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LINKING EAST AND WEST BANGLADESH: THE JAMUNA BRIDGE PROJECT

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Abstract: The Jamuna Bridge project is a case that illustrates an integrated approach to project appraisal. An integrated approach allows analysts to examine financial, economic, distributive, and risk analysis in conjunction with each other such that no single aspect is left to be examined in isolation. The economic analysis, which looks at the project's impact on Bangladesh's overall economy, presents a method of computing the real economic benefits of the bridge, including savings in vehicle operating costs, and the value of time savings gained by passenger and freight traffic. The financial analysis of such an infrastructure project checks on the sustainability of the service agency (the Bridge Authority) over time. Sensitivity and risk analyses are central to the evaluation of this project because they identify the most critical variables and allow a probability distribution of values to be used in the model, rather than a single deterministic value. The distributive analysis identifies who would gain or lose if the bridge project was undertaken, which, in turn, indicates who would be likely supporters or opponents of the project.

Résumé: Le projet du pont Jamuna est un cas qui illustre la manière d'envisager dans son intégralité l'évaluation d'un projet. Cette méthode intégrée permet d'analyser les risques ainsi que les aspects financiers, économiques et distributifs dans leurs imbrications mutuelles de façon qu'aucun élément ne sera examiné séparément. L'analyse économique, qui porte sur les conséquences du projet pour l'économie du Bangladesh, constitue une méthode de calculer les avantages économiques réels du pont, y compris les économies faites sur les coûts de fonctionnement des véhicules et la valeur du temps gagné dans la circulation des personnes et des marchandises. L'analyse financière d'un tel projet d'infrastructure vérifie la possibilité qu'aura l'organisme de tutelle (l'administration du pont) de se maintenir. Les analyses de l'instabilité et des risques sont d'une grande importance dans l'évaluation de ce sujet puisqu'elles mettent en évidence les variables les plus critiques et permettent une distribution des valeurs de probabilités à utiliser dans le modèle plutôt qu'une valeur déterministe unique. L'analyse distributive désigne les gagnants et les perdants au cas où le projet sera mis à exécution, ce qui, à son tour, indique qui serait prêt à avaliser ou à contrecarrer le projet.

The Jamuna, the Meghna, and the Padma constitute a system of rivers that physically divides Bangladesh into east, southwest, and northwest regions. The east region is relatively more developed because it includes the capital, Dhaka, and the most important port of the country, Chittagong. The west region includes Rajshahi (northwest) and Khulna (southwest) divisions. The northwest region, with more than 27 million people and highly fertile land, is bounded by the Ganges on the south and the Jamuna on the east and remains relatively isolated from the rest of the country.

Most of the major centers within each region are connected by road or rail. However, all the connections between regions depend on the inland waterway transport system. The service provided at these river crossings is of poor quality, subject to many interruptions owing to the adverse geographical and meteorological conditions, and involving waiting times of up to many hours or days for freight traffic.

The transportation services across the Jamuna river are provided by several agencies. Passenger and freight transport is carried out by the Bangladesh Inland Water Transport Corporation (BIWTC), the Bangladesh Railway (BR) ferries, and by some privately owned launches and country boats. The most important transport services connecting the east to the northwest regions are provided by BIWTC through two ferry routes (Aricha–Nagarbari, 22 km; and Bhuapur–Sirajganj, 18 km). The Aricha–Daulatdia ferry, also run by BIWTC, connects the east to southwest regions. Traffic on this route will not be significantly affected by the proposed Jamuna Bridge.[1]

The services provided at these crossings face numerous problems that threaten the stability of the inter-regional transportation system. For instance, ferry ports have to be moved because of changing levels of silt deposited by the Jamuna; erosion swallows up access roads; navigation channels are too narrow; and maintenance standards are substandard.

> The whole ferry system has reached the limits of its capacity owing to geographical difficulties and inherent managerial problems. It has coped with the 50% traffic growth since 1986, even though the truck-waiting time of about 30–40 hours has remained unchanged during the period. A further 30% increase in traffic is expected by 1998 (the proposed bridge opening year), which will raise the waiting time for all types of vehicles. Although marginal capacity additions are still feasible, any significant increase in capacity to cope with even normal traffic growth over the next few years will call for substantial ferry improvements (river-training works, new channels, new port facilities, etc.) unless a bridge is built over the river (Asian Development Bank [ABD], 1994, p. 6).

PROJECT DESCRIPTION

Project Objectives and Scope

The Jamuna Bridge project is designed to provide a permanent, non-management-intensive crossing under all-weather conditions for the existing and potential east–northwest traffic. The project also includes a railway connection. In addition, the project will allow transmission of electricity and transfer of natural gas between the east and the west regions.

The project includes the following components:

1. construction of a bridge about 4.8 km long and 18.5 meters wide to carry four road lanes with sidewalks; the bridge will also be capable of supporting a power interconnector, a gas pipeline, telecommunication facilities, and a meter gauge railway;
2. construction of two bridge end viaducts, about 128 meters each, connecting the bridge to the approach roads;
3. construction of two guide bunds, about 2.2 km each, and a flood protection bund on the east bank to regulate the river at the selected site;
4. construction of two approach roads, about 16 km to the east and 14 km to the west. The approach roads will have a two-lane single highway with paved shoulders;
5. measures to mitigate the project's impact on the environment;
6. implementation of a resettlement plan; and

7. technical assistance, including project management and training of bridge maintenance staff (ABD, 1994, pp. 11–12).

