

## **Effectiveness Of Infrastructure Service Delivery Through Earmarking: The Case Of Highway Construction In China**

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### **ABSTRACT**

Cost overruns in Chinese highway construction projects arise both from poor construction quality and delays in completion. Due to the lack of an effective control mechanism linking project initiation with funding availability, new projects are initiated without sufficient budget to support completion as planned. Project managers are forced by the budget constraints to either sacrifice construction quality or slow down the pace of construction. This paper develops a system dynamics model to understand the cost overrun problem in Chinese highway construction projects. Three policy options, (1) introduction of feasibility studies, (2) loan financing of the cash-strapped projects and (3) the raising of user charges, are evaluated using this model. The introduction of feasibility studies has the potential to be an effective policy, yet it is impossible to implement due to organizational constraints. Loan financing leads to dependence on loans rather than sustaining service delivery. The raising of user charges is found to be the most effective policy, although it is politically not very attractive.

## **Introduction:**

China is one of the few countries of the world where expenditures for highway construction rely primarily on revenues generated from user charge fees, in the spirit of what is known as earmarking practice. Earmarking of financial resources to ensure an adequate allocation of resources for highway construction has been suggested by many researchers (Swaroop 1994, Peterson and Evanston 1985). Earmarking can be considered as benefit taxation (Musgrave and Musgrave 1976) and in some instances may increase allocation efficiency by ensuring more rational individual choices since with earmarking the individual can appraise more closely the relevant costs and benefits of a particular project (Buchanan 1963). Earmarking policy in China has, however, been neither effective nor efficient. It has been observed that China's performance in highway construction since the 1950's has been insignificant compared with India's or Brazil's (World Bank 1995). The poor performance of highway service provision in China is not only evident in the low density of highways but also in poor construction quality. A World Bank policy study on road deterioration in the developing countries classified China among the countries with an extensive but obsolete road network in need of modernization to meet rapid growth in road transport demand (World Bank 1985, 1994a). The key problem in Chinese highway service provision seems to lie in the lack of attention paid to economic efficiency in investment decision making (Seiichi 1982, Curry 1990). Projects are often initiated without a guarantee of funding, which results in construction delays and rising construction costs (Xu 1996). Costs per kilometer during the Fourth Five Year Plan period (1971-1975) were three times the level in real terms of the First Five year Plan period (1953-1957). Meanwhile, highway quality is sacrificed to meet the limited budget. Until the 1960s, most regional roads at the county level in China were simply dirt tracks not suitable for motorized traffic, while less than half of all roads were blacktopped in the late 1970s (Lynos 1985).

In this paper we present a system dynamics model we have built to examine the decision making processes underlying the Chinese highway service delivery system that has led to its poor performance. Experimentation with this model suggests that, as earlier observed by Mashayekhi (1996) for the case of Iran, the lack of an effective control mechanism to manage the initiation rate of new projects is one of the major reasons for the poor highway service performance in China. Projects are initiated without adequate financial resources for project completion. Highway quality is sacrificed in order to reduce the

construction cost. Simulation experiments with the model also indicate that the use of feasibility studies to limit the number of new projects could offer an effective solution to this problem. In reality, however, this policy means a radical change in the relationships of different role players in the highway service decision making system which may be difficult to achieve. Policies which facilitate the obtaining of international and domestic loans cannot radically change the decision rules behind the initiation of new projects. They instead weaken the constraints that should normally limit the starting rate during the grace period of the loan, thus intensifying the financial crunch in the future. Although a policy of increasing the user fee charges that increase earmarked funds for the highway service may alleviate the financial problems that create project time and cost overruns, the availability of abundant resources for the ongoing projects may often invoke overspending to complete projects in record short time, which of course increases project cost.

### **Highway Service Delivery in Developing Countries**

The level of highway service is an important factor that attracts investment thus offering long term benefit to the local economy (Taylor 1992, Diewart 1986, Frederikensen 1980). Thus, the construction of highways is expected to foster economic development. However, in the developing countries, the levels of highway service provided are relatively low. Also, roads connecting new regions are often built for political rather than economic reasons, while the benefits from road construction are perceived to be linked with broader development objectives rather than to meeting existing demand. The expansion of highways is usually supported by the government through development projects in the hope that the highways will facilitate economic growth. The research on the management of highway development projects at the macro-level has, however, been very limited, hence systematic procedures for the selection of highway projects are lacking (Lemer, et. al., 1995). In default, the allocation of funds to the prospective projects is driven rather by a bargaining process (Khan 1984). We have determined in this paper that it is the unregulated bargaining process that leads to mismanagement of new project initiation, which in turn results in construction time overruns as well as in a lowering of the quality of the roads built.

### *Characteristics Of Highway Infrastructure*

Highway infrastructure can be considered in terms of two “products”: (1) highway capacity, in the form of traffic lanes, to meet traffic volume and (2) durability, in the form of thickness of pavement to facilitate heavy motor vehicle traffic (Winston 1991). The quality standards of highway infrastructure are closely related with durability. Determination of normal cost to construct one unit of highway is an important factor to achieve efficiency and effectiveness of highway construction. Stronger roads will have lower maintenance costs but higher construction costs. Technically there are difficulties in planning road durability, especially when the life span of the pavement is also considered (Rao 1982). Should the pavement be designed for a 20 year life, as is the practice in the United States, or for a 40 year life span, as in Western Europe? China's current practice is to design pavement for a 15 year life span. Empirical evidence shows that although the lower initial construction cost accelerates the expansion of the total highway stock, it also accounts for much higher maintenance and rehabilitation costs later, as well as higher user operating cost (Winston 1991). However, in developing countries, the social returns for new highway construction are universally high (University of California, 1970) and the demand for highway services far exceeds the building and maintenance capacity made possible by the available user fees. Therefore, there is a strong tendency in the developing countries to maximize the quantity of highway construction, while ignoring the quality.

Construction quality standards for highway infrastructure are seldom discussed in the economic literature. The assumption is that the desired quality of the project (generally the thickness of the pavement) will be achieved and controlled according to the standards based on economic analysis. Generally speaking, it is reasonable to assume that highway quality control is not a big problem for highway projects since most important decisions regarding quality are made during the design and planning stages rather than during construction. Quality control during construction consists largely of ensuring conformity to the original design (Hendrickson and Au 1989). However, whether the owners, contractors and construction companies stick to the design is questionable in many developing countries, especially when the owners and contractors are all in the public sector and job responsibilities and accountability criteria are difficult to discern. The low quality of highway infrastructure brings about losses to users and various social groups, and thereby reduces the efficiency of highway projects.

