A strategic model for evaluating investment strategies to establish operational and financial sustainability of Pakistan Railways

Arif Mehmood
United Arab Emirates University
P.O. Box 17555
College of Engineering
Al Ain, UAE.
Tel: ++ 97050-2330396
Email: amehmood@uaeu.ac.ae

Abstract

This paper formulates and analyzes a strategic model for the Pakistan Railways. The objective of the model is to understand the potential consequences of investment strategies aimed at establishing operational and financial sustainability of the Pakistan Railways. The model replicates a wide range of inter-connected causal relationships between different factors to reflect the decision making process in the sectors including Rolling stock (passenger coaches and locomotives), Maintenance of Rolling stock, Tracks, Maintenance of Tracks, and Finance. The model incorporates how these sectors interact to each other over time. The model can be used for evaluating potential outcomes of individual and combinations of individual investment strategies implemented at different times. The conclusion derived from the model experimentations indicates that a better operational policy for the Pakistan Railways to improve its operational performance and financial sustainability would constitute expanding the track capacity with increased provision for maintenance capacity.

Keywords: Railways, Investment strategies, operations and financial sustainability, maintenance capacity, transportation.

Introduction

It has been recognized that railways could meet intercity passengers and freight demand in a more energy efficient, more economical, and less environmentally harmful way (Paul et al., 1992, Eastham, 1995). Despite the efficacy of railways, over the last decades the transport share of railways has been shifted to roads in many developing countries, for example, Philippine, China, India, Pakistan and Thailand. The need to improve the operational efficiency of railways in developing countries has been increasing. As roads are being over saturated with traffic, and resulting in increased traffic congestion on the roads (Jimenes, 1990). One of the solutions to relieve traffic congestion on the roads might be to improve the railways.

This paper focuses on the operational and financial problems of the Pakistan Railways (PR). PR is a state owned enterprise, which is responsible for planning, monitoring, and controlling the operations of railway network throughout the country. Currently, PR is under a large debt with poor service delivery. This has instigated a problematic situation further burden due to lack of financial investment in its operations. A number of studies on the PR's operations and finance have been conducted since mid 1980's by the World Bank and Japan International Cooperation Agency (JICA). These studies have identified that continuously lack of investment during the last three decades to replace old and obsolete rolling stock (passenger coaches and locomotives) resulted in poor level of service for the PR. The need for investment in the PR is understandable, yet no study has emphasized on the operational problems that has caused poor level of service, and how to allocate given scarce financial resources that can improve the poor operation performance as well as financial situation of the PR.

This paper presents a System Dynamics model which can be used to evaluate operational polices with regard to investment in different sectors of the PR. Through model analysis and experimentation the best policy is presented, which offers a performance and financial sustainability to the PR not only in the short run but also for the long run.

An Overview of the Pakistan Railways

The history of the PR dates back to 1861, when the first railway track of 174 Km, between two cities; Karachi and Kotri was commissioned. The railway network has been progressively expanded. At present, the main routes connect the large cities such as Karachi, Hyderabad, Multan, Lahore, Rawalpindi, Peshawar, Quetta and Zahedan. Most of the sections of these routes are single track (one-way), only one section of 1,037 Km between Karachi and Khanewal is double track (two-way).

The performance of the PR in terms of passenger and freight carried has been declined for the last several years. Due to which the financial situation of the PR has been deteriorating. During 1994-95 the budget deficit of the PR was reached to 2.3 billion rupees. However, demand for transport services has been increasing every year (Jane's World Railways 1995-96, Corporate plan, 1995-96). As shown in Figure 1, the number of passenger km carried by the PR has been stagnated, whereas passenger-Km carried by road has been increasing every year since 1972-73. However, the total number of passengers (total transport demand) for transport services has been growing because of population growth, economic growth and transition towards an urban industrial economy.

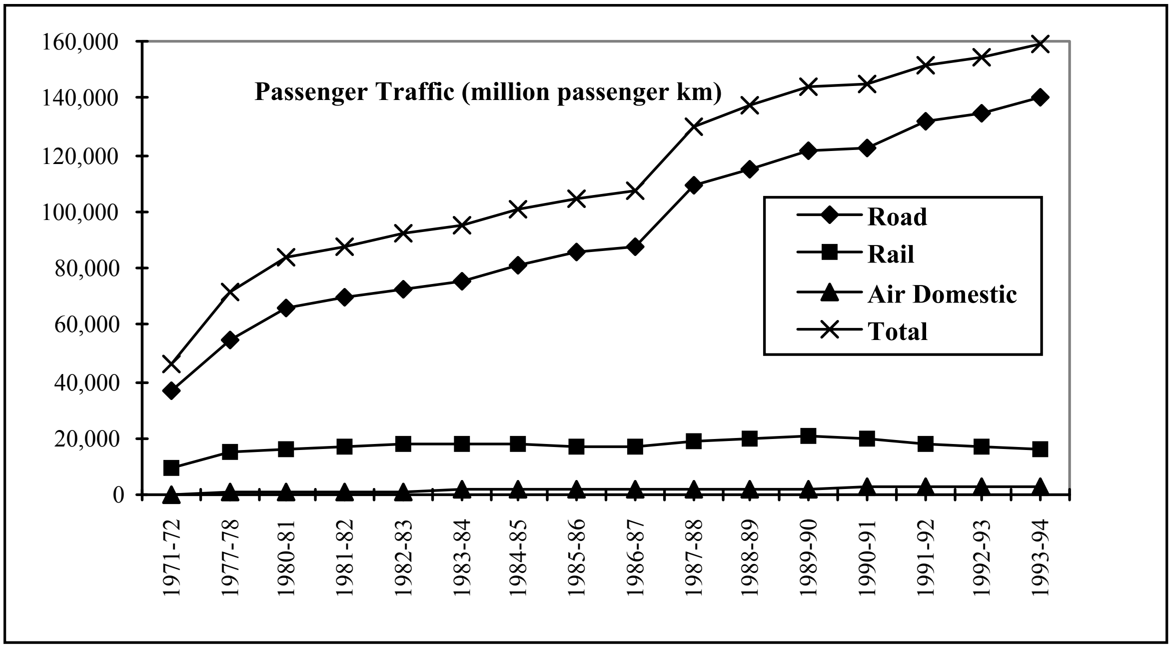

Figure 1 Comparative performance of the PR in terms of carried passengers -km.
Source: Corporate Plan 1995-96, Year Book of PR 1994-95, Pakistan Economic Survey 1986-87 to 1991-92.

Figure 2 shows the number of rolling stock (passenger coaches and locomotives) owned by the PR As shown in figure 2, the number of rolling stock has been declining for the last several years. During the interview for data collection, the PR officials described the reason for decline in the number of rolling stock is lack of investment during the last three decades to replace the old and obsolete rolling stock. Due to non availability of funds over the period of last several years there was no new induction of rolling stock and about 40 percent of the existing rolling stock has completed their economic life. The machinery installed in major workshops for maintenance of rolling stock has completed their service life and require replacement. Due to these old facilities overhauling time of the rolling stock has been increased (PR Officials[1], 1996).

The pattern of route Km owned by the PR is shown in Figure 3, which has been stagnated during the last several years. PR has not constructed any new routes since 1982 and the existing track is as old as 100 years, which yields the poor quality of track. At present, 5,920 Km of track has completed its life for which replacement is necessary. Due to poor quality of track there are an excessive number of speed restrictions and breakdowns of rolling stocks. Because of this sometimes travel time increases more than 60 percent of the regular travel time (Corporate plan, 1995-96).

[1] Information gathered from senior officials of the PR during data collection.

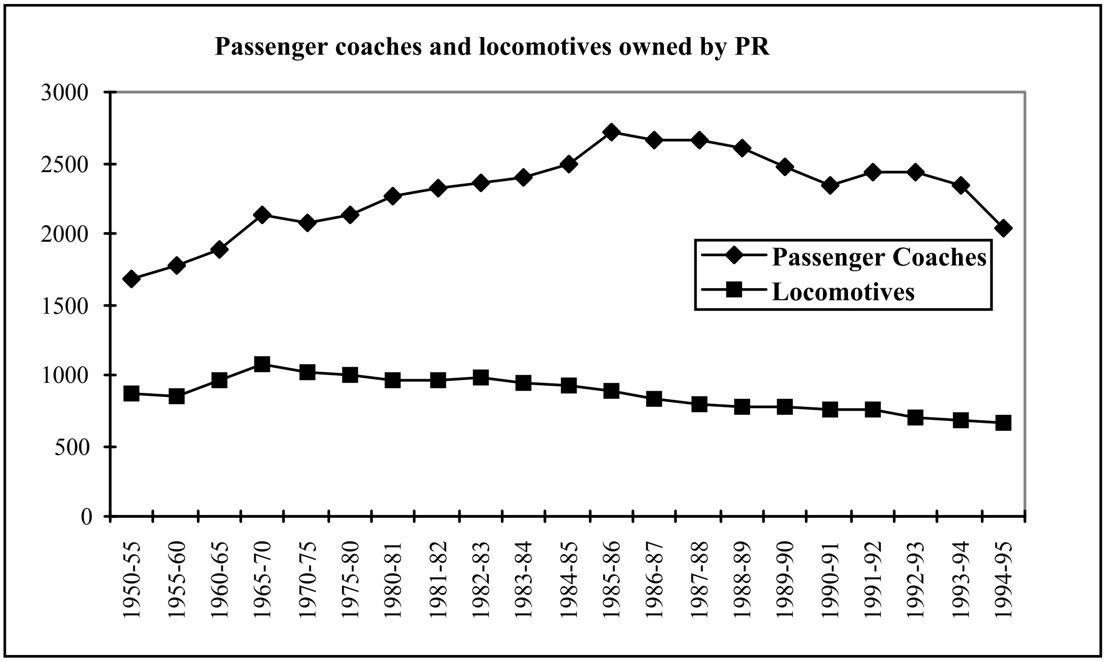

Figure 2 Passenger coaches and locomotives owned by PR.
Source: Year book of PR 1994-95.

