On the Role of Transportation in Regional Economic Efficiency in Bangladesh: A Data Envelopment Analysis

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Abstract

In Bangladesh investment patterns and criteria under which resources are allocated among competing sectors and projects might have created investment bias towards already developed regions and resulted in economic inefficiency. For this reason, the role of transportation investment on regional economic development of Bangladesh is examined in more detail here. The Data Envelopment Analysis (DEA) technique is used to examine economic efficiency of investment in transportation infrastructure development for each region of the country. National investment policy appears to be inclined for more investment in the comparatively more developed regions under the pretext of higher aggregate production. Investments in infrastructure development of less efficient regions seem to be more effective by providing higher rate of return. Using DEA in the paper specific investments are identified for specific regions and their impact assessed.

1. Introduction

Optimal allocation of resources for infrastructure facilities is a critical issue in planning for development activities. Studies that identify and measure transportation investment's impact on economic development have been proposed in Berechman (1994), Buffington et al. (1992), Perera (1990), Seskin (1990), and Weisbrod and Beckwith (1992). There are also regional studies addressing the impact of transportation infrastructure on local regional economic development. Typical criteria used for the assessment of these investments are *Gross Domestic (Regional) Product or private output* as in Allen et al., 1988, and in Wilson et al. 1985, *benefit-cost ratios and/or difference*s as in Weisbrod and Beckwith, 1992, and Buffington et al., 1992, *property values* as in Palmquist, 1982, and *new business creation/location* as in Hummon et al., 1986. The debate emerging from these studies is a two pronged one in which research attempts to: a) assess the effects of transportation infrastructure investments requiring a method that is able to compare and contrast the effects of investments in one region versus the effects in another; and b) identify other important factors that influence and enable economic development functioning as catalysts when infrastructure investment in taking place in a region. In this paper we focus on the first issue.

Identification of the need and the effect of transportation infrastructure investment is particularly important when development resources are scarce as in the context of a developing country and/or region. From the perspective of the decision makers it involves identification and assessment of the need for infrastructure development, accurate estimation of the need that allows for effective budgeting and financing of the projects, informed decisions while evaluating individual projects, and above all a balanced distribution of resource and efficiency through incentives for competition. All these aspects have generated considerable research interest in the analysis of investment needs and optimal allocation of resources. At the core of investment decisions is economic performance.

Performance of invested resources is usually measured by an efficiency factor, which is the ratio between output and input factors of production. In the case of investment in infrastructure for development the output factors are usually expressed in different forms of aggregate production and the input factors include natural resources, land area, population and accessibility. Transportation is considered to be one of the most important infrastructure components influencing production. For this reason there exists considerable pressure for investment in the transportation sector. The statistical analysis of Aschauer (1990) shows that a one percent increase in the nonmilitary public capital stock (16 billion dollars in 1985) is estimated to result in a rise in the corporate profit rate of 10 basis points (1/10 of one percentage point) in the US. The study incorporated streets and highways, water supply, sewerage and publicly owned electricity and gas facilities, which constitute over half of the total public capital stock in 1990. Streets and highways represent almost 61% of the core infrastructure in 1990. Other studies such as by Aschauer (1989), Biehl (1986) and Blum (1982) suggest that the differences in levels of infrastructure spending might also be capable of partially explaining the cross-country differences in productivity growth. Aschauer (1990) cited the example of Japan, which has invested 5.1% of output in public facilities and achieved productivity growth of 3.1% per annum, while the US has had a low public investment ratio of 0.3% and inferior productivity growth of 0.6% per annum. Concentrating on only the effect of transportation infrastructure, it is demonstrated that due to increase in paved roads and rural road density aggregate crops output increases by 0.26% and 0.12% in one developing country (Emmanuel, 1995).

Transportation improvements affect both economic development and productivity. “Pure” economic development effects are usually regional in nature and result from improved access to labor pools or to larger markets (NCHRP, 1998). While considering the economic development of different regions of a country, transportation infrastructure and the overall system may play a significant role in removing regional economic disparities. Within the same country and under the same development policies, significant role for transportation implies that regions with better transportation infrastructure will have better access to the locations of input materials and markets and thus will, ceteris paribus, be more productive, competitive and hence more successful than regions with inferior transportation accessibility (Vickerman et al., 1995). Better accessibility and mobility also plays a significant role in human resource development of a region. There seems to be a clear positive correlation between transportation infrastructure endowment or interregional accessibility and the level of economic indicators, such as, GDP per capita (Beihl, 1986).

But many a times it is observed that investment in transportation far exceeds commensurate investment in other input factors, and thereby resulting in wastage of resources and reducing efficiency. In fact the critical question in connection with resource allocation is to determine the marginal rate of return for the input factors of production. It also leads to the identification and quantification of slack or surplus of the input factors. Existence and magnitude of slackness determines the need for further investment.

