments are treated as an operating cost. Similarly, most HSIPR services will operate on a new railroad, and costs will be incurred as summarized in the railroad operations and maintenance box in Figure 4-1. However, part of the service, such as on the approaches to urban stations, may operate on an existing railroad. In such an instance, access charges would be payable to the owner of existing railroad. These charges will be in addition to operating and maintenance costs for the newly built railroad. The average charge to access a railroad owned by another company, when viewed as a cost per train-mile operated, may be very different to that for a new build railroad, which is entirely within the control of the entity providing the HSIPR service. In more extreme cases, one organization may construct and operate the new railroad and sell timetable slots to a variety of HSIPR operators who then only need to focus on delivering the train service outputs.

Developing the cost estimate

In the cost benefit appraisal, the values of all benefits are estimated irrespective of the organization or entity that receives them. Similarly, when developing operating cost estimates, it is essential to identify all costs incurred, irrespective of the contractual party who will deliver them and incur the cost. The estimate should cover the full geographical extent of the proposed train service and include the costs of operating HSIPR trains, the railroad and stations.

The parameters that have the largest influence over train service operating costs are the number of annual train-miles and -hours operated, and the number and size of stations served. However, the level of customer service offered can also have a significant impact on cost.

These parameters can then be used to estimate resource quantities for each of the six key cost areas presented in Figure 4-1. This will include the number of trains required to operate the HSIPR timetable, staff required on the trains, energy consumed and number of maintenance examinations and therefore engineers, spare components, equipment and depots required.

Unit rates can then be applied to the estimated resource quantities. As the project develops in detail, the key quantities will become better defined. For example, the estimate of annual train-miles will evolve from a straightforward calculation (number of trips per day X distance of trip X number of days per year) to a detailed plan for the service operated by each train set every day, including non-revenue miles to and from depots and lay up points and the period when the train is under maintenance.

As the level of knowledge about the key quantities improves, so also will the detail on unit costs, such as staff. The roles required to be undertaken by staff will be more clearly defined in the later stages of a project and therefore differences in employment conditions can be incorporated. For example, a driver is likely to be paid more than customer service staff at a station and will also work fewer

productive hours per shift due to the safety critical nature of the job. Flexibility of duties (for example, establishing whether train guards can undertake ticket checks/sales as well as train dispatch, therefore potentially saving costs) will also be better understood as the proposal progresses through the stages of development.

Similarly, estimates of quantities of assets requiring maintenance will evolve from an assumption based on route miles, to actual values based on detailed design.

Figure 4-2 and Figure 4-3 summarize the relationships between the key components that determine train service and railroad operating and maintenance costs, respectively.