## *Effective Financing Policy For Highway Infrastructure*

An efficient financing policy can dramatically improve the performance of the highway service delivery (Winston 1991). Traditionally, it is believed that since highways are invariably a non-marketable commodity, there is little or no potential to recover the costs through user charges. In a study of developing countries, Heggie (1991) discovered that highway service consumers generally receive subsidies on road services. User charges were significantly less than total expenditures on highway construction and maintenance. Only China and Turkey financed road construction completely through user charge fees. Usually, subsidies may take the form of direct government subsidies, foreign loans with low interest, and earmarking user charges (Eichengreen 1995, Swaroop, 1994).

Modern road supply theory suggests that efficient pricing and self-financing road policies are compatible. Thus, under efficient pricing, highway infrastructure should be self-financing (Newbery 1990). Efficient pricing also takes into account the costs that users of highway services impose on themselves and others by contributing to congestion and by wearing out the infrastructure, which necessitates maintenance expenditures to repair pavement and vehicles (Winston 1991, Keeler and Small 1977, Newbery 1990). Table 1 shows the various highway financing policies and their underlying assumptions.

Little work has, however, been done to understand the dynamics of implementation of these policies, particularly in the developing country context, which we have attempted in this study using China as a case. A system dynamics model incorporating key decisions in the Chinese highway service delivery system is developed and experimented with to identify the weak control mechanisms causing decay in highway service delivery. Through experimentation with the model, we are able to test the effectiveness of the various highway financing options outlined in Table 1.

<b>policies</b>	<b>financing options</b>	<b>assumptions</b>
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<b>pure self-financing</b>	<ul style="list-style-type: none"> <li>&lt; user charge</li> <li>&lt; borrowing with market interest</li> </ul>	<ul style="list-style-type: none"> <li>&lt; highway users as a group do not provide any positive or negative externalities to the outside groups.</li> </ul>
<b>self-financing with favorable policy</b>	<ul style="list-style-type: none"> <li>user charge with</li> <li>&lt; earmarking, or</li> <li>&lt; favorable interest rates</li> </ul>	<ul style="list-style-type: none"> <li>&lt; highway users are the main beneficiaries from highway construction.</li> <li>&lt; Positive externalities are limited.</li> </ul>
<b>government funding</b>	<ul style="list-style-type: none"> <li>financial resources allocation through general tax either by</li> <li>&lt; earmarking</li> <li>&lt; non earmarking</li> </ul>	<ul style="list-style-type: none"> <li>&lt; highway users only benefit from a small part of highway construction</li> </ul>

Table 1. Financing options for highway services and their underlying assumptions

### **Key role players in highway construction projects in China**

The performance of Chinese highway service delivery is greatly influenced by the underlying administrative structure (Hu 1995). In order to understand and assess the effectiveness of the highway project design and implementation, there is a need to understand the major role players and their decision making processes which follows:

#### *Highway Agencies*

At every level of government, from the county level to the central government level, the highway sector in China is under the responsibility of the Agencies of Communication (in this paper, we use the term “highway agencies” in an aggregate sense). The highway agencies assume full responsibility to deliver

highway services and are empowered to collect and administer user charges. A large number of the state-owned enterprises for highway construction and maintenance work are also under their control.

Chinese highway agencies are regulated and influenced by governments, social groups and other highway service users. Highway agencies are under pressure to construct as many highways as possible in the shortest possible time. In the medium term, the main objective of the highway authorities will be to ensure that the highway systems help integrate China's economy (World Bank 1994a, Minami 1994). However, the availability of the financial resources needed to construct these highways cannot be guaranteed. It is the highway agencies who control the managerial information concerning the technical details of highway services delivery. It would entail a high cost for outsiders to verify the information provided by highway agencies rapidly and accurately. The governments and other social groups only perceive the performance of highway projects after a lengthy time delay. Awareness on the part of the highway agencies that the governments and user groups can easily perceive the construction rate in a short time but *cannot* easily perceive construction quality shortfalls means that the highway agencies tend to sacrifice construction quality for quantity.

#### *Road construction companies*

The majority of the construction companies are state-owned and are subsidiaries of the highway agencies. The relationship between the highway agencies and these state-owned subsidiary enterprises has been referred to by some authors as "father and son" (Hu 1994, Pan and Luo 1995). The highway agencies typically delay payments for work which has already been initiated (World Bank 1994a), thus limiting the construction companies' working capital. Also, public works are always put into bidding at abnormally low prices and only provide small margins for working capital and the updating of equipment. Only these state-owned companies are able to or forced to meet the low prices since they do not face any risk for poor performance. Therefore, quality standards are not strictly evaluated. The construction companies have inadequate laboratory and field testing equipment, which is essential for quality control. The equipment they use is generally old and suffers frequent breakdowns (World Bank 1994a).

#### *Government at all levels*

Governments, central and provincial, have direct administrative power over the highway agencies. The governments are assumed to represent the highway users. Governments deliver demand pressure directly to the highway agencies and also fix user charge fees. However, they themselves are also free riders of highway construction projects. They benefit politically from more highway construction. More highway construction means more attraction for investment, more political achievement and more support from other free riders. Although the governments are more concerned with quality issues than the highway agencies, the incentives for governments to control quality are not strong. It is relatively easy for the governments to communicate to the public their achievements in the development of highway services using easily measured and understood quantitative data, such as highway completion rates, or total stock. However, there are no easy indicators by which the governments can demonstrate highway service quality to the public. Also, it is operationally difficult for the governments to obtain information on highway quality and associated costs. Governments are aware that highway agencies are monopolists and have the potential to not use their productive capacity fully. An operational way to push highway agencies to provide more service is to intensify the demand pressure on the highway agencies (Hu 1994).

### *Highway customers*

In theory, customers are the driving force for the provision of highway services. However, the Chinese economic system is a supply driven system (Hu 1994). The highway agencies have the power to decide how much and what kind of products are to be supplied. The highway customers have little influence on the supply decisions. The feedback from the users on the performance of the highway service is delayed and consequently makes little impact. Highway service users are thus in a disadvantaged position to monitor and guarantee their own economic and social welfare.

### *Free-riders*

Free-riders will deliver their demand for highway construction through political pressure on the governments.