The bridge will be built about 7 km south of Sirajganj. This site was selected after extensive studies of 10 potential sites. In-depth studies for the selected site were carried out to determine the optimal length of the bridge and the required embankments.

Project Cost and Financing

The total cost of the project is estimated at US$ 696 million, with a traded component of US$ 509 million (Table 1). The cost estimates are based on actual prices obtained through international competitive bidding, and provide for physical and price contingencies.

The ABD, OECD, and International Development Agency (IDA) will finance the project through three loans of US$ 200 million each at 1% nominal rate of interest. The low cost of financing is critical for the financial sustainability of the project. The Bangladesh government will provide the balance of US$ 96 million with a grant (Table 2).

Project Life

The project life, for financial and economic evaluation purposes, is considered to be 50 years after the bridge opens to traffic in 1998. Although the design life is 100 years, benefits beyond 50 years and salvage values have been ignored, which makes the financial and economic rates of return estimates more conservative.

Project Implementation and Management

The project will be implemented by the Jamuna Multipurpose Bridge Authority (JMBA) as the executing agency. JMBA was specifically established in 1985 in the Ministry of Communications for the construction of the Jamuna bridge. The government is planning to amend JMBA's charter to make it responsible for collection of tolls and operation and maintenance of the bridge (ABD, 1994, p. 15).

TRAFFIC PROJECTIONS

It is estimated that the average daily traffic in 1993 on the two relevant crossing channels (Aricha–Nagarbari and Bhuapur–Sirajganj) consisted of 271 buses, 140 light vehicles, and 770 trucks. The average annual growth rate of traffic in the bridge corridor was about 7.5% during 1986–1993. The annual traffic growth rates from 1993 to 1998 are estimated at 6.6% for buses and trucks and 8.2% for light vehicles.[2] From 1998 to 2025, the bridge traffic is estimated to grow at 5% per year. After the year 2025, when the bridge capacity would be fully utilized, traffic is assumed not to increase until the 50th year.

The reduction in waiting time and vehicle operating costs arising from construction of the bridge would generate additional passenger and freight traffic on the bridge. The base year (1998) newly generated traffic was estimated based on the price elasticity of

Table 1
Project Cost (Million 1994 US$)

Item	Traded	Nontraded	Total
Contract 1:			
Main bridge	178.97	41.43	220.40
Contract 2:			
River training	207.20	36.85	244.05
Contracts 3 & 4:			
Approach roads	26.18	26.72	52.90
Contract 5:			
Consulting services	22.68	4.32	27.00
Others		52.50	52.50
Total Base Cost	435.03	161.82	596.85
Contingencies			
Physical	45.33	10.87	56.20
Price	28.64	14.31	42.95
Total Investment Cost	509.00	187.00	696.00

Table 2
Project Financing (Million 1994 US$)

ADB	200.00
IDA	200.00
OECD	200.00
Bangladesh government grant	96.00
Total financing	696.00

demand for transport services.[3] It is also assumed that the 1998 newly generated traffic would require a period of approximately eight years to build up. Starting with the base year (1998), the incremental traffic for the three types of vehicles builds up gradually, starting with 20% of the total volume, increasing to 40%, and then increasing by increments of 10% until reaching 100% in 2005. The rate of growth of the incremental traffic from 2005 onward is assumed to be the same as that of the diverted traffic.

APPRAISAL OF THE JAMUNA BRIDGE UNDER ALTERNATIVE SCENARIOS

The economic appraisal of the bridge project has been performed on incremental terms by making reference to two alternative "without project" scenarios: (a) the current or base case situation with minor additions to maintain the current capacity; and (b) an improved ferry scenario where major investment costs are undertaken to provide a capacity as close as possible to that of the bridge. The economic return of the improved ferry system as compared to the current situation has also been estimated to check whether this option is economically justifiable on its own.

A brief summary of the main features of these two scenarios plus the bridge scenario is given below.

Base Case Scenario

Additional investments to the existing ferry system need to be done on a continuing basis to enable it to absorb the 5% traffic growth per annum estimated for the next 30 years. These investment costs required by the ferry system are not included in the present analysis, except for the purchase of additional ferries amounting to $10 million in 1998. Hence, the economic returns of the bridge and improved ferry projects vis-à-vis the current ferry are biased downward.

Waiting time under the current ferry system is assumed to remain constant at the 1993 observed level (light vehicles and buses: 1 hour; trucks: 36 hours) until year 2000, in spite of the normal traffic increase. A one-time increase in truck waiting time from 36 hours to 45 hours is assumed from 2000 onward (Bernardino, Pankaj, & Chen, 1993, p. 15). This is a conservative assumption, considering the likely exponential growth in waiting time due to the near-full utilization of capacity.

Improved Ferry Scenario

This scenario will provide enough capacity to considerably reduce the waiting time, absorbing regular traffic as well as the generated new traffic growth brought about by a reduction in waiting time and vehicle operating costs. The improved ferry, however, would still be subject to the vagaries of weather and problems of shifting of channels, and would require intensive management of the ferry system. Hence, a minimum level of vehicle waiting time is expected. In this analysis it is assumed that light vehicles and buses would have a waiting time of 1 hour and trucks of 3.5 hours (Bernardino, Pankaj, & Chen, 1993, p. 15).

Bridge Scenario

The bridge is an all-weather facility, and there will be no delay or waiting on the crossing points. Nominal toll rates for crossing the bridge are set in the base case at one-half the current ferry tariffs.