FIGURE 4-2. COMPONENTS OF THE TRAIN SERVICE OFFER

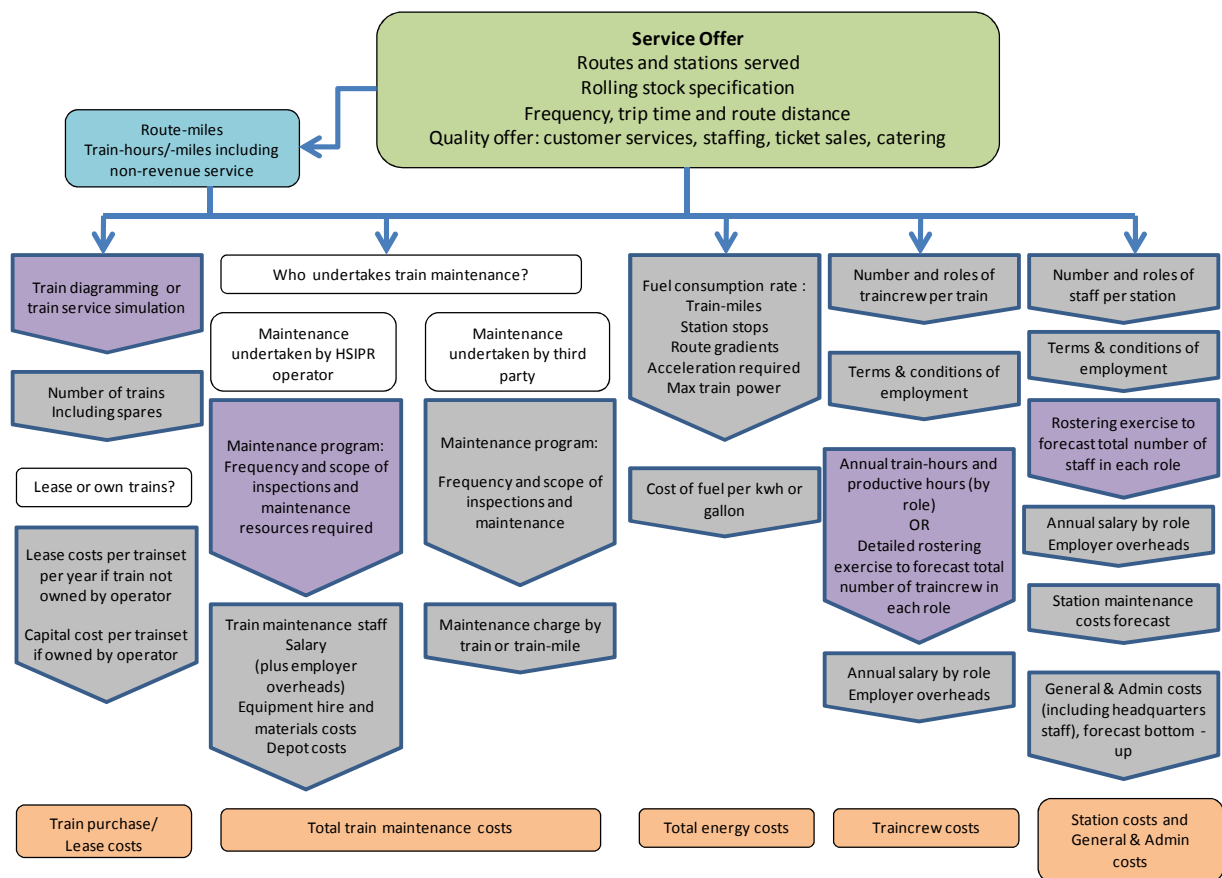
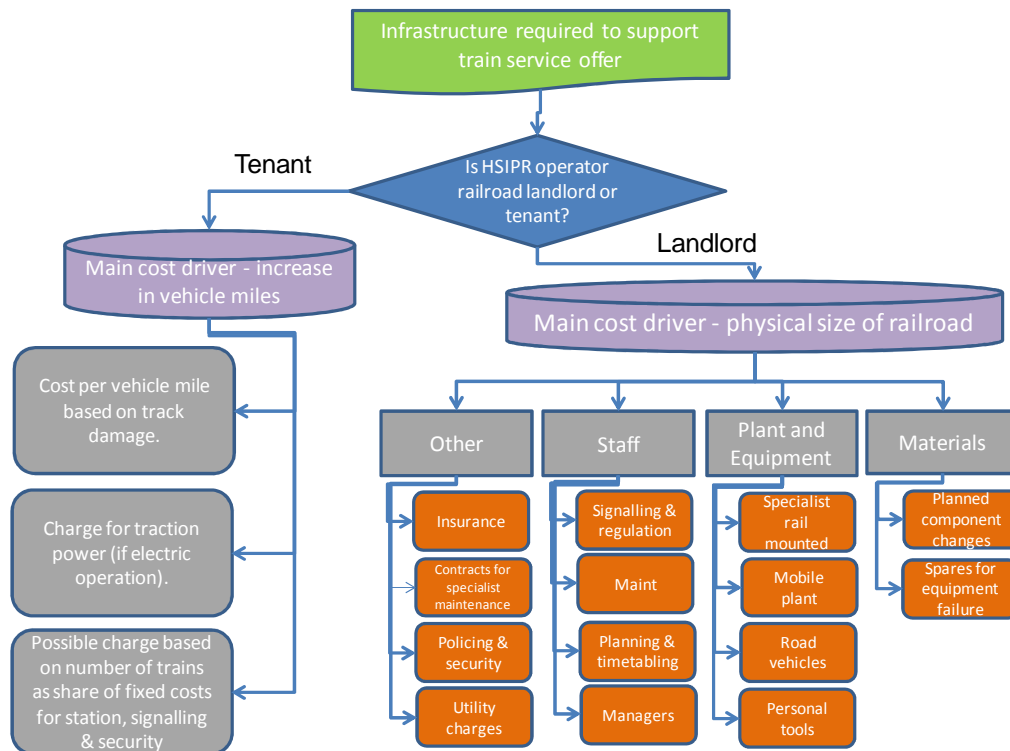