## **Modeling highway service delivery in China**

We have developed a system-dynamics model for the purpose of analyzing the decision making process underlying the Chinese highway service delivery system. The model is based on Mashayekhi's generic model of development projects. Although it is argued that it is absurd to attempt to decide where and when to build or improve highways by financial calculation, in developing countries, initiating a project within the available financial resources is the first step in guaranteeing the consumers' benefits. Mashayekhi's model has shown that, when there are no effective means by which to optimize the resource allocation between progress resources and base resources, development projects usually undergo cost and time overruns due to shortage of available progress resources. Two substantial modifications are made for the case of the Chinese highway delivery system based on Mashayekhi's model. These modifications make the total resources available for highway construction and normal unit cost endogenous variables in place of the original exogenous variables. The first modification accounts for the earmarking policy in China; the second represents the replacement of standard quality projects with lower quality projects in order to reduce the time overrun of projects. Three policies, (1) feasibility study, (2) loan financing and (3) raising of user charges are then evaluated using the modified model.

### *Mashayekhi's model*

Conventional techniques to improve the effectiveness and efficiency of project construction focus on the definition of the project work structure and on detailed schedules and budgets for monitoring and controlling performance throughout the project life cycle (Nicholas 1990, Mashayekhi 1996). A well managed project progresses in well defined stages to completion. It assumes that the organizational background in which the projects is situated is stable (Rodrigues and Bowers 1996). The boundary of the project is defined in a way that the objective of the project is clearly understood by the client and the project managers. The clients and project managers have substantial control over their own decisions. However, in highway construction projects in the developing countries, the management of highway service projects is not a micro-level bounded problem. Mashayekhi (1996) points out that many factors causing the cost overruns are outside of the project manager's span of control, for example, lack of

balance between the aggregate development budget and the required resources for development projects. Development projects are investments, undertaken by the governments of the developing countries, to construct infrastructure and production capacity to enhance and facilitate the development process. Mashayekhi's model is a generic system dynamics model of cost escalation in development projects. The model considers multiple concurrent projects nationwide.

Mashayekhi divides costs for development projects into two categories: *base cost* and *progress cost*. Base cost consists of all cost elements necessary to keep a project in readiness for physical progress. Base cost includes such items as the salaries and overhead costs of project managers and staff, costs of having construction machinery and equipment ready on the project site and the organizational overheads incurred by the project. Progress cost consists of those cost elements that can create physical progress. It includes such items as construction materials, construction labor and operating cost. A project is completed only when the progress cost has been met for completing all necessary activities. Base cost has, however, priority over progress cost because base cost must be paid in order to create conditions in which progress can be effected. The model assumes that the completion rate of the ongoing projects is a function of the resources allocated for progress cost, unit cost and the number of ongoing projects. Therefore, when the base costs are too high, the resources for progress will be inadequate. Projects will slow down or even stop during construction due to the lack of financial resources to maintain operation cost, hire workers or purchase raw materials. In the developing countries, there is often no effective way to directly control the desired starting rate in accordance with the capital budget. The starting rates for new projects can only be checked when the role players become aware of inordinately long completion rates and of the limitation of financial resources.

The behavior of Mashayekhi's model is shown in figure 1. The model is initially set in equilibrium and the exogenous starting rate is increased from its equilibrium value by a step at year 1. The starting rate then jumps up above the completion rate and the number of projects in progress increases. As the number of projects in progress increases, the required base budget increases, meaning fewer resources are available for progress cost. As a result, the project completion rate drops and the completion time lengthens. The inadequate progress budget and the lengthening of completion time causes the starting rate to diminish. When the starting rate drops down to the level of the completion rate, the growth rate

of projects in progress slows down. The number of projects in progress reaches its maximum at about year 19 when the starting rate is equal to the completion rate. The number of projects in progress reaches a new equilibrium above its initial value. The completion time index and the completion cost index also increase to above their initial values. When the exogenous desired starting rate is increased above initial equilibrium, pressure arising from the constraint on funding availability and the long completion time force the system to lower the starting rate to the original level of the completion rate.

Figure 1. Simulation run of Mashayekhi's model

In order to better understand the basic structure of the system and gain confidence in the explanation of problem behavior, we conducted sensitivity tests. For the sensitivity analysis three parameters were selected: (i) highway budget, (ii) problem perception time, and (iii) normal completion time. The sensitivity analysis shows that the budget available for initiating projects is crucial in controlling the overrun of project cost. The normal time to complete a project unit is also important. When the time to complete the project is reduced, the total resources that are allocated to the base cost will be reduced. Thus, more resources are available for project progress and cost overrun problems are relieved to a certain degree, so projects can be completed at a higher rate while maintaining a smaller stock of ongoing projects. The third parameter, the problem perception time is insensitive.

#### *A model of the Chinese Highway Service Delivery Process*

It was necessary to make two modifications to Mashayekhi's model for representing the case of the Chinese highway service delivery system. First, since all the resources that are paid for highway construction in China are earmarked fee receipts, which are a function of the total stock of highways, a resource allocation sector had to be added. Second, the quality reduction problem was taken into consideration.

Figure 2. Overall structure of the Chinese highway service delivery model

Our model of the Chinese highway service delivery system contains three sectors, *Highway Project Development*, *Resource Allocation* and *Project Initiation* (see figure 2). The *Highway Project Development Sector* has a single stock representing ongoing projects. These ongoing projects can be completed either with standard quality (the quality specified in the design) or reduced quality according to the availability of progress resources. Two other stocks represent the completed standard quality and reduced quality highway infrastructure. The *Resource Allocation Sector* represents the decision-making processes underlying resource allocation between base cost and progress cost. It also incorporates the mechanisms by which standard quality is shifted to reduced quality when the highway producers and construction companies face financial burdens. The *Project Initiation Sector* outlines the decision-making process underlying project initiation.

The diagram of the *Project Initiation Sector* shows that the decision to initiate a project is a function of four major factors: (i) the normal starting rate (NorStartingRate), (ii) the effect of progress budget availability on initiation rate (EffBudgetOnStarts), (iii) the effect of project quality on initiation rate (EffQualityIndexOnStarts) and (iv) the effect of unit project completion time on the initiation rate (EffCompTimeIndexOnStarts). The normal starting rate represents the indicated planned initiation rate of highway projects with the assumptions that adequate progress resources are guaranteed and that the project will be constructed with standard quality and timeliness. The effect of the progress budget on the initiation rate reduces the starting rate when inadequate resources are available. This represents the pressure from highway agencies and construction companies to stop initiation of new projects when they face management difficulties due to the lack of working capital. The effect of project quality on initiation rate takes effect when more and more low quality projects are commissioned. Users' complaints will eventually be perceived by the government and highway authorities after a lengthy delay period. Action will then be taken for better quality control, and fewer projects will be allocated for initiation until the quality problem can be institutionally corrected. The effect of unit project completion time on the initiation rate comes from the government's awareness of delays in project completion. Time overruns of

highway construction are relatively easily perceived by government officers. All three effects that influence initiation rates of highway projects involve delay processes.