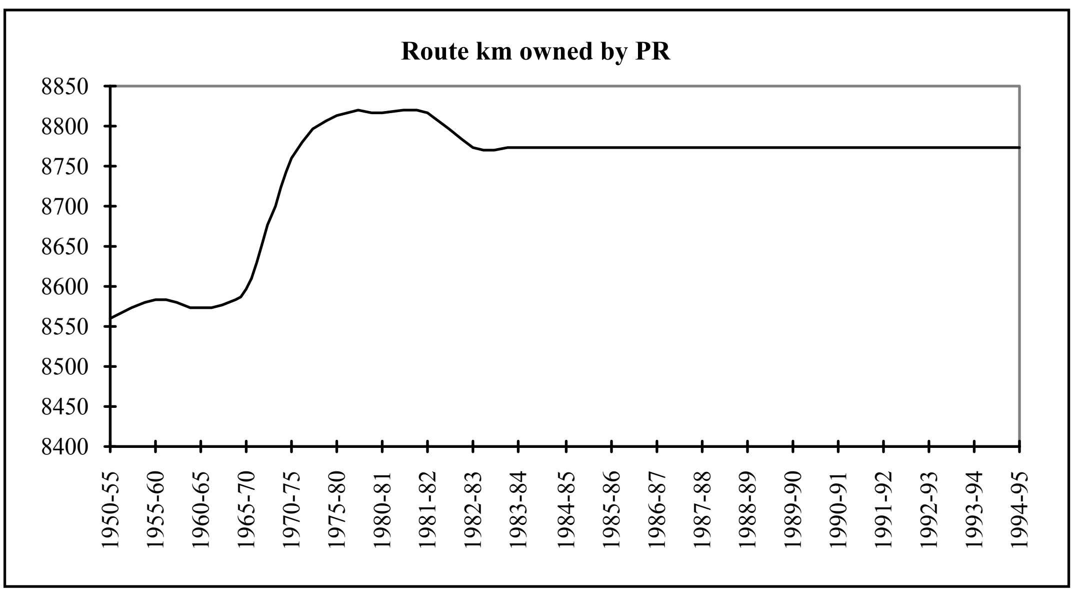

Figure 3 Total route kilometer of Pakistan Railways.
Source: Year book of PR 1994-95.

The financial situation of the PR is shown in Figure 4, which shows that the PR has been incurring loss for the last several years. The revenue earned by the PR during the last two decades is less than its expenditures. The expenditures includes operation and maintenance cost of rolling stock and tracks, administration cost, depreciation reserve fund, repayments of foreign loans and interest on debt.

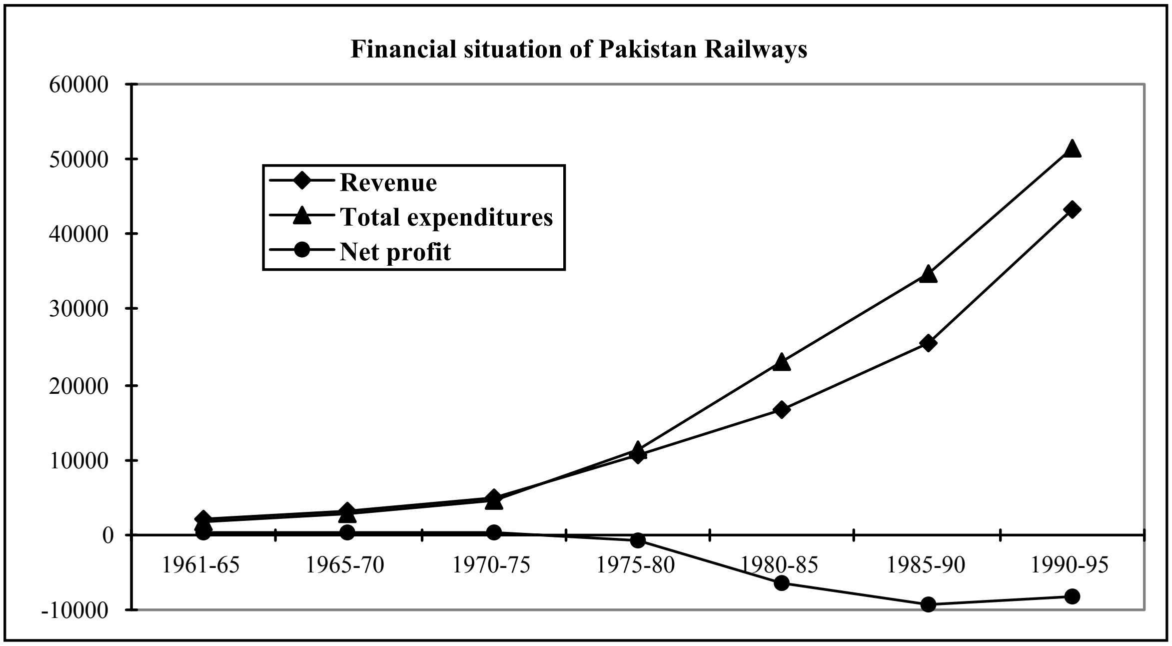

Figure 4 Financial situation of the PR
Source: Corporate plan, 1995-96, Year book of PR, 1994-95.

Research Objective and Scope

The objective of this research is to develop a simulation model to understand how different elements of the PR's system interact to each other over time to generate operational and financial problems. The model integrates the main sectors of the PR such as Rolling stock, Tracks, Maintenance of Rolling Stock, Maintenance of Tracks, and Finance into a one integrated system. The model can be used for evaluating potential outcomes of individual or/and combinations of individual investment strategies implemented at different times for establishing operational and financial sustainability of the PR.

Model Overview

Figure 5 depicts the model overview that illustrates the interdependence between the different elements of the sectors considered in the model. The model consists of five sectors namely, Rolling stock, Tracks, Maintenance of Rolling Stock, Maintenance of Tracks, and Finance. These sectors perform certain functions and interact with each other over time. The selection of these sectors and interdependence between these sectors are based on outcome of several meetings with the senior level management officials in the PR.

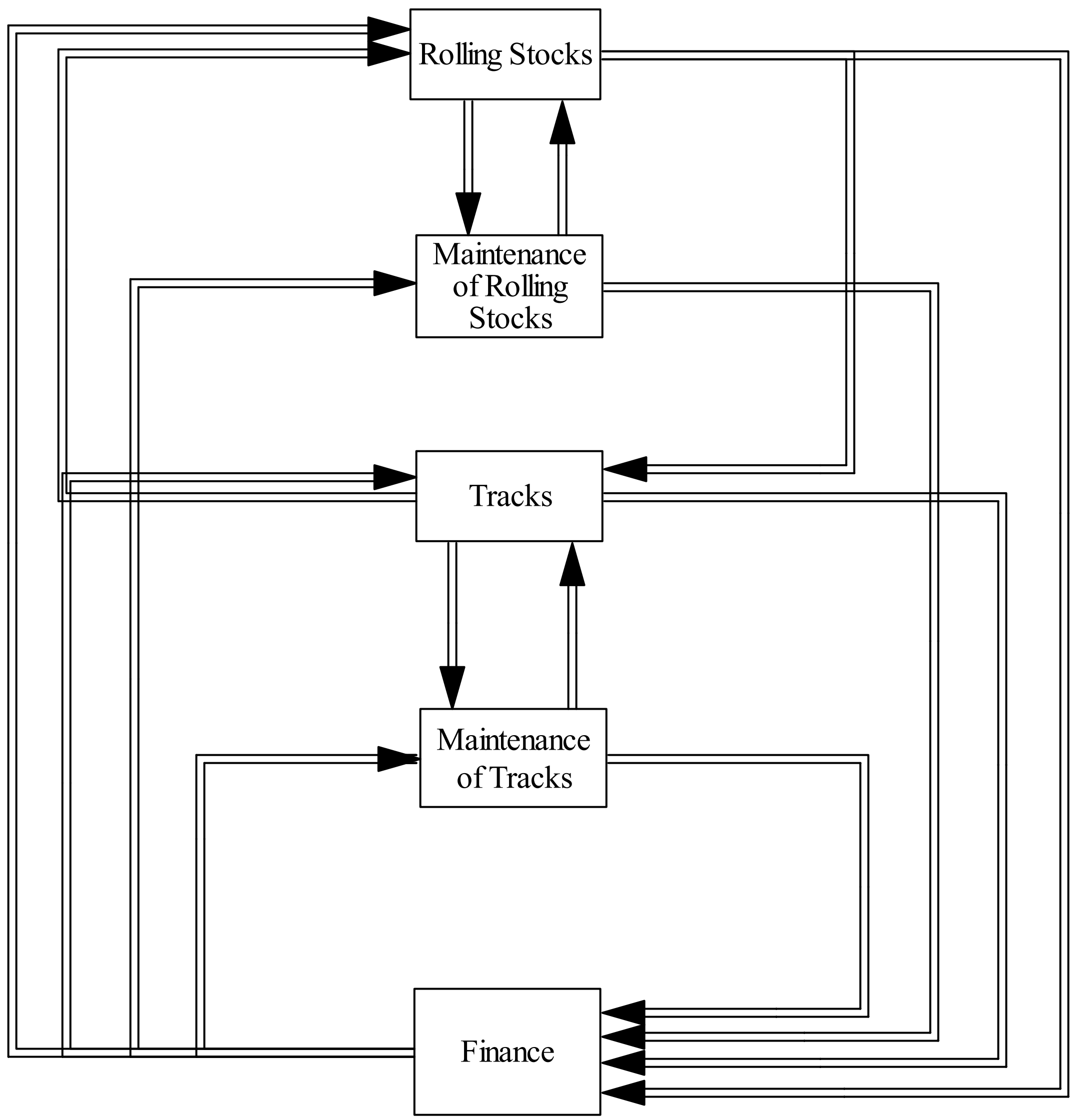

Figure 5 Model overview

The sector "Rolling stock" determines the number of Rolling stock in service, and the number of Rolling stock that needs maintenance. The number of Rolling stock required maintenance indicates the demand for maintenance capacity of the Rolling stock. The demand for maintenance capacity of Rolling stock and actual maintenance capacity both are estimated in the "Maintenance of Rolling stock' sector. The sector, Tracks, calculates the tracks in service (new tracks) and also tracks in service (old tracks) that needs maintenance. In case of tracks, unlike the Rolling stock the tracks that need maintenance are also considered in the service. However, relatively if more tracks requiring maintenance are in service, the quality of tracks in service would decrease, and may cause more breakdowns of the Rolling stock (PR Officials[2], 1996). 1996). Similar to the Maintenance capacity of the Rolling stock, the Maintenance capacity of Tracks is determined based on the old tracks in service that needs maintenance.

[2] Information gathered from senior officials of the PR during data collection.

