ABSTRACT

PLANNING TOOL FOR THE EVALUATION OF RAILWAY PROJECTS IN DEVELOPING COUNTRIES

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The funds available for railway investments are becoming tighter almost everywhere. Thus, both a more efficient use of existing capital and labor resources and better investment decisions are necessary. In addition, greater consistency is needed between investment and operating decisions and the current or likely commercial practices of the railway. The paper first reviews the nature and objectives of railway investment analytical tools and modelling demands. It brings out that analysts responsible for evaluating railway investments need a tool which is easy to use in a wide range and hierarchy of investment and operational decision situations.

The paper then sets out the structure of an analytical, computer based tool that has been developed by the World Bank to address such situations. The types of analysis or computations that can be performed under conditions specified in plain language by the user are illustrated. These may range from the aggregated, railway-wide impacts of different levels and types of traffic demands, and the investments needed to meet them, to detailed analysis at the specific line, yard or sub-system levels. The degree of output detail - in terms of, among other things, cost summaries, rates of return, operational statistics and financial data - is determined by the user in the light of his decision or analytical needs and the time and resources available.

The views offered are those of the authors and not necessarily those of the World Bank and its staff.

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Planning Tool for the Evaluation of Railway Projects in Developing Countries

Introduction

The World Bank made its first loan in 1946. This post-war general reconstruction loan to France included funding to rehabilitate the railway. By the end of 1982, out of a total in excess of $18 billion of Bank financing for transport, over $5 billion was for the railway sector. Much greater amounts have been mobilized by the Bank's borrowers from their own resources, from other lenders and bilateral donors to implement railway improvements inside or outside of Bank-financed projects. The Bank's sustained effort over the past 35 years is testimony of its belief that efficient railway services are needed in many borrowing countries. This perception will remain at the center of the Bank's continued efforts to bring about institutional, operational, financial and investment decision improvements in railways. A recent Bank policy document[1/] summarizes the Bank's experience in lending for railways and charts the course for its future involvement in the sector.

This paper is in three parts. First, it provides a brief sketch of the main thrust of the Bank's policy towards the problems faced by railway policy planners and managers. Secondly, it summarizes the evolution of some key analytical planning tools used by railways, particularly in North America - although similar developments have taken place elsewhere. Finally, it sets out the structure and uses of RAIL (Railway Analysis Interactive Language) - a planning tool that has been developed by the Bank to assist in the design and appraisal of railway investment projects.

I. Orientation of future Bank support for railways

The focus of future Bank support for railways will be on: (i) institution building and technical assistance; (ii) operational improvements; (iii) financial and economic efficiency considerations; (iv) optimizing investment decisions in terms of size, timing and location; and, more generally, the best use of resources encompassed within (i) through (iii) above.

(i) Institution building and technical assistance. Railways are management-intensive organizations, especially in the middle, supervisory grades. For efficient operation they also need abundant, wide ranging technical skills. The skills and managerial experience needed are in short supply in many developing countries. Thus, large and continuing training efforts are required to improve railway management and operating staff

1/ "The Railways Problem," January 28, 1982 [4].

performance. Such investment in human resources can have major benefits by increasing the productivity of the railway's total asset base. The pay-off comes, however, only where those who have been trained are able to use their new knowledge. This may often mean, however, that attitudes within railway enterprises as well as government policy directives to the railways need to change and sometimes dramatically.

(ii) Operational Improvements.
In addition to the familiar technical efforts to yield the highest possible output from the railway technology in use, operational improvements include the best application of managerial and other staff skills to developing and continuing railway services for which there are comparative advantages. Recent Bank reviews have shown, for instance, that there are abundant opportunities for substantial operational improvements in many railways at low, or almost zero, investment cost. In a number of instances these can be attained by re-organizations, greater freedom in decision making to managers, policy modifications and so on. Doing more with less is a priority objective of using the same asset base to increase carrying capacity substantially.

(iii) Financial and economic efficiency considerations.
From this focus on identifying the comparative advantages of railways and exploiting the maximum potential from them, the possibility of financial viability emerges on the basis of cost-reflecting tariffs. Such pricing is advantageous to railway users as a group, since it reflects comparative advantages, real resource consumption, and avoids cross-subsidization. The need to use available railway resources efficiently as a driving force to bring about operational improvements also implies a continuous focus on factors influencing costs. Therefore, cost analysis and related information systems for decision-making purposes will be areas of increasing attention in future Bank railways work.