In the *Highway Project Development Sector* (Figure 3) there are three stocks which represent the states of highway projects, (i) highway projects in progress, (ii) completed standard quality highway stocks and (iii) completed reduced quality highway stocks. When highway projects are initiated, they enter the stock of highway projects in progress. The projects in progress are depleted by both the completion rates of standard quality projects and low quality projects according to the prevailing financial situation. Completion rates of both standard quality projects and reduced quality projects are determined by the progress budget allocated for each, and the average actual cost required to complete one project unit.<sup>1</sup> It is assumed that average cost to complete one unit of reduced quality project is 75 percent of the average cost to complete one unit of standard quality project. Standard quality and reduced quality highway capacity stocks begin to accumulate when projects in progress are completed. Because it is difficult for the government agencies and consumers to distinguish low quality from standard quality projects, both are put into total projects in use which constitutes the base for user charges. In statistical reports, the two rates are categorized as one completion rate. Highway infrastructure capacities are depleted by the capacity depreciation rate. 15 years is used for standard quality project life and 12 years for reduced quality projects.

Figure 3. Project initiation and projects in progress

The *Resource Allocation Sector* describes the decision making process behind resource allocation (See Figure 4). The revenue of the highway sector comes from user charges, which is a function of (i) the highway capacity in use, (ii) the user charge per unit, and (iii) net borrowing for highway construction. The use of highway services depends solely on the traffic volume-capacity ratio (Hau

1992). Historical data shows that only 25% of the total revenue is allocated to highway construction (highway construction budget) from the total highway budget (World Bank 1994a, 1995). The remainder is used for administration fees, maintenance fees, etc. When the highway construction budget is assigned, it is first allocated to meet the base cost for ongoing projects (base budget). The base budget is a function of the number of projects in progress and the base unit cost. The remainder is for the progress budget which is allocated for buying materials and paying laborers' wages in order to complete ongoing projects. Ideally, the progress budget is used to complete projects according to designed standards. However, when there is financial pressure, the tendency to reduce the quality of projects increases. In the model this is represented as a non-linear graph function (effect of budget ratio on resources used on low quality projects).

Figure 4. Resource allocation process

### **Understanding the Chinese highway service delivery system**

The model is initialized in equilibrium representing a hypothetical state which is a point of reference. This state is disturbed by stepping up exogenous pressure on the starting rate of new projects. This disturbance represents the high demand placed by economic growth on highway service delivery. The behavior of the base run is shown in Figures 5-a and 5-b. After the initiation rate is stepped up, new projects begin to flow into the construction progress stage. As projects under construction increase, the base cost rises. Since the total budget can increase only after ongoing projects are completed and since base costs have increased, the remaining budget for construction progress work decreases. In China, it is often politically risky to overrun the completion time for projects. Therefore, when the highway authorities are under financial pressure, the quality control for ongoing projects is relaxed. The tendency to construct low quality projects is very strong in the Chinese planned economy. Since the same amount

of progress budget can complete more low quality projects, the perceived overall completion rate does not decrease. Instead, it rises. Therefore, the total stock of completed projects rises. Yet, one can see from figure 5-b that during the process, a large share of the completed projects are of low quality. Perceived completion time, perceived progress budget and perceived quality index are three controlling variables that determine the behavior of the starting rate for the new projects. When the starting rate is stepped up, the availability of progress budget declines, and completion time for the ongoing projects rises. Therefore, the starting rate is dragged down. However, when a large volume of low quality highway projects is built, completion time for the ongoing projects decreases after an initial upheaval. Meanwhile, the accumulation of low quality projects also contributes to increased revenue for highway construction. Availability of the progress budget increases after an initial decline. The starting rate, which is largely determined by the completion time and the availability of the progress budget, first declines and then picks up. Even though the increase of low quality highway capacity has some effect on the starting rate, this effect remains very small.

Compared with Mashayekhi's original model, the starting rate of new projects remains at a higher level because a substantial fraction of projects are completed with reduced quality. Quality reduction process is often not easily recognizable. In reality, the quality standards generally are eroding targets. After a decline in quality has occurred, the existence of a percentage of low quality products becomes the normal phenomenon which is widely accepted. As we have discussed earlier, due to the tolerance of low quality highway construction, the effect of the budget constraint and completion time on reducing the starting rate will be weakened. The system will reach a new equilibrium when the starting rate is equal to the sum of the completion rates of standard and reduced quality projects. The high completion rate is maintained because the total revenue for highway projects is increased and the total construction cost is reduced by lowering quality. At the new equilibrium stage, projects in progress remain at a higher level than at the original equilibrium. The completion time is longer, the budget available for progress cost is still limited, and a certain portion of the projects are of low quality.

Figure 5-a. Base run of Chinese highway project cost dynamics

Figure 5-b. Base run of Chinese highway project cost dynamics

Figure 6 shows the key feedback loops formed by the model interactions that precipitate the system behavior. There are three major feedback loops that control the initiation rate of new projects. When the initiation rate rises, more projects enter the construction phase. More resources are allocated for base cost and, consequently, fewer resources are available to complete projects in progress. The first controlling feedback loop takes effect when the shortage of resources allocated for progress budgets becomes serious enough to be perceived by the authorities. The shortage of resources for progress budget is only perceived after a time delay. It invokes action that will reduce the project initiation rates. The second controlling feedback loop comes from the time overrun of projects. Although time overrun of projects also involves perception time, it is easily detected and action will be taken to reduce the initiation rate relatively quickly. In relative terms, this feedback loop is the most significant of the three. The third negative feedback represents the effect of project quality control.

Figure 6. Controlling feedback loops of Chinese highway service delivery

When construction companies are facing working capital pressure, they tend to reduce project quality. Low quality projects accumulate until, after a certain time delay, the poor quality is detected by the consumers and acknowledged by governments and highway agencies. Actions are then taken to reduce the initiation rate until the quality problems are solved. However, this controlling feedback loop is the least effective in reducing the initiation rates in the short run. There is another compensating feedback from the construction of low quality projects which weakens the three controlling feedback loops. When there is a shortage of progress resources, more projects are constructed with reduced quality. Since the

reduced quality projects cost less, the completion rates of projects will not fall. Total completed projects, which contains both quality projects and reduced quality projects, still rise. Therefore, more revenue can be generated from user fees. The shortage of progress resources is therefore relieved to a certain degree. The other two controlling effects, the pressure of progress budget shortage on initiation rates and the pressure of project completion rates, will be weakened and initiation rates of new projects will remain high. However, there is also another positive feedback loop which can strengthen the controlling mechanism. When fewer resources are available for progress budget, completion rates of projects begin to decline, fewer projects are completed and in readiness for use by consumers. Therefore, less revenue is collected for further highway construction and fewer resources will be available for the progress budget. Substandard quality thus acts as the “safety valve” in the Chinese system that keeps the expansion going strong, despite inadequate budgets.