The objective of the study reported in this paper is to examine the role of accessibility, provided by multi-modal transportation facilities, in aggregate efficiency of production of different regions. The study focuses on Bangladesh, one of the least developed countries in the world. During the last couple of decades transportation attracted more than twenty percent of national investment, most of which is concentrated in road transportation sector. In addition, it is observed that there exists severe disparity in the spatial distribution of this investment. Although this investment has increased aggregate production in many areas, its relative effectiveness and marginal rate of return of the input factors requires further investigation. Aschauer (1990, 1993) and Vickerman et al. (1995) discuss the role of transportation on aggregate production, those studies do not explicitly examine issues like relative efficiencies and imbalance in input factors. The spatial variation of input resources and observed distribution of outputs provide a potential context for analyzing economic efficiency through the application of a non-parametric mathematical programming technique known as Data Envelopment Analysis (DEA). The efficiencies are measured in terms of output productions, input factors and their weights, which are determined endogenously. The inputs include land area, population density and accessibility, and the outputs include gross domestic production of each of the study areas. The accessibility measure includes travel time and cost of transportation among zones (regions - spatial subdivision in Bangladesh), and considers multi-modal facilities.

2. Scope of the Study: Bangladesh Perspective

Bangladesh is one of the least developed countries in the world. GNP and GDP levels of the country are quite low. Present per capita income of the people is about US $362.00 per annum (FY 2001-02). The gross area of the country is approximately 147,570 square km. According to the latest population census, which was conducted in 2001, the population of the country is 123.14 million. The average population density is about 827 persons per square km. According to 1995-96 Labor Force Survey, the total Civilian Labor Force of the country was estimated at 56.0 million of which, 34.7 million are males and 21.3 million are females.

2.1 Transportation System of Bangladesh

2.1.1 Transportation Infrastructure

The transport system of Bangladesh consists of four modes, road, rail, inland waterways and airways. The transportation network of the country is shown in Figure 1. At present the total of National Highway, Regional Highway and Feeder Road Type A amounts to

21,174 km in the country. 'National Highways' are the roads connecting the national capital with divisional headquarters, old district headquarters, port cities and international highways. 'Regional Highways' are the roads connecting different regions with each other, which are not connected by national highway system. 'Feeder Road Type A' roads connect Upazila (each district consists of a number of upazilas) Headquarters and important growth centers with the main arterial road networks. 'Feeder Road Type B' roads connect growth centers with other growth centers and Upazila Headquarters. Table 1 presents the inventory of major road network of the country, which is considered in this study.

Table 1: **Roadway Inventory of Bangladesh** (Length in Km)

Survey Year	National Highway	Regional Highway	Feeder Road Type A and B	Total
2001	3086	1751	16337	21174

(**Source**: Economic Review of Bangladesh 2002)

Rail transport is a public sector concern. Bangladesh Railway has a total 2,768 route kilometers at the end of the financial year 2000-01 and operates through 452 rail stations nationwide. About ninety percent of the country's area is accessible by railway.

The navigable waterways of the country consist of approximately 5,968 km of rivers and channels during monsoon, which reduces to approximately 3,600 km during the dry season (BIWTA, 99). The waterway network facilitates natural drainage of the country and serves as one of the major means of transportation for some areas, specifically the southern districts of the country.