The Finance sector in the model keeps track of the Cash and Debt of the PR. There are two sources of funding: revenue and borrowing, which increase the level of cash. Whereas operation and maintenance cost of Rolling stocks and Tracks, investment in different portfolios of PR, and debt payments decrease the level of Cash. The level of available Cash can be allocated among four portfolios: induction of new Rolling stock, construction of maintenance capacity of Rolling stock, construction of Tracks, and construction of maintenance capacity of Tracks. The model described in this paper helps in understanding the potential outcome of allocating available cash among these portfolios.

Dynamic hypothesis of the model

Figure 6 illustrates the dynamics hypothesis of the model presented in this paper. This dynamic hypothesis depicts eight reinforcing and three balancing feedback loops. The reinforcing feedback loops R1, R2, R3, and R4 represent the allocation of available cash among four portfolios including induction of new Rolling stock, construction of maintenance capacity of Rolling stock, construction of Tracks, and construction of maintenance capacity of Tracks respectively. The reinforcing feedback loops R5 and R6 represent the process of expanding maintenance capacities for Rolling stock and Tracks respectively. The reinforcing loop R7 illustrates construction of new tracks to expand the track capacity that will allow induction of more rolling stocks in service. Induction of more Rolling stock in service will raise the revenue and in turn cash will increase.

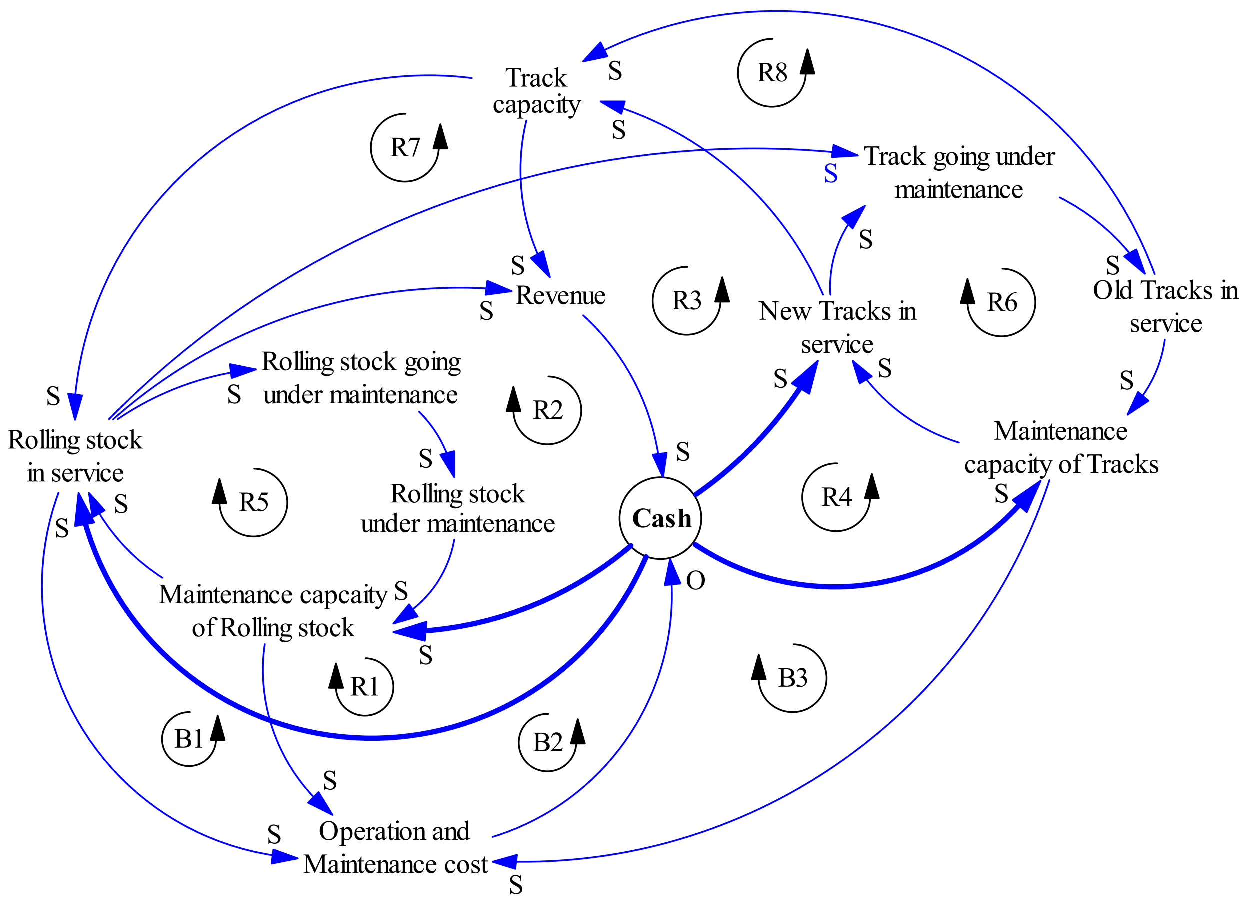

Figure 6 Dynamic hypothesis of the model

The balancing feedback loops B1, B2, and B3 shown in figure 6 represent the process for operation and maintenance cost of Rolling stock in service, maintenance capacity of Rolling stock, and maintenance capacity of Tracks respectively. The increase in the operation and maintenance cost of Rolling stock and tracks will decrease the level of cash.

Stock-flow structure of the Model

Following the dynamics hypothesis of the model described in the previous section, a formal system dynamics model is developed in this section. The model consists of five sectors: 1) Rolling stock, 2) Maintenance capacity of Rolling Stock, 3) Tracks, 4) Maintenance capacity of Tracks, and 5) Finance. Each sector performs certain functions and interacts with the other sectors. The main functions of these sectors are described below.

1. Rolling stock

In this sector the process for estimating induction of new Rolling stocks and Rolling stocks going for maintenance is simulated. The stocks and flows structure of this sector is depicted in Figure 7. Based on information gathered form PR officials, it is found that induction of Rolling stock depends on the number of passengers, available cash, and track capacity. The equation 1 is applied to determine the induction of new Rolling stock.

Rolling stock induction rate = (Rolling stock in service * Normal induction of Rolling stock * Effect of cash on Rolling stock induction rate * Effect of Track capacity on Rolling stock induction rate * Induction multiplier of Rolling stock) / Rolling stock induction time (1)

In equation (1) "Rolling stock in service" represents the current number of Rolling stock in service. The "Normal induction of Rolling stock" represents the induction of Rolling stock to balance the depreciation of Rolling stock each year. The "Effect of cash on Rolling stock induction rate" and "Effect of Track capacity on Rolling stock induction rate" is assumed as convex (with a positive slope) functions of "Average cash ratio" and "Track capacity ratio" respectively. The "Average cash ratio" is defined as a SMOOTH function of the ratio between "Cash" and "Desired Cash". Cash and desired cash both are determined in the "Finance" sector of the model. The "Track capacity ratio" is defined as a ratio between Tracks in service and tracks required based on current number of Rolling stock in service. These two nonlinear functions ("Effect of cash on Rolling stock induction rate" and "Effect of Track capacity on Rolling stock induction rate") are considered as constraints on the induction of new Rolling stock. The third non-linear function in equation 1 is "Induction multiplier of Rolling stock" that represents the pressure for inducting new Rolling stock. This function is assumed as a concave function of the adequacy of Rolling stocks in service with a negative slope. Adequacy of Rolling stock in service is defined as a ratio between total number of Rolling stock in service and indicated number of Rolling stock in service based on demand of passengers.

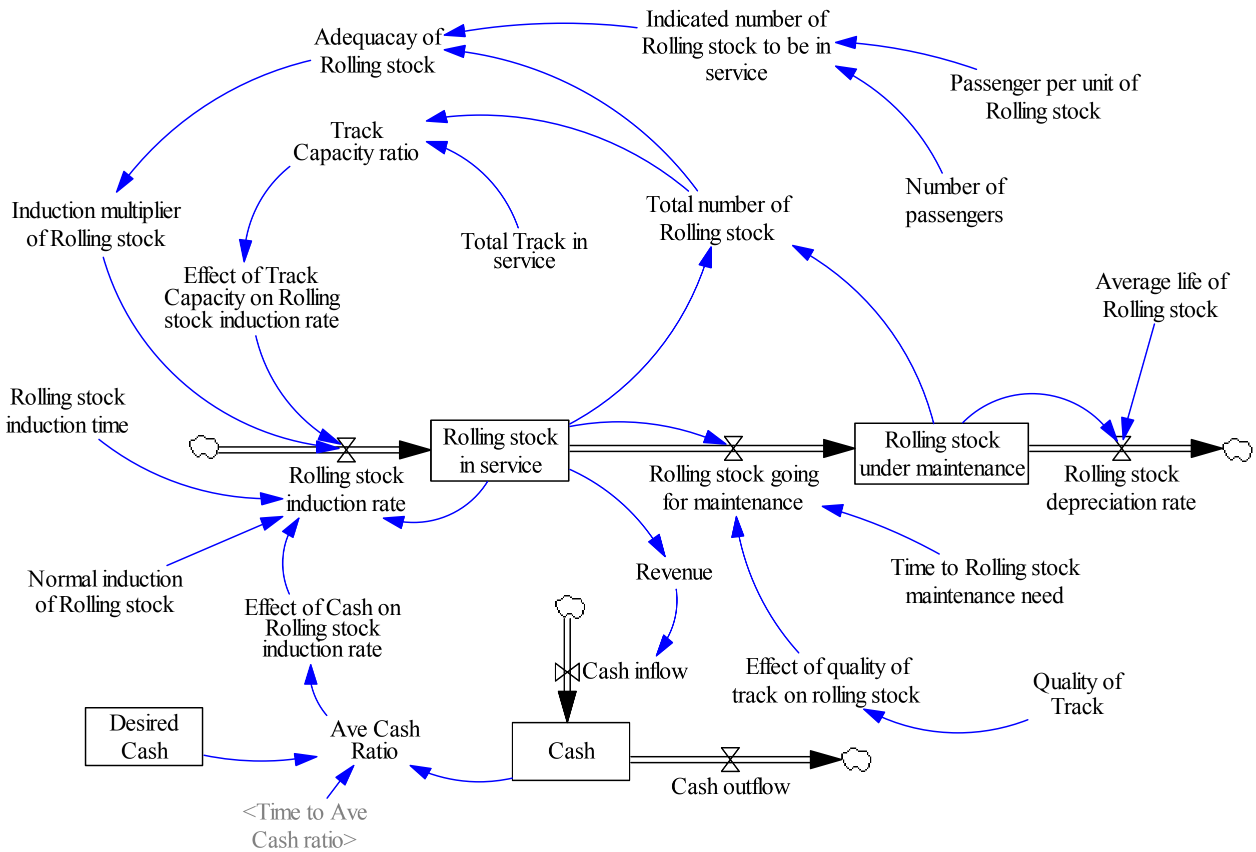

Figure 7 Stock-flow structure of Rolling stock sector

The equation (2) is used to determine the Rolling stocks going for maintenance.