(iv) Optimal or near optimal investment policies.
Many sound opportunities exist for additions to rail-carrying capacity, and for the renewal of various capital items. The problem for railway planners is to find the optimal set of investments, out of usually large number of

> perceived needs, which brings minimum costs within the railway sector for those railway services showing comparative advantages in a specific country. This optimal set (or something approximating it) will flow from operational improvements which move the railways toward maximizing internal cost reductions, and from pricing which responds to the resource cost of the services provided. It will also ensure the financial flows required to continue operations and finance expansion of services in response to demand increases. This approach, the Bank considers, offer the best route to the substantial reduction and eventual elimination of government subsidies to railways which, experience suggests, are generally of dubious equity and economic value, not least because of the long-term distorsions to the location of economic activity which can result [4, 6]. The Bank, therefore, will seek to assist its borrowers to attain more rigorous standards of investment appraisal. In particular, emphasis will be on ensuring optimal sizing, timing, resource mix, and maintainability, among other factors.

In summary, the thrusts of the Bank's future involvement in the railway sector derive from a recognition that railways generally will face much tighter resource constraints than in the past. As a result, they will need to pay careful attention to seeking cost effectiveness and financial independence; providing services for which they have clear advantages; rearranging the mix of services to take the fullest advantage of the existing asset base; and the need to develop sound managerial and technical skills as well as efficient institutional procedures.

II. Evolution of analytical tools

The evolution of analytical tools in the railway field reflects both changes in the way railway planners and managers have perceived the nature of the problems they were faced with, an expanding 'state-of-the-art,' the falling cost and wider availability of computers. The path from simple rail simulation models to more analytic, optimizing models in the U.S. and Canada, has been extensively reviewed by Petersen [2]. This section draws heavily from it.2/

2/ While the illustrations are drawn from the North American scene many railways in Europe and elsewhere developed and applied either system designed or 'off-the-shelf' models of various kinds.

- Rail Simulation Models

The first applications of modelling techniques in railways involved major efforts to develop train performance calculators that simulated the movement of trains over a track of given profile. These accurately calculated acceleration, deceleration and free running times over a line and enabled engineers to select the best combination of locomotives for a given train consist. It also is necessary for the calculation of train schedules. Many railways developed or obtained the use of such a model. A typical example among many is the Canadian National (CN) train performance calculator.

The next major development was on network simulation models. These models simulated the movement of trains and cars through a network of lines and yards based on a given set of train schedules and the line and yard operations policies. The user had to input a complete set of train itineraries, the marshalling rules at each yard which prescribe how cars are blocked, the take policy for each train which controls the order in which a train will "lift" blocks until it has its required consist, and the traffic flow included the time cars became available for movement. The simulation model would move the traffic through the network based on the input rules. Output from these models included the congestion at points in the system, the transit times for traffic and the utilization of rail resources. This permitted the analyst to evaluate the operation in detail and to test alternate operating policies.

A typical application in the early seventies used this type of model to simulate 100 trains operating over a network of 41 nodes. These models had the major shortcoming that it was necessary to prepare enormous amounts of data as input to them. In addition, large amounts of computer time was required; for example, CN claimed it could simulate trains operating 400 times faster than real time. This meant that one hour of computer time was required to simulate operation of the network for a two-week period. Thus, while considerable detail could be included, limited numbers of policy options could actually be evaluated to test their cost and other effectiveness.

The latter part of the 1960's also saw the development of detailed simulation models that could be used to evaluate either the design of a new yard or the operation of existing ones. Typical of these are the New York Central yard model which is a large GPSS model. Again, the difficulties include large input data and computer time requirements. In addition, they have the characteristics of all large simulation models in that as they become as complex as the real system, insight into improvement options become difficult to discover.

Recent uses of simulation techniques have tended to focus more on specific rail problems. North American railroads, for example, are currently studying mainline capacity limitations on the basis of several simulation models that have been developed and used with considerable acceptance. We note three major limitations of these models, however, that restrict their continued use in varying degrees. They are: (i) inflexible structures, arising from a model design for a specific railway problem; (ii) the substantial and fixed data requirements needed to operate the model; and (iii) a difficulty in handling high-intensity traffic due to line blockage (i.e., a coarse representation of line congestion).

More recently, work by Petersen (op.cit.) has shown a general structure for modeling rail lines on the basis of closed form algebraic expressions, and developed computationally simple conditions that ensure trains will not be dispatched so as to block a line. Optimization procedures and simulation models of the line can be implemented using this approach.