### **Policy designs to improve the performance of Chinese highway service delivery**

The problems of low effectiveness and low efficiency in the Chinese highway delivery system are acknowledged by policy makers. Policies to reform the system are being adopted and implemented gradually. There is a need to evaluate these policies before intensive corrective efforts are in place.

#### *Policy option 1: introduction of feasibility studies*

Feasibility studies help to demonstrate the benefits gained from development projects and to rank the projects and select the most profitable option when funds are limited. Introducing feasibility studies in the Chinese highway system, however, amounts to the transfer of an exogenous new technology to an existing institution. If the institutional structure for managing highway projects remains unchanged the new technology will not be effective. During a feasibility study, technically, many items like social benefits, social costs, and price distortions are impossible to quantify. The results of benefit/cost analyses under the circumstances are not compelling when project options are ranked. There is no data which demonstrates the percentage of projects that are proposed but finally rejected through feasibility studies. In China, feasibility studies are generally only a formality and almost all feasibility studies for

highway development projects can demonstrate positive gains over cost. Therefore, feasibility studies in reality only delay the starting rate of new projects for the period of the study. Figure 7 illustrates the changes in the decision structure when feasibility studies are introduced. A stock is added to represent projects under feasibility study. The inflow to this stock, the feasibility study rate, is constructed as the starting rate of new projects in the base run. There are, however, two outflows from this stock. One is the starting rate of construction, which is also the inflow into projects in progress. It is defined as the stock of projects under feasibility study divided by time required for the feasibility study. The second outflow is the project discard rate defined as a normal discard rate given by a fractional discard rate multiplied by the projects under feasibility study, modified by the effect of budget availability, but this is set to zero since the studies are not taken seriously. The simulation run shown in figure 8-a represents this case. Compared with the base simulation run, the only difference is a shift of the patterns by approximately 2 years into the future.

Figure 7. Submodel of feasibility study

Ideally some of the projects would be discarded according to their viability and to the availability of financial resources. A second simulation demonstrates the result of effective implementation of the feasibility study policy. It is now assumed that a normal fraction of projects under feasibility study will be discarded. In the model, this fraction is equal to the step up of the starting rate. The discard rate is modified by the availability of resources for progress cost. The simulation result is shown in figure 8-b. The behavior of the model including feasibility study is similar to the base run. However, the problem of the increasing completion time is somewhat less severe than without feasibility studies. When feasibility study is introduced, fewer projects are initiated and projects in progress are consequently reduced. More resources are available for the progress budget, therefore more projects are completed on schedule. **Meanwhile these projects can be accomplished with the guaranteed quality. Very few low quality projects only occur at the initial stage.**

However, the problem of this policy is that it is impossible to identify an implementation process. Curry (1990) points out that project analysis in China does not help much to improve investment efficiency. He mentions that the main obstacle in implementing project analysis is the problem of prioritization of projects at all levels of government. The appetite for investment cannot be limited under the present institutional arrangements, hence the discard rate of projects is not significant even when feasibility studies are undertaken.

Figure 8-a Policy test one: introduction of feasibility study without discard rate

Figure 8-b Policy test one: introduction of feasibility study with discard rate

*Policy option two: loan financing policy*

A new sector is introduced to represent loan financing policy (Figure 9). This policy allows the highway sector agencies to borrow money from domestic or international banks. From the standpoint of effectiveness, borrowing is often suggested as an operational policy to finance highway construction in developing countries (Swaroop, 1994). Swaroop suggests that it is better to finance a temporary increase in spending by borrowing rather than by increasing user charges. User charges over time can then be designed to include not only interest but also depreciation. Such a financing scheme allows the highway agencies to carry some surplus. Obtaining loans to finance highways has recently become more common. Twelve highway projects in China have received loans from the World Bank since 1980 (World Bank 1995). When the highway departments see that there is a discrepancy between the available progress budget and the required progress budget, they place orders for money. There is generally a delay in the approval and transfer of the borrowed money for highway departments to use for highway construction. The stock, *money on order*, represents money requested but not yet transferred. The stock, *total loans*, is the accumulated principal and compound interests. It is assumed that one year is required for the money to become available.

We assume that there is a grace period of five years and a fifteen year loan duration with an annual interest rate of seven percent. This is based on the World Bank loan policy on LIBOR-based single currency loans<sup>ii</sup>. After five years, the highway departments must begin to pay back the loan. The total loan money that can be used for highway construction in a given year is the borrowing arrival rate minus the loan pay back rate.

Figure 9. Submodel of loan financing process

The simulation run of Figure 10 shows that the loan financing policy yields a counter-intuitive result. Although the completion time does not rise as much as in base case over the overshoot, it equilibrates at a higher level. Projects in progress also equilibrate at a higher level, and starting rate at a lower level than the base case. Under the loan financing policy, money can be borrowed from banks, meaning that more resources are available in the early stages for meeting progress costs which, in turn, shortens the completion time. The constraint on the project starting rate is, therefore, weakened, as a result of which, fewer reduced quality projects are undertaken that pulls down project completion rate. After the grace period is over, the highway agencies have accumulated a large amount of debt which they must repay. This puts a drain on the progress budget. In the meantime, the project starting rate remains high and projects continue to flow into the progress stage. The budget constraint means that completion time increases and the project quality is greatly reduced. A number of years will be required before actions are taken to reduce the starting rate to the level of the completion rate.

Figure 10. Policy test two: loan financing policy

Sensitivity studies were carried out to understand the policies of favorable interest rate, grace period and loan duration. The sensitivity runs of interest rate show that favorable interest rate policy will not change the behavior radically. However, when the interest rate is reduced to zero, completion time for projects will decline to a lower level than in the base run, but still remain higher than at the initial equilibrium point. When the interest rate is raised higher than 7 percent, the system cannot reach equilibrium. In fact, the completion time rises exponentially in the later stages when the highway agencies are forced to borrow money to cover debts. Sensitivity runs of the grace period and loan duration show that these parameters do not influence the behavior patterns significantly. However, longer grace periods or loan duration will cause completion time to settle at a higher level at the new equilibrium.