Rolling stock going for maintenance = (Rolling stock in service * Effect of quality of track on Rolling stock) / Time to Rolling stock maintenance need (2)

In equation (2) "Effect of quality of track on Rolling stock" is assumed as a convex (with a negative slope) function of "Quality of Track" that reflects the effect of track's condition on maintenance need of Rolling stock. Quality of track is defined as a ratio between new and old tracks in service. It is assumed that as quality of tracks drops, the break downs of Rolling stock may increase and number of Rolling stock going for maintenance would rise. In equation (2) "Time to Rolling stock maintenance need" represents the normal routine time for maintenance need of the Rolling stocks.

2. Maintenance of Rolling stock

In this sector the process for estimating construction of maintenance capacity of Rolling stock and maintenance rate of Rolling stock is simulated. The stocks and flows structure of this sector is shown in Figure 8. The construction rate of Rolling stock maintenance capacity is calculated by equation 3.

Construction rate of Rolling stock maintenance capacity = (Maintenance capacity of Rolling stock * Normal construction of Rolling stock maintenance capacity * Construction multiplier of Rolling stock maintenance capacity * Effect of Cash on construction of Rolling stock maintenance capacity) / Construction time of Rolling stock maintenance capacity (3)

In equation (3) "Maintenance capacity of Rolling stock" represents the current maintenance capacity of Rolling stock. The "Normal construction of Rolling stock maintenance capacity" represents the construction of Rolling stock maintenance capacity to balance the depreciation of maintenance capacity each year. The "Construction multiplier of Rolling stock maintenance capacity" in equation (3) is assumed to be a concave (with a negative slope) function of "Adequacy of Rolling stock maintenance capacity". It is assumed that as adequacy of Rolling stock maintenance capacity drops, the pressure to construct maintenance capacity will rise with an increasing rate. The adequacy of Rolling stock maintenance capacity is defined as a ratio between current and indicated maintenance capacity. The indicated maintenance capacity of Rolling stock is estimated based on the number of Rolling stock under maintenance. The budget constraint for the construction of Rolling stock maintenance capacity is considered by "Effect of cash on construction of Rolling stock maintenance capacity". This is formulated by a nonlinear graphical function of the average cash ratio. It is assumed that when the average cash ratio is zero, there will be cash constraint on the construction of the rolling stock maintenance capacity. However, when it is equal to or more than one, then there will be no cash constraint. When the average cash ratio decreases the cash constraint rises sharply because when the pressures to cut costs rise, management normally reacts by decreasing the cash for maintenance (Mashayekhi, 1995).

In Figure 8, the "Rolling stock maintenance rate" is assumed to depend on the adequacy of the existing maintenance capacity and the normal time that Rolling stock requires for maintenance. The normal time is the routine time that Rolling stock takes for maintenance. This normal maintenance time may change with the change in the adequacy of Rolling stock maintenance capacity. The rate of change in the maintenance time is determined by an S-shape (with a positive slope) function of "Adequacy of Rolling stock maintenance capacity". This function is represented by "Effect of Rolling stock maintenance capacity on maintenance rate".

As shown in Figure 8, revenue of the PR is also calculated in this sector. The equation (4) is used to calculate the revenue of the PR.

Revenue = Total Track in service * Rolling stocks in service * Fare per passenger Km (4)

It is assumed that Revenue of the PR will increase in proportion to increase in the Total Track and the Rolling stocks in service. In equation (4) Rolling stocks in service represents the number of passengers traveling by the PR, and Total Track in service represents the distance traveled by the passengers using the PR. The Fare per passenger Km in equation (4) is an assumed constant that represents the fare per passenger Km to calculate the Revenue of the PR.

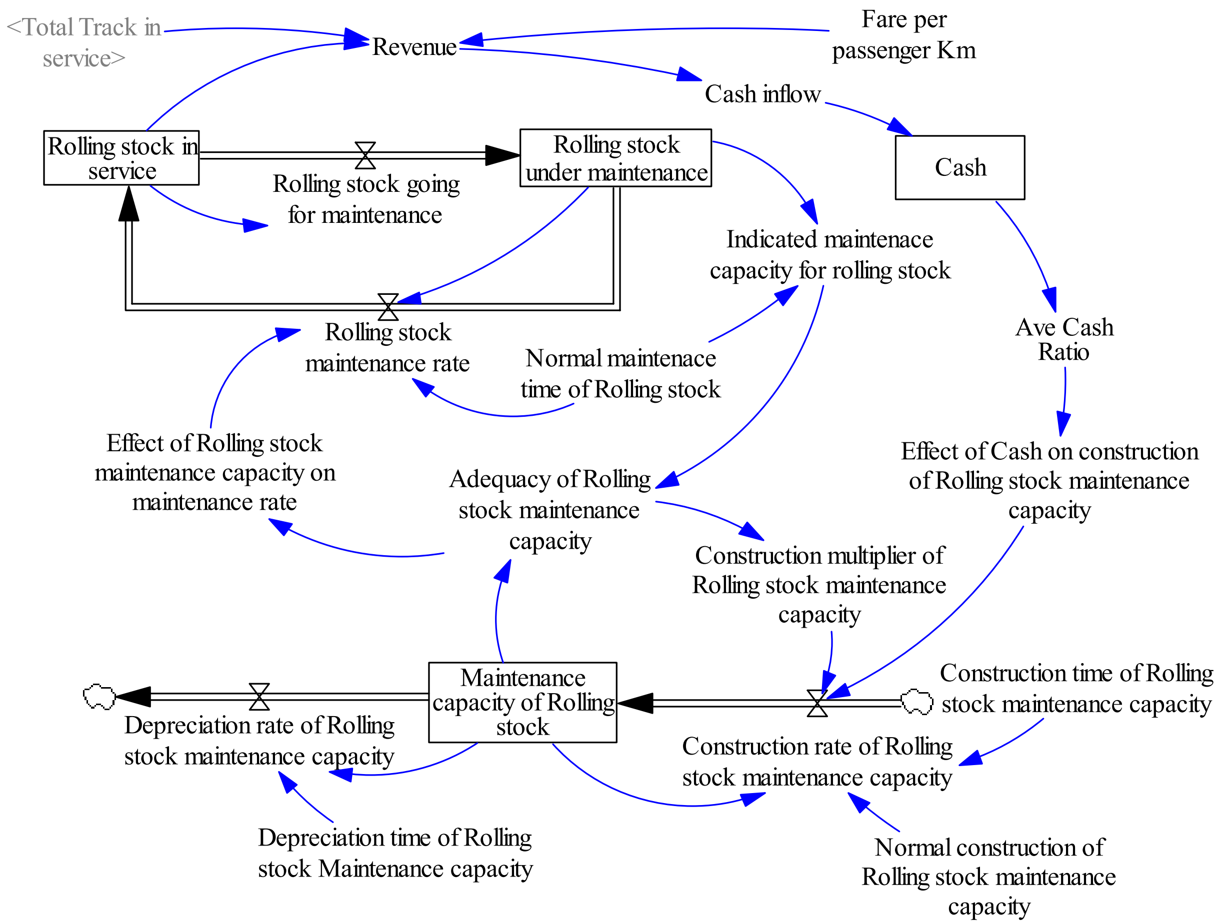

Figure 8 Stock-flow of Rolling stock maintenance sector

3. Tracks

The stocks-flow structure of this sector (shown in Figure 9) is similar to the structure of the Rolling stock sector described above. In this sector the process for construction of new Tracks and process for Tracks going for maintenance are simulated. The construction of new Tracks is assumed to depend on the adequacy of Tracks in service, and the available cash. Similar to the Rolling stock and maintenance of Rolling stock sectors, the available cash is considered as a budget constraint on the construction of new Tracks. The adequacy of Tracks in service is defined as a ratio between existing and indicated Tracks in service, and used as an input to a concave (with a negative slope) function called "Construction multiplier of tracks" that reflects the rate of change in the construction of tracks as adequacy of Tracks changes.

Similar to the rate, "Rolling stocks going for maintenance" it is assumed that the rate, "Tracks going for maintenance" depends on the routine time for maintenance need and the usage of tracks. The usage of tracks is reflected by an S-shape (with a positive slope) function of a ratio between the number of Rolling stock in service and the total existing tracks. This relationship assumes that as number of Rolling stock in service increases beyond a certain limit, the maintenance need for tracks will also increase.