- The Use of Analytical Models of Rail Operations

The 1970's saw a major shift in the development of analytic models of rail operations. The large simulation models became cumbersome to use and did not permit the application of optimization procedures. Thus more theoretically-based models were required if analysts were to evaluate actual or potential operating policies or facilities.

(a) Analytic Line Models:

Petersen [2] developed a steady-state analytic model of a rail line to assist in the analysis of the following type of problems:

1. Calculation of the expected performance of each type of train over a particular line,
2. Assessment of line capacity,
3. Evaluation of line performance as a function of traffic type and volume,
4. Parametric analysis of performance as a function of line or operating variables, and
5. Evaluation of alternative line upgrading strategies.

This LINE model calculates the expected train running time over a rail line, including the effects of meets, overtakes and dispatch delays. It is capable of handling a variety of train classes and signalling and control systems. Partial double-tracking, variable siding spacing, slow running orders, bottlenecks, and variable train priorities are permitted. These characteristics can be dependent on the direction of travel. Computation time is minimal since the model is analytic, i.e., in equation form. In addition, allows parametric type analysis to be easily performed, such as exploration of relationships between expected transit time and the volume of traffic, train speeds, siding spacing, etc.

The LINE model first calculates the delays encountered when meets and overtakes occur. Based on the track configuration, the signalling system, and the train classes and their relative priorities, a matrix of expected delay times between each pair of train classes is calculated. In describing the line configuration, different levels of detail may be specified.

The model then calculates the transit times for the bottleneck or most congested section along the line. Trains queue to be dispatched over this section and by using queueing theory the expected dispatch delay per train class is calculated.

Given the matrix of interference delays and the expected dispatch delays, the number of trains per day of each class, and their congestion-free running times, the number of meets and overtakes per day is simultaneously calculated, for each pair of train classes and each direction. The expected point-to-point transit times are then calculated.

(b) Analytical Yard Models

Several researchers have applied queueing theory or other analytic models to yard processes. Typically they describe the different yard operations in a classification yard and empirically fit delay relationships to observed data. Queueing models have also been used to calculate the optimal number of receiving tracks in marshalling yards.

Yards may be classified according to their structure and resources as being one of the following types:

1. simple yard
2. single-ended flatyard
3. double-ended flatyard
4. directional flatyard
5. hump yard.

Each car passing through a yard encounters five major operations or delays which contribute to the put-through time. They are:

(i) arrival and inbound inspection
(ii) train breakup and classification
(iii) waiting for connections
(iv) train marshalling or assembly
(v) outbound inspection and departure

Each and all of these operations can be modeled using queueing theory.

First the YARD model calculates the switching required to classify and to assemble each train. These calculations take into account the physical layout of the yard including the configuration of the switching leads and the number of classification tracks. The number and relative size of the marshalled blocks also affect the switching workload. The switching workload determines the rate at which trains can be classified and assembled. Limited standing capacity within the yard modifies these processing rates.

The classification and assembly operations are modeled using M/G/s (Markov/General/Servers (#)) queues, with the connection delays represented by a $M/E_k/1$ (Markov/Erlang k/1 server) bulk queue. Arrival and departure inspections are modeled by fixed service times.

(c) Optimizing Network Models

Optimizing network models search for the routing of traffic through a rail network that minimizes an objective function such as total cost or total delay. These models require traffic to be specified on an origin-destination (OD) basis.

In their more complex conception these models, as in work done at Queen's University, Canada [2], may use the previously described analytic line and yard models to represent the delays incurred in each facility as a function of its volume of traffic utilizing. The model routes traffic from origin to destination so as to minimize total yard and line delays.

Other investigators have formulated rail network models that help to determine optimal operating policies for a railroad from the view point of hierarchical decision-making. That is, by distinguishing tactical from operational issues, and integrating the routing and the train make-up decisions by explicitly considering the effect of train composition on the classification delay at a yard. The resulting model has the usual structure of a multi commodity flow problem characterized by nonlinearities in the objective function.

(d) Optimal Marshalling and Train Scheduling Policies

The marshalling policy dictates for each yard the number of freight-car blocks that traffic is sorted into, and how these blocks are used to make-up the departing trains. The train schedules prescribe the times each train departs, its itinerary including its origin and termination and its intermediate yard stops.

These policies are interdependent and any formulation that includes these interrelationships quickly becomes totally unmanageable in size. Therefore, train marshalling or blocking, train scheduling, and train timetabling are usually separated into three separate problems and decisions. Formulating them as optimization problems results in large, mixed integer, nonlinear programming models that can be solved for only small numbers of yards and trains (see [2] for reference list). Attempts to devise good heuristic solution procedures have had limited success.