*Policy option three: Raising user charge*

Another sector is introduced to represent the policy of raising the user fee (figure 11). Because the highway user charge is used to finance all highway service provision, it is assumed that the escalating user charge arises from the financial burden that the highway agencies must carry. This effect is controlled by a non-linear function, the effect of budget index on price. The financial burden is represented by the index of the desired resources for finishing ongoing projects on time and the total resources available. When this index is greater than 1, the user charge will rise gradually. However, price adjustment of user charges is a politically sensitive matter and therefore a slow process. In our model, 2 years are required to adjust the price. It is assumed that the intensity of highway use is price inelastic

Figure 11. Submodel of the price sector .

Figure 12. Policy test three: price policy

The simulation result of this policy is shown in figure 12. At the beginning of the simulation, the behavior follows the same pattern as seen in policy tests one and two. When the starting rate is stepped up by the central government's promotion policy, more projects flow into the feasibility study stage. Then more and more projects undergo construction, and the resources available for project progress declines. With the decline of resources for project progress, the completion rate declines, cost rises and low quality projects increase. User charge fees will be increased due to the lack of resources. After a 2 year delay, resources will be collected at a higher rate. Gradually, more resources become available for project progress and the completion rate begins to rise. The completion time shortens and the project starting rate begins to rise again. The starting rate now exceeds the level of the stepped up initiation rate, because resources for highway construction are adequate. Since more resources are available for progress costs, the tendency to build low quality projects is reduced and gradually all the projects become standard quality. The entire system reaches a new equilibrium featuring a higher project starting rate.

In line with the practice in China, it is assumed in our model that managers tend to complete projects ahead of time when resources are abundant. Extra cost is involved in this process. At the final equilibrium level, the completion time is reduced to a lower level than the planned level. Cost first declines and then rises to a higher level because of the extra cost associated with completing projects ahead of time.

From the simulation runs of the base simulation and the policy test cases, we can conclude that if the decision to initiate a project is determined without a strong controlling feedback from the availability of resources for highway construction, there is a high likelihood that project costs will be increased. The rising project cost is revealed as the absolute increase in cost to complete a project unit and in reduced quality. Under the Chinese institutional system, sacrifice of quality is likely to occur. Under the earmarking financing system, the consumers pay all the inefficiency cost.

The means of selecting an effective policy brings up another debate. The feasibility policy is most effective compared with the other 2 policies analyzed (Figure 13). However, the means of implementing this policy is an unsolved question in the model. This policy is difficult to implement in present day China

because the initiation of projects is intertwined with social and political factors. Saeed (1994) states that an operational policy design should aim at mobilizing the internal forces of a system and should influence the day-to-day decision making processes of the major role players in the system toward radical change. Mashayekhi (1996) suggests that the starting rate of projects should be determined endogenously, this means that the starting rate of highway construction should first incorporate the availability of financial resources. If there are no financial resources guaranteed for the project, no project should be initiated. The policies of loan financing and raising user charges attempt to endogenously address the problem. However, the loan financing policy explored above seems to not effectively address the three negative feedback loops that control the optimal rate of initiation of new projects. The policy of increasing the user charge appears to be the most effective. This policy is also advocated by staff researchers from World Bank (1994 a), who suggest that by using a gasoline tax to replace revenue registration tax and transportation revenue tax, it is possible to increase the user charge fee effectively and quickly. This policy creates another strong feedback loop to increase the revenue for highway construction rapidly. Yet, it does not effectively reduce project cost since there is a tendency to finish the project ahead of time. Meanwhile, it gives highway authorities more freedom to raise user charge. Highway users will have to pay more for the extra cost for highway construction as long as there is exogenous pressure to initiate new projects.

Figure 14. Comparison of effectiveness of policies

Two additional policies not directly analyzed here could offer effective solutions to the problem, although these can be inferred from the experiments carried out with our model. The first is to consider multiple channels for financing highways. It is proposed that when a highway project is initiated, highway agencies and the government should both finance the projects from general tax revenue. Therefore, direct users and free-riders both pay for the highway services. This view is consistent with policies suggested by the World Bank on the general issues of infrastructure (World Bank 1994 b). The second is to consider setting up an independent supervision team. The supervision team would be mandated to

guarantee that adequate funds for new projects exist and that initial tendering prices are at reasonable levels.

## **Conclusion**

In this paper, a system dynamics model has been developed to demonstrate and test our hypothesis that a lack of an effective mechanism controlling the initiation of new highway projects is a major reason contributing to the ineffectiveness of highway service delivery in China. Experimentation with the model demonstrates that an earmarking policy may lead to increasing cost to highway users when the investment decision making is external. Three different policies, (1) feasibility study, (2) loan financing policy and (3) the raising of user charges, may relieve the problem to some extent. However, these policies seem not to address the momentum behind over-investment directly. The introduction of a supervision system and multi-channel financing to fund highway service provision may be a fundamental solution to this problem. The introduction of this policy requires a fundamental structural change in the highway organization. Further research is needed to evaluate that direction of policy design.

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<sup>i</sup> The calculation of project completion rates in the model embodies the assumption that returns to scale in construction are constant. Constant return to scale means that the costs of building and maintaining roads are proportional to road capacity. However, evidence of economies of scale in road construction is mixed (Hau 1992, Winston 1991). There is evidence of increasing returns in rural road construction

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with costs rising less than proportionately with capacity. In urban road networks there are diseconomies of scale due to the complex geometry of intersections.

ii The interest rates of LIBOR-based single currency loans are currency specific and equal to the applicable 6 month London or Paris Interbank Offered Rate for the value on the first day of the interest period, plus a total spread.