FINANCIAL ANALYSIS

The financial analysis of the bridge project is conducted considering both the total investment and the point of view of the Bridge Authority. The financial analysis of the improved ferry alternative project has also been performed. An incremental approach is used for both scenarios, as the two projects build on the current ferry situation. Some of the important parameters used are:

1. Inflation rate: domestic 6%, foreign 3%
2. Foreign exchange rate: 39.8 takas/US$
3. Real financial discount rate: 10%

Financial Benefits and Costs

The financial benefits and costs of the bridge and the improved ferry system are indicated below.

Bridge:
Benefits
- Toll revenues from diverted and newly generated traffic
- Electricity interconnector fees

Costs

- Investment cost plus operating and maintenance costs of bridge

Improved ferry system:
Benefits

- Tariff revenue from newly generated traffic

Costs

- Investment cost plus operating and maintenance costs of the improved ferry system

The annual revenue for both scenarios is obtained by multiplying the diverted and newly generated traffic for the three types of vehicles by their corresponding tariff. As mentioned earlier, the bridge toll is assumed to be 50% of the current ferry tariff. The proposed bridge tariffs for the three classes of vehicles are: light vehicles 137.5, buses 725, trucks 372.5 (figures are in takas). Ferry and bridge tariffs are assumed to remain constant in real terms throughout the project life. The annual interconnector fees are 75 million takas per year starting from 2000.

Methodology

The financial analysis of the two alternative projects is conducted from both the total investment and equity holder's points of view. Unlike total investment, the equity holder's point of view includes in the cash flow profile of the project the loan and the government grant as sources of funds and the loan repayments as cash outflows. The pro forma cash flow statements are first developed in nominal terms in order to take into account the effects of inflation. The cash flow items are then deflated to arrive at their real values. Finally, the real net cash flows are discounted by the real overall cost of capital of 10% to get the net present value.

Cash Flows and Results

A summary of the financial net present values of the two alternatives is presented in Table 3. As the project financing is subsidized, the net present values of the two projects from the total investment and equity holder's points of view are different. The net present value of the two projects from the total investment point of view plus the net present value of respective financing (loan and government grant) at the real overall cost of capital of 10% equals the net present value of the projects from the equity holder's point of view. The bridge project is financially viable from the Authority's point of view. On the other hand, the improved ferry system has a negative net present value from the equity holder's point of view. It should be noted, however, that owing to the public utility nature of the bridge and its low operating costs, its financial net present value may not be as critical a variable as in either the case of the ferries with their high operating costs or for other activities that are expected to cover their total investment costs without subsidies.

In the evaluation of the financial sustainability of the bridge, it turns out that the project is expected to have negative net cash flows during the early years of the debt repayment period. The net cash flow profile from 1994 to 2015 is shown in Figure 1. However, the positive net cash flows in the early years of operation would be enough to cover the deficits in the later years. On the other hand, the improved ferry system does not seem to be financially sustainable, and will require an annual subsidy from the government to continue operations.

The analysis assumes that the nominal tariff rates are increased every year to remain fixed in real terms. The financial analysis was also conducted under the different assumption that the tariff rates are adjusted for inflation every five years. The results of this analysis are shown in Table 4. As expected, the NPVs of the two alternatives would be lower, but are not very sensitive to the time lag in tariff adjustment.

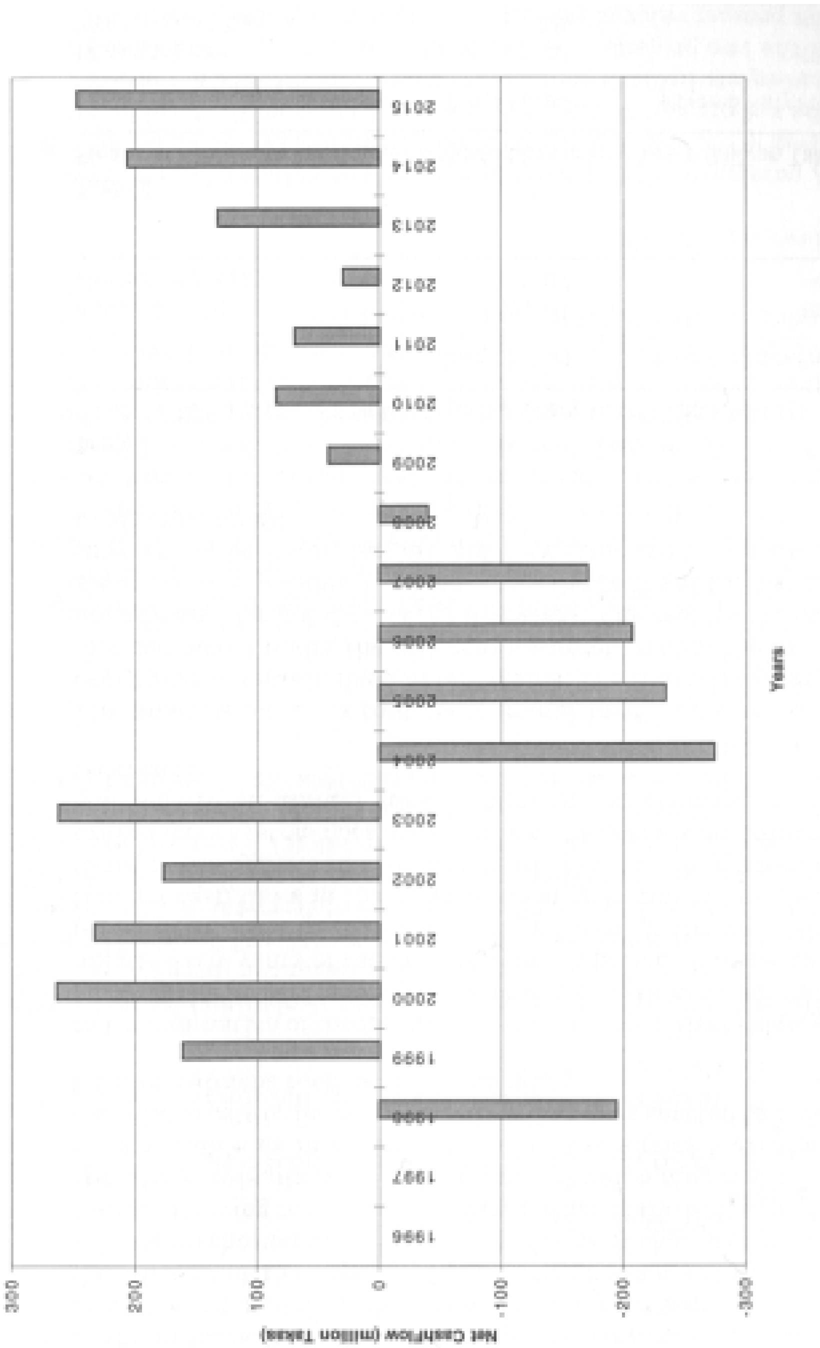
Table 3
Financial NPVs with Tariff Rates Adjusted Every Year (Million Takas)