At the most detailed operational level is the problem of optimal train dispatch. This involves the decisions regarding how train meets and overtakes are programmed so that the maximum performance can be achieved (see [2] for reference list).

(e) Optimal Utilization of Rolling Stock and Motive Power

High utilization of rolling stock is essential for the efficient operation of a railroad and requires that wagons of the right type be in the right place at the right time. This problem has been successfully solved using linear programming, and has found acceptance with many railroads [2].

The motive power scheduling problem involves moving locomotives on the network so that all scheduled train movements have the required power. Numerous attempts to solve it by using optimization techniques have been made with some measure of success.

(f) The next step

It might appear from the foregoing discussions that we have models (whether simulation based or analytic), to analyse most railway problems and to predict the physical consequences of changes in operating policies or facilities. In reality, we are much more limited in our ability to optimize these. And, while the accomplishments are impressive, several challenges remain if the analytical support required by future Bank involvement in the railway sector is to be well founded. First, is the need to address the economics of rail transportation. Most rail models deal with physical operations, such as equipment utilization or transit times and tend not to include costs. This reflects the research emphasis in most railways which is engineering oriented, focusing on physical and technical factors in the system. Short term, local cost minimization is followed, in a yard, for example, the yard master is responsible for the control and minimization of his variable costs. This translates into maximizing the utilization of his switching engines and yard crews which, in turn, implies an "optimal" operation which has long queues with large yard put-through times. The yard master is not charged car delay costs nor do the incentives he faces encourage him to consider these.

A second illustration of the lack of economic considerations usually comes up in plan expansion decisions. For example, the capacity of a line to move trains is usually expressed in terms of when the delays become unacceptable for the operation of the line. A number of U.S. railways consider a line is at capacity when the delays encountered by a train is some fraction (say 50%) of the free running time. Others base capacity on the maximum allowable crew times. While these are important components, they can only be related to the benefits of increased line capacity if they are translated into costs.

Costing models based on econometric analysis of railway accounts have been developed [2] which are valuable for freight rate setting and regulatory purposes. They do not, however, assist the rail manager in selecting optimal facilities or operating policies. Rather, analysts and managers need costing models that are sensitive to changes in both facilities and operating policies. This requires extension of our current models of physical activities to include costs and benefits. This is a challenge that will permit the development of planning tools which better reflect the economics of rail transport.

A second challenge is the need to gain a stronger appreciation and understanding of the managerial and organizational processes functioning in railroads and how changes in these are fed into cost performance. Most of the models described earlier study the process that is being controlled by managers, but they fail to appreciate the managerial requirements actually involved for decision making. For instance, how often are the results from our models in a form that managerial personnel of even modestly sophisticated numeracy can understand and readily use them? Do they have data output which is timely and in a form which permits good decisions to be taken? Finally, can managers easily make changes to operations or organization forms, or is the model being used so dominated by standard operating procedures that it is incapable of easily responding to alternative practices or procedures? Simple, suboptimal or second best techniques and policies that can be understood and adopted by a railway management may be much more effective in improving the operation of a railway than more elaborate, rigorous procedures that may be doomed to failure.

Experience has shown that if existing models are to be successfully used in operational situations their processes and results must be translated into recognizable standard operating procedures and measurements which the organization can use. If this is not possible, major organizational redesign of the models is usually required. Experience also suggests that before railway managements and planning groups can benefit strongly from models these must reflect and be responsive to the economic realities and market place in which the organizations operate.

III. RAIL: A Planning and Decision Support System

From a realization that (i) the tasks facing the Bank's borrower railways called for specific support, and (ii) the models available have reached the point at which they can be used to generate railway supply functions, we decided to take up the challenges indicated at the end of the previous section and embark in the development of RAIL (Railway Analysis • Interactive Language). This section outlines the main characteristics of the system.

The objectives of RAIL are:

(1) to accomplish a cost-benefit analysis of planned investments in a railway system;

(2) to offer several levels of complexity, i.e., it must be usable whether the analyst has only a minimum of data, expressed as global averages, or whether he has detailed line, yard or network data;

(3) to be equally capable of analyzing a single item of a rail system (one line or one yard), an entire system, or a portion of it;

(4) to be easy to use and understand by using a command-based user interface, in language usage common to railway economists, financial analysts, and engineers;

(5) to be modular, i.e., so that additional or different algorithms can be built in it and invoked by the user as desired, without a re-programming effort.