FIGURE 4-3. COMPONENTS OF RAILROAD OPERATION AND MAINTENANCE



Computational support

Spreadsheets are the principal tool used to develop estimates of operating cost. Their complexity is proportional to the number of discrete cost elements and the level of detail available in the project at that time.

Verification of point-to-point trip times and the overall timetable performance is modeled on specialist software packages. Such modeling also gives confidence that assumed turnaround times at terminus stations will be met and that rolling stock and staff resources are being used in the most efficient way.

Resource planning software packages are used to efficiently allocate trains and staff to operate each service in the timetable. Most staff involved in delivering a HSIPR service will work shifts, and these packages help derive the most efficient number of Full Time Equivalent (FTE) staff from the numbers required at a particular time of day to operate and maintain the train service.

Operating cost estimation for different study stages

As a HSIPR project progresses through preliminary, intermediate and final study stages, the evolving train service specification and railroad design provides more detailed information, which is used to further disaggregate the quantities estimated for each of the six key cost areas into more discrete elements of resource - e.g., different grades (and therefore salaries) of staff to reflect different jobs, energy consumed on hilly rather than flat sections of the railroad or estimates of spare parts used for maintenance. This in turn allows more specific unit rates (rather than blended aggregated rates) to be applied to each, thereby improving the accuracy of the estimate.

Preliminary studies

At preliminary stage, a large number of different railroad alignment and train service alternatives are usually under consideration and a screening analysis is used to select a relatively small number of these for further development at intermediate stage. Design of the railroad alignment and train service specification will be very high level, possibly not even at feasibility level of detail and each option will be underpinned by large numbers of unverified assumptions.

The purpose of the operating cost estimate is therefore not to give a detailed estimate within very narrow tolerances of accuracy but to quickly and efficiently compare the cost of each option under consideration while also giving an understanding of the likely scale of the final operating cost.

A simple spreadsheet comparator model is usually developed with a dozen or so key inputs used to differentiate the costs of each option. These would typically be based around:

- Annual train-miles: multiplied by aggregated unit rates to give train maintenance and energy costs;
- Annual train-hours: divided by assumed staff productivity metrics and multiplied by an aggregated unit rate to give traincrew costs;
- Number of railroad miles: multiplied by aggregated unit rates to give railroad operations and maintenance costs;
- Number of stations: usually presented as a fixed annual cost for intermediate and terminus stations (which are generally larger) covering elements such as staff, building maintenance and utilities; and
- A percentage markup to the sub total of the above elements to cover general and administrative costs.

A sizable contingency (40% to 50%) must finally be applied to account for the many uncertainties that are inevitably associated to project specification and cost components. Nonetheless, this type of estimate will give a high level indication of the likely actual operating cost of each alternative under consideration at this stage.

Intermediate studies

These studies consider only a relatively few discrete alternatives. There is more focus on the accuracy of the estimates, but the estimates must not require excessive effort to prepare. The train specification will be more detailed than at preliminary stage, with trip times and turnaround at terminus stations verified by modeling; however a full working train timetable is not prepared. If a new railroad is to be provided, feasibility design will have been completed and the method of operation confirmed (for example, in-cab or lineside signaling, and diesel or electric powered trains). This gives a significantly improved understanding of the railroad capacity (in trains per hour) and of the equipment that will need to be maintained.