	Bridge Project	Improved Ferry Project
Without financing	-21,042	-18,558
With financing (equity)	1,077	-4,044

Table 4
Financial NPVs with Tariff Rates Adjusted Every Five Years (Million Takas)

	Bridge Project	Improved Ferry Project
Without financing	-21,351	-19,198
With financing (equity)	768	-4,684

Figure 1
Net Cash Flow Profile of the Bridge Project (1994–2015), Authority's Point of View



SENSITIVITY AND RISK ANALYSIS OF FINANCIAL APPRAISAL

Sensitivity Analysis

A sensitivity analysis has been conducted to determine the impact of changes in key variables on the financial NPV of the bridge project. The variables tested are the rate of inflation, the bridge tariff rate, the growth rate of traffic, the nominal rate of interest on the loans, and the project cost. The results show that the project's outcome is very sensitive to the bridge tariff rate, the growth rate of traffic, and the investment cost over-runs. The sensitivity analysis also reveals the following:

- As the bridge tariff rate (as a percentage of current ferry rate) is increased within the range of 0% to 140%, the financial NPV goes from -2,751.4 to 6,073.7 million takas. However, increasing the tariff rate will decrease the volume of traffic on the bridge. Therefore, raising the tariff rate has two impacts on the financial NPV, acting in opposite directions.
- The outcome of the project is highly sensitive to the growth rate of traffic. When the average annual vehicle traffic growth rate (1998–2025) goes from 0% to 10%, the corresponding change in the NPV is from -404.8 to 4,489.4 million takas. Furthermore, growth rates of traffic higher than 5% (the deterministic value) over the projected period are considered more likely than lower growth rates.
- The likelihood of a higher-than-anticipated investment cost, in the context of project implementation in Bangladesh, is a key factor in the overall evaluation of the bridge proposal and in the determination of the riskiness of the project. The availability of subsidized financing of the cost over-runs also is critical to determine the financial viability of the project from the Authority's point of view. The financial NPV is very sensitive to cost over-runs if they are financed by equity or loans at the real market rate of 10%. On the other hand, the project still remains financially viable if soft financing is available to fund cost over-runs up to 25% above the base case estimates (the analysis assumes the same conditions as the original loan: a foreign loan at 1% nominal interest rate). For a range of negative 20% to positive 35% in divergence from the original cost estimate, the corresponding change in the NPV (without soft-financing of cost overrun) is 5,888.0 to -7,341.2 million takas, and the corre-

sponding change in the NPV (with soft-financing of cost over-run) is 1961.9 to -470.5 million takas.

- The outcome of the project is highly sensitive to the nominal interest rate charged on the loan. The project is financially viable only at very low nominal interest rates, which are provided by the foreign loan. The net present value of the project falls gradually with a rise in inflation rate, but is not sensitive to it. This is because the project does not pay income taxes, nor does it require substantial working capital.

Risk Analysis

Risk analysis, using the Monte Carlo simulation technique, is applied to test how the financial NPV of the bridge project responds to possible variations in the values of the critical variables. According to the sensitivity analysis, the variables "growth rate of traffic" and "investment cost over-runs" have the largest impact on the project's financial viability. The financial outcome of the project is also sensitive to the tariff rate. However, the tariff rate is not considered a risk variable, as it is set by the government.

The risk analysis is developed with two alternative scenarios of investment cost over-runs (an optimistic one and a pessimistic one). The availability of subsidized financing in each scenario is also taken into account. The probability distributions and range limits of the selected risk variables are shown in Table 5.