General Structure of RAIL

As a tool for the economic appraisal of rail projects, the model focuses on comparing the situation "with the project" versus the "without the project" case. RAIL determines the traffic volumes to be carried by the railway project and the benefits generated in accommodating this traffic. Then, using given investment costs, it goes on to compute net present value, rate of return, and the optimal timing of the project. Rail operating statistics, revenue and cost data are also calculated for the user of RAIL.

The user of RAIL creates the railway system to be analyzed by defining ELEMENTS to be included in the model. Eight element types are permitted; however, the model may have as many elements as the same type as the analyst recognized with the exception of PROJect. The ELEMENTS are:

PROJect	:	defines parameters for the project as a whole; (e.g., foreign exchange rate, oportunity cost of capital, etc.)
LOCOmotive	:	defines a locomotive used and its parameters;
WAGOn	:	defines a coach or wagon used and its parameters;
ROUTe	:	defines a route or portion of the rail system, and in its most detailed expression it becomes a chain of LINES to be traversed;
SERVice	:	defines a rail service and the rolling stock used to provide that service;
SERO (service-route)	:	defines the traffic for a service on a route and yards used;
LINE	:	defines a track or line section of the railway system;
YARD	:	defines a yard or switching activity.

For each element recognized by the user of RAIL, there is a file that contains the data necessary to describe its related variables.

The key ELEMENTs are the SEROs, which hold the traffic for a SERVice on a ROUTe, together with the switching or YARD activities called for. The SERVice elements link motive power and rolling stock, LOCOmotive and WAGOn, while the ROUTe elements provide the linkage to the individual railway LINEs. We should emphasize that data for the alternatives without and with the project are specified for the years included in the planning horizon.

The user of RAIL defines the components of the railway system to correspond with the project and the available data. The representation can be aggregate by using railway average data at the level usually found in annual reports. At the other extreme, a very detailed model including each line and yard, with several services and different types of rolling stock can be formulated. This is completely under the control of the user who defines which routes, services, SEROS, rolling stock and motive power are available. For example, a single representative type of freight wagon may be used in the model, or the user may define several different types (e.g. flat, box, hopper, etc.) with the different services using specialized wagons.

RAIL can analyze an entire rail system, a portion of the system, or specific services. The level of detail is specified by the user. One or more "routes" may be specified and there can be one or more "services" on each "route". A "route" could be defined as a major artery, an origin-destination link, an area or, for a completely aggregated analysis, a complete rail system. A "service" could encompass one or any combination of homogeneous traffic types, commodities, train types, etc. To a great degree these definitions are user-dependent.

Normal traffic level, i.e. traffic levels if cost characteristics remained unchanged, for each service and each route are specified (in an element called a "SERO") for the planning horizon of the study. Operating statistics, costs and revenues may be calculated for each sero and are then aggregated by services, routes or project for the analysis. Supply-demand relationships are then used to calculate the traffic levels with and without the project, together with the changed operating statistics, costs and revenues.

Reports on the economic analysis, financial analysis and operating statistics at different levels of aggregation are provided by RAIL at the user's discretion.

Types of Analysis

RAIL provides a range of types of models that are available to the user under the name of ANALYSIS TYPE. The analysis type controls whether or not costs, handling times and traffic assignments are exogenously specified and independent of the volume of traffic, or are internally calculated within the model. As more variables are made traffic dependent, and thus calculated by RAIL, more data must be specified by the user. The following Table lists the analysis types available, describes which types of variables are specified exogenously (given), and those which must be calculated by sub-models within RAIL. [Note: the analysis type does not control the level of detail modeled, but rather it controls whether variables are fixed and supplied by the user or are calculated by sub-models of the program.] The analysis type specifies the hierarchical level at which RAIL is operated.

Table I

ANALYSIS TYPES

Analysis Type	Variables				Comments
	Normal Traffic	Road Time	Line Haul Cost	Yard Time	
MEXO	given	given	given	given	all line and yard costs and times supplied by user
MLIN	given	calc	calc	given	line times and cost calculated by RAIL
MYAR	given	given	given	calc	yard times calculated by RAIL
MLY	given	calc	calc	calc	line and yard models
LINE	given	calc	calc	NA	line model
YARD	given	NA	NA	calc	yard model
NTLY	calc	calc	calc	calc	network with line and yard costs calculated by RAIL