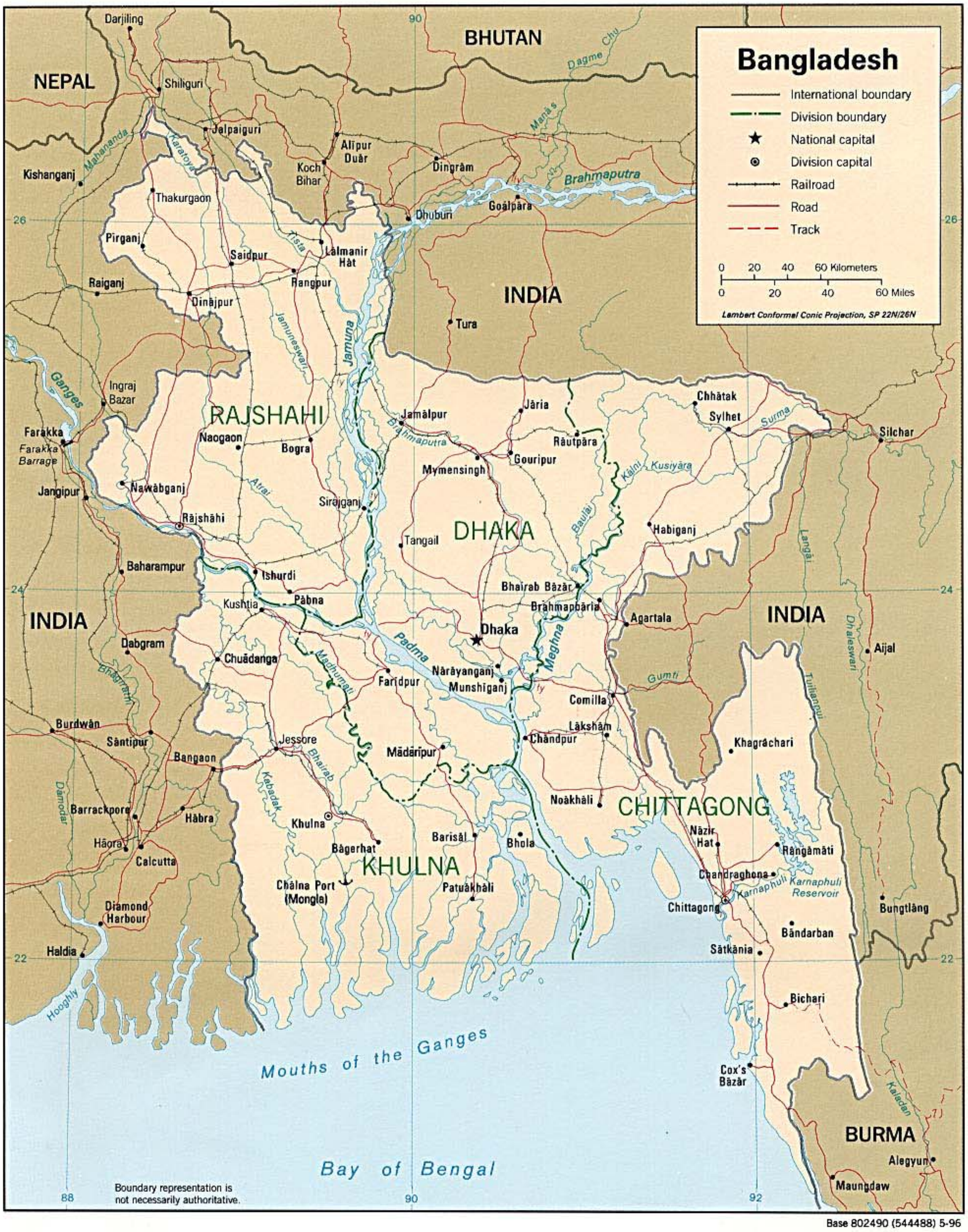

Figure 1: Map of Bangladesh showing Transportation Network.

Air transportation in Bangladesh is predominantly a public sector concern. Very recently a handful number of private airlines started operating their flights for domestic air transportation only. Biman Bangladesh Airlines is the state owned air transportation service provider. At present, Biman is operating at 7 domestic and 26 international destinations. Compared to other modes, the role of air transportation in passenger and freight movement is negligible.

2.1.2 Modal Share

Modal share of both passenger and freight transportation in Bangladesh is dominated by roadways. According to the most recent study (BITSS, 1998) roadway carries about 73 percent of passengers and 65 percent of freight as shown in Table 2 and Figure 2 respectively.

Table 2: **Share of different modes of transport**

Year	Passenger Transportation [%]			
	Road	Rail	Water	Total
1974-75	54	30	16	100
1984-85	65	20	16	100
1988-89	68	17	15	100
1992-93	75	12	13	100
1996-97	73	13	14	100

(**Source**: BITSS, 1998)

Like other countries of the world, reliability on road transportation for passenger transportation has been increasing very rapidly. Inland water transport is the second most widely used mode of transport providing accessibility into the remotest parts of the country at the cheapest fare.

The modal share of railway in both passenger and freight transportation reduced for more than 30 percent in 1974 to about 13 percent in 1997. Although the number of rail passengers has declined over time, recently introduced inter city passenger services have gained popularity because of improved quality of service.

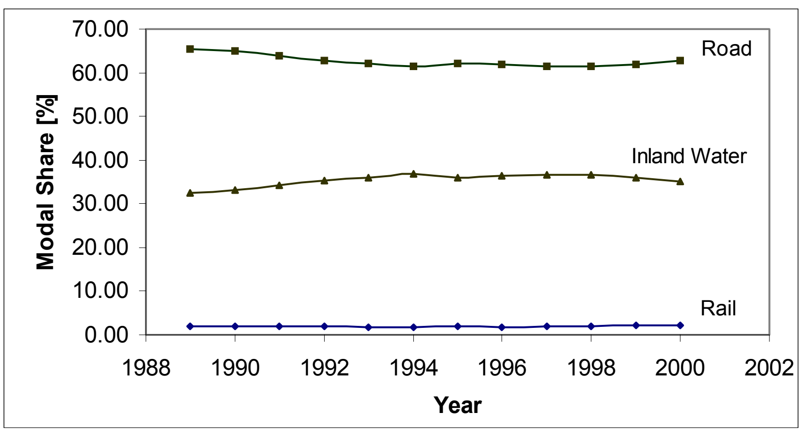

Figure 2: Freight Transportation Trend in Bangladesh.

Road and inland water modes carry the largest share of freight. The dominance of water transportation is due to relatively cheaper fare and higher accessibility particularly in the coastal area. About 50% of the land area and three fourths of the economic activities in the country are located within a distance of 10 km from the nearest navigable waterways (BITSS, 1998).