Table 5
Risk Variables and Probability Distributions

Risk Variable	Probability Distribution	Base Value	Range (%)	Probability (%)
			Optimistic	
Divergence from original cost estimate	Step	0	0–5	75
			5–10	20
			10–15	5
			Pessimistic	
	Step	0	0–5	25
			5–15	50
			15–35	25
Average annual growth rate of traffic	Normal	5%	3–7	

The risk analysis confirms the results of the sensitivity analysis, showing that the financial profitability of the bridge project from the Authority's point of view is highly dependent on the likelihood of cost over-runs in the investment cost and the availability of subsidized financing of the over-runs. The results are shown in Table 6. In the optimistic scenario, the project has a 38% chance of obtaining a negative return. In the pessimistic scenario, the probability of having a negative NPV rises to about 78%. The expected loss ratio in the optimistic scenario is 0.474.[4] In the pessimistic scenario, the chance of having a negative return is 78%, but 95% of the project's overall expected NPV is a result of the occurrence of these losses. With subsidized financing of the over-runs, the probability of the project having a negative return ranges from 0% to 15%.

ECONOMIC ANALYSIS

The Jamuna bridge will have an impact on the economy of Bangladesh by eliminating a physical barrier that divides the country into two parts. It will enable freight and passenger traffic to move faster by road and, in the future, by rail. It will also allow transmission of electricity and transfer of natural gas from the east to the northwest region. These indirect benefits to the economy are difficult to quantify. Hence, in the present analysis, the economic analysis of the bridge is limited to the benefits accruing to the traffic crossing the Jamuna, the direct environmental benefits, the savings from

Table 6
Financial Risk Analysis Results

Financial NPV, Bridge Authority's Point of View (Million Takas)
Scenarios without subsidized financing of cost over-runs

	Expected Value	Standard Deviation	Probability of Negative Return (%)	Expected Loss Ratio
Optimistic	29.2	733.8	38.2	0.474
Pessimistic	-1,801.0	2,145.9	77.8	0.946

Financial NPV, Bridge Authority's Point of View (Million Takas)
Scenarios with subsidized financing of cost over-runs

	Expected Value	Standard Deviation	Probability of Negative Return (%)	Expected Loss Ratio
Optimistic	905.6	308.1	0.0	0.000
Pessimistic	553.5	486.4	15.0	0.065

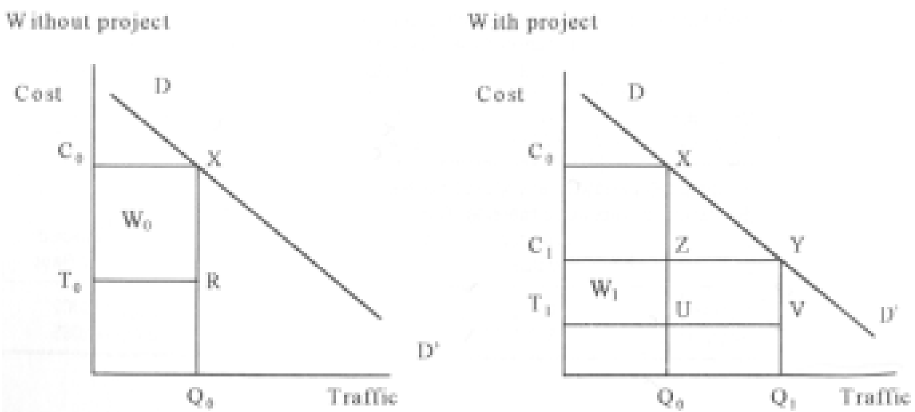
not having to build a separate electric power interconnector across the river, and the reduced costs of operating the ferry system.

Methodology

The direct benefits of the bridge or the improved ferry alternative project involve the savings of vehicle operating costs gained by the diverted traffic. Additional savings beyond those connected directly with vehicle operating costs include the saving of time for passengers and for freight traffic. In addition to the direct benefits accruing to the diverted traffic, the analysis also considers the net economic benefits received by the newly generated traffic.

A graphical representation of the transport-related benefits is shown in Figure 2. DD^1 represents the demand function for Jamuna crossing services by type of vehicles. The price that each successive unit of traffic would be willing to pay for crossing the Jamuna River is measured on the vertical axis. Without the project, the total cost (tariff plus operating and waiting time costs) per kind of vehicle is C_0 and the traffic level is Q_0, including all the traffic units willing to pay C_0 or more. With the bridge project, the toll will be one half of the current ferry tariff, and the vehicle operating and waiting time costs will decrease. Therefore, the total cost will fall to C_1 and traffic volume will expand to Q_1.

Figure 2
Graphical Representation of Economic Benefits



where:
T_0 = real financial ferry tariff rate, without project
T_1 = real financial bridge tariff rate, with project
W_0 = vehicle operating and waiting time costs, without project
W_1 = vehicle operating and waiting time costs, with project
C_0 = total cost faced by vehicles, without project (T_0+W_0)
C_1 = total cost faced by vehicles, with project (T_1+W_1)

The economic benefits of the project are the direct benefit accruing to the traffic that would in any case have crossed the Jamuna — the savings of time and vehicle operating costs borne by the current travelers (T_0C_0XR - T_1C_1ZU) — plus the net benefits received by the newly generated traffic — the gross benefits measured by Q_0XYQ_1 less the time and vehicle operating costs borne by the incremental traffic UZYV. In turn, the economic benefits of the project can be expressed as the savings in vehicle operating costs and waiting time gained by the existing traffic (T_0C_0XR - T_1C_1ZU) plus the financial tariff revenue generated by the newly generated traffic (Q_0UVQ_1) plus the gain in consumer surplus to the incremental traffic (ZXY).