### **Annex: Model Equations**

$$\text{AccumulatedLoan}(t) = \text{AccumulatedLoan}(t - dt) + (\text{BorrowArrivalRt} + \text{Interest} - \text{LoanPayBackRt}) * dt$$

(Accumulated bank borrowings for highway construction (yuan))

INIT

$$\text{AccumulatedLoan} = 0$$

INFLOWS

$$\text{BorrowArrivalRt} = \text{BorrowInOrder} / \text{BorrowArrivalTime}$$

(Money received by Highway Agencies(yuan/year))

$$\text{Interest} = \text{AccumulatedLoan} * \text{InterestRt}$$

(Annual Interest(yuan/year))

OUTFLOWS

$$\text{LoanPayBackRt} = \text{Delay}(\text{AccumulatedLoan} / \text{Loantime}, \text{GracePeriod})$$

(Rate of paying back to bank borrowing (yuan/year))

---

$BorrowInOrder(t) = BorrowInOrder(t - dt) + (BorrowOrderRt - BorrowArrivalRt) * dt$   
(Borrowing put in order(yuan))

INIT

$BorrowInOrder = 0$

INFLOWS

$BorrowOrderRt = (DesiredLoanMoney - BorrowInOrder) / MoneyOrderTime$   
(Borrowing order rate(yuan/year))

OUTFLOWS

$BorrowArrivalRt = BorrowInOrder / BorrowArrivalTime$   
(Money received by Highway Agencies(yuan/year))

$LowQualPjctCapa(t) = LowQualPjctCapa(t - dt) + (LowQualPjctCompRt - LowQualPjctCapaDecayRt) * dt$   
(Project in progress with low quality (capacity units))

INIT

$LowQualPjctCapa = 0$

INFLOWS

$LowQualPjctCompRt = ProgBudgetLowQualPjct / ActualLowQualPjctUnitCost$   
(Completion rate of low quality project(capacity units/year))

OUTFLOWS

$LowQualPjctCapaDecayRt = LowQualPjctCapa / AveLowQualCapaDepreTime$   
(Depreciation rate of low quality projects (capacity units/year))

$PjctInFeasStudy(t) = PjctInFeasStudy(t - dt) + (FeasStudyRt - StartRt - PjctDiscardRt) * dt$   
(Initial Projects Under Feasibility Study (units))

INIT

$PjctInFeasStudy = 20$

INFLOWS

$FeasStudyRt = NorStartRt * EffBudgetOnStarts * EffCompTimeIndexOnStarts * EffQualIndexOnStarts$   
(Rate of projects flowing into feasibility study stage ( Units/year))

OUTFLOWS

$StartRt = (NorStartRt * EffBudgetOnStarts * EffCompTimeIndexOnStarts * EffQualIndexOnStarts * FeasibilityPolicySwitch) + (PjctInFeasStudy / TimeForFeas) * (1 - FeasibilityPolicySwitch)$   
(starting rate of new projects(capacity units/year))  
 $PjctDiscardRt = PjctInFeasStudy * DiscardRt$   
(Rate of projects under feasibility study which are discarded ( units/year))

---

$PjctInProg(t) = PjctInProg(t - dt) + (StartRt - QualPjctCompRt - LowQualPjctCompRt) * dt$   
(Highway projects in progress(capacity units))

INIT

$PjctInProg = N\_PjctInProg$

INFLOWS

$StartRt = (NorStartRt * EffBudgetOnStarts * EffCompTimeIndexOnStarts * EffQualIndexOnStarts * FeasibilityPolicySwitch) + (PjctInFeasStudy / TimeForFeas) * (1 - FeasibilityPolicySwitch)$   
(starting rate of new projects(capacity units/year))

OUTFLOWS

$QualPjctCompRt = ProgBudgetQualPjct / ActualQualProgUnitCost$   
(Project completion rate of quality project (capacity units/year))  
 $LowQualPjctCompRt = ProgBudgetLowQualPjct / ActualLowQualPjctUnitCost$   
(Completion rate of low quality project(capacity units/year))

$QualPjctCapa(t) = QualPjctCapa(t - dt) + (QualPjctCompRt - QualPjctCapaDepreRt) * dt$   
(Capacity of quality project(capacity units))

INIT

$QualPjctCapa = N\_QualPjctCapacity$

INFLOWS

$QualPjctCompRt = ProgBudgetQualPjct / ActualQualProgUnitCost$   
(Project completion rate of quality project (capacity units/year))

OUTFLOWS

$QualPjctCapaDepreRt = QualPjctCapa / QualPjctCapaDepreTime$   
Quality Highway capacity decay rate( capacity units/year)

$UserCharge(t) = UserCharge(t - dt) + (PriceChgnRt) * dt$   
(user charge (yuan/unit capacity))

INIT

$UserCharge = N\_Usercharge$

INFLOWS

$PriceChgnRt = IndiUserCharge / PriceAdjTime$   
(user charge change rate (yuan/capacity unit/year))

$ActualLowQualPjctUnitCost = ActualQualProgUnitCost * FracLowPjctCost$   
(Actual to finish one unit capacity of low quality project(yuan/capacity unit))

$ActualQualProgUnitCost = 0.9 + 0.1 * EXP(3 * LOGN(ProgBudgetAvail))$

---

(Actual cost to complete one unit capacity of quality highway(yuan/capacity units))

AveLowQualCapaDepreTime = 12  
(Low quality Highway Capacity decaying Time (year))

BaseBudget = BaseUnitCost\*PjctInProg  
(Resources for base cost of highway projects(yuan/year))

BaseUnitCost = .1  
(cost of base cost for one capacity unit (yuan/capacity unit\*year))

BorrowArrivalTime = 0.5  
(Time for bank to allocate Lending(year))

CompTimeIndex = (PjctInProg/(QualPjctCompRt+LowQualPjctCompRt))/NorCompTime  
(Index showing time over run(dimensionless))

ConstructionBudget = (FracResForConstruction\*TtlHighwayBudget)  
(Total resources allocated for highway construction(yuan))

DesiredLoanMoney = (DesProgressBudget-ProgBudget)\*BudgetPressureBorrow  
(Desired borrowings from bank (yuan))

DesProgressBudget = ActualQualProgUnitCost\*NorlCompRt  
(Disired budget for projects in progress(yuan))

DiscardRt = step((1.5/20\*0+NorDiscardRt\*EffBudgetAvailOnDiscardRt),3)

ExternalPressureControl = 0+step(1.5,1)  
(Parameter to control the initial step up of starting rate)

FeasibilityPolicySwitch = 0

FracLowPjctCost = 0.75  
(Fraction to complete one capacity unit of low quality project of quality unit project (dimensionless))

FracPjctInProg = 20/150  
(Fraction of project in progress of the total project ( dimensionless))

FracResForConstruction = 0.25

---

(Fraction allocated for highway construction ( dimensionless))

GracePeriod = 5  
(Grace period (year))

IndiUserCharge = UserCharge\*EffBudgetAvailOnPrice  
(Indicated user charge (yuan/capacity unit))

InterestRt = 0.07  
(Favorable interest rate (/year))

Loantime = 15  
(Duration for loan (year))

MoneyOrderTime = 3  
(Time for bank lending to be ranced(year))

NorAnnualProgBudgetPerPjct = 0.5  
(Normal annual progress budget for a project (Yuan/capacity unit/year))