More thought will have been given to the types of trains that will be used, and to the acceleration, braking and maximum speed characteristics required to meet the trip times specified by the timetable and to make best use of the available capacity.

This design work allows the key metrics such as track-miles, annual train-miles and annual train-hours to be more accurate than those presented at preliminary stage for the equivalent options. For example, estimates of train-miles and -hours will now include an allowance for train movements when not in revenue service (such as trips to and from the depot).

Based on these metrics, the quantities of key resources are estimated. This includes the number of trains (including an allowance for “maintenance spares”), the number of staff in each role (where traincrew staff and station staff comprise several defined roles, such as driver, guard and catering staff) and the volume of energy required to operate the service.

The unit cost rates applied to the key quantities will be more disaggregated than those used at preliminary stage, making it possible to improve accuracy by benchmarking against other HSIPR projects in a more informed way.

While train and railroad maintenance costs will usually be forecast on the basis of unit costs applied to track-miles and annual train-miles, at intermediate stage it is reasonable to expect some form of separate verification, by estimating the labor and equipment that would be required to undertake the maintenance work. This is usually achieved by estimating the number of maintenance inspections per annum required on the full HSIPR railroad and train fleet.

General and administration costs (including head office costs) are estimated by identifying a number of key cost categories such as directors, internet and call centre ticket sales, head office staff, and specialist support services and estimating high level costs for each of these.

Contingency still needs to be applied and would usually be around 20% to 30%.

Final studies

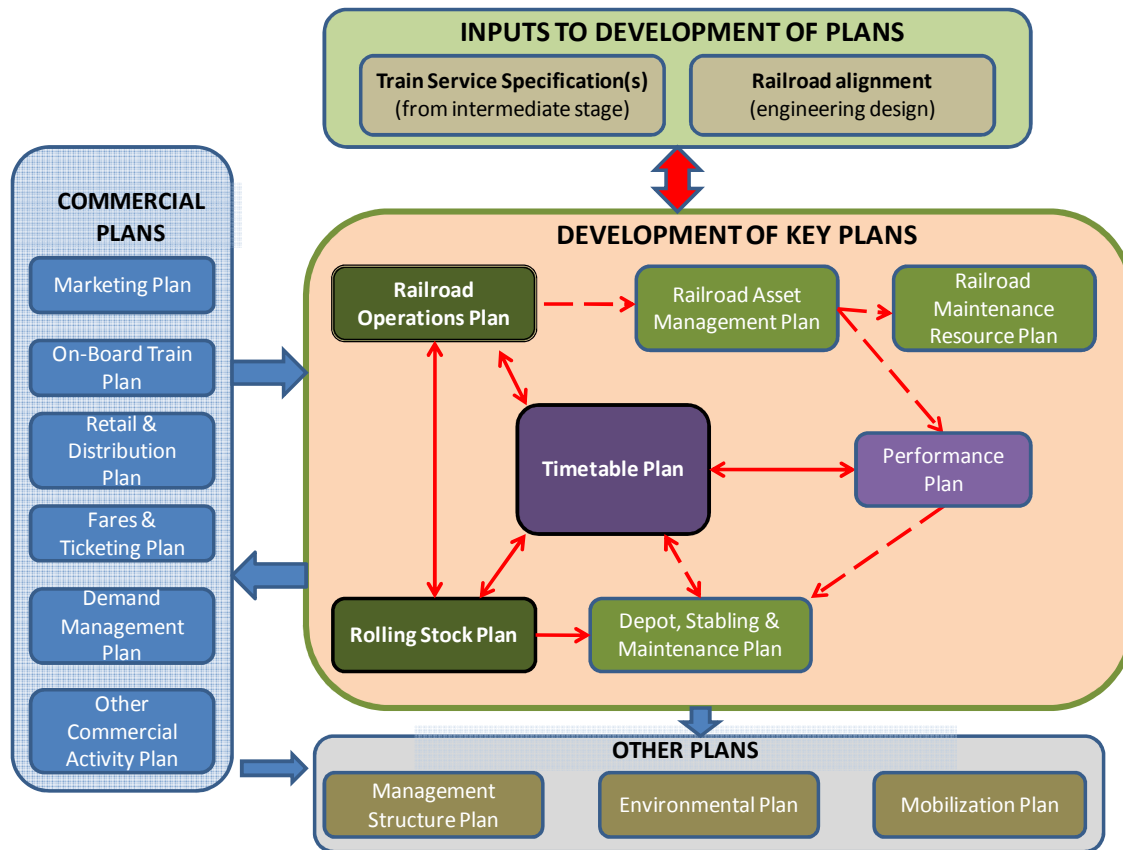
Operating costs prepared for a HSIPR project at final stage will represent a step-change both in terms of the detail and the accuracy to which costs are prepared. This reflects the fact that only one railroad alignment and train service option is now under consideration. Forecasts are prepared using a bottom-up approach, based on a detailed specification of all aspects of the HSIPR proposal, and using modeling to estimate the key resource quantities.