Estimating Project Benefits and Costs

Vehicle operating costs include fuel, oil, the tire wear, repairs and maintenance, and depreciation. The estimates for the operating costs by kind of vehicles (light vehicles, buses, and trucks) are based on the Bangladesh Road Master Plan Study (1992) and the Nalka-Bonpara Road Feasibility Study developed by the China International Engineering Consulting Corporation in 1993 (Bernardino, Pankaj, & Chen, 1993, p. 13).

The estimates of the savings on passenger trips are based on the individuals' hourly income. The analysis followed the practice of the Indian Road Manual, which values business travelers' time at 110% of their hourly income, the time of the remaining economically active passengers at 50% of their hourly income, and the time of non-business travelers at 25% of their hourly income. The hourly income of each of these three groups was estimated using the Bangladesh Household Survey for 1985–86 updated to 1993 price levels by the Consumer Price Index and the annual growth rate of 1.7% in per capita GDP observed in the period 1968–1990 (Bernardino, Pankaj, & Chen, 1993, p. 14).

The time savings for freight traffic is reflected in the reduction of inventory costs, losses, and damage (especially to perishable agricultural goods). Because of the unavailability of reliable data, these indirect time-related costs are assumed to be equal to 10% of vehicle operating costs (Bernardino, Pankaj, & Chen, 1993, p. 14).

The direct benefits accruing to the diverted traffic are estimated by multiplying the unit savings in operating and waiting time costs (Bernardino, Pankaj, & Chen, 1993, pp. 20–21) for the types of vehicles by their corresponding traffic level. The gain in consumer surplus to the newly generated traffic is obtained by multiplying the unit differential of total cost per type of vehicle by half of their corresponding incremental traffic. The operating costs saved by type of vehicle due to the implementation of the project are then adjusted by their corresponding conversion factors[5] in order to get the real resource value of the savings and increase in consumer surplus. The time savings are not adjusted, as labor is assumed to receive its market price and its conversion factor is assumed to be equal to 1.

The real economic values of the investment cost items are computed by adjusting the real financial cash flows using appropriate conversion factors. The conversion factors and the foreign exchange premium of 30.4% used in this study are derived from Jenkins and El-Hifnawi (1993). The foreign exchange premium of 30.4% is mainly due to the high average rates of tariffs in Bangladesh.

Results

As mentioned above, the economic appraisal of the bridge project was developed by making reference to the current and the improved ferry system, respectively. The economic evaluation of the improved ferry vis-à-vis the current ferry system has also been developed. The analysis for each scenario has been conducted on incremental terms, and therefore includes the values of the investment, operating costs and waiting time saved by not operating the alternative system.

The economic benefits of the bridge project are:

1. the savings in vehicle operating costs gained by the diverted traffic
2. the value of time saved for existing passenger and freight traffic

3. the net benefits received by the newly generated traffic (equal to the gain in consumer surplus plus the financial toll revenue)
4. the value of the investment saved by not constructing a stand-alone power interconnector
5. the value of the investment, and operating and maintenance costs saved by not improving the current ferry system
6. the value of the increase in truck waiting time saved from the year 2000 onward by not operating the current ferry system
7. the environmental benefits of preventing embankment erosion in areas close to the bridge and increasing agricultural production during the monsoon season (Bernardino, Pankaj, & Chen, 1993, p. 24).

The economic cost of capital for Bangladesh used to discount the statements of economic benefits and costs is estimated to be 12.21% (Jenkins & El Hifnawi, 1993, pp. 71–77). The economic NPV of the bridge versus the improved ferry is 1.7825 billion takas (Table 7). The bridge is clearly the better option. The real economic NPV of the bridge project vis-à-vis the current ferry is 7.77 billion takas. On the other hand, the economic NPV of the alternative improved ferry project vis-à-vis the current ferry is 1.39 billion takas (Table 7).

It should be noted that the incremental economic NPVs for the bridge and the improved ferry vis-à-vis the current ferry scenario are understated, as the investment costs to maintain the operational level of the current ferry are not included. A further economic benefit of the project is not considered in the analysis owing to lack of data. This is the reduction in waiting costs for the Aricha–Nagarbari ferry owing to the expected lower traffic volume resulting from the diversion of most of the existing traffic to the bridge.

Table 7
Economic NPVs

	Economic NPV (Million Takas)
Bridge vs. improved ferry	1,782.5
Bridge vs. current ferry	7,774.9
Improved vs. current ferry	1,395.3

SENSITIVITY AND RISK ANALYSES OF ECONOMIC APPRAISAL

Sensitivity Analysis

A sensitivity analysis is conducted on the economic NPV of the bridge vis-à-vis the current ferry scenario. The variables tested are the bridge tariff rate, the growth rate of traffic, investment cost over-runs, the savings in vehicle operating costs, and time savings for passenger and freight traffic. The sensitivity tests also reveal the following:

- Unlike the financial NPV, the economic NPV of the project decreases as the bridge tariff increases. This is due to the fact that the bridge tariff affects the volume of both diverted and newly generated traffic. Fewer vehicles passing through the bridge results in lower economic benefits. Hence, there is a tradeoff between the financial and economic performance of the bridge with respect to the tariff rate. For a range of 0% to 140% in bridge tariff rate (as a percentage of current ferry tariff), the corresponding change in the economic NPV is 8,172.6 to 6,834.9 million takas.
- The economic NPV of the project is very sensitive to the growth rate of traffic. As the annual traffic growth rate (1998–2025) goes from 0% to 9%, the economic NPV changes from -4,418.4 to 20,767.7 million takas. As said above, growth rates of traffic higher than 5% over the projected period are considered more likely than lower growth rates. The economic efficiency cost of raising the financial revenues through higher tolls is between 10% to 15% of the total toll revenues collected. The marginal economic efficiency cost per unit of financial revenue rises as the level of toll is increased.
- The economic outcome of the project is sensitive to investment cost over-runs. For a range of negative 20% to positive 30% in divergence from original cost estimate, the NPV changes from 13,585.0 to -940.3 million takas. As loans represent a flow of funds and not real resources, the way of financing the cost over-runs does not have an impact on the economic results.