NorCompTime = 2  
(Normal Time to Complete a capacity Unit (year))

NorDiscardRt = 1.5/20

NorlCompRt = PjctInProg/NorCompTime  
(Desired project unit completion rate(capacity units/year))

NorStartRt = 10+ExternalPressureControl  
(External pressure on starting rate ( unit capacity/year))

N\_LowQualPjctCapa = 0

N\_PjctInProg = FracPjctInProg\*N\_QualPjctCapacity

N\_QualPjctCapacity = NorStartRt\*QualPjctCapaDepreTime

N\_QualProgUnitCost = 1

N\_Usercharge = (N\_PjctInProg\*(BaseUnitCost+N\_QualProgUnitCost/NorCompTime))  
/(FracResForConstruction\*N\_QualPjctCapacity)

---

(Initial user charge (yuan/unit capacity))

$\text{PercvdCompTimeIndex} = \text{SMTH3}(\text{CompTimeIndex}, \text{TimePercvdCompTimeIndex})$   
Perceived ratio of a unit capacity completion time (dimensionless)

$\text{PercvdProgBudgetAvail} = \text{SMTH1}(\text{ProgBudgetAvail}, \text{TimePercvdProgBudgetAvail})$   
Perceived progress budget ratio (dimensionless)

$\text{PercvdQualIndex} = \text{SMTH1}(\text{PjctQualIndex}, \text{TimePercvdQualIndex})$   
Perceived project quality index (dimensionless)

$\text{PjctQualIndex} = \text{Smth1}(\text{LowQualPjctCompRt}, 1) / \text{smth1}(\text{QualPjctCompRt} + \text{QualPjctCompRt}, 1)$   
(Index to show the ratio of quality project in total projects (dimensionless))

$\text{PriceAdjTime} = 2$   
(Price adjustment time (5 year))

$\text{ProgBudget} = (\text{ConstructionBudget} - \text{BaseBudget})$   
(total resources allocated for progress (yuan/year))

$\text{ProgBudgetAvail} = (\text{ProgBudget} / \text{PjctInProg}) / \text{NorAnnualProgBudgetPerPjct}$   
(Availability of budget resource to complete one unit capacity project (dimensionless))

$\text{ProgBudgetLowQualPjct} = \text{ProgBudget} - \text{ProgBudgetQualPjct}$   
(Budget allocated for low quality projects (yuan/year))

$\text{ProgBudgetQualPjct} = \text{ProgBudget} * \text{EffBudegetOnQualPjct}$   
(Resources allocated for quality projet (yuan/year))

$\text{QualPjctCapaDepreTime} = 15$   
(Capacity of quality project decaying time (year))

$\text{TimeForFeas} = 2$   
(Normal time to carry out feasibility study)

$\text{TimePercvdCompTimeIndex} = 2$   
(Time to perceive the project completion time)

$\text{TimePercvdProgBudgetAvail} = 1$   
(Time to perceive the shortage of progress budget (year))

---

TimePercvdQualIndex = 1  
(Time to perceive highway quality index (year))

TtlCompRt = LowQualPjctCompRt+QualPjctCompRt

TtlHighwayBudget = UserCharge\*TtlPjctCapa+BorrowArrivalRt-LoanPayBackRt  
(Total revenue from highway users (yuan/year))

TtlPjctCapa = QualPjctCapa+LowQualPjctCapa  
(Total highway capacity (capacity units))

BudgetPressureBorrow = GRAPH(PercvdProgBudgetAvail)  
(0.00, 1.50), (0.1, 1.34), (0.2, 1.26), (0.3, 1.20), (0.4, 1.15), (0.5, 1.11), (0.6, 1.08), (0.7, 1.05),  
(0.8, 1.03), (0.9, 1.01), (1, 1.00)  
(Pressure from progress budget ratio on borrowing(dimensionless))

EffBudegetOnQualPjct = GRAPH(PercvdProgBudgetAvail)  
(0.00, 0.465), (0.1, 0.48), (0.2, 0.505), (0.3, 0.525), (0.4, 0.545), (0.5, 0.58), (0.6, 0.625), (0.7,  
0.68), (0.8, 0.755), (0.9, 0.85), (1, 1.00)  
(Perceived progress budget ratio (dimensionless))

EffBudgetAvailOnDiscardRt = GRAPH(PercvdProgBudgetAvail)  
(0.5, 1.99), (0.6, 1.66), (0.7, 1.39), (0.8, 1.23), (0.9, 1.11), (1, 1.00), (1.10, 0.89), (1.20, 0.73),  
(1.30, 0.56), (1.40, 0.32), (1.50, 0.01)  
(Effect of progress budget ratio on discard rate of project which can pass feasibility study  
(dimensionless))

EffBudgetAvailOnPrice = GRAPH(PercvdProgBudgetAvail)  
(0.00, 0.115), (0.2, 0.115), (0.4, 0.11), (0.6, 0.095), (0.8, 0.055), (1.00, 0.00), (1.20, -0.06), (1.40,  
-0.115), (1.60, -0.16), (1.80, -0.195), (2.00, -0.205)  
(Effect of perceived progress budget ratio on user charge (dimensionless))

EffBudgetOnStarts = GRAPH(PercvdProgBudgetAvail)  
(0.00, 0.015), (0.167, 0.383), (0.333, 0.66), (0.5, 0.825), (0.667, 0.922), (0.833, 0.985), (1, 1.00),  
(1.17, 1.21), (1.33, 1.33), (1.50, 1.42), (1.67, 1.48), (1.83, 1.50), (2.00, 1.50)  
(Effect of budget ratio on starting rate (dimensionless))

EffCompTimeIndexOnStarts = GRAPH(PercvdCompTimeIndex)  
(0.00, 1.50), (0.167, 1.48), (0.333, 1.44), (0.5, 1.35), (0.667, 1.22), (0.833, 1.05), (1, 1.00), (1.17,  
0.95), (1.33, 0.91), (1.50, 0.852), (1.67, 0.787), (1.83, 0.715), (2.00, 0.611)

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(Effect of unit capacity completion time on starting rate (dimensionless))

EffQualIndexOnStarts = GRAPH(PercvdQualIndex)

(0.00, 1.00), (0.1, 1.00), (0.2, 0.994), (0.3, 0.988), (0.4, 0.979), (0.5, 0.969), (0.6, 0.952), (0.7, 0.93), (0.8, 0.894), (0.9, 0.846), (1, 0.8)

(Effect of perceived quality index on starting rate ( dimensionless))

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