At this stage a detailed specification will exist for the trains to be used, and a full, detailed service timetable will have been prepared. The timetable will cover every hour from start to end of service, for weekdays, Saturdays and Sundays. and will have been validated through modeling. This will confirm that trip times are realistic given the rolling stock, station calls and railroad alignment. The modeling will also verify that the individual services operating on the HSIPR railroad do not conflict with each other, particularly at junctions and on the approaches to stations, and that the whole system operates reliably. The forecast of annual train-miles and train-hours will now be very accurate.

Management and technical plans will have been prepared to document all aspects of the HSIPR service delivery. These plans provide the data that underpins the operating cost estimate; for example, the locations of train and traincrew depots will have been defined and the number and grades of staff estimated. A variety of detailed plans define the train service timetable, how the trains (rolling stock) will be operated and maintained, and how the railroad will be operated and maintained. The types of plans typically produced and the relationships between them are summarized in Figure 4-4.

Specialist resource planning software will be used to quantify the number of staff working each shift at stations and depots and to allocate trains and traincrew to each service in the timetable. This planning takes into account the labor contract terms and conditions, and ensures that there is adequate cover for holiday, sickness and training.

FIGURE 4-4. MANAGEMENT AND TECHNICAL PLANS



Energy consumption modeling is undertaken to provide accurate forecasts of the amount of energy (kWh of electricity or gallons of diesel) that the service will consume on an annual basis. Key inputs to the modeling are the railroad alignment, timetable (particularly station stops and point-to-point trip times) and rolling stock specification.

The types and frequency (usually on a mileage basis) of inspections and servicing will be fully defined for the type of trains proposed for use. The labor, materials and equipment required to undertake each type of inspection and service will be defined.

The railroad design will provide information on actual quantities of assets that will require inspection and maintenance and will define the technologies used. The HSIPR operator will forecast the volume of resources required to undertake the maintenance based on the railroad maintenance plan. This plan defines the scope and frequency of each inspection for the different railroad assets, and will prepare an annual maintenance schedule that takes into account the availability of the railroad for maintenance at different times.

The timetable, train operations plan and the customer service plans (such as the ticket distribution plan) will define the number of staff required at each station. Numbers of staff at each station will also be influenced by the station design plans, which will also determine the costs of utilities and of materials for maintenance.

At final stage, the General and Administrative (G&A) cost category fully specified. Head office costs will be quantified by identifying the management structure and the supporting staff, based on defined roles and grades.

The selection of unit cost rates at final stage will reflect discussions with suppliers (such as train manufacturers, unions and energy suppliers) regarding the likely terms and conditions of contracts. Labor costs will reflect the salaries, employer overheads, and terms and conditions of each role and grade. Unit costs should no longer be based upon benchmarking.