Risk Analysis

Risk analysis was also applied to test how possible changes in the values of the critical variables affect the economic returns of the project. The risk variables used in the analysis are the growth rate of traffic, the investment cost over-runs, the savings in vehicle operating costs, and time savings for passenger and freight traffic. The range limits and probability distributions of the selected variables are shown in Table 8.

As in the financial evaluation, the risk analysis of the economic appraisal is developed with two alternative scenarios of investment cost over-runs (an optimistic one and a pessimistic one). A summary of the results is presented in Table 9.

Table 8
Risk Variables and Probability Distributions

Risk Variable	Probability Distribution	Base Value	Range Values	Probability (%)
			Optimistic	
Divergence from original cost estimate	Step	0	0%–5%	75
			5%–10%	20
			10%–15%	5
			Pessimistic	
	Step	0	0%–5%	25
			5%–15%	50
			15%–35%	25
Average annual growth rate of traffic	Normal	5%	3%–7%	
Vehicle operating costs factor	Normal	1.00	0.80–1.20	
Passenger time value factor	Normal	1.00	0.80–1.20	
Freight time value factor	Normal	1.00	0.80–1.20	

Table 9
Risk Analysis Results: Economic NPV (Million Takas)

Year	Expected Value	Standard Deviation	Minimum Value	Maximum value	Probability of Negative Return (%)
Bridge vs. current ferry (optimistic scenario)	6,484.1	2,482.8	-625.4	13,272.5	0.2
Bridge vs. current ferry (pessimistic scenario)	4,305.5	3,232.5	-4,757.7	15,036.2	10.6
Improved vs. current ferry	1,486.9	1,430.0	-2,050.9	5,362.7	15.8

The analysis reveals that the likelihood of investment cost over-runs is a key factor in the determination of the overall riskiness of the economic returns of the bridge project. In the optimistic scenario the economic net present value of the bridge vis-à-vis the current ferry has a very negligible chance (0.2%) of becoming negative. In the pessimistic scenario, on the other hand, the probability of having negative economic net present values falls to 10.6%.[6] The economic net present value of the improved vis-à-vis the current ferry system has a 15.8% chance of being negative.

DISTRIBUTIVE ANALYSIS

A project generates externalities when its economic benefits and costs are different from its respective financial flows. The purpose of a distributive analysis is to establish the gainers and losers from the implementation of a project and to quantify the amounts involved. In the case of the Jamuna Bridge, the difference between economic and financial values is a result of two factors: (a) the financial and economic benefits and costs of some items are different as a result of conversion factors not equal to 1; and (b) the bridge project generates economic benefits that are not captured as financial benefits.

The steps followed in the distributive analysis are:

1. Identification of externalities item by item by subtracting the financial from the economic flows
2. Reduction of each item's flow of externality into a single figure by computing the net present value of each stream at the economic discount rate of 12.21%
3. Allocation of externalities to various affected groups in the economy

The net present value at the economic cost of capital of the externalities generated by the bridge project vis-à-vis the current ferry scenario amounts to 7,132.3 million takas. The vehicle owners, bus passengers, truckers/shippers, and the environment would gain if the bridge project were implemented. The ferry operators and the government/external aid agency would have a loss.

A graphical representation of the externalities generated by the project is shown in Figure 3. As discussed earlier, the economic benefits of the project are equal to the savings in vehicle operating costs and waiting time gained by the existing traffic (T_0C_0XR - T_1C_1ZU), plus the gain in consumer surplus to the incremental traffic (ZXY), plus the financial toll revenue from the incremental traffic (Q_0UVQ_1). The financial benefits of the project are equal to the toll revenues from the diverted and incremental traffic (OT_1VQ_1).

Thus, the externalities falling to the vehicle owners, bus passengers, and truckers/shippers can be expressed as follows:

Economic benefits = $T_oC_oXR - T_1C_1ZU + ZXY + Q_0UVQ_1$ (2)

Financial benefits = OT_1VQ_1 (3)

Externalities =
(2)-(3): $T_oC_oXR - T_1C_1ZU + ZXY + Q_0UVQ_1 - OT_1VQ_1$ (4)

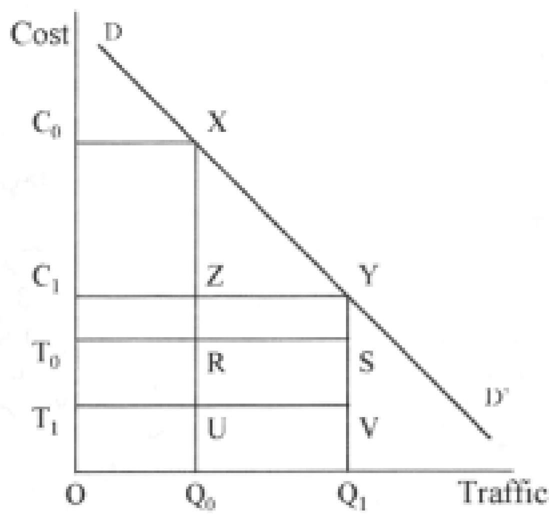
But $OT_1VQ_1 = OT_1UQ_0 + Q_0UVQ_1$ (5)

Substituting Equation (5) into Equation (4), we have:

$Q_0UVQ_1 + T_oC_oXR - T_1C_1ZU + ZXY - OT_1UQ_0 - Q_0UVQ_1$

or: $T_oC_oXR - T_1C_1ZU + ZXY - OT_1UQ_0$

Figure 3
Graphical Representation of Externalities



Therefore, the distributional impacts of the project are:

T_oC_oXR - T_1C_1ZU = gain to the diverted traffic equal to the vehicle operating and waiting time saved.