2.2 Macro-Economic Features of Bangladesh

2.2.1 Sector-wide Contribution to GDP

Bangladesh is an agriculture-based country. Agriculture contributes 22.54 percent to national economy which is followed by industry and trade services. Annual contribution of important sectors to the GDP of the country in recent years at base 1995-96 constant market prices is shown in percent in Table 3. In recent years, there is a trend of decreasing agricultural contribution in the total GDP and increasing contribution of industry and trade services.

Table 3: **Sector-wise Contribution to GDP in Current Market Price (**Figures in %)

Important Sectors	**92-93**	**93-94**	**94-95**	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	**01-02**
1. Agriculture	25.28	24.73	25.33	24.64	24.73	24.48	25.25	24.62	23.31	22.54
2. Mining & Quarrying	1.01	1.01	1.01	1.00	1.00	0.98	0.94	0.97	1.04	1.08
3. Industry	14.35	14.75	14.73	14.82	14.98	15.62	14.92	14.69	14.98	15.16
4. Construction	6.01	6.14	6.36	6.62	6.73	6.92	7.11	7.43	7.63	7.75
5. Transport, Storage & Communication.	9.53	9.37	8.87	8.71	8.62	8.36	8.21	8.33	8.74	8.90
6. Power, Gas, Water & Sanitary Services	1.56	1.56	1.49	1.44	1.41	1.32	1.29	1.30	1.32	1.35
7. Trade Services	12.54	12.67	12.95	12.98	12.77	12.99	12.99	12.93	13.45	13.68
8. Housing	8.66	8.86	8.59	9.09	9.02	8.81	8.91	8.92	8.83	8.85
9. Public Admin. & Defense	2.48	2.50	2.42	2.42	2.45	2.48	2.53	2.63	2.65	2.67
10. Banking & Insur.	1.44	1.48	1.47	1.51	1.53	1.49	1.53	1.54	1.55	1.55
11. Professional & Miscellaneous.	17.14	16.93	17.18	16.82	16.77	16.55	16.32	16.64	16.50	16.47
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Economic Review of Bangladesh 2002

2.2.2 Region-wide Contribution to GDP

Dhaka, the capital of Bangladesh, contributes about 13 percent of national income, which is followed by Chittagong, the major industrial and port area of the country. Figure 3 represents relative contribution of 20 regions of Bangladesh (known as districts) into the country's GDP expressed as percentage of the total. It may be observed that during the last ten-year period the relative contribution of the districts in national GDP has not changed significantly.

Since independence in 1971, many development projects, including infrastructure development activities, have been implemented throughout the country. Infrastructure facilities such as health facilities, educational institutions, electricity transmission lines, and drinking water facilities have been provided more uniformly across districts than transportation infrastructure. Although, many transportation infrastructure elements such as roads, inland water transportation facilities, rail stations, and new airports have been built in both rural and urban areas of the country, there exist significant regional disparities. It is frequently observed that investment priorities concentrate more on already developed areas under the pretext of higher rate of return. Consequently such investments are expected to result in imbalance in production factors and inefficiencies in the production process. It is possible that with relatively excellent transportation infrastructure facilities some districts are not producing as efficiently as other districts would with a modest investment. Again, some districts might have economic potential but poor accessibility and this may act as an inhibitor for efficient economic activities resulting in relatively poor contribution to GDP. This study aims at identifying regions with potential for more efficient production.

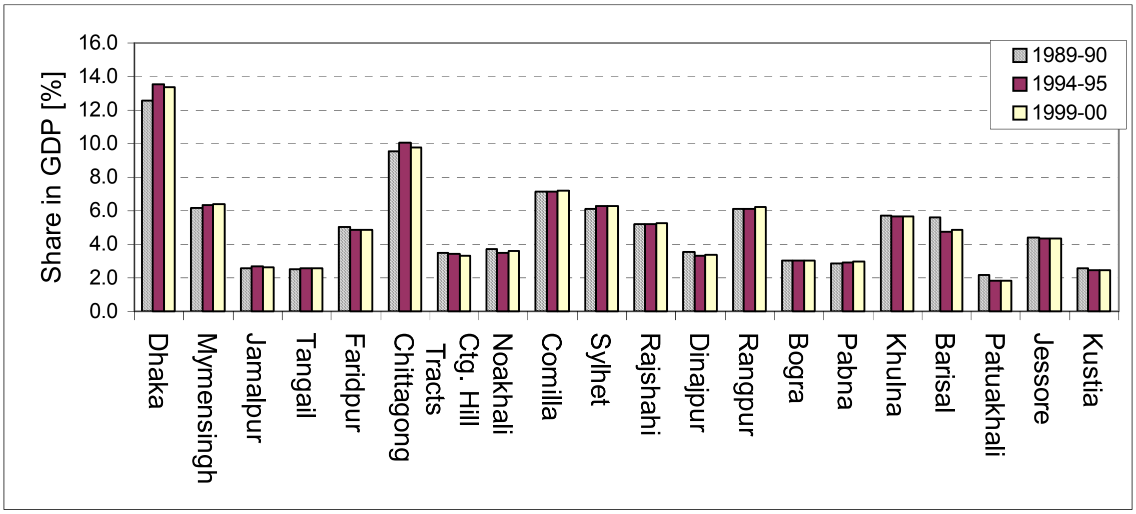

Figure 2: Regional Share in GDP of the Country. (Source: BBS, 2001)