A provision for contingency is still required, but it will be determined through identification and quantification of risks rather than by applying a single markup to the sub total. The total level applied for contingency will be of the order 10% to 20%.

Commercial closeout

Prior to being granted a concession to operate a HSIPR service, a firm commercial offer has to be provided by the operator. At this point, detailed engineering design will have been undertaken for both the railroad and the trains.

The HSIPR train service operator will have a detailed plan to deliver the specified services, based on refinement of the management and technical plans developed at final stage and shown in Figure 4-4. These will include full shift rosters for traincrew, station and maintenance staff along with training and development programs. Negotiations will have been undertaken with labor unions to finalize the terms and conditions of staff who will be employed to operate and maintain the HSIPR service.

Preferred suppliers for trains, energy, plant and equipment and constructing/refurbishing the railroad, stations and depots will be identified and firm costs agreed for the supply of services.

The key difference between a final stage and commercial closeout estimate is that the later will use unit rates which have been negotiated with suppliers rather than estimated. The allocation of commercial risk between the HSIPR operator, financier and other parties involved in the contractual arrangements will have been defined.

By commercial closeout, there will be few uncertainties and the risks identified at final stage will have been substantially closed or mitigated. Contingency would be of the order of 5% to 10%.

Established and evolving approaches

For most HSIPR projects, it is acceptable to prepare preliminary and intermediate stage operating cost estimates in a top-down manner, with appropriate contingency applied. However, a step change in detail is required at final and commercial closeout stage, with the estimate prepared on a bottom-up basis, and a quantified risk assessment of the full HSIPR project undertaken.

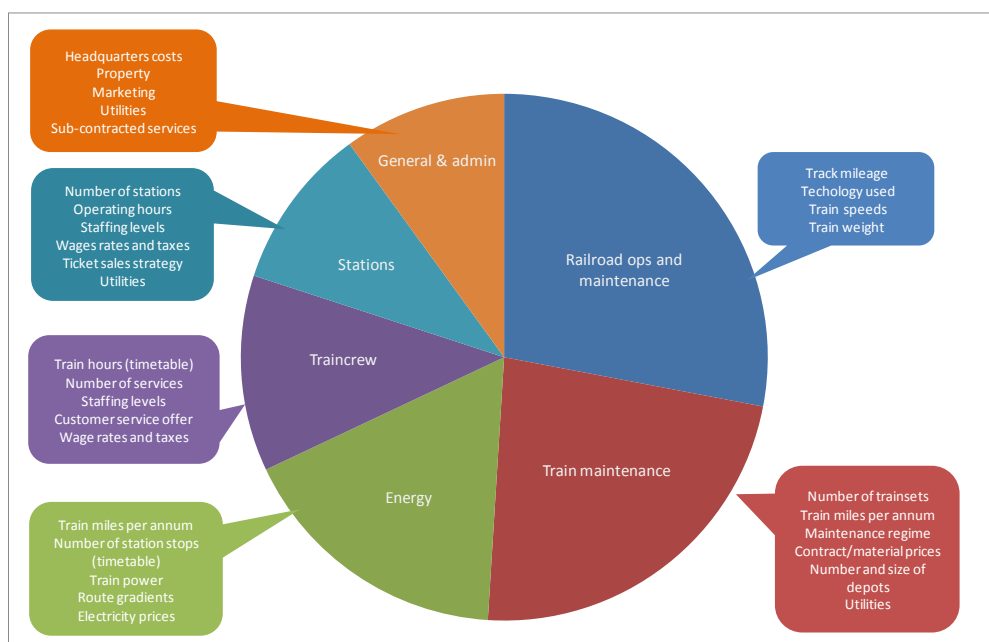
Timetable modeling and resource planning software must be used in final stage proposals to confirm that the proposed train service is deliverable given the railroad capacity, and to accurately forecast the level of resources (trains, staff and fuel) required to operate the service. Some timetable modeling should also be undertaken at intermediate stage to confirm that the trip times proposed in the train service specification (and upon which ridership and benefit forecasts are prepared) are deliverable given the expected characteristics of the railroad, the trains and the proposed station stops. As with all software models, the accuracy of outputs depends on the quality of user inputs, and it is important that the modelers have both a proven track record of using the software (and interpreting its outputs) and also understand the nuances of the proposed HSIPR service.