At the simplest level, called MEXO (for Macro analysis with EXOgenous Operational data), all costs and times are specified by the user and are constant with different traffic volumes. MLIN, (Macro analysis with LINe times and costs computed by RAIL), MYAR (Macro analysis with YARd times and costs computed by RAIL), and MLY (Macro analysis with Line and Yard times and costs computed by RAIL), specify whether line, yard or both line and yard costs and times are calculated by sub-models, respectively. When costs incurred are calculated, then the actual traffic is determined by RAIL using a supply-demand equilibrium criteria (traffic other than normal traffic may take place). The analysis type LINE is used to analyze a single line and operates the LINE sub-model only at levels of detail which may exceed those of MLIN. This is useful if the project consists of upgrading a line and the analyst wishes to study different investment options. Similarly, the YARD analysis type operates the yard sub-model at levels of detail which may exceed those of MYAR. The above analysis types assume that the normal traffic on a SERO is supplied by the user. NETWORK assumes that the traffic supplied by the user implies an origin-destination basis, and the specified seros form a network. The origin-destination traffic is then reassigned to this network so that transportation costs are minimized and supply and demand are in equilibrium.

The Command Language

All data input and all actions to be performed by RAIL will be recognized through commands issued by the user. This section gives an introduction to the structure of the commands.

RAIL will be available as both batch mode and as a time-sharing system. The computer system will recognize the mode being used and then all commands issued within that application will be expected to come from the same source. When in a time-sharing mode, the user may elect to have results printed on a high-speed printer rather than at the terminal.

Data files must be created prior to any analysis and are stored as an INPUT BLOCK. The INPUT command enables data entry. To delete or alter data that was previously INPUT, the ERASE and EDIT commands are available. Data that is INPUT may be made permanent by telling the system to SAVE it; saved data remains intact until deliberately ERASED. An echo of data INPUT is available through the PRINT command.

Files created by a user become his/her responsibility. If they are SAVEd, they will remain on the system until ERASEd. The LIST command can be used to list the names of all files a user has created or to print the contents of specific files.

After data is entered and verified as correct, the user may proceed with the analysis. Data for related ELEMENTS included in one application of RAIL must be GROUPed together. The SETUP command states a particular analysis type and makes available the groups needed for execution. The membership of GROUP and SETUP may be changed via the CHANGE command and displayed via the LIST command.

The REPORTS command tells RAIL what types of output are desired and the level of detail it should have. The EXECUTE command carries out the analysis as declared by the SETUP command.

Sensitivity analysis may be performed for any SETUP and is initiated by the SENSITIVITY command (available in later versions of RAIL).

The STOP command disconnects the user from the RAIL system.

Data is stored as an INPUT block, with the analyst having a different INPUT block for each application. The COPY demand is used to move data both within and between INPUT block. Each user's data will be stored separated within the system, and cannot be ERASEd or EDITed by another user.

Input Data Structure

Input data for RAIL is stored in files called ELEMENTS, each ELEMENT being a collection of variables corresponding to the element type. The element types available are:

PROJ	project variables
ROUT	route variables
SERV	service variables
SERO	service on a route variables
LOCO	locomotive variables
WAGO	wagon or car variables
LINE	line variables
YARD	yard variables

For example, the PROJECT element contains the parameters and costs that pertain to the complete project. A ROUT and SERV element is created for each route and service included in the analysis. Similarly, LOCO and WAGO elements are created for the rolling stock.

The higher the level of analysis, the less the data that must be entered. Based on the analysis type selected, RAIL prompts the user for the information essential to perform the analysis.

Data may be entered by using the metric or US system of measures and using any desired currency.

For example, for the MEXO analysis type, the following data is required:

PROJECT:

- country, project and analyst's identification
- timing of the project (starting year, number of years)
- opportunity cost of capital
- investment and other costs which are not divisible among routes and services, and
- fixed asset depreciation information

ROUT:

- route description data
- distance
- route capital charges if applicable, and
- depreciation and maintenance information if different from project level

SERV:

- service identification data
- rolling stock used in providing service
- number days per year service operates
- tariff information, and
- investment and crew cost for service

LOCO and WAGO:

- equipment identification
- life and replacement cost
- availability, and
- pay load

SERO:

The service per route data comprises the majority of all input. It includes

- service and route identification
- average haul
- loco delays per trip
- average road and working time
- yard switching delays and costs
- operating costs, and
- traffic data

Since in MEXO the operating costs are provided by the user, LINE and YARD elements are not required.

After the data is entered and checked, the analyst then GROUPs together all elements of the same type that will be used in the analysis. These groups are included in a SETUP which is then EXECuted.

Sample results

The reports attached are samples of the information generated by RAIL in a very simplistic test of macroanalysis with exogenous cost data. The structure of these reports remain stable as the analysis becomes more complex. New formats are introduced to convey operational results such as those of LINE or YARD, in either selected instances or for all instances in which they have been used as the case may be. However, the synthesis back to services, and ultimately to the global report for the railway project is presented in the same format.

**REPORT NUMBER 1: RAIL OPER

WORLDBANK
UPGRADEM, GA.
RAIL OPERATIONS
FREIGHT/MAINLINE - WITHOUT THE PROJECT

ANALYSIS TYPE: MEXO
USER NAME: *UNDEFINED*
SETUP USED: SETUP1
MEASURE SYSTEM: METR
CURRENCY: BUCKS
CONVERSION RATE TO US$: 0.6400
LOCOMOTIVE TYPE: DIESEL
NUMBER OF LOCOMOTIVES PER TRAIN: 1.0
LOCOMOTIVE TURN-AROUND TIME (DAYS): 2.2
LOCOMOTIVE AVAILABILITY: 85.00%
WAGON TYPE: GOODS
WAGON TURN-AROUND TIME (DAYS): 3.7
WAGON AVAILABILITY: 80.00%
LENGTH OF HAUL (KM): 806.00
NUMBER OF LOADED WAGONS PER TRAIN: 30.0
LOAD PER WAGON: 30.0
NUMBER OF EMPTY WAGONS PER TRAIN: 27.0
NET TRAIN LOAD: 900.00
GROSS TRAIN LOAD: 1570.00

	1981	1982
NUMBER OF TRAINS	2380.0	2499.0
LOCOMOTIVE-KM (000)	1918.28	2014.19
TRAIN-KM (000)	1918.28	2014.19
NET TRAILING TON-KM (000)	1726452.00	1812774.60
GROSS TON-KM (000)	3011699.60	3162284.58
WAGON-KM (000)	109341.96	114809.06
EQUIPMENT REQUIRED IN SERVICE		
LOCOMOTIVES	17.8	18.6
WAGONS	1690.1	1774.6
EQUIPMENT REQUIRED IN STOCK		
LOCOMOTIVES	20.9	21.9
WAGONS	2112.6	2218.3
UNIT OPERATING COSTS PER		
NET TRAILING TON-KM	0.0174	0.0174
CAPITAL COST OF LOCOMOTIVES		
PET NET TRAILING TON-KM	0.0000	0.0000
CAPITAL COST OF WAGONS		
PER NET TRAILING TON-KM	0.0000	0.0000
CAPITAL COST OF WAY AND WORKS	1690.10	1774.60

WORLDBANK
UPGRADEM, GA.
RAIL OPERATIONS
PASS/MAINLINE - WIHTOUT THE PROJECT

ANALYSIS TYPE: MEXO
USER NAME: *UNDEFINED*
SETUP USED: SETUP1
MEASURE SYSTEM: METR
CURRENCY: BUCKS
CONVERSION RATE TO US$: 0.6400
LOCOMOTIVE TYPE: DIESEL
NUMBER OF LOCOMOTIVES PER TRAIN: 1.0
LOCOMOTIVE TURN-AROUND TIME (DAYS): 0.3
LOCOMOTIVE AVAILABILITY: 85.00%
WAGON TYPE: COACH
WAGON TURN-AROUND TIME (DAYS): 0.3
WAGON AVAILABILITY: 85.00%
LENGTH OF HAUL (KM): 166.00
NUMBER OF LOADED WAGONS PER TRAIN: 15.0
LOAD PER WAGON: 3.20
NUMBER OF EMPTY WAGONS PER TRAIN: 0.0
NET TRAIN LOAD: 48.00
GROSS TRAIN LOAD: 598.00

	1981	1982
NUMBER OF TRAINS	16170.0	16978.5
LOCOMOTIVE-KM (000)	2684.22	2818.43
TRAIN-KM (000)	2684.22	2818.43
NET TRAILING TON-KM (000)	128842.56	135284.69
GROSS TON-KM (000)	1605163.56	1685421.74
WAGON-KM (000)	40263.30	42276.47
EQUIPMENT REQUIRED IN SERVICE		
LOCOMOTIVES	14.9	15.7
WAGONS	223.7	234.9
EQUIPMENT REQUIRED IN STOCK		
LOCOMOTIVES	17.5	18.4
WAGONS	263.2	276.3
UNIT OPERATING COSTS PER NET TRAILING TON-KM	0.1246	0.1246
CAPITAL COST OF LOCOMOTIVES PER NET TRAILING TON-KM	0.0000	0.0000
CAPITAL COST OF WAGONS PER NET TRAILING TON-KM	0.0000	0.0000
CAPITAL COST OF WAY AND WORKS	223.68	234.87

***REPORT NUMBER 2: ECON SUMM

WORLDBANK
UPGRADEM, GA.
ECONOMIC REPORT

ANALYSIS TYPE: MEXO
USER NAME: *UNDEFINED*
SETUP USED: SETUP1
MEASURE SYSTEM: METR
CURRENCY: BUCKS
CONVERSION RATE TO US$: 0.6400

	1981	1982
TRAFFIC		
WITHOUT THE PROJECT		
FREIGHT TONS (000)	2142.0	2249.1
FREIGHT TON-KM (MILLIONS)	1726.5	1812.8
PASSENGERS (000)	9702.02	10187.1
PASSENGERS-KM (MILLIONS)	1610.5	1691.1
PROJECT GENERATED		
FREIGHT TONS (000)	0.0	0.0
FREIGHT TON-KM (MILLIONS)	0.0	0.0
PASSENGERS (000)	0.0	0.0
PASSENGER-KM (MILLIONS)	0.0	0.0
TOTAL WITH THE PROJECT		
FREIGHT TONS (000)	2142.0	2249.1
FREIGHT TON-KM (MILLIONS)	1726.5	1812.8
PASSENGERS (00)	9702.0	10187.1
PASSENGER-KM (MILLIONS)	1610.5	1691.1
SAVINGS DUE TO		
NORMAL TRAFFIC	0.00	0.00
GENERATED TRAFFIC	0.00	0.00
MAINTENANCE	0.00	0.00
LOCOMOTIVES	0.00	0.00
WAGONS	0.00	0.00
WAYS AND WORKS	0.00	0.00
YARD ACTIVITY	0.00	0.00
OTHER	0.00	0.00
TOTAL SAVINGS		
COSTS		
INVESTMENT	0.00	0.00
OTHER	0.00	0.00
TOTAL COSTS	0.00	0.00
NET BENEFITS	0.00	0.00

***REPORT NUMBER 3: FINA SUMM

WORLD BANK
UPGRADEM, GA.
FINANCIAL REPORT

ANALYSIS TYPE: MEXO
USER NAME: *UNDEFINED*
SETUP USED: SETUP 1
MEASURE SYSTEM: METR
CURRENCY: BUCKS
CONVERSION RATE TO US$: 0.6400

	1981	1982
REVENUES		
TRAFFIC (000)	71944.69	75541.92
SUBSIDY (000)	0.00	0.00
TOTAL REVENUE (000)	71944.69	75541.92
EXPENSES		
OPERATING COST (000)	46168.63	48477.06
DEPRECIATION (000)		
LOCOMOTIVE	0.00	0.00
WAGON	0.00	0.00
WAY AND WORKS	0.00	0.00
MAINTENANCE (000)		
LOCOMOTIVE	5388.69	5658.13
WAGON	11408.13	11978.53
WAYS AND WORKS	12196.63	12806.46
CAPITAL CHARGES (000)		
LOCOMOTIVE	0.00	0.00
WAGON	0.00	0.00
WAY AND WORKS	0.00	0.00
INFRASTRUCTURE	0.00	0.00
PERSONNEL (000)	0.00	0.00
OVERHEAD/MGT (000)	62263.00	62263.00
TOTAL EXPENSES (000)	137425.08	134858.61
EXCESS (SHORTAGE) OF REVENUES OVER COSTS (000)	-65480.39	-59316.69
REQUIRED SUBSIDY (000)	25776.06	33389.43
OPERATING RATIO		
BEFORE SUBSIDY	1.91	1.79
AFTER SUBSIDY	1.91	1.79
WORKING RATIO		
BEFORE SUBSIDY	1.91	1.79
AFTER SUBSIDY	1.91	1.79

Concluding remarks

The system briefly described is undergoing final tests prior to release to users inside the Bank as well as to outsiders who might request it.

RAIL allows the evaluation and exploration of a hierarchy of situations. It responds to the nature of the situation recognized by the user, as well as the findings of previous analyses, within a single integrated structure with internal consistency checks.

The degree to which a problem is disaggregated into ELEMENTS, the type of the analyses themselves, and the nature and number of reports to be received are controlled by the user in a "friendly" environment. As our experience with the system grows, we expect to respond to the suggestions of users on how to "enhance this friendliness" as well as extend the types of analyses provided under the system. We look forward to our future exchanges with an active community of users both inside and outside the Bank.

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