3. Data Envelopment Analysis (DEA)

A method that can identify optimal allocations of investments is the Data Envelopment Analysis first introduced by Charnes et al. in 1978. This method is used to evaluate relative efficiency of manufacturing units, hospitals, educational institutions, banks, retail stores and so forth. It is a linear programming based technique for measuring the relative performance of organizational units where the presence of multiple inputs and outputs makes comparisons feasible. DEA computes a scalar measure of efficiency and determines efficient levels of inputs and outputs for the organizations under evaluation. This empirically based methodology was originally intended for use as a performance measurement tool for organizations that lacked a profit motivation, e.g., not-for-profit and governmental organizations. However, since its introduction, it has been further developed and expanded for a variety of uses in for-profit as well as not-for-profit situations (Bowlin, 1999). DEA found its way to transportation analysis in a variety of assessments and it has been used in benchmarking of railways (Tsamboulas and Frangos, 2003), aviation and airport performance assessments (Humphreys and Francis, 2000, Saffarzadeh and Bahramian, 2002), and public transportation systems evaluations (Karlaftis, 2000).

A common measure for relative efficiency is given by the following expression

$$Efficiency = \frac{Weighted \ \ sum \ \ of \ \ outputs}{Weighted \ \ sum \ \ of \ \ inputs}$$

It can be defined mathematically as follows

$$Efficiency \ of \ \ Decision \ Making \ Unit \ \ j = \frac{u_1 y_{1j} + u_2 y_{2j} + .. + u_k y_{kj} .}{v_1 x_{1j} + v_2 y_{2j} + .. + v_l y_{lj} .} \leq 1 \qquad (1)$$

Where, u_k = weight of output k

y_{kj} = amount of output k from unit j

v_l = weight of input l

x_{lj} = amount of input l to unit j

It is assumed that under a given production process each Decision Making Unit (DMU) will optimize its efficiency under the constraint of availability of input factors.

Consequently, for a known input-output volume, Equation 1 becomes an optimization problem. Here the solution produces weights, which are most favorable to unit *j* and provides a measure of efficiency. Following this concept, Charnes et al. (1978) developed the following model, which is often called the Charnes, Cooper and Rhodes (abbreviated as CCR) version of DEA model.

Model 1: $$Max\ h_0 = \frac{\sum_r u_r y_{rj_0}}{\sum_i v_i x_{ij_0}} \quad \text{for each unit } j. \tag{2}$$

Subject to,

$$\frac{\sum_r u_r y_{rj_0}}{\sum_i v_i x_{ij_0}} \leq 1;$$

$$\frac{\sum_r u_r}{\sum_i v_i x_{ij_0}} > \varepsilon;$$

$$\frac{\sum_r v_i}{\sum_i v_i x_{ij_0}} > \varepsilon;$$

$$\varepsilon > 0;$$

The $(y_{rj}, x_{ij}) > 0$ in the model are constants which represent observed amounts of the r^{th} output and the i^{th} input of the j^{th} decision making unit, where, $j = 1,2,3,\ldots n$ number decision making units (DMU) to convert inputs into outputs. ε *r*epresents a non-Archimedean constant, which is smaller than any positive valued real number. h_0 is the efficiency of j_0, the DMU whose relative efficiency is to be calculated with respect to other DMUs and $h_0 \leq 1$. The solution to the above model gives a value h_0 and the weights leading to that efficiency.

The model described above is a fractional linear program. To solve the model it is necessary to convert-it into linear form so that the methods of linear programming can be applied. In the objective function it can be observed that while maximizing a fraction or ratio it is the relative magnitudes of the numerator and denominator that are of interest rather than their individual values. It is thus possible to achieve the same effect by setting the denominator equal to a constant and maximizing the numerator. The resulting linear programming model is shown below (model *2*):

Model 2: $$Max \quad h_0 = \sum_r u_r y_{rj_0} \tag{3}$$

Subject to, $$\sum_i v_i x_{ij_0} = 1$$

$$\sum_r u_r y_{rj_0} - \sum_i v_i x_{ij_0} \leq 0, \qquad j = 1, 2, \ldots n$$

The efficiency of the target unit in a set can be obtained by solving model *2*. The solution to this LP provides a measure of the relative efficiency of the target unit and the weights leading to that efficiency. These weights are the most favorable ones from the point of view of the target unit. To obtain the efficiencies of the entire set of units it is necessary to solve a linear program focusing on each unit in turn. Clearly as the objective function is varying from problem to problem the weights obtained for each target unit may be different. In solving each linear program the solution technique will attempt to make the efficiency of the target unit as large as possible. This search procedure will terminate when either the efficiency of the target unit or the efficiency of one or more other units hits the upper limit of 1. Thus for an inefficient unit at least one other unit will be efficient with the target unit's set of weights. These efficient units are known as the *peer group* for the inefficient unit. It is sometimes useful to scale the data on the peer units so that a better comparison of the inefficient unit with the peer units can be made. Input data of the peer units are to be scaled in such a way so that each peer unit may use no more of an input than the inefficient unit. The solution to the DEA model thus provides a relative efficiency measure for each unit in the set, a subset of peer units for each inefficient unit, and a set of targets for each inefficient unit.