One area of costs that is evolving, especially in Europe, is the allocation of railroad maintenance costs between different operators to reflect the capacity used and track wear and tear produced by the trains of each operator.

First- and second-order effects

Figure 4-5 shows typical proportions of total HSIPR operating costs accounted for by each of the six cost categories. Around 65% of operating costs are accounted for by train maintenance, railroad maintenance and energy. These costs therefore represent first-order effects. If trains are leased or financing payments are included as an operating cost, this will be sufficiently large and hence should also be considered a first-order effect. Traincrew cost is the largest of the second order costs.

FIGURE 4-5. PROPORTIONS AND KEY DRIVERS OF OPERATING COST



While Figure 4-5 provides a useful indication of the relative magnitude of each of the cost categories, the proportions will vary according to the characteristics of the proposed HSIPR. For example, the proportion of energy costs will be lower on a 100mph service across generally level terrain with no intermediate station stops compared with a 200mph service across hilly terrain with several station stops. Furthermore, where proportions of cost in an estimate vary significantly from those presented in Figure 4-5, it is often the case that the particular HSIPR has some specific characteristics that mean that the “rule of thumb” is not applicable.

In practice, second-order costs (such as traincrew costs) are easier to forecast than first-order costs (such as train maintenance), and therefore tend to be more accurately forecast. Because first-order costs of train maintenance, energy and railroad maintenance are difficult to estimate, these can often be over-simplified and under-estimated in preliminary and intermediate stage studies.

Common errors and pitfalls

Preliminary studies

The main reason for poor quality operating cost forecasts at the preliminary stage is a failure to reflect the specific characteristics of the HSIPR service being proposed. Without a clear understanding of the railroad route, the level and quality of train service that will be offered and the standards that must be complied with, it is likely that costs will be incorrect by an order of magnitude, through a combination of underestimation of some elements and omission of others.

Estimates developed at preliminary stage are primarily used to compare between different railroad alignment and train service alternatives, but can often be misrepresented as also giving an accurate value for the likely cost of operating the HSIPR service. If a large contingency is not applied, the high-level nature of preliminary stage estimates will generally underestimate the true cost of operating the HSIPR service.

Intermediate studies

At intermediate stage, estimates often take an over-optimistic view of the implications of standards, either assuming that the costs to meet them will be low or that a derogation to the standards will be granted. Specific examples include assuming that standard European HSIPR trains can comply with FRA standards without modification and that trains can be operated with a single driver.

Other pitfalls at the intermediate stage include choosing inappropriate unit cost rates for train or railroad maintenance or energy consumption, resulting in total operating costs being significantly higher or lower than they should be. If unit cost rates are derived from benchmarking other HSIPR operations, it is essential that the relative characteristics and standards of the HSIPRs are understood in order to identify a realistic benchmark rate.

Care must be taken when using benchmarked rates for projects which have a low train service frequency (hourly or less) or run over shorter distances (<100 miles per trip). These factors will result in a very low value for annual train-miles compared to the norm. Maintenance costs are not fully proportional to train-miles operated because a minimum level of inspection is required and energy costs are determined by train speed, number of station stops and the gradients and curvature of the railroad. Published benchmarks of energy and maintenance costs per train-mile generally reflect large HSIPR operations and may not be appropriate for use on smaller projects.

When forecasting labor costs, one of the most common pitfalls is estimating these as a single cost category rather than disaggregating staff into separate cost categories to reflect different competencies and responsibilities such as shown in Figure 4-1. For example, staff responsible for maintaining trains should be included in the train maintenance cost category and station staff should be included in station costs. This issue most often arises as a result of a poor train service specification and a lack of understanding of the different roles and responsibilities of staff. Failure to understand the different roles involved and the functions that they perform often leads to under-estimates of number of staff required and inappropriate unit cost rates (salaries plus overheads).