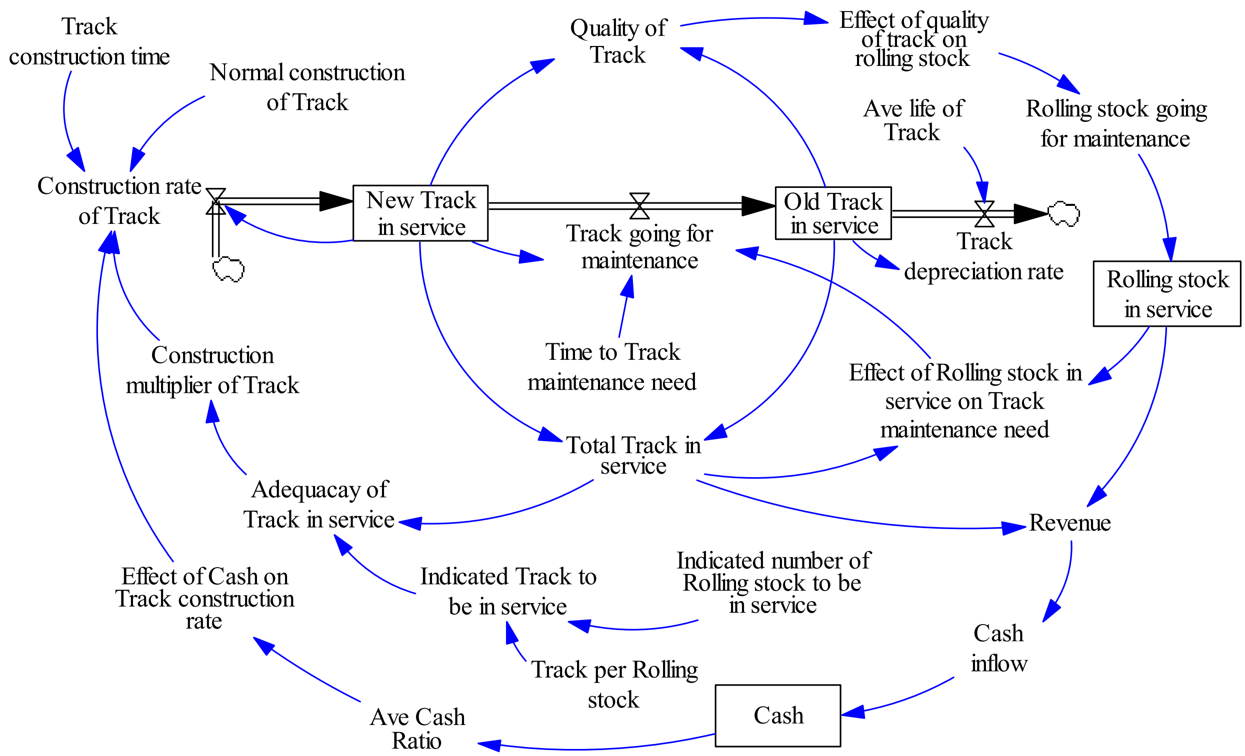

Figure 9 Stock-flow structure of Tracks sector

4. Maintenance of Tracks

In this sector the process for construction of Tracks maintenance capacity and process for Tracks maintenance rate are simulated. As shown in Figure 10, the stocks-flow structure of this sector follows the same logic as described for the Maintenance capacity of Rolling stock sector.

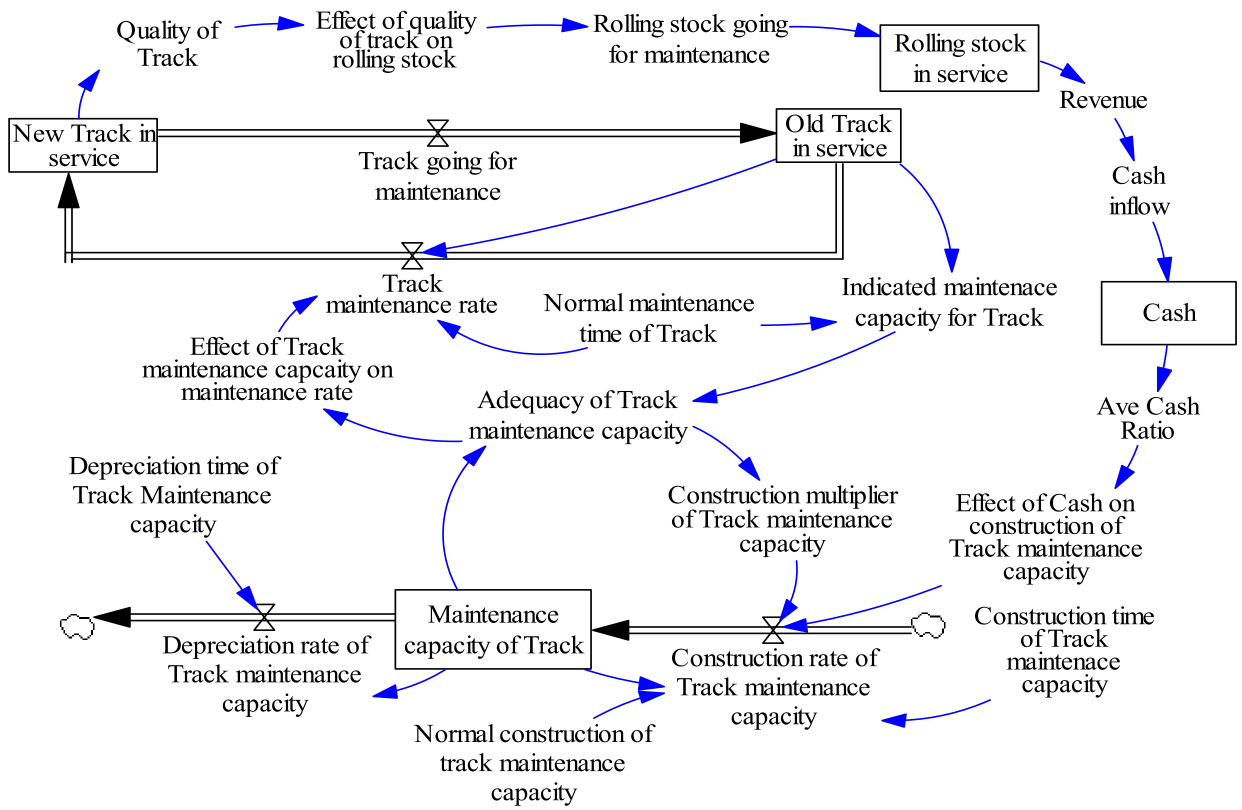

Figure 10 Stock-flow structure Track Maintenance sector

5. Finance

Figure 11 shows the stock-flow structure of the Finance sector. In this sector the Cash, Desired cash and Debt of the PR are calculated. The level of Cash represents the available cash balance of the PR, the level of Desired cash represents the averaged expenses of the PR, and the level of Debt represents amount borrowed from external financial sources such as World Band and local banks.

As shown in figure 11, it is assumed that cash level the PR increases with revenue and borrowing, and decreases with the annual expenses that include total operation and maintenance cost, total investment to different portfolios of the PR, and debt payments. The revenue of the PR is calculated in the Rolling stock maintenance sector that depends on operations of the PR. While for the borrowing it is assumed that borrowing occurs only when the level of desired cash is more than the level of cash. However, there is a limit to borrowing considered in the model. The limit to borrowing is represented by a nonlinear graphical function called Percent debt-financing. Percent debt-financing is an assumed convex (with negative slope) function of the debt-equity ratio. It is assumed that when debt-equity ratio is equal to or more than two, borrowing is prohibited. Such a constraint is usually imposed by the financial markets (Lyneis, 1988). The equity in the model is calculated as the summation of the level of cash and the value of the assets owned by the PR.

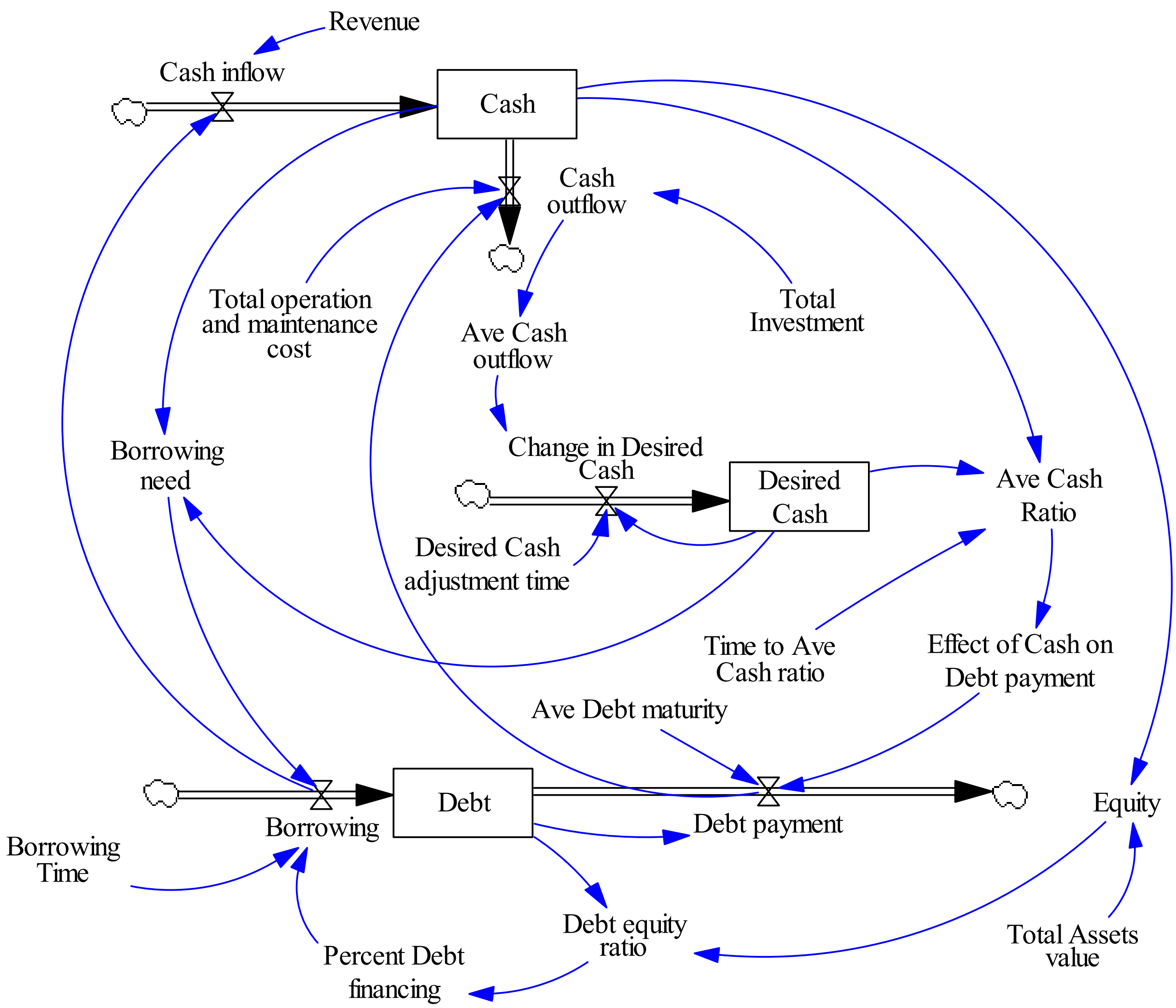

Figure 11 Stock-flow structure of Finance sector

Simulation results

Base run

Initially the model is parameterized in a way that equilibrium exists in all stocks. To test the dynamic hypothesis articulated in this paper, the model is driven from equilibrium state and an exogenous disturbance is introduced. The step input, a sudden one-shot disruption of the system's equilibrium state, is a very simple and uncomplicated, yet informative, disturbance (Lynies, 1988). Such a test is important for understanding any tendency internal to the system (Saeed, 1987). The equilibrium of the model is disturbed by a 10 percent step increase in the number of passengers at time 10. This increase in the number of passengers represents the increase in the transport demand due to population growth, economic growth, and transition towards an urban economy. All other parameters and nonlinear graphical functions remain unchanged. Figure 12 shows simulation results of the base run scenario over a hypothetical period of 80 years. The base run scenario represents the status quo situation which assumes strategies implemented for future years are same as implemented in the past. Figure 12 (a) and (b) show the behavior of the rolling stock in service and the maintenance capacity of rolling stock respectively. Figure 12 (c) and (d) show the behavior of the tracks in service, and the maintenance capacity of tracks respectively. The behavior of the financial situation of PR is shown in figure 12 (e), and (f).