The method is applied in this study to measure the relative economic efficiency of different regions (districts) of Bangladesh and to examine the significance of transportation infrastructure with respect to other production factors in achieving the efficiency level.

3.2 Input and Output Variables

As mentioned earlier, regional efficiencies are measured as a weighted ratio of output and input elements. In the following sections these elements are illustrated in more detail.

3.2.1 Input Variables

The input variables considered in the analysis include regional population, usable land resources and accessibility. Data regarding population and land area are obtained from national census report (BBS, 2001). Accessibility is measured as a composite impedance function given by Equation 4.

$$A_i = \sum_j P_j \exp(-\mu t_{ij})$$
$$t_{ij} = \frac{-1}{\lambda_{ij}} \ln \sum_m \exp(-\lambda_{ij} t_{ijm}) \tag{4}$$

Here λ_{ij} and μ are scale factors. t_{ijm} is the travel impedance for the m-th mode between zone i and j. The travel impedance between two zones is estimated by using a transportation model. Although usually λ_{ij} is considered to vary with the value of travel impedance, in the analysis it is assumed to be constant. Accessibility of zone i (A_i) is defined as the population weighted sum of negative exponential of travel impedance for all the destination zones.

3.2.2 Output Variables

The output variable considered in the analysis includes Gross Domestic Product (GDP) in current market price of each of the regions (districts). For the purpose of the analysis GDP is further classified into three categories, which include primary (agricultural) sector GDP, secondary (manufacturing) sector GDP and tertiary (service) sector GDP. Information regarding regional contribution to GDP is obtained from a national economic census. For the purpose of analysis all the data are normalized with respect to maximum value of corresponding variable. Basic data required for the analysis are presented in Table 4.

4. Results of the Analysis

The following sections illustrate the results obtained here. The first analysis deals with efficiency on the basis of aggregate production, measured by total GDP, and provides information regarding overall efficiency. In the second analysis the contribution of primary, secondary and tertiary sectors are considered separately.

Table 4. Input and Output Variables used in the Analysis

Zone	GDP in Million Taka				Area, Sq. Km	Pop. Density	Accessibility Index
	Total	Agriculture	Industry	Service			
Dhaka	104425	13629	32516	58280	6166.5	2311.87	6.218
Mymensingh	47011	17981	4657	24368	8745.3	819.55	3.176
Jamalpur	20205	6668	4643	8895	3056.7	953.13	1.178
Tangail	19195	6917	2703	9577	3082.4	927.42	1.529
Faridpur	36127	10772	4331	21024	5720.8	854.02	1.560
Chittagong	78834	14695	29296	34843	5667.6	1067.78	1.783
Ctg. Hill Tracts	21620	12052	1704	7863	12236	99.64	0.170
Noakhali	26467	8848	3366	14283	3662.5	870.18	1.258
Comilla	54637	15034	7555	31047	5095.4	1364.35	2.694
Sylhet	48978	17285	6660	24699	10930.6	627.18	1.536
Rajshahi	37578	13990	3710	19878	8365	802.78	2.055
Dinajpur	25568	10549	2708	12312	6234.5	697.99	1.021
Rangpur	45761	18283	4754	22724	7992.8	938.75	2.234
Bogra	22233	8839	2326	11069	3448.7	986.62	1.063
Pabna	22074	7589	3013	11470	4133.5	998.36	1.471
Khulna	41387	13334	6444	20709	10478.4	466.18	1.641
Barisal	35506	11465	3736	20304	5234.7	705.81	1.715
Patuakhali	14690	6971	1728	5992	3274.3	453.05	0.521
Jessore	33348	14025	3291	15185	5913.4	836.61	1.642
Kustia	18392	6552	2981	8848	3216	938.48	1.099

Such differentiation facilitates identification of the relationship between output and specific inputs. In particular, it provides significant insight regarding the role of accessibility in various sectors of production.

4.1 Aggregate GDP Model

Aggregate GDP model defines efficiency as the ratio of weighted total GDP and weighted sum of input factors. The estimated efficiency explains the overall level of economic activity with respect to the input factors. The higher the efficiency, the better is the utilization of input resources. Also higher values of the weights of the input variables imply that such variables become binding constraints in the process of optimization. Marginal rate of return for further investment is provided by the values of the weights. A uniform value of the weight implies a balanced utilization of resources. The result of aggregate GDP model is shown in Table 5. It is observed that only three regions, among the twenty regions considered in the analysis, operate at highest efficiency level. But even among these three regions there exists imbalance in utilization of input factors. In the case of Dhaka unavailability of land area is more prominent. On the contrary, both Chittagong and Chittagong Hill Tracts regions suffer from lack of accessibility. In the case of Dinazpur, Bogura and Patuakhali lack of accessibility is identified as the most significant cause of inefficiency.