While HSIPR cost forecasts at this stage generally include forecasts of what are felt to be the main operating cost components, it is not unusual for costs of managing and administering the operation, payments to smaller third party suppliers, advertising and marketing costs, IT costs and utilities costs to either be completely excluded or significantly underestimated. If key cost items are omitted, this will result in a significant under-estimate of operating costs.

Lastly, perhaps the main omission in intermediate operating cost estimates is a failure to include a contingency provision. Contingency is required to reflect the fact that the cost forecasts are prepared to a relatively short timescale, on a top-down basis, often using unit cost rates derived from other HSIPR services or studies.

Final studies

Operating cost forecasts at final stage must be prepared on a bottom-up basis to produce the level of required accuracy. However, train and railroad maintenance costs in particular, continue to be forecast at final stage using a unit cost per train-mile or track-mile rather than by developing estimates of workload required based on the maintenance needs of the actual equipment that will be used.

The level of work undertaken to develop HSIPR operating costs at final stage should reflect considerable analysis of cost drivers and unit cost rates. If the unit cost rates at final stage are the same as those of intermediate stage, costs forecasts are likely to be incorrect. Annual labor costs are an example of this: at final stage, these should reflect specific employment terms and conditions (employer insurance and pension payments, holiday and sick pay, etc.)

Where the costs of compliance with legislative standards have been under-estimated or omitted at intermediate stage, this is often carried through to final stage forecasts. For example, driver costs may be under-estimated by as much as half if it is assumed that a HSIPR operation will be granted a derogation of the safety standards, which implicitly require double-staffing for some types of services. Similarly, leasing or financing costs for new trains may be significantly under-estimated if it is assumed that “off the shelf” European type trains will fully comply with FRA safety standards. In reality, modifications are likely to be required to European trains to comply with US standards.

A similar pitfall is failing to verify that cost discounts included in the forecasts are achievable in practice. For example, forecast energy costs may be erroneously low if it is assumed without verification that electricity returned to the system can be re-used by other trains: train service frequencies may prevent this, or it may simply not be practical to export the regenerated power.

One of the main pitfalls encountered at final stage is inconsistency with the assumptions that underpin the separately-developed cost and ridership forecasts. This usually arises from failing to integrate decisions taken in forecasting passenger ridership and revenue into the operating cost estimate (and vice versa). For example, a commercial decision may be taken to increase farebox revenue by offering a higher level of on-board customer service. However, if this decision is not communicated properly within the study team the traincrew operating costs are likely to be under-estimated as the number of customer service staff will be lower than required in reality. This type of error is more likely where the time period for developing the final stage proposal is tight, or where the Intermediate stage costs or ridership have not been prepared in accordance with best practice.

A HSIPR final stage estimate should include a quantified risk assessment to provide a forecast of the contingency required. One key pitfall encountered at final stage is an over-simplified assessment of risks, both in terms of their identification and their quantification (and inclusion in operating costs).

Commercial closeout studies

At commercial closeout, the HSIPR operator must develop operating cost estimates to a level of detail sufficient for its governing board to agree to a commercial contract to provide the service. Accordingly, operating cost forecasts at this stage must be based on firm prices from suppliers of

trains, maintenance labor, spare components or services. Significant inaccuracies can arise if cost forecasts are not supported by firm prices, or if the terms of the supply contracts are misinterpreted.

Commercial closeout estimates should provide very accurate forecasts of operating costs for a “steady state” year. However, they can often fail to consider how these costs will change over time during the concession period. Costs may change in response to variations in the unit costs of inputs (such as the cost of fuel or staff salaries), or if the quantity of inputs change (for example, if train consists or frequency change to accommodate growth in passenger demand). The impact of future changes in standards is often omitted in operating cost forecasts: for example requirements for lower emissions from locomotives at a specified date in the future.