Due to an increase in the number of passengers at time 10, the demand for number of rolling stock in service increases that in turn increase the demand for tracks in service, and demand for maintenance capacities of the rolling stock and tracks. Following the increase in demand, the number of rolling stock in service, tracks in service, and their maintenance capacities start to increase but not with the same rate as demand increase because of time delayed involved in induction of rolling stocks, construction of tracks, and construction of maintenance capacities. As shown in figure 12 (a), the "Rolling stock index", that represents the percentage of rolling stock in service with respect to total number of rolling stock, declines in the long run. The decline of Rolling stock index shows a decreased number of rolling stock in service, or an increased number of rolling stock under maintenance. The number of rolling stock under maintenance increases due to inadequate maintenance capacity. Figure 12 (b) shows maintenance capacity of the rolling stock increases in response to increase in the number of rolling stock under maintenance, however, this increase does not sustain long because of the cash constraint, delay involved in construction of maintenance capacity, and depreciation of the maintenance capacity. The demand for maintenance capacity increases faster than the actual maintenance capacity. Due to inadequate maintenance capacity, a larger number of rolling stock remains out of service, in turn, the revenue declines which further enforce the cash constraint on construction of maintenance capacities, induction of new rolling stocks, and construction of new tracks.

Figure 12 (c) shows the behavior of "Track index" that represents decreased percentage of new tracks in service with respect to total tracks in service. The "Track index" represents the condition of tracks in service; decline in track index means that a larger percentage of tracks in service require maintenance, i.e., quality of tracks in service is poor. Poor quality of tracks in service is another factor responsible for increasing the number of rolling stock under maintenance. As shown in figure 12 (d), maintenance capacity of the tracks follows the same pattern as observed for maintenance capacity of the rolling stock.

Figure 12 (e) shows the behavior of "Average cash ratio" over the simulation period of 80 years. Average cash ratio is defined as a ratio between actual and desired cash level. Initially, this ratio is assumed as one that illustrates actual cash level of the PR is equal to the desired level of cash. Due to poor operations of the PR as illustrated in figure 12 (a) to (d) expenses of the PR including operation and maintenance cost, investment cost, and debt payments increase faster than increase in the cash inflow by revenue and borrowing activities, in turn, average cash ratio declines. Therefore, debt continuously rises as shown in figure 12 (f).

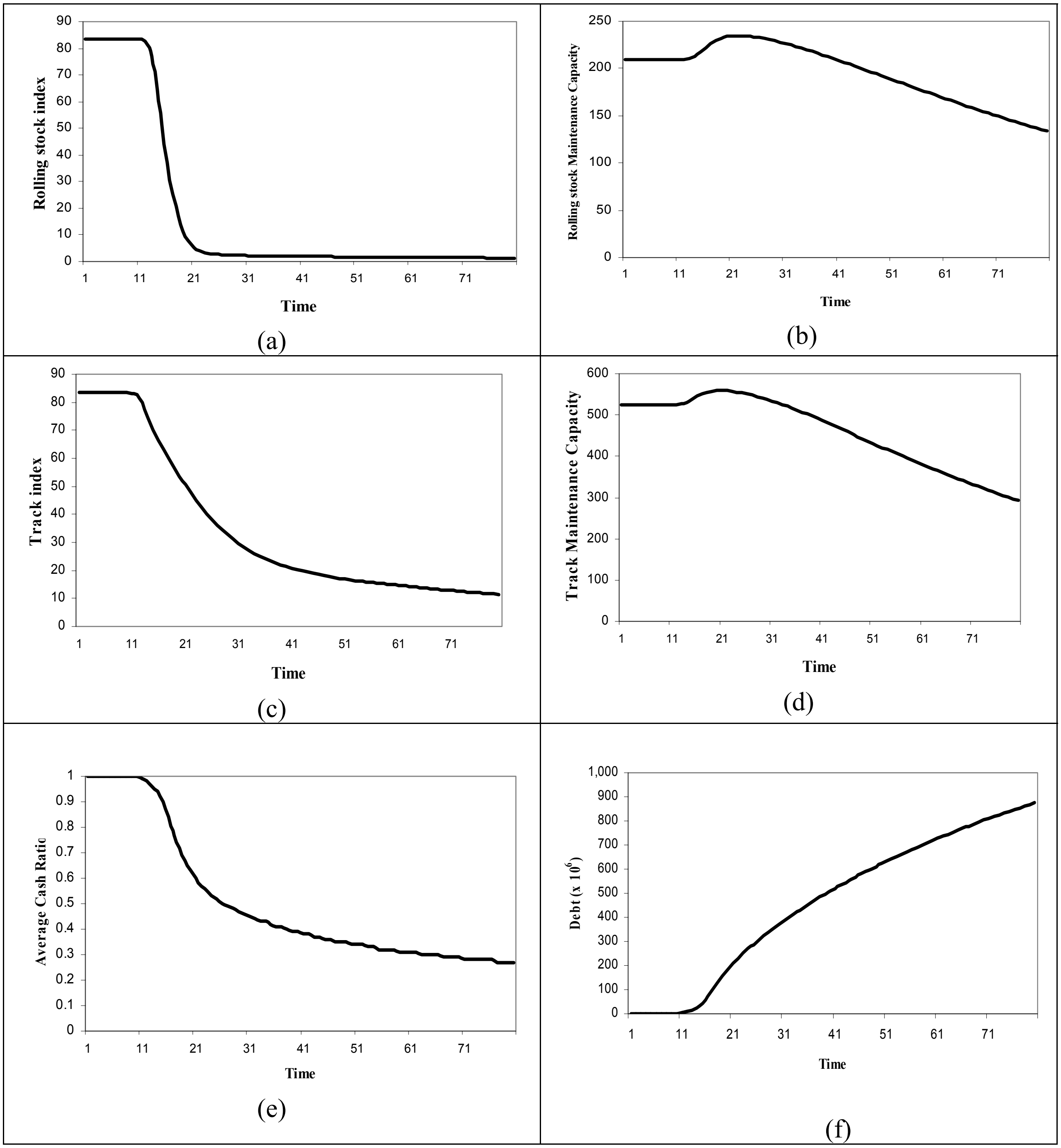

Figure 12 Simulation results of the base run

The simulation results of the base run discussed above qualitatively suggest that the model produced behavior is consistent with the observed behavior for financial and operational conditions of the PR. In order to further investigate the validation of the model, sensitivity analysis of the model parameters and nonlinear relationships is carried out.

Sensitivity analysis of the model

In general, System Dynamics models are not behaviorally sensitive to the changes in the most of the parameters and behavioral relationships, as are the real complex systems (Roberts, 1981). However, sensitivity analysis is an important process to identify entry points into a system. The sensitivity analysis of the model parameters is carried out by changing the base run value of the parameters around 25 to 50 percent. And sensitivity analysis of the nonlinear relationships of the model is carried out by changing the slope of functions considered in the base run. The change in the slope of the graphical functions represents the change in the strength of the nonlinear relationships, as the steeper is the slope of a function, the stronger is the effect and vice versa.

Each individual simulation run with the changed parameters and changed slope of the nonlinear relationships is compared with the base run simulation to find out whether the parameters and nonlinear relationships are behavioral sensitive or not. The results of the sensitivity analysis show that the model is behaviorally quite insensitive to the change in the parameters and slope of the graphical functions of the model. It infers that the uncertainty and the estimation error in the model parameters and nonlinear relationships do not affect the pattern of the model behavior.

Policy experiments

A number of policy experiments are carried out on the base run of the model to understand the implications of different strategies aimed at improving operational and financial situation of the PR. This section describes five of these policy experiments. All policies are implemented at time 50 of the simulation period of 80. These policy experiments are:

1) <u>Induction of Rolling stocks</u>: This policy involves the induction of new rolling stock (passenger coaches and locomotives). It can be interpreted that, the induction of new rolling stock would increase the rolling stock in service, which will improve the performance as well as the financial situation of the PR. In the model this policy is implemented by stepping up the “Normal induction of rolling stock” at time 50.
2) <u>Construction of more new Tracks</u>: In this policy experiment the “Normal construction of Track” is stepped up at time 50, which implicitly represents more investment in construction of new tracks. Construction of more new tracks will increase the track capacity, and increased track capacity would allow more induction of rolling stock in service. Consequently, number of rolling stock in service and tracks in service will rise and revenue will increase, hence, financial and operational condition of the PR will improve.
3) <u>Construction of maintenance capacities:</u> Under the existing policies of the PR, maintenance capacity of the rolling stock and track increases as their respected demand increases. The delay involved in the construction of maintenance capacity could result in increased number of rolling stock and track under maintenance. In order to reduce the

impact of delayed maintenance capacity, one strategy could be to adopt the proactive maintenance policy. In this experiment, the proactive policy for maintenance capacities is implemented by stepping up of the normal construction of rolling stock and track maintenance capacity at time 50. This policy assumes that increased maintenance capacities would complete maintenance of rolling stock and tracks within their normal maintenance time. Consequently, due to improvement in the maintenance capacity of rolling stock the number of rolling stock in service would increase. And due to improvement in the maintenance capacity of tracks the quality of tracks will improve that would help in reducing the breakdowns of rolling stocks. Hence, the number of rolling stock in service will rise, which will increase the revenue, and eventually financial and operational condition of the PR will improve.