Table 5: **Relative efficiency and weights of input and output – Aggregate GDP Model**

Districts	Efficiency	Weights			
		GDP	Area	Pop. Density	Accessibility
Dhaka	1.00	1.00	1.80	0.04	0.054
Mymensingh	0.71	1.58	0.23	2.35	0.010
Tangail	0.42	2.30	3.38	0.01	0.59
Jamalpur	0.46	2.40	3.52	0.01	0.61
Faridpur	0.56	1.62	0.23	2.41	0.01
Chittagong	1.00	1.32	0.59	0.27	2.08
Ctg. Hill Tracts	1.00	4.83	0.34	9.36	9.62
Noakhali	0.52	2.03	2.98	0.01	0.52
Comilla	0.72	1.38	2.03	0.01	0.35
Sylhet	0.88	1.88	0.27	2.80	0.01
Rajshahi	0.58	1.62	0.23	2.42	0.01
Dinajpur	0.53	2.14	0.31	0.01	5.13
Rangpur	0.63	1.43	0.21	2.13	0.01
Bogura	0.47	2.22	0.32	0.01	5.30
Pabna	0.38	1.79	2.63	0.01	0.46
Khulna	0.93	2.36	0.34	3.50	0.01
Barishal	0.66	1.94	0.28	2.88	0.01
Patuakhali	0.59	4.17	0.59	0.01	9.99
Jessore	0.52	1.64	0.23	2.44	0.01
Kustia	0.41	2.31	3.39	0.01	0.59

As shown in Figure 4, the most under developed regions are Kustia, Jessore, Patuakhali, Pabna, Bogra, Dinajpur, Noakhali, Chittagong Hill Tracts, Tangail and Jamalpur. Form Table 5, it is observed that most of these districts are inefficient with relative efficiencies lower than 60 percent. Considering that the districts with relative efficiencies lower than 60% are economically lagging regions from the perspective of their lower contribution into national GDP and lower relative efficiency, it is possible to examine the role of accessibility in lower state of economic development. For this purpose the weight of accessibility is normalized with respect to the weight of the output variable. The level of efficiency is compared with the normalized weight of accessibility, which is presented in Figure 3. It is evident that accessibility is acting as a hindrance for higher economic development for Chittagong, Chittagong Hill Tracts, Patuakhali, Bogra, Pabna Tangail, Jamalpur, Noakhali, Pabna and Kustia.

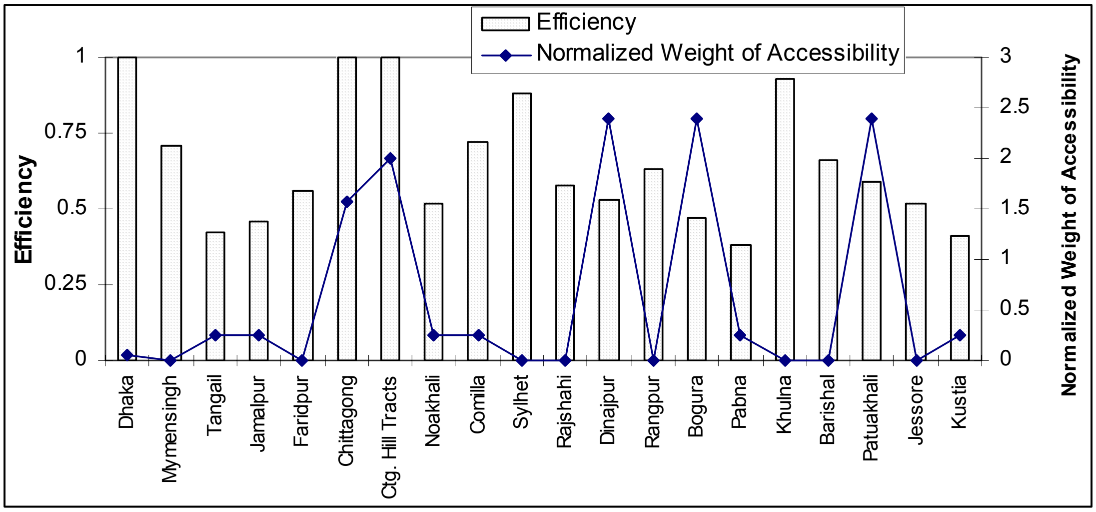

Figure 4: Relative efficiencies and normalized weights of accessibility index

4.2 Sector-wide GDP Model

Sector-wide GDP model provides knowledge regarding the interaction among the input variables and production of different sectors. In the second analysis all three sectors of GDP – primary (agriculture), secondary (industry and construction) and tertiary (trade and services, transportation etc.) have been considered in the output. The result of the analysis is presented in Table 6. It is observed that the estimated efficiencies of sector-wide model are higher than the same measures of the aggregate model. The efficiencies in this model correspond to individual sectors of the economy. It is observed that the role of secondary (manufacturing) sector is relatively less significant in the efficiency of economic activities. For the districts like Tangail, Jamalpur, Faridpur, Pabna, Bogura and Kustia primary sector is the driving force. For all these districts efficiencies are still low and accessibility is a binding constraint. For the case of Chittagong Hill Tracts and

Pautuakhali, the accessibility situation is extremely poor although the districts are performing efficiently with respect to the limitation of resources.