ZXY = gain in consumer surplus to the generated traffic.

OT_1UQ_0 = loss to the ferry operators equal to the bridge toll revenue from the diverted traffic (this is a portion of the total revenues lost by the ferry operator).

The total revenue lost by the ferry operators is equal to the ferry tariff multiplied by the traffic diverted to the bridge (OT_0RQ_0). OT_0RQ_0 can be broken down into its two following components: the bridge toll revenue from the diverted traffic (OT_1UQ_0), and the gain to the passengers/shippers due to the reduction in tariff (T_1T_0RU). This is a transfer from the ferry operators to the passengers/shippers.[7]

Vehicle owners and bus passengers would gain 627 million takas (US$ 15 million) and 1,951 million takas (US$ 49 million), respectively. Truckers/shippers would realize a savings of about 31,094 million takas (US$ 781 million), which is more than the entire investment cost of the bridge. The bridge crossing site and its surroundings are estimated to gain 457 million takas (US$ 11 million) of environmental benefits from the increased net incomes from enhanced agricultural production and the environmental benefits from the prevention of embankment erosion.

The government/external aid agency would have a negative externality of about 27,700 million takas. This is mainly due to the subsidy on the loan (19,851 million takas), the government grant (2,455 million takas), and the premium lost on the foreign exchange used to purchase the traded goods component of the investment cost of the bridge (the total loss of the government on the investment cost is 5,358 million takas). It should be noted that the government is also losing tax and tariff revenues on the imported components of vehicle operating costs saved because of the project. The ferry operators would have a loss of 1,840 million takas, as the ferry services are replaced by the bridge.

CONCLUSION

The main conclusions that can be drawn from the integrated financial-economic-distributive analysis of the project are as follows:

1. The Jamuna Bridge project is very attractive from the economic point of view. On the other hand, the alternative improved ferry project is not recommended from the economic perspective.
2. The bridge, operating on a cost recovery basis, is likely to be financially viable because of its low operating and maintenance costs. It will have negative cash flows during the early years of loan repayment. However, the analysis of the cumulated cash flows reveals that the positive net cash flows in the years prior to loan repayment would be large enough to cover the deficit years. Hence, a sinking fund arrangement could be arranged so that the cash surpluses in the early years remain with the Bridge Authority.
3. The risk analysis of the project shows that the financial NPV with low cost financing has a relatively small chance of being negative, whereas the economic NPV has no probability of becoming negative. The project is economically attractive owing to the large benefits generated by time savings for passengers and freight, savings in vehicle operating costs, and savings in costs of building an electrical interconnector.
4. The analysis assumes that the bridge toll will be equal to one-half of the present ferry tariff rate. There is a tradeoff between the financial and economic performance of the bridge with respect to the tariff rate.
5. The truckowners/shippers and light vehicle and bus passengers would gain if the project was implemented. The ferry operators and the government/external aid agencies would lose financially.
6. The truckers/shipper of goods and the producers of these commodities are the main beneficiaries of this project. They gain an amount that is larger than the entire cost of the bridge. Although these shippers now have the lowest priority in crossing the river via ferry, with the bridge they will be free to move with the rest of the traffic. Hence, the economic benefits created by the bridge will tend to have a large impact on the economy through the agricultural and industrial producers of the commodities that are more competitive now as a result of lower transportation costs.

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NOTES

1. After the bridge is completed, the Bhuapur–Sirajganj ferry will be closed, and the Aricha–Nagarbari ferry is expected to remain in operation at a reduced scale for traffic that will not divert to the bridge (Asian Development Bank, 1994, p. 5).

2. Figures are estimated on the basis of past traffic growth trends and taking into account population and per capita GDP growth rates as well as estimated price and income elasticity of demand for transport services.

3. The price elasticities of demand for transport by light vehicles, buses and trucks used in the analysis are -1.0, -1.5, and -0.6, respectively (ADB, 1994, p. 16).

4. The expected loss ratio is a measure indicating the magnitude of expected loss relative to the project's overall expected NPV. It is equal to the absolute value of expected loss divided by the sum of expected gain and absolute value of expected loss.

5. These are the weighted averages of the conversion factors of the vehicle operating cost components.

6. The expected loss ratios are 0.000 and 0.041 in the optimistic and pessimistic scenarios, respectively.

7. As the difference between the ferry tariff and the bridge toll is neither an economic nor a financial benefit of the project, the transfer from the ferry operators to the passengers/shippers does not appear in the table of the allocation of externalities (which is derived from the difference between the financial and economic statements). Vehicle owners/bus passengers and truckers/shippers would gain an

additional 75,588 and 1,178 million takas, respectively. On the other hand, the ferry operators would lose an additional 1,840 million takas.

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