4) <u>Combination of experiment 1 and 3</u>: This policy represents the investment in the induction of new rolling stock, and construction of maintenance capacities of rolling stock and tracks. Implementation of this policy is done by stepping up the "Normal induction of rolling stock", and normal construction of maintenance capacity of rolling stock and tracks at time 50. The underlying assumption of this policy is that combined affect of policy experiment 1 and 3 both will yield outcome that would improve the financial and operation conditions of the PR at a faster rate.
5) <u>Combination of experiment 2 and 3</u>: Similar to policy experiment 4, in this case policy experiment 2 and 3 are combined. This policy is implemented by stepping up the normal construction of tracks and normal construction of maintenance capacity of rolling stock and tracks at time 50. It is expected that implementation of two policies together would help in improving the financial and operational conditions of the PR.

The simulation results of above policy experiments are shown in Figure 13 to 18. These figures illustrate the comparative outcomes of the above five policy experiments.

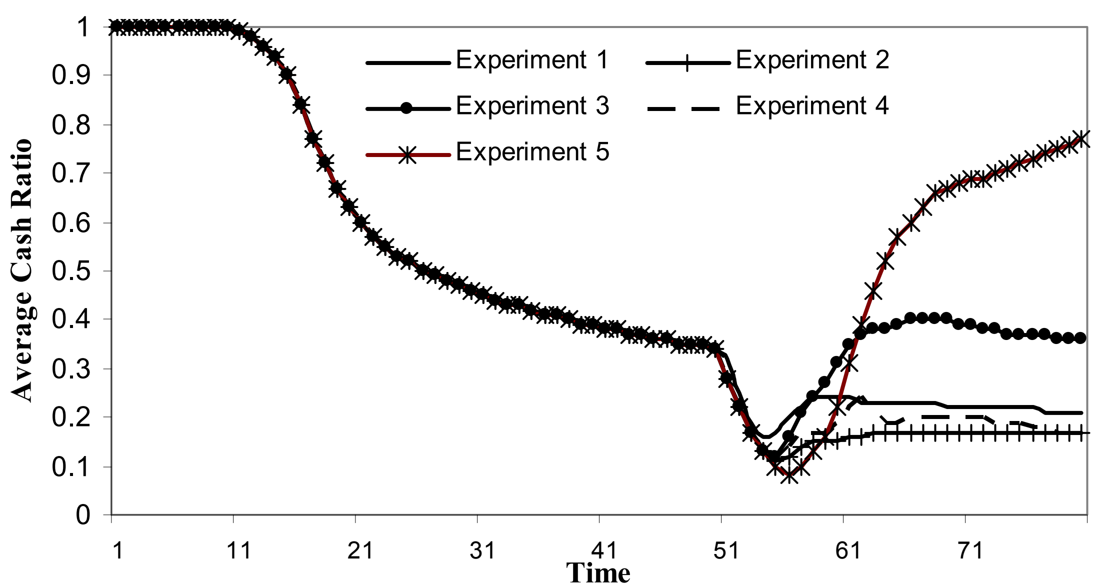

Figure 13 Behavior of Average cash ratio in policy experiments

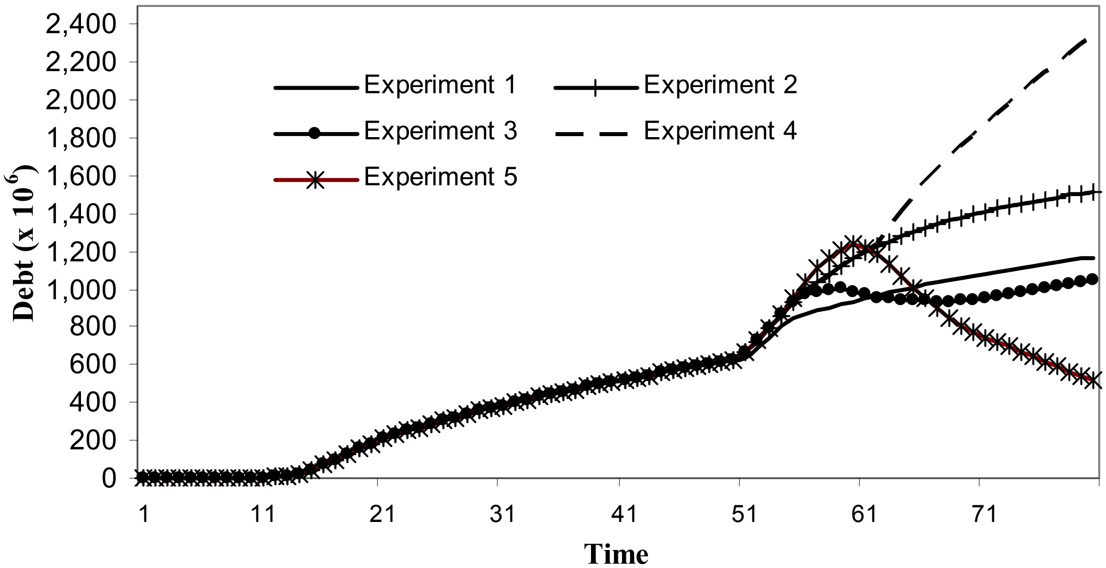

Figure 14 Behavior of Debt in policy experiments

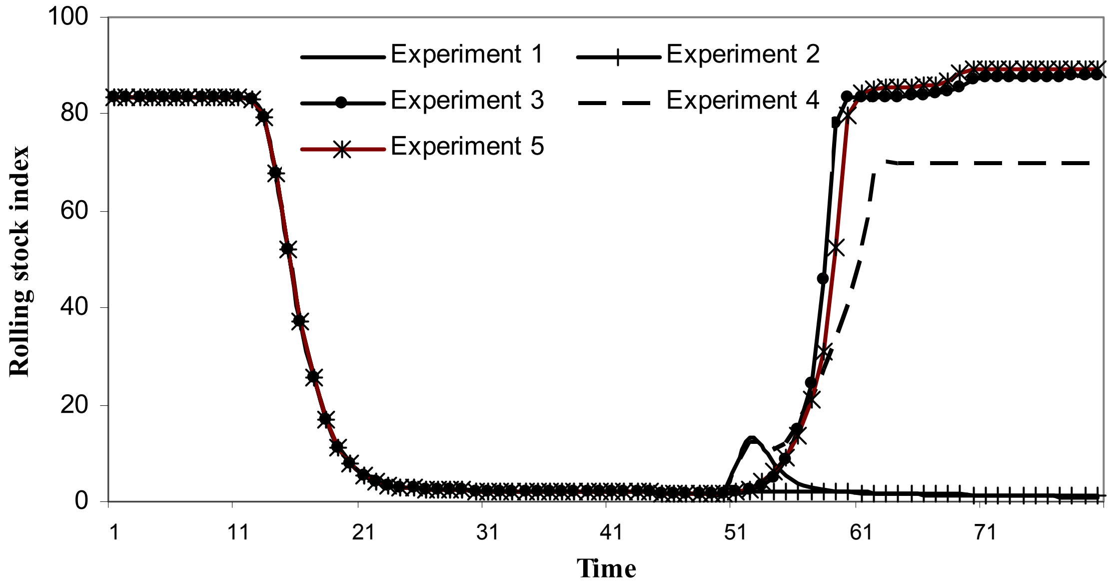

Figure 15 Behavior of Rolling stock index in policy experiments

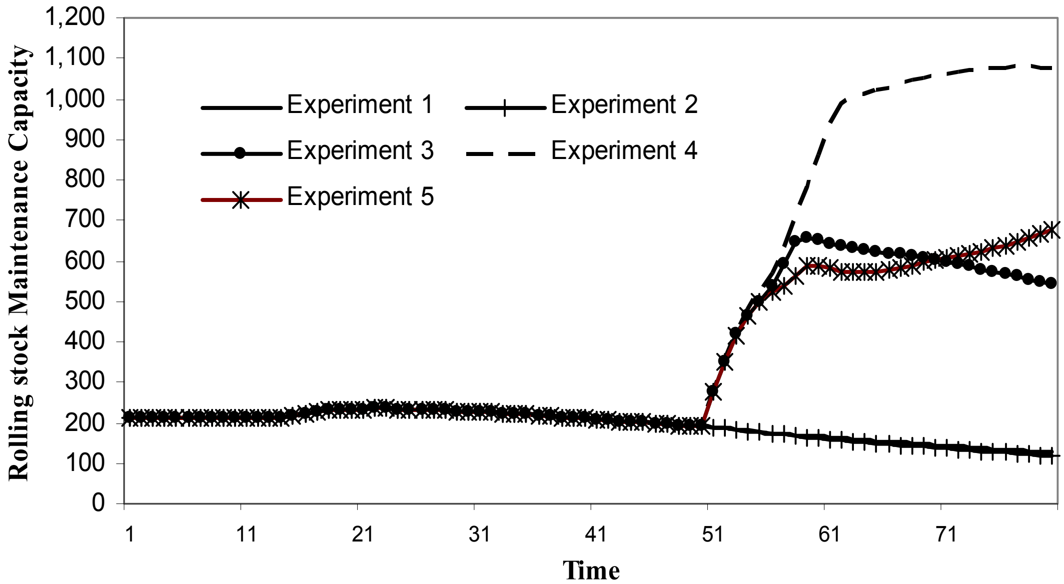

Figure 16 Behavior of Rolling stock maintenance capacity in policy experiments

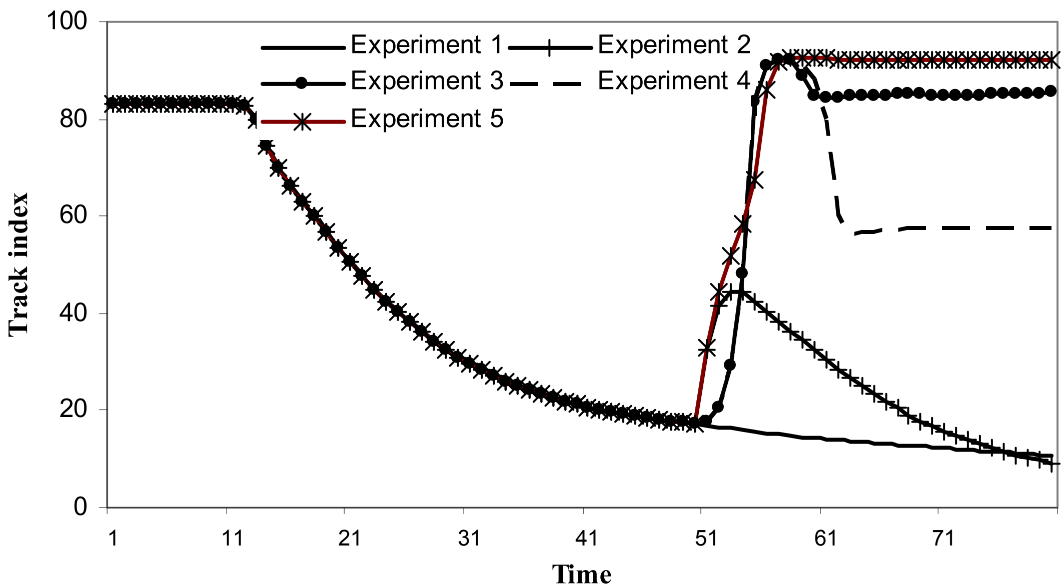

Figure 17 Behavior of Track index in policy experiments

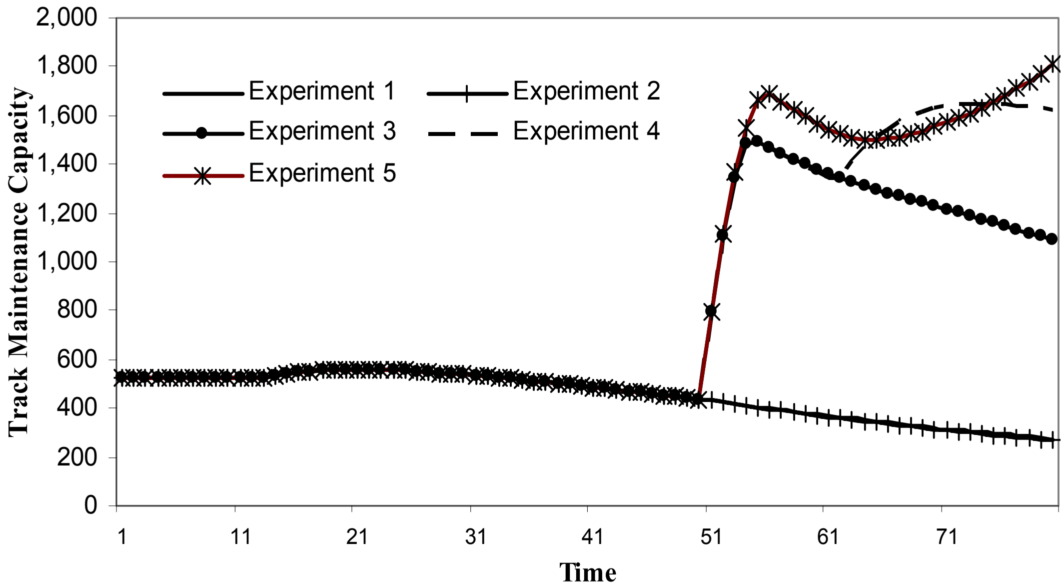

Figure 18 Behavior of Track maintenance capacity in policy experiments

The simulation results of the policy experiments shown in figure 13 to 18 demonstrate that individually implemented policies such as policy experiment 1, 2, and 3 are not able to improve the problematic behavior of the PR. However, when these polices are combined they form synergistic environment instigating behavior improvement of the PR. Model experimentation using different combination of policies assured that one appropriate policy (experiment 4: Induction of new rolling stock combined with construction of rolling stock and track maintenance capacity) improves the performance of the PR by increasing the revenue. This policy was proposed by the JICA who recommended, the induction of new rolling stock with assumption that tracks are well maintained is the best policy for the PR. The assumption made by the JICA that tracks are well maintained is satisfied through incorporation of increased tracks maintenance capacity. However, system analysis and experimentation assured that the policy recommended by the JICA is not the most appropriate policy for performance and financial sustainability of the PR, although this policy improves the performance of the PR by increasing the revenue. However, this increase in revenue does not eliminate the PR's debt burden. In fact, the increase in the revenue is not sustained in the long run because of constraint of track capacity on the induction of rolling stock. Thus, this policy temporarily improves the performance as well as financial situation of PR or offers a short term solution to the PR.