Table 5: **Relative efficiency and weights of input and output – Sectorwise GDP Model**

Districts	Efficiency	Weights					
		Primary	Secondary	Tertiary	Area	Pop. Density	Accessibility
Dhaka	1.00	0.024	0.065	0.917	1.78	0.04	0.022
Mymensingh	1.00	0.899	0.040	0.264	0.23	2.35	0.010
Tangail	0.77	2.044	0.001	0.001	2.83	0.01	1.15
Jamalpur	0.80	2.201	0.001	0.001	3.05	0.01	1.24
Faridpur	0.80	1.218	0.001	0.236	0.80	0.88	1.19
Chittagong	1.00	0.163	0.900	0.097	1.30	0.33	0.87
Ctg. Hill Tracts	1.00	1.264	1.299	0.738	0.37	9.31	8.67
Noakhali	0.91	1.889	0.001	0.001	2.62	0.01	1.06
Comilla	1.00	0.770	0.017	0.682	2.06	0.07	0.24
Sylhet	1.00	0.366	0.098	1.496	0.36	2.35	0.17
Rajshahi	0.83	0.874	0.001	0.484	0.70	1.34	0.16
Dinajpur	0.86	1.397	0.001	0.271	0.92	1.01	1.36
Rangpur	1.00	0.958	0.006	0.106	0.82	1.00	0.17
Bogura	0.99	2.054	0.001	0.001	2.25	0.01	2.11
Pabna	0.69	1.657	0.001	0.001	2.29	0.01	0.93
Khulna	1.00	0.002	0.109	2.752	0.29	3.59	0.09
Barishal	0.95	1.156	0.001	0.641	0.93	1.78	0.22
Patuakhali	1.00	2.581	0.158	0.079	1.54	0.13	6.69
Jessore	1.00	1.302	0.006	0.002	1.51	0.58	0.89
Kustia	0.77	2.148	0.001	0.001	2.97	0.01	1.21

4.3 Implication of the Results

The analyses presented above clearly demonstrate the deficiency of accessibility in a couple of zones of the country, which include Chittagong Hill Tracts and Pautuakhali. The other areas where investment in accessibility is deemed necessary include Tangail, Jamalpur, Faridpur, Bogura, Dinajpur. In all these districts accessibility primarily depends on the roadway network. Lack of facilities for alternative transportation modes and its influence on efficiency is clearly demonstrated in the analysis. In the analysis it is also observed that Chittagong, which is the main port of the country and one of most important industrial cities, suffer from lack of accessibility.

Compared with the investment scenario of transport sector, it is observed that there exists severe disparity in spatial allocation of resources. Most of the investment in transport sector concentrates on improving accessibility of Dhaka. Also, relatively higher priority is provided on road sector. The analysis here suggests that investment in improving the accessibility of peripheral districts is required and it should be increased with more priority in improving multi-modal accessibility.

5. Conclusion

In this paper, the role of accessibility in regional production has been studied using a relatively new method in investment and decision-making. The paper presents an elaborate analysis of the significance of accessibility in the efficiency of regional production with respect to Bangladesh. A new approach is developed to identify and assess the need for investment in improving accessibility and its spatial distribution.

The approach is devised on the basis of a Data Envelopment Analysis (DEA) framework. Considering Gross Domestic Product (GDP) in current market price as the output and, usable land area, population density and accessibility as input in the production process, efficiency is estimated as the weighted ratio between output and input. Initial analyses have shown that most of the zones perform inefficiently thereby causing imbalance in input factors of production and waste of resources. It also identified specific regions where production efficiency is severely constrained by lack of accessibility. Such regions include Chittagong Hill Tracts, Pautuakhali, Dinajpur, Bogura, Pabna. The analysis also suggests that investment to improve accessibility in Tangail, Jamalpur, Faridpur and Chittagong will be beneficial.

Analysis of efficiency on the basis of sectoral production suggests that the regional economy is still primarily dependent on the agricultural sector. Although the service sector plays a significant role in a few regions, the role of the manufacturing sector is insignificant. In many zones where agriculture is the driving force in economic activity, there exist scope for investment in transportation sector with relatively higher marginal rate of return.

Further investigation is required to differentiate the impact of natural resources and other investment. This will also provide further insight into the impacts of various input factors on production. Finally, performing similar analysis on time series data will enable validation of the methodology as well as the development of a new planning tool for planners and decision makers.

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