The best policy is the policy run 5 (Construction of tracks combined with construction of rolling stock and track maintenance capacity) which is verified through the model analysis and experimentation. Further, figure 19 and 20 can be used to explain how policy run 5 produces performance and financial sustainability for the PR. As illustrated in figure 19, it seems obvious that strengthening loop R1 by making investment in inducting rolling stock would yield immediate benefit of increasing revenue of the PR. However, by reinforcing loop R1 the number of rolling stock in service grows faster to its limit defined by the available track capacity. At saturated level of track capacity (loop B1) the breakdown of trains, and delay in trains' travel time increases that undercut the strength of the loop R1. Reinforcing the loop R1 without controlling the limiting factors that create resistance in strengthening the loop R1 is a symptomatic solution with which problem resurface in the long run. This implies a sustainable solution would be to control the limiting factors that create resistance in the loop R1. One of these limiting factors is the track capacity constraint on induction of rolling stock which can be removed by controlling the balancing loop B2.

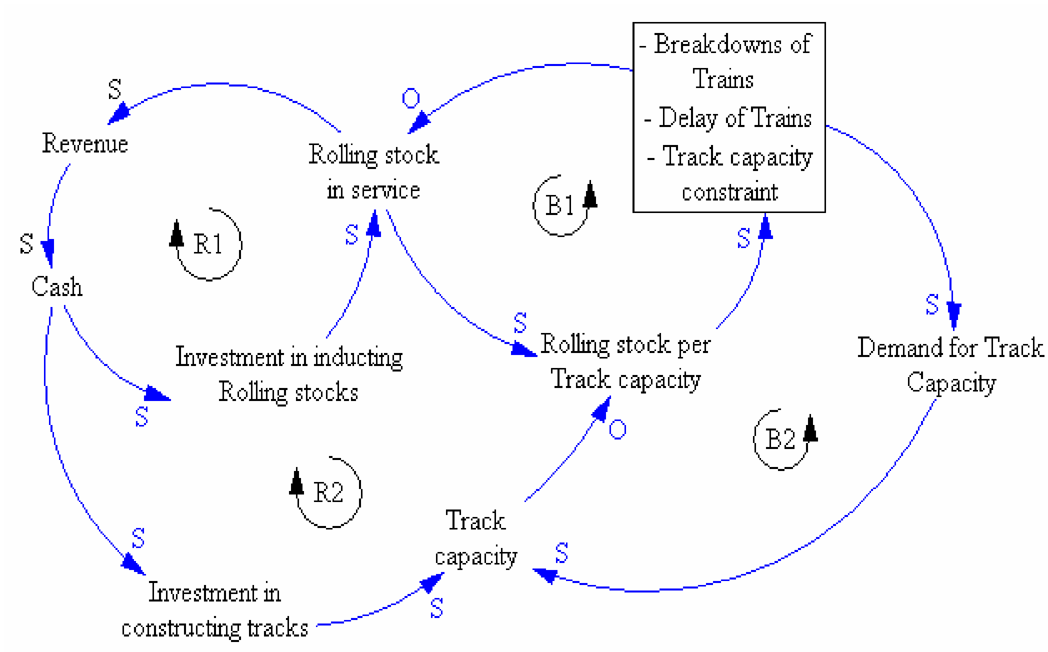

Figure 19 Loops explaining the best policy for the PR

The other limiting factor for the loop R1 is the maintenance capacity. As number of rolling stock in service increases, so does the demand for maintenance capacity. Limited maintenance capacity increases the maintenance time and therefore, rolling stocks remain out of service for longer period of time that undercut the strength of the loop R1. Increased provision of the maintenance capacity in balancing loop B4 (figure 20) supports the sustained strength of the loop R1.

Hence, due to the increased maintenance capacity and track capacity the number of rolling stock in service increases. Therefore, frequency of trains increases and eventually revenue increases. In turn, the average cash ratio rises, which increases the debt service ability so that the level of debt decreases in the long run. Thus, the high level of revenue eliminates the debt and provides support for investment in other sectors of the PR. Hence, this policy offers a performance and financial sustainability to the PR not only for the short run but also for the long run.

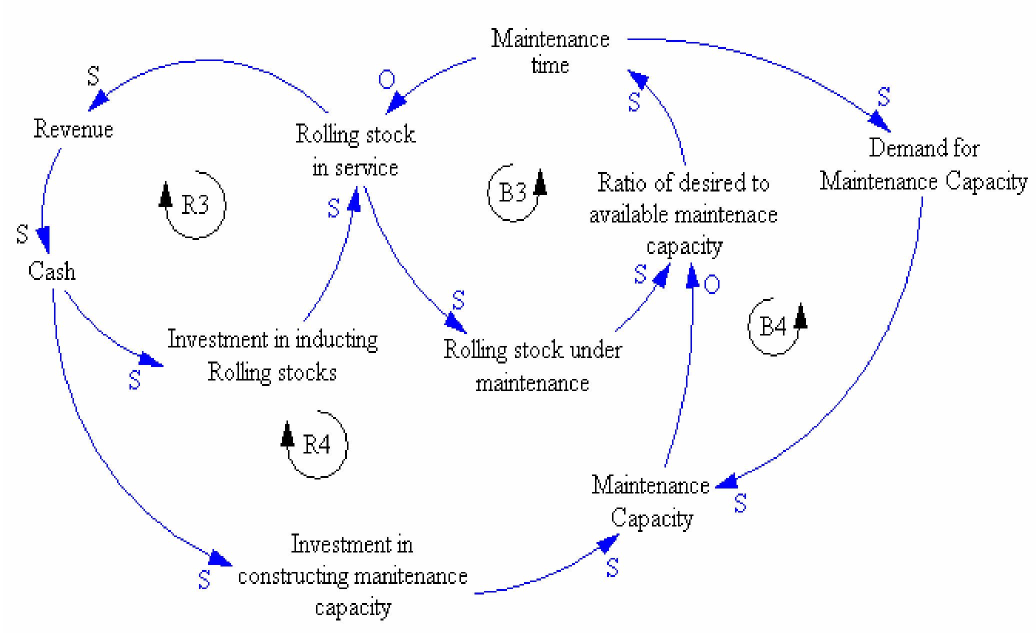

Figure 20 Loops explaining the best policy for the PR

The model experimentations helped in identifying the actual cause that created problematic behavior of the PR. Based on the model experimentations it is found that limited track capacity of the PR is one of major causes that creates constraint for establishing a sustained desired outcome. In addition, increased provision of the maintenance capacities is also has been found an important element for improving financial and operation problems of the PR not only for the short run but as well as for the long